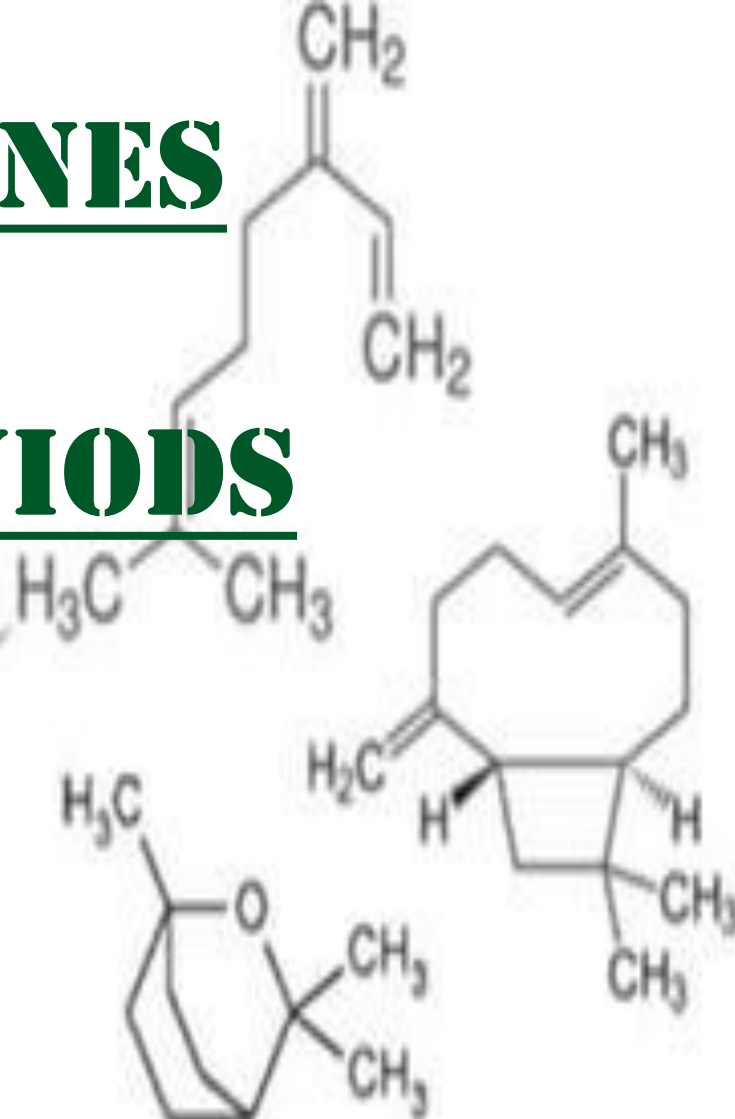


TERPENES & TERPENIIDS



Dr. Mishu Singh

Department of Chemistry

Maharana Pratap Govt. P.G. College Hardoi

www.mpgpgcollegehardoi.in



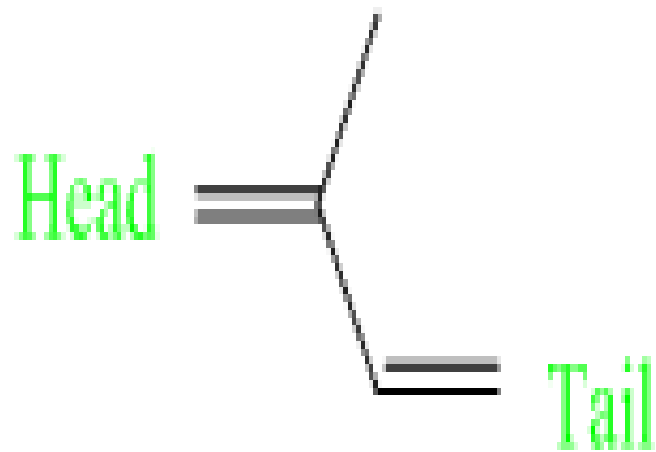
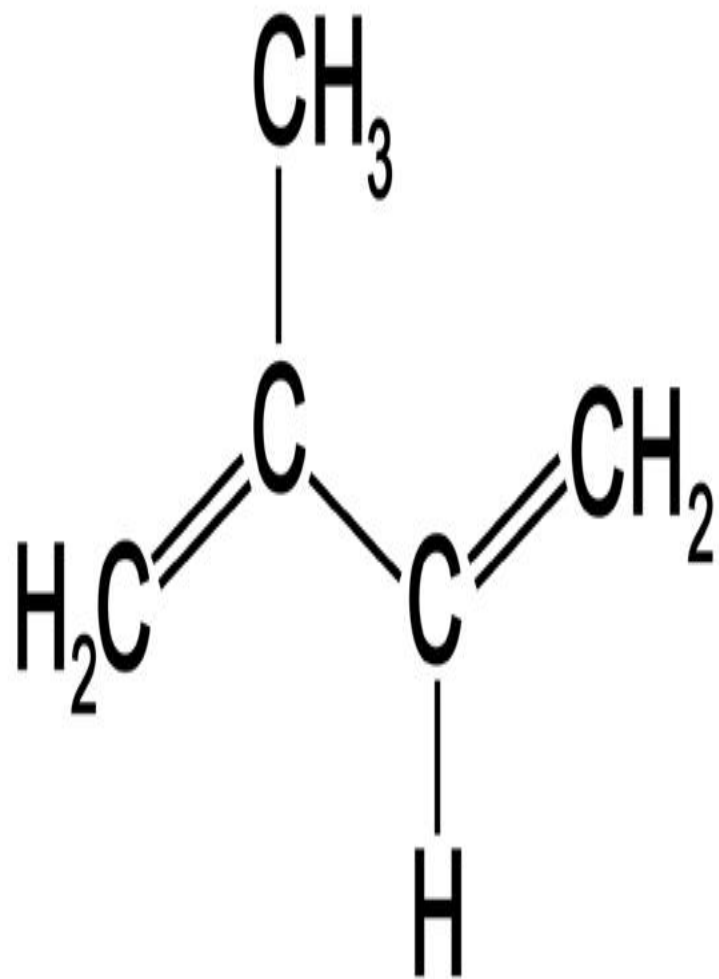
❖ During the 19th century, chemical works on turpentine led to name "**terpene**" the hydrocarbons with the general formula $C_{10}H_{16}$ found in that complex plant product. These terpenes are frequently found in plant essential oils.

❖ **Terpenoids** (isoprenoids), a subclass of the **prenyllipids** (terpenes, prenylquinones, and sterols), represent the oldest group of small molecular products synthesized by plants.

- ❖ They are universally present in small amounts in living organisms, where they play numerous vital roles in plant physiology as well as important functions in all cellular membranes.
- ❖ On the other hand, they are also accumulated in many cases, and it is shown that the extraordinary variety they then display can be due to ecological factors playing an evolutionary role.

❖ The terpenoids, sometimes called isoprenoids, maybe defines as a large and diverse class of naturally occurring organic chemical compounds derived from varoius but definite number of five-carbon isoprene units named Hemiterpene or methylbuta -1,3-diene

❖ The isoprene units may be linked together "head to tail" to form linear chains or they may be arranged to form rings.



(2-methyl-1,3-butadiene)

Isoprene Unit

Isoprene Rule

Terpenes are composed of "Isoprene Units" bonded Head-to-Tail.



Isoprene

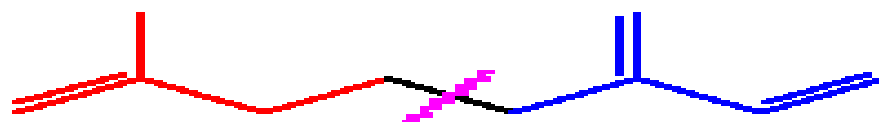


"Isoprene Unit"

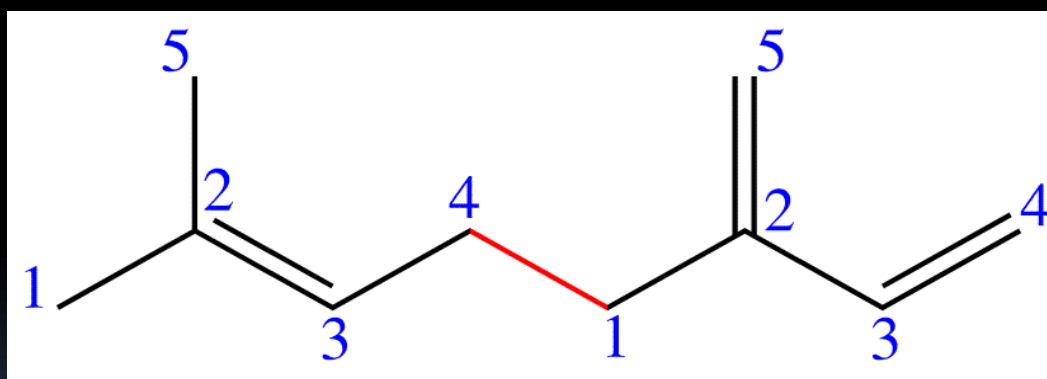


Head

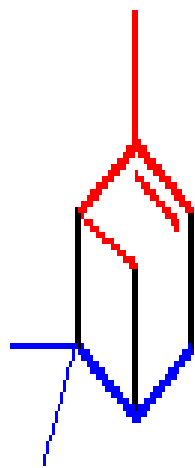
Tail



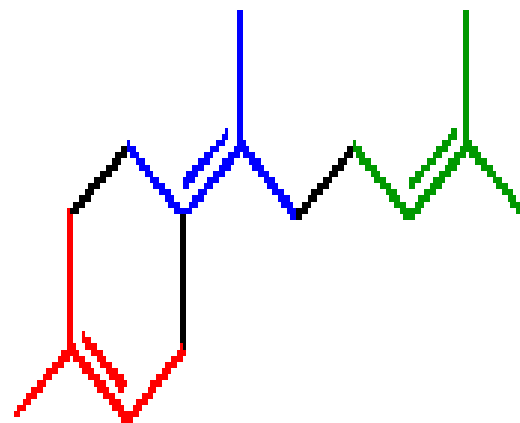
Myrcene (oil of Bay)



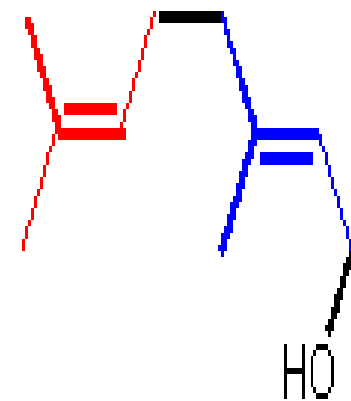
Isoprene unite in Myrcene are joined head to tail



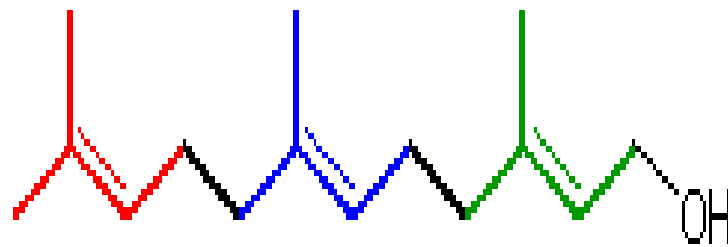
α -pinene



γ -bisabolene

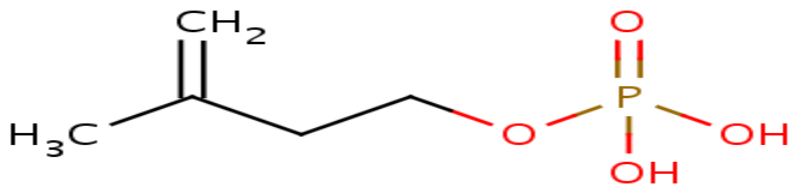


geraniol

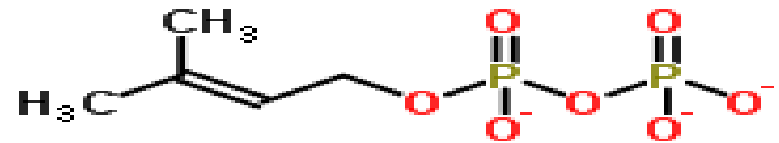


farnesol

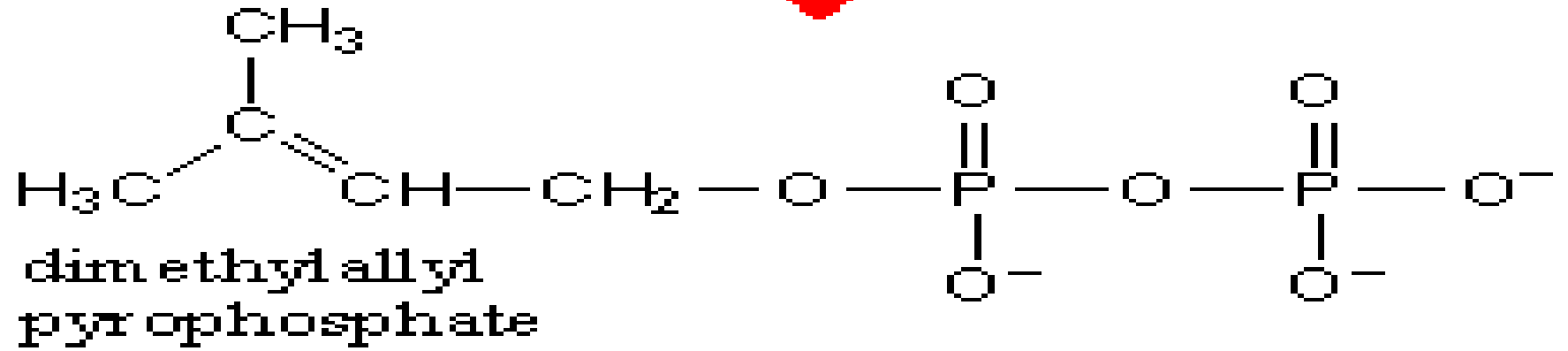
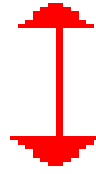
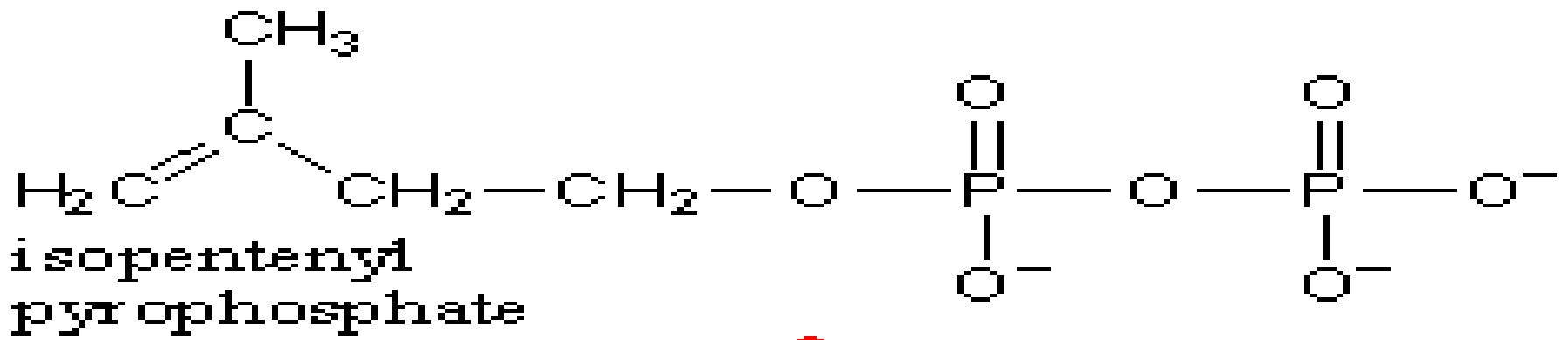
Isoprene itself does not undergo the building process but rather activated forms, isopentenyl pyrophosphate IPP and dimethylallyl pyrophosphate DMAPP, are the components in the biosynthesis.



IPP

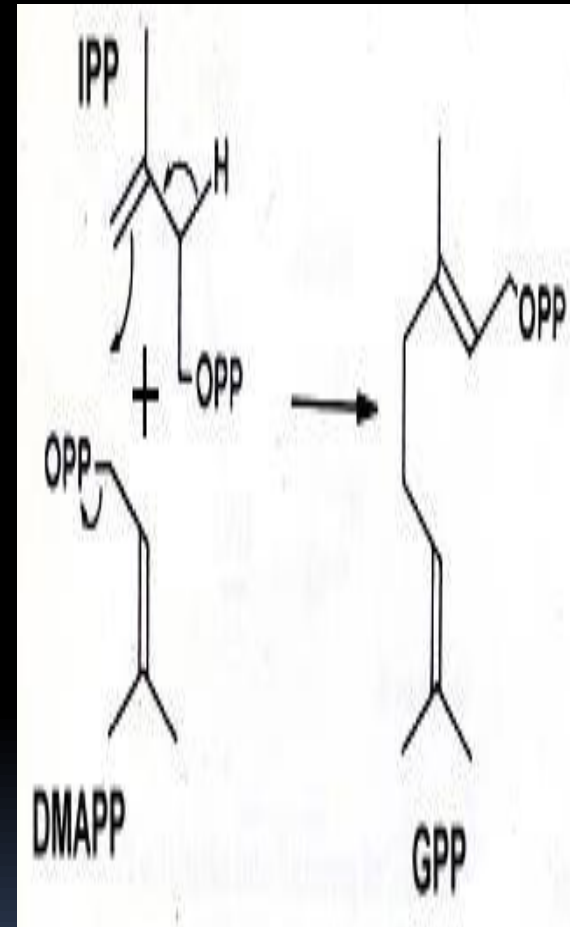


DMAPP



Isopentenyl pyrophosphate is interconvertible with 2-methylallyl pyrophosphate.

Terpenoids are extraordinarily diverse but they all originate through the condensation of the universal phosphorylated derivative of hemiterpene (Isoprene), isopentenyl diphosphate (IPP) and dimethylallyl diphosphate (DMAPP) giving geranyl pyrophosphate (GPP).



CLASSIFICATION OF TERPENOIDS

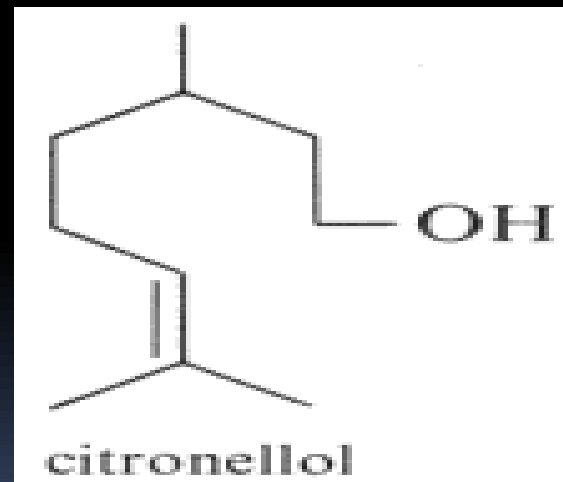
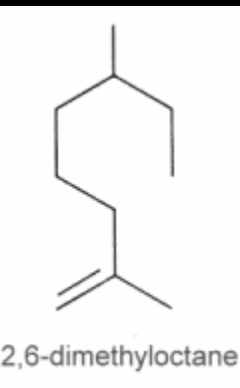
S.NO	TYPES	MOLECULAR FORMULA	ISOPRENE UNITS	EXAMPLE
1	Monoterpenoids	10 C	2	Pinene,limonene, Carene, Sabinene, Camphene, Thujene. Camphor, Borneol
2	Sesquiterpenoids	15 C	3	Zingiberene, Vetivazulene ,Guaiazulene. Cadinenes, Caryophyllene
3	Diterpenoids	20 C	4	Abietic Acid, Aphidicolin, Cafestol, Cembrene.
4	Sesterterpenoids	25 C	5	Gascardic Acid, Ophiobolin A, Ceroplastol.
5	Triterpenoids	30 C	6	Sterols
6	Tetraterpenoids	40 C	8	Carotenoids
7	Polyterpenoid	Not Fixed	infinite	Rubber

MONOTERPENOIDS

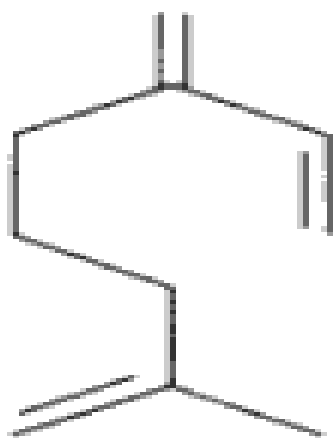
- ❖ They are the terpenoids that have been known for several centuries as components of the fragrant oils obtained from leaves, flowers and fruits.
- ❖ Monoterpenes, with sesquiterpenes, are the main constituents of essential oils.
- ❖ While a few, such as camphor, occur in a near pure form, most occur as complex mixtures, often of isomers difficult to separate.
- ❖ These essential oils have numerous actions, such as allelochemical functions between plants and between plants and predators.
- ❖ A role in wound healing was also observed.

ACYCLIC MONOTERPENOIDS

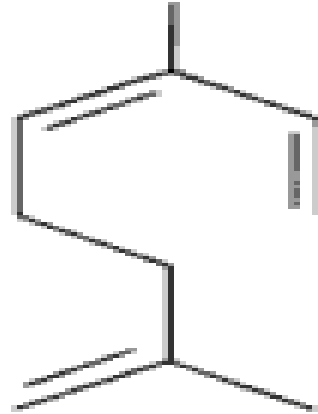
❖ They can be considered as derivatives of 2,6-dimethyloctene.



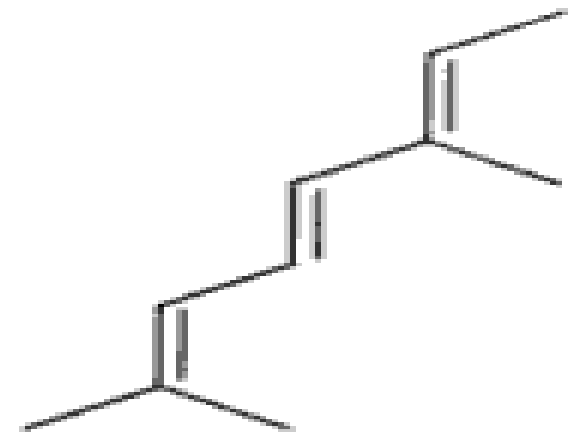
Among natural molecules, the followings are well known and have several structural isomers



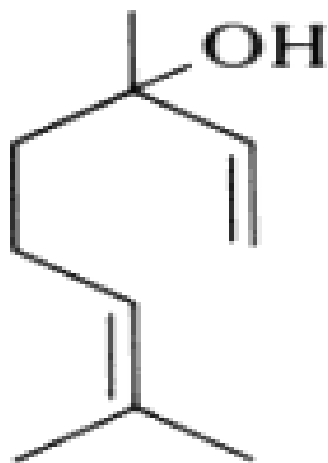
α -myrcene



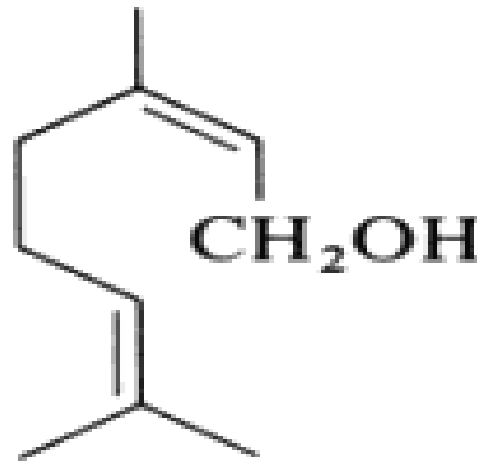
cis- α -ocimene



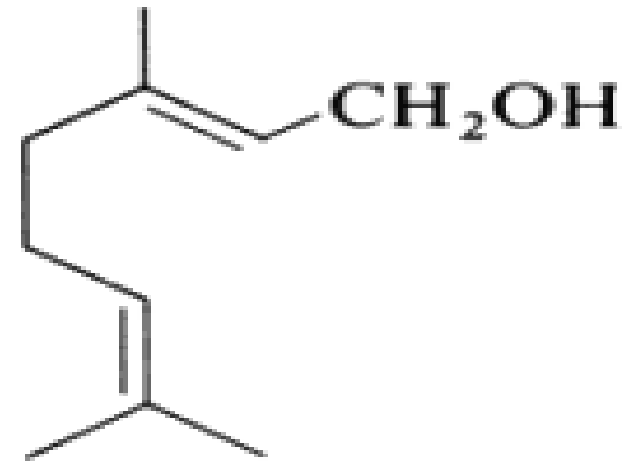
4-*trans*-6-*trans*-
allocimene



Linalool

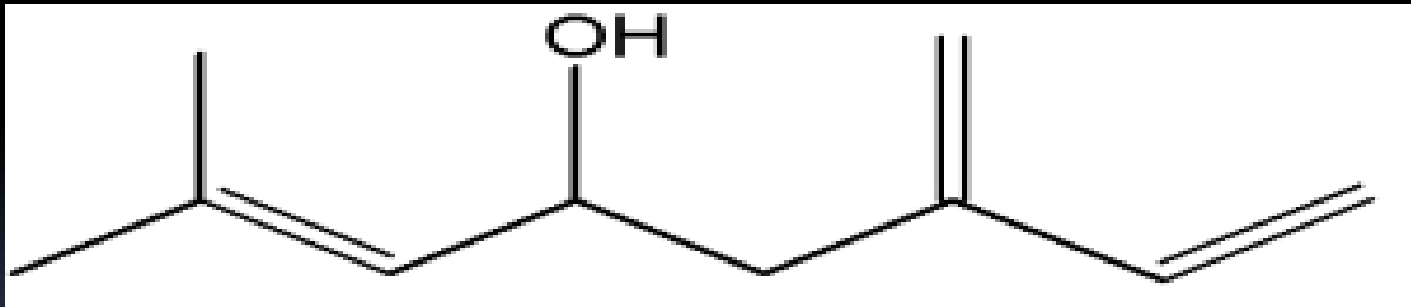


Nerol



Geraniol

- ❖ A great number of orchid species in the New World tropics have coevolved with the insects **Euglossini** by producing floral scents, highly attractive to insect males over great distances, for efficient pollination.
- ❖ **Ipsdienol** has been shown to be the main attractive component of the orchid scent.

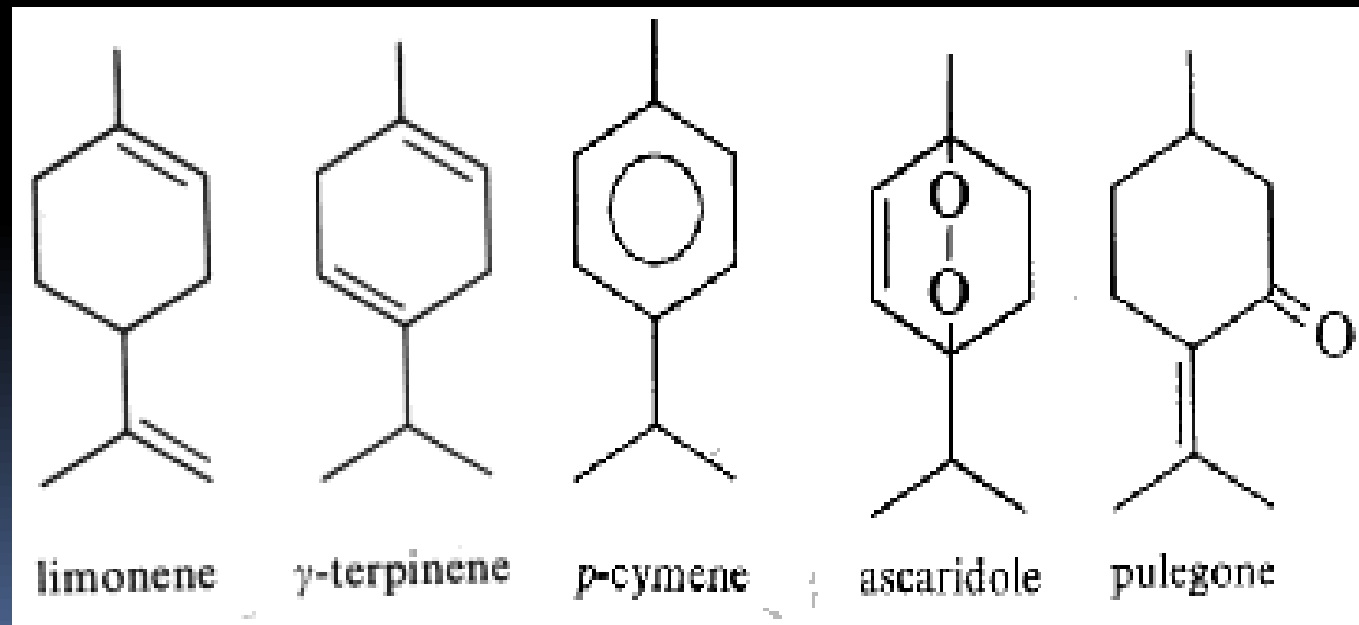


Ipsdienol

MONOCYCLIC

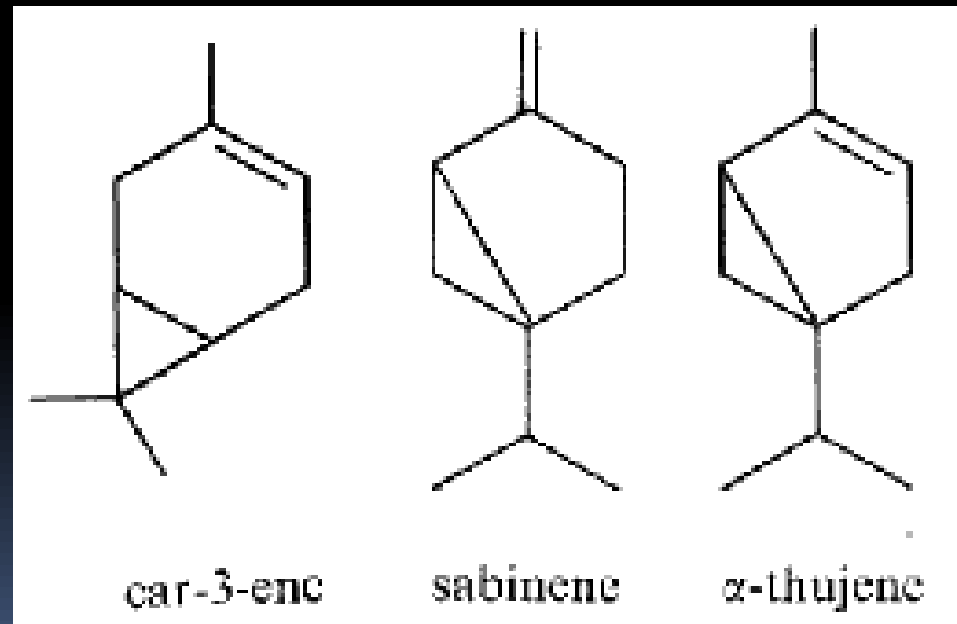
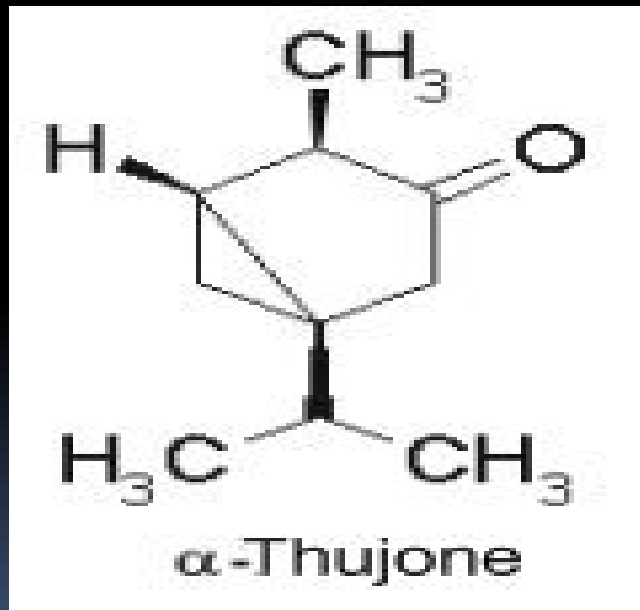
MONOTERPENOIDS

- ❖ They are derived from cyclohexane with an isopropyl substituent.
- ❖ **Limonene** is an important volatile emitted by the **holm oak tree** and inhibits seed germination of other plant species.

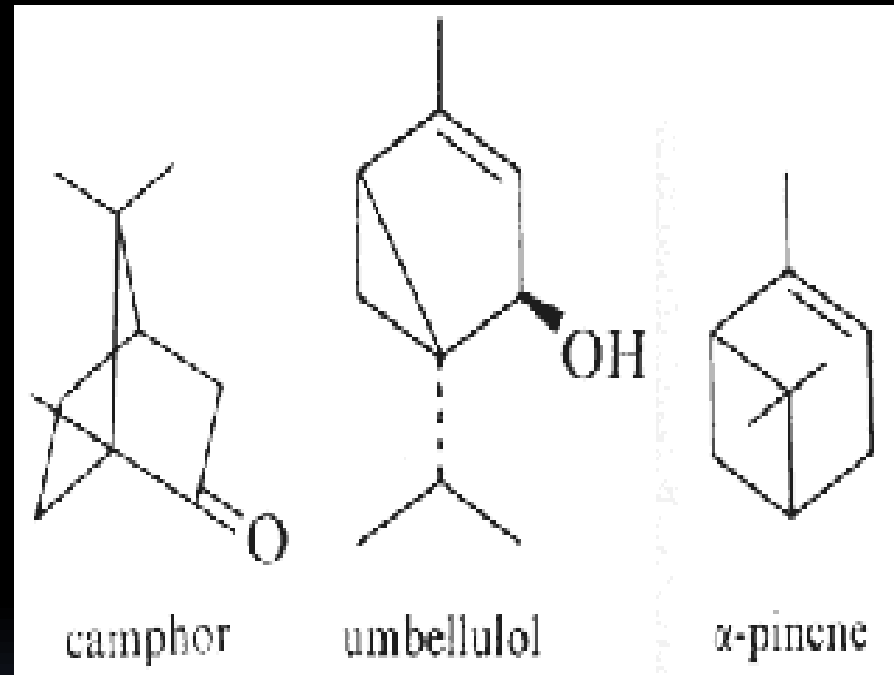


BICYCLIC MONOTERPENOIDS

Thuyone is best known for being a toxic chemical in absinthe, a product extract from *Artemisia absinthium*.



- ❖ **Pinene** is, as limonene, an allelochemical emitted by the roots of *Quercus ilex*.
- ❖ **Camphor** and **pinene** are also allelochemicals emitted by *Salvia leucophylla*.



- ❖ **Iridoids** are a class of bicyclic monoterpenes found in a wide variety of plants and in some animals. typically found in plants as glycosides, most often bound to glucose.
- ❖ They are produced by plants primarily as a defense against herbivores or against infection by microorganisms.
- ❖ It can also be used as a mosquito repellent.
- ❖ As other terpenes, iridoids may function as protective substances in the animal kingdom, especially for insects.
- ❖ They have also antioxidant properties, **g-terpene** and **hydroxytyrosol** being among the most effective.

SESQUITERPENOIDS

❖ **Sesquiterpenoids** are defined as the group of **15 carbon compounds** derived by the assembly of **3 isoprenoid** units and they are found mainly in higher plants but also in invertebrates.

❖ Sesquiterpenes, with monoterpenes, are an important constituent of essential oils in plants.

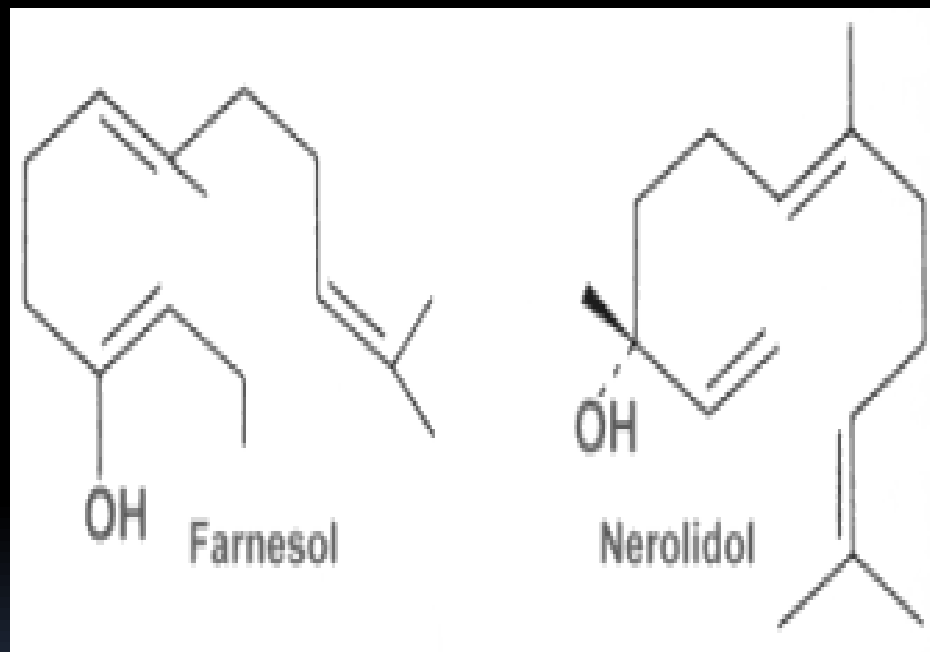
❖ They are the most diverse group of isoprenoids.

❖ In plants, they function as **pheromones** and **juvenile hormones**.

❖ Sesquiterpene structures present several **acyclic, mono-, bi-, tri-, and tetracyclic systems**.

ACYCLIC COMPOUNDS

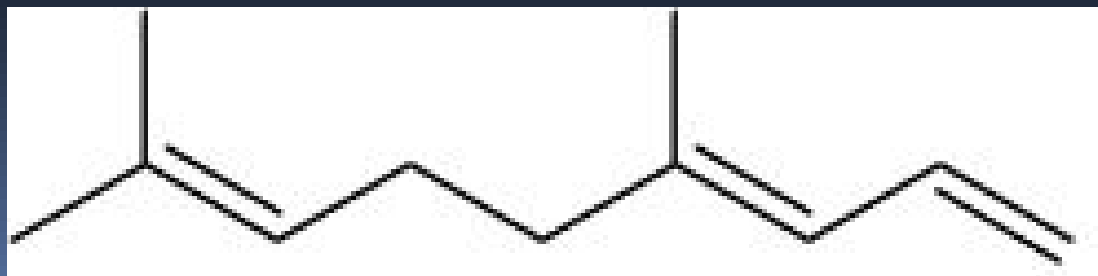
- ❖ The acyclic representative are also called **farnesans**, term derived from the basic structure, **farnesol**.
- ❖ **Farnesol** and **nerolidol** are very common and are isolated from essential oils of various sources



- ❖ Farnesol is widely distributed in many essential oils such as citronella, neroli, cyclamen, lemon grass, tuberose, rose, musk, and balsam.
- ✘ It is used in perfumery to emphasize the odors of perfumes.
- ✘ Moreover, it is a natural pesticide for mites and is also a pheromone for several insects and mammals, including elephants.
- ✘ Farnesol was also shown to be the “quorum-sensing molecule” identified in fungi.

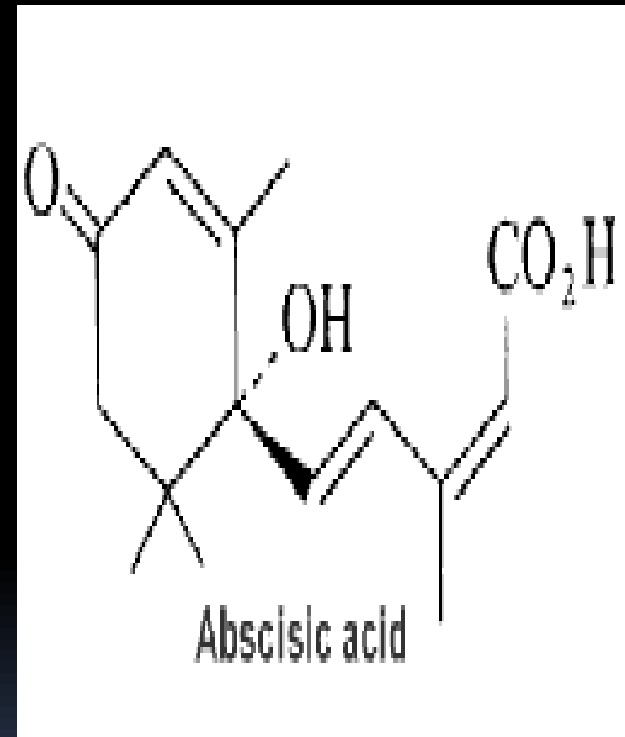
- ❖ Nerolidol is present in neroli, ginger, jasmine, lavender, tea tree and lemon grass.
- ❖ The aroma of nerolidol is woody and reminiscent of fresh bark.
- ❖ It is used as a flavoring agent and in perfumery.
- ❖ It was also shown to be produced by the leaves of a large number of plant species in response to herbivory insects and then to be transformed into a C11-homoterpene (4,8-dimethyl-1,3,7-nonatriene) which attracts predatory insects.

4,8-Dimethyl-1,3,7-nonatriene

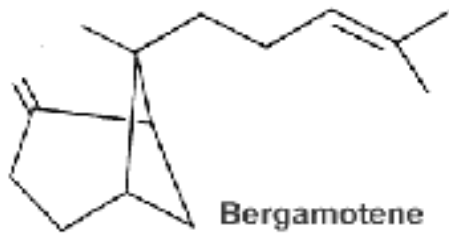


CYCLIC COMPOUNDS

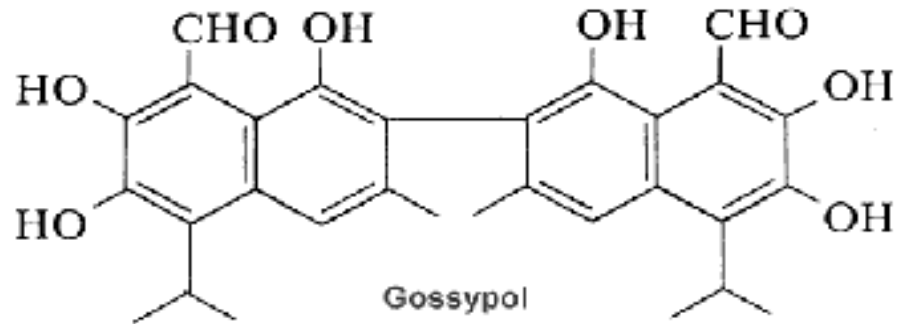
- ❖ Abscisic acid plays a key role in plants in the regulation of stomatal closure by regulating ion channel activities and water exchanges across the plasma membrane of guard cells.



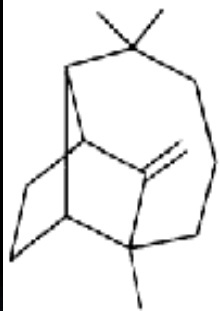
SOME IMPORTANT



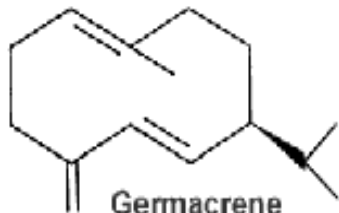
Bergamotene



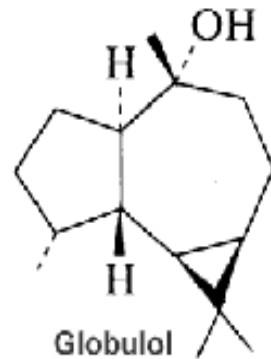
Gossypol



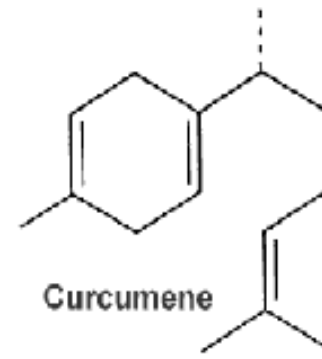
Longifolene



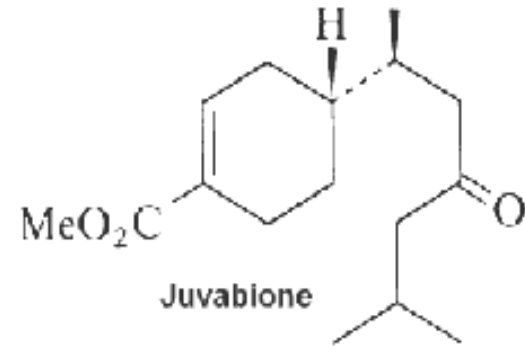
Germacrene



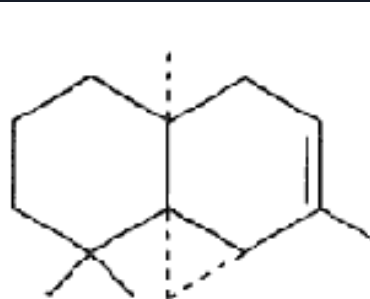
Globulol



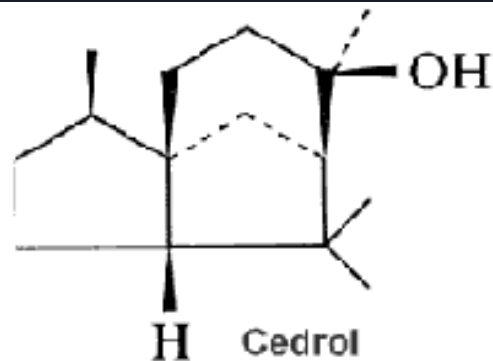
Curcumene



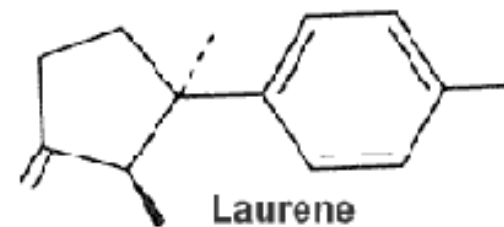
Juvabione



Thujopsene



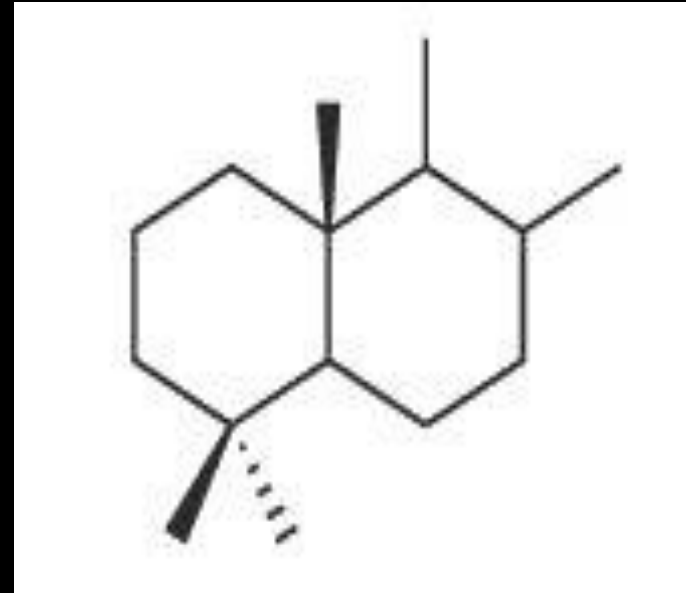
Cedrol



Laurene

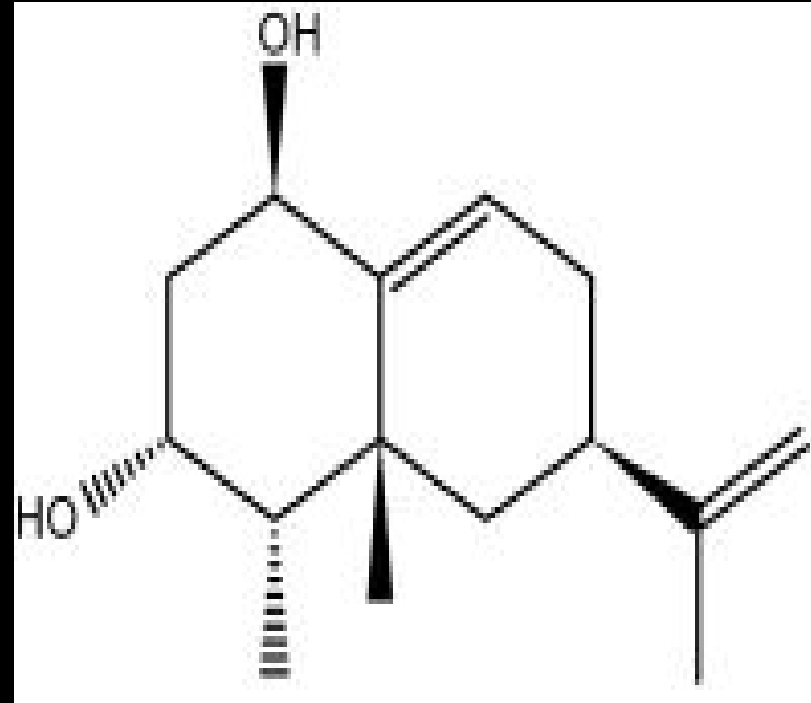
- ❖ The function of **curcumene** as insecticide, repellent, and insect feeding deterrent has been previously reported.
- ❖ A parent compound, **bisabolol** is isolated from essential oils of a variety of plants,
- ❖ **Gossypol**, a sesquiterpene dimer found in all the cotton plants is formed from two cadinane units.
- ❖ Terpenoids occurs as a mixture of two enantiomers but each has different biological activities.
- ❖ For nonruminant animals (rodents, chickens, humans), (–)-gossypol is significantly more toxic than the (+) enantiomer. It has anti-cancer properties and inhibits male fertility in humans. In contrast, cotton plants containing high levels of (+)-gossypol are resistant to insect damage. These terpenes must be removed from the plant parts and oil before use as animal foods.

- ❖ Bicyclic sesquiterpenes with a drimane unit are widespread in plants, liverworts, fungi and certain marine organisms (sponges).
- ❖ Some drimanes have been identified in petroleum and are probably derived from a microbial source.
- ❖ They have generally potent antibacterial and antifungal activities, and they are toxic to several invertebrates and also in fish.



Drimane skeleton

- Capsidiol is a sesquiterpenoid compound that accumulates in tobacco *Nicotiana tabacum* and chili pepper *Capsicum annuum* in response to fungal infection. It is considered as a phytoalexin.



Capsidiol

- They have 20 carbon atoms and are derived from geranylgeraniol pyrophosphate.
- They are of fungal or plant origin and are found in resins, gummy exudates, and in the resinous high-boiling fractions remaining after distillation of essential oils.
- The rosin remaining after distilling pine turpentine, for instance, is rich in diterpenoids.
- In ancient times, conifer exudates were used for caulking boats and waterproofing ropes.
- Resin secretion is also recognized to be part of the resistance mechanism conifers employ against bark beetles and their associated pathogenic fungi..

▪ Diterpenoid groups that are physiologically active include:

Examples:

-vitamin A (retinol),

-phytohormones that regulate plant growth and germination, e.g. gibberellin,

-fungal hormones like trisporic acid

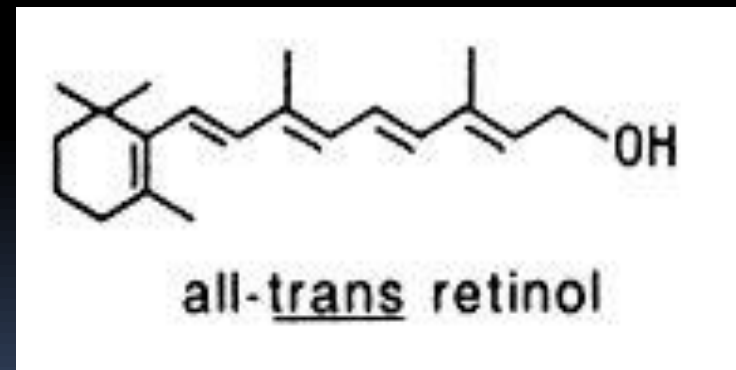
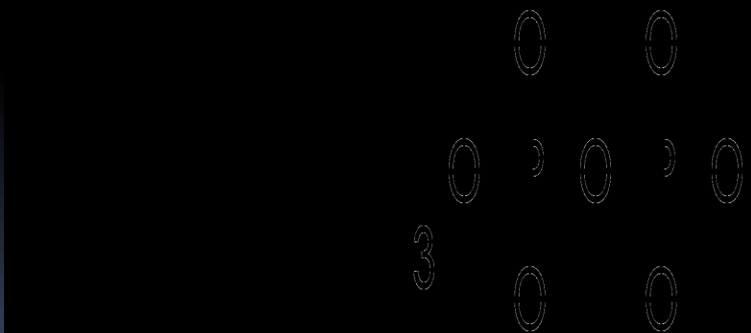
-disease resistance agents (phytoalexins), e.g. casbene and podocarpic acid, the anticancer drug,

- taxol, from the bark of the yew tree

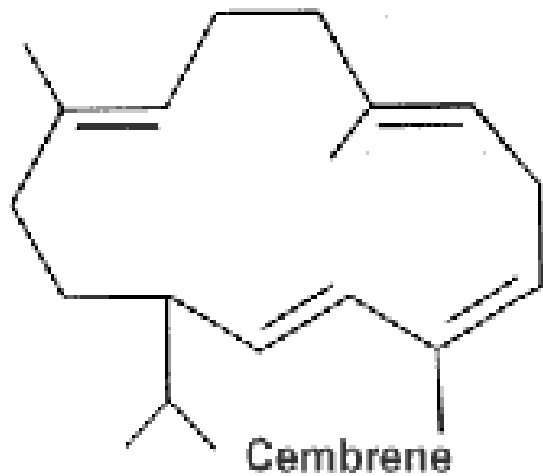
- the cancer promoter, phorbol, and natural cannabinoids

DITERPENOIDS

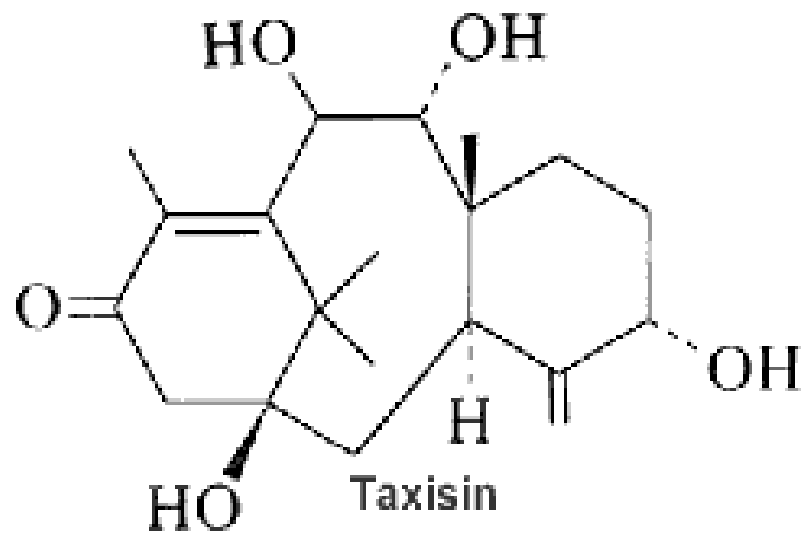
The diterpenes have exceptionally open chain compounds derived from geranylgeranyl phosphate which forms a part of chlorophyll and the side chain of vitamin E and K, and crocetin which is a diacid diterpenoid and the lipid part of the crocins, glycosylated derivatives present in saffron. Diterpenes form the basis for biologically important compounds such as retinol, retinal, and phytol.



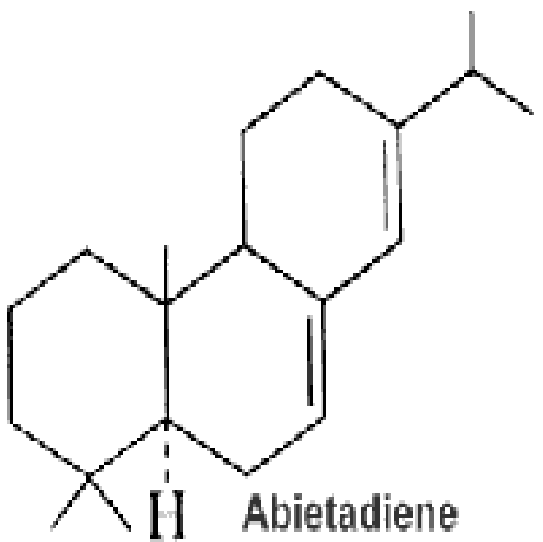
Geranylgeranyl phosphate



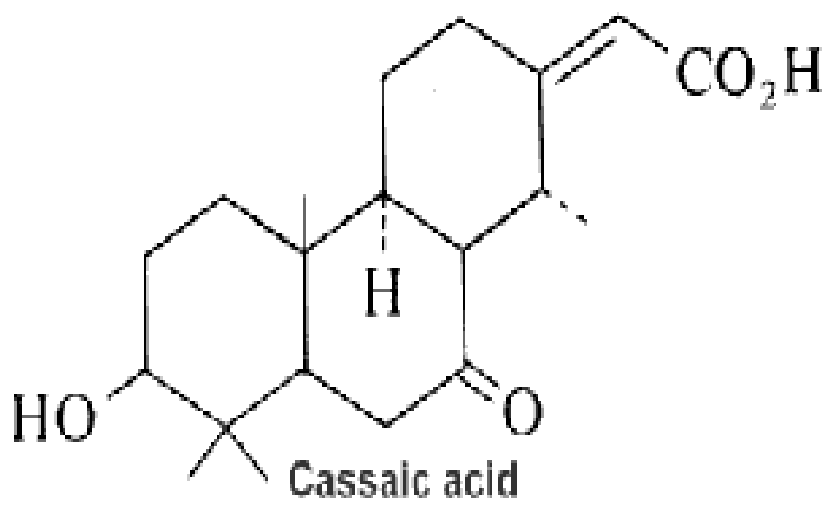
Cembrene



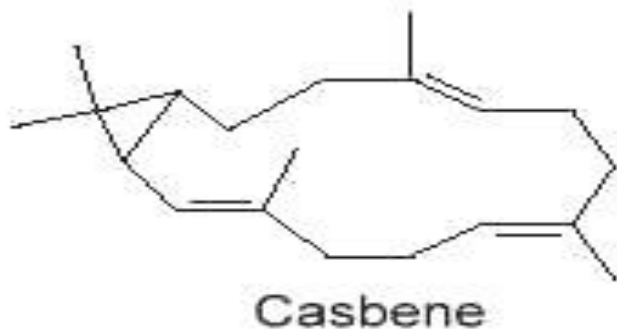
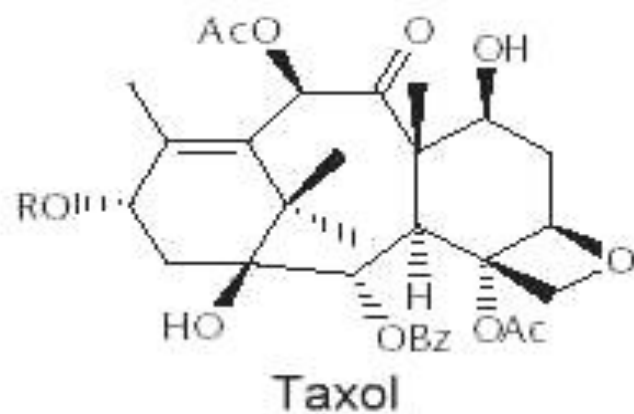
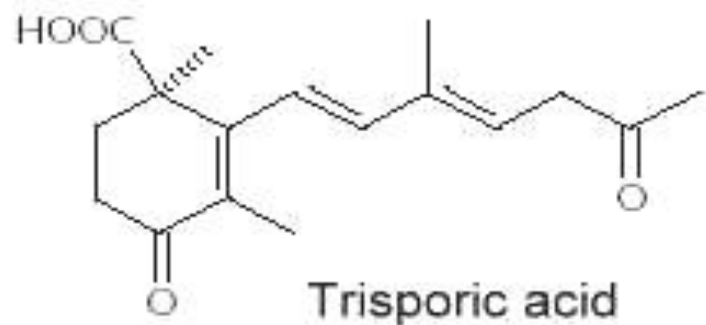
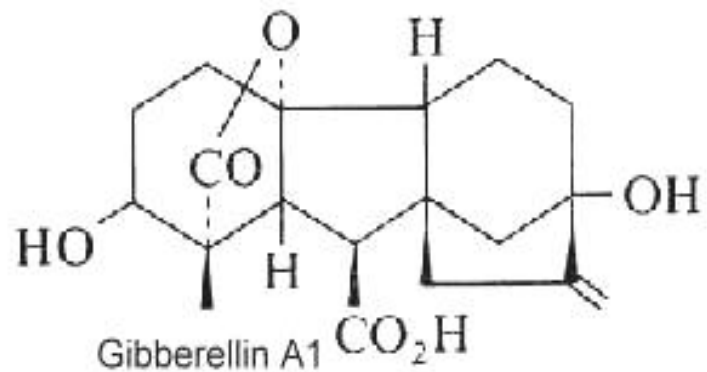
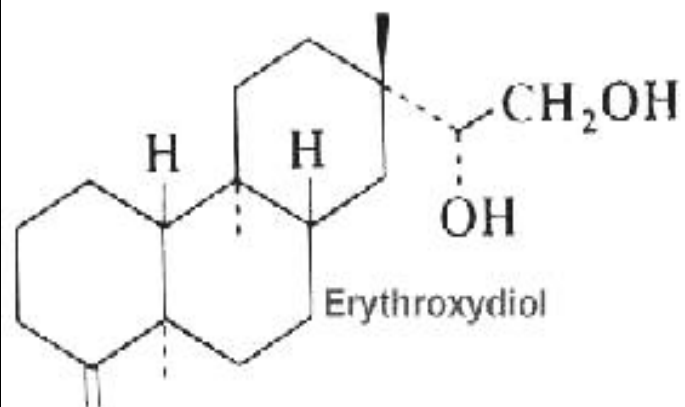
Taxisin



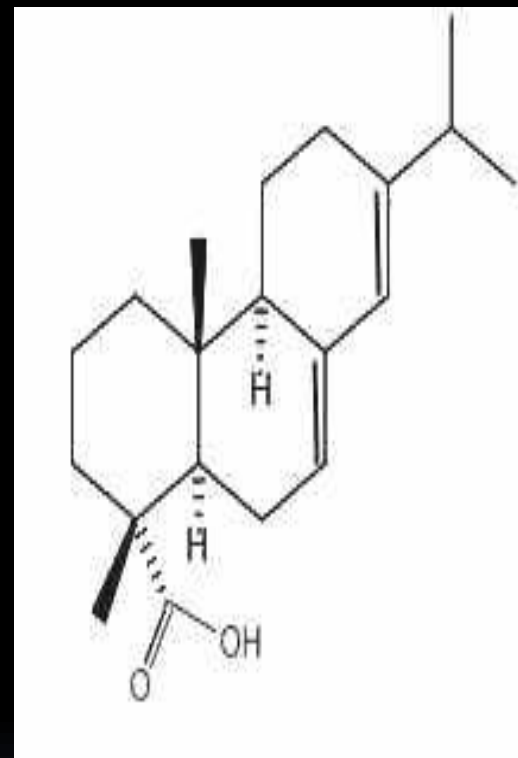
Abietadiene



Cassaic acid



- ❖ **Abietic acid** is an irritant compound present in pine wood (coniferous trees) and resin.
- ❖ It is mainly used to make and varnishes and metal resins.
- ❖ These resins are produced in reacting abietic acid (or a similar compound) with a metal salt (gold, indium, nickel, palladium, platinum, silver etc) and used in a wide variety of applications where high purity metals in organic solution form is needed viz. printing inks, vitrifiable colors, antifouling agent, dryers for paints and varnishes .

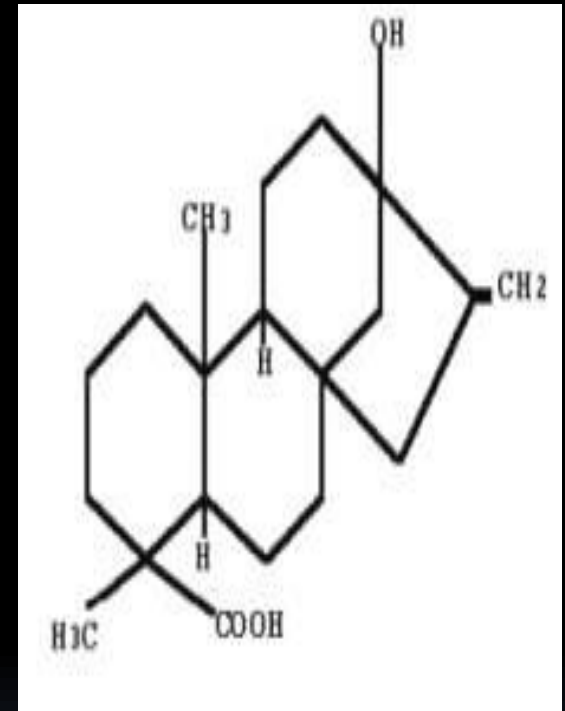


Abietic acid

❖ **Steviol** is the aglycone of **stevia's** **sweet** glycosides, one of them being formed by replacing one hydrogen atom (bottom) with glucose via an ester link, and another hydrogen atom (top) with a disaccharide (glucose and rhamnose).

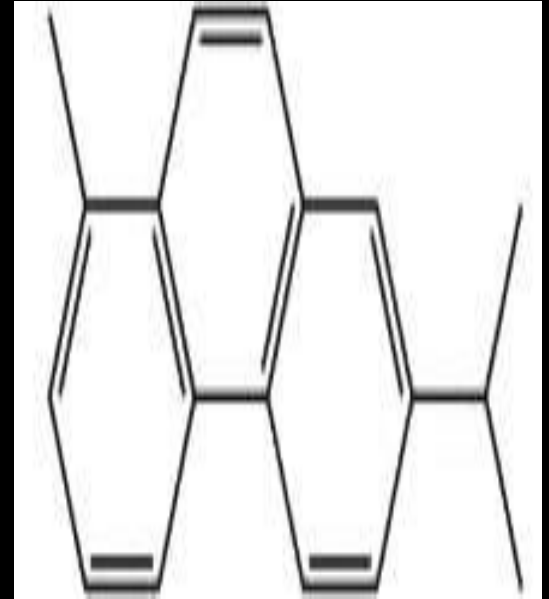
❖ The steviol glycosides are responsible for the sweet taste of the leaves of the *stevia* plant (*Stevia rebaudiana*, Asteraceae).

❖ These compounds are 40 to 300 times sweeter than sucrose. They are developed to be used in sweet drinks.



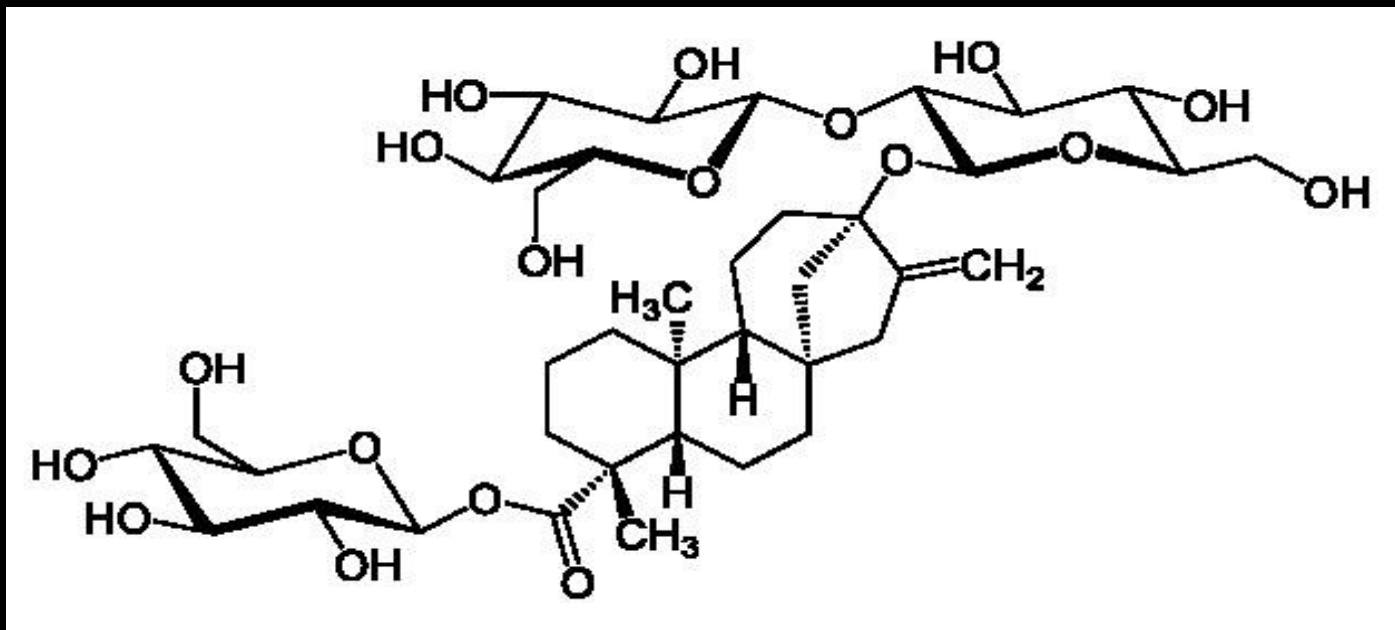
Steviol

- ❖ **Retene** is present in tars obtained by distillation of resinous wood, it is an important pollutant eliminated by the paper factories.
- ❖ This diterpene is present in geological sediment where it is formed by diagenesis from abietic acid, several intermediates having been recognized.
- ❖ Thus, with cadalene (sesquiterpene), retene, which is a diterpenoid dehydrogenation product, is used in paleobotany to estimate the importance of ancient pine forests.

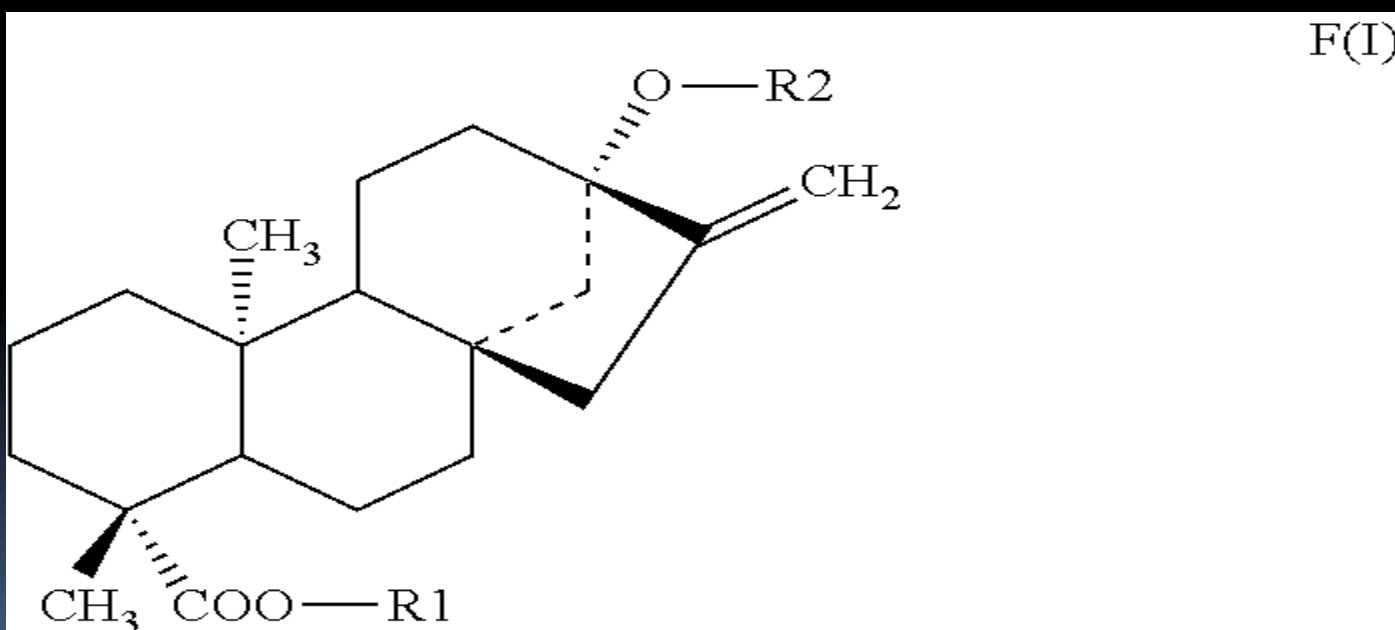


Retene

- ❖ **Gibberellins** are a family of compounds, over 130 members exist whose structures and occurrence can be found on the web.
- ❖ The most important in plants is **gibberellin A1** which is responsible for **stem elongation**.
- ❖ The most widely available compound is gibberellic acid.
- ❖ Among the physiological properties, gibberellins are involved in stem growth, seed germination and fruit setting and growth.

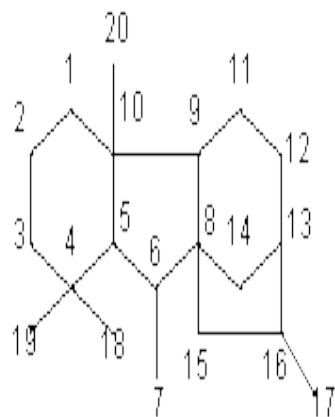


F(I)

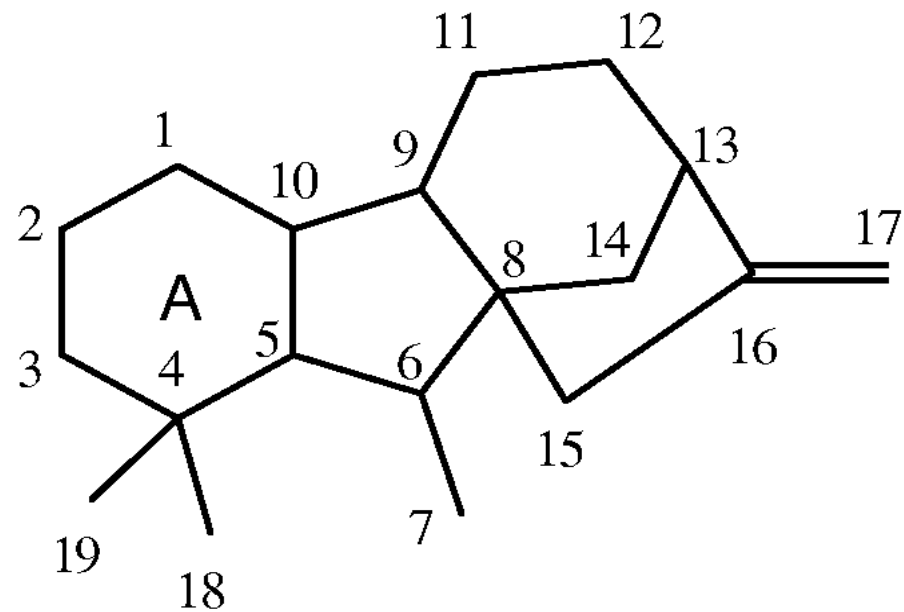


Steviol glycosides

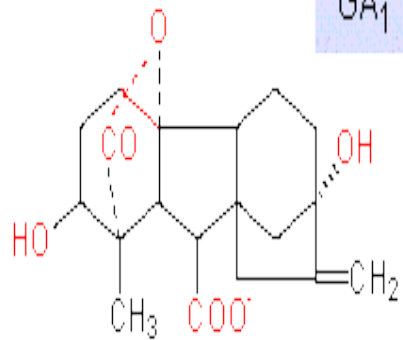
gibberelins



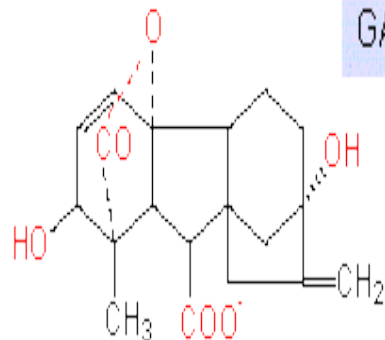
basic structure



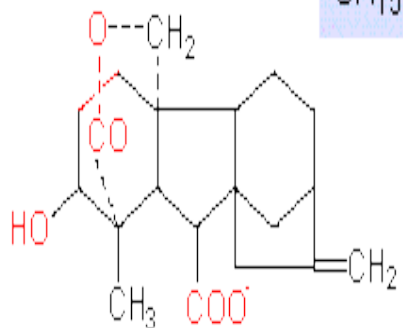
GA₁



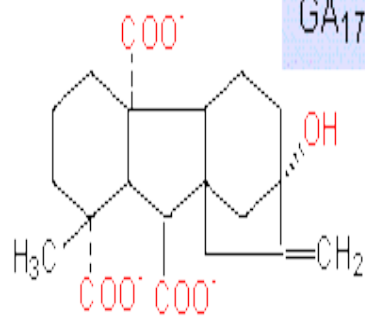
GA₃



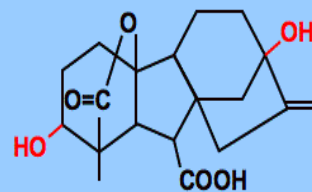
GA₁₅



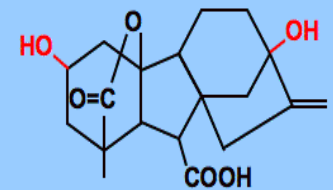
GA₁₇



Of the many gibberellins found to date, those with hydroxylation at the 2 position are functionally inactive



GA₁ is a more-polar active gibberellin

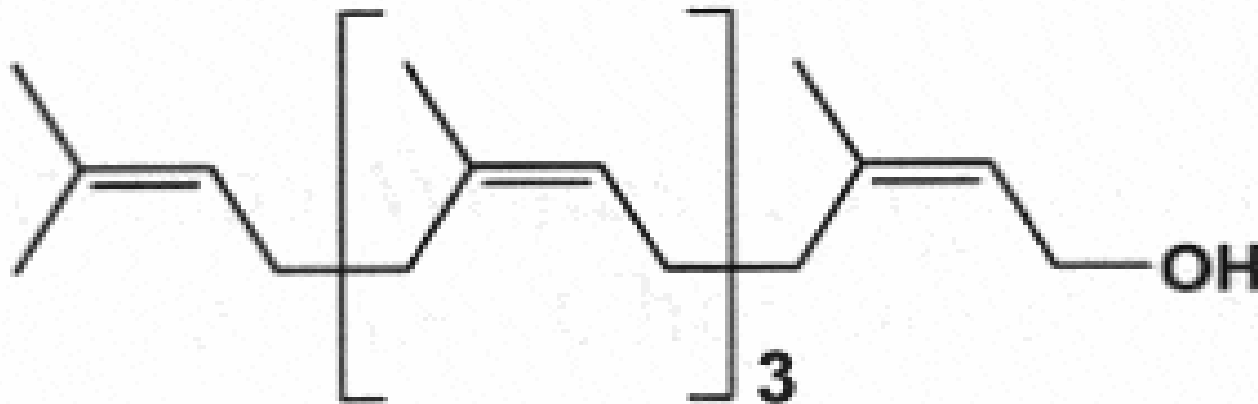


GA₂₉ is an equally-polar but inactive gibberellin

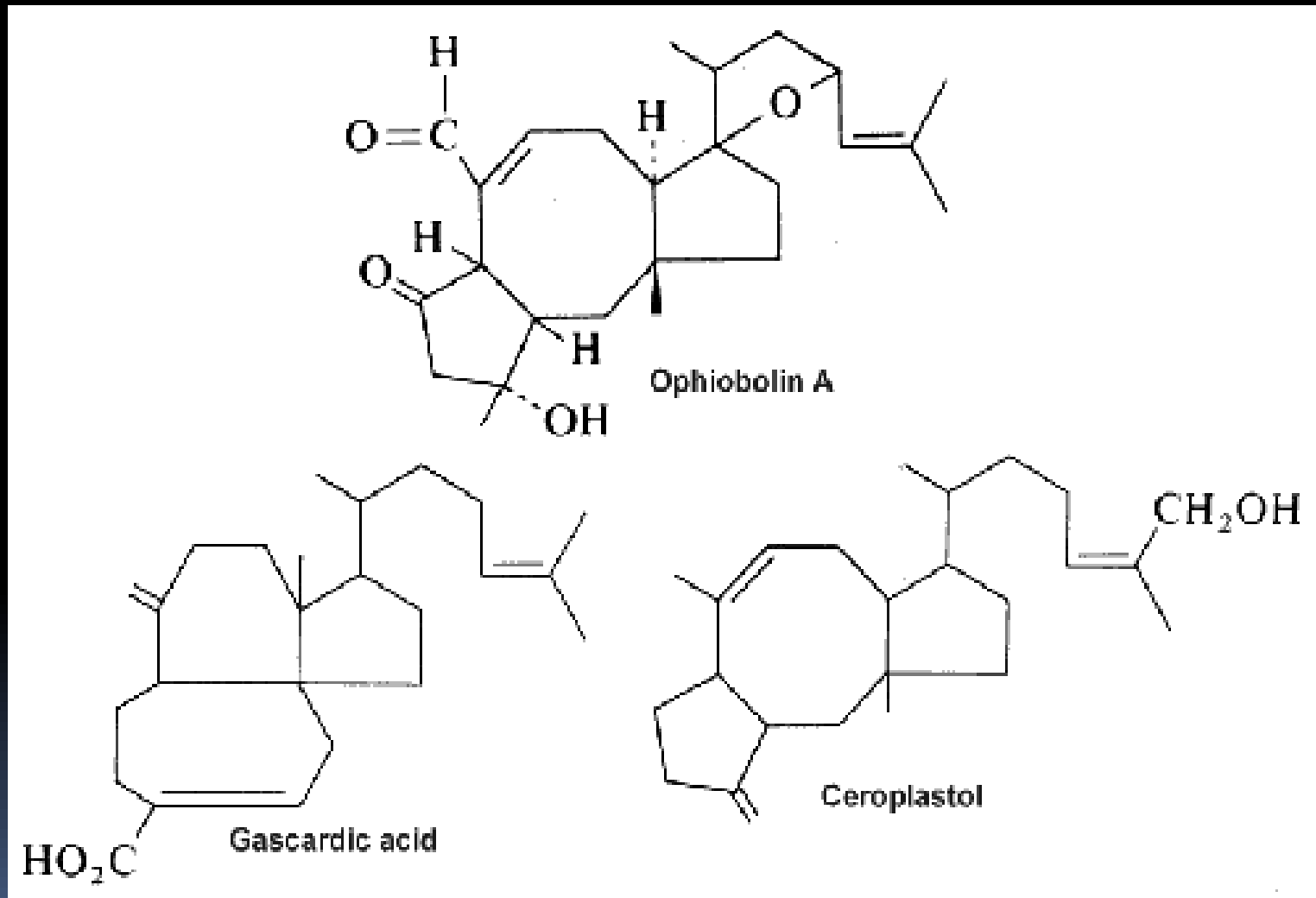
SESTERPENNOIDS

- ❖ They are derived from geranylarnesol pyrophosphate and have 25 carbon atoms. They were isolated from insect protective waxes and from fungal sources.

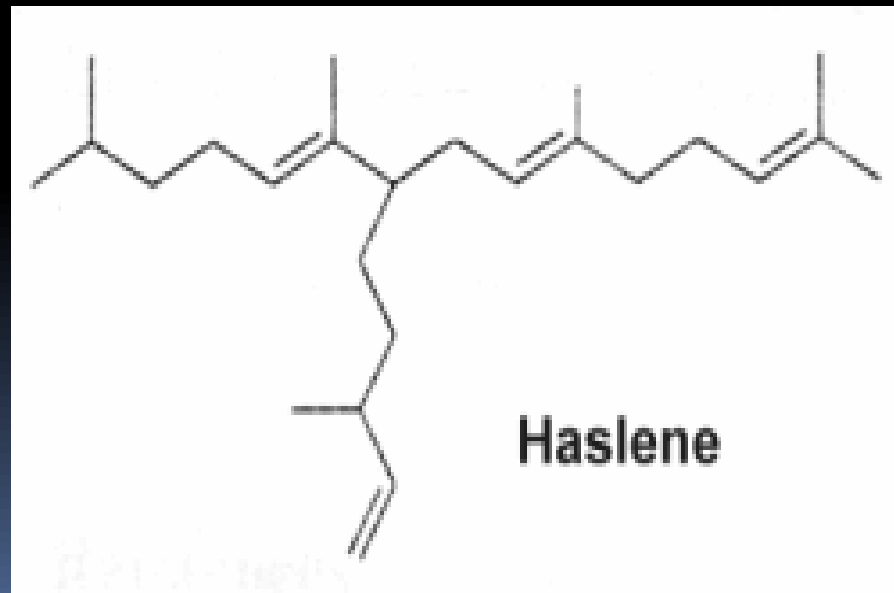
Geranylarnesol



- Three examples of sesterpenes are shown below.

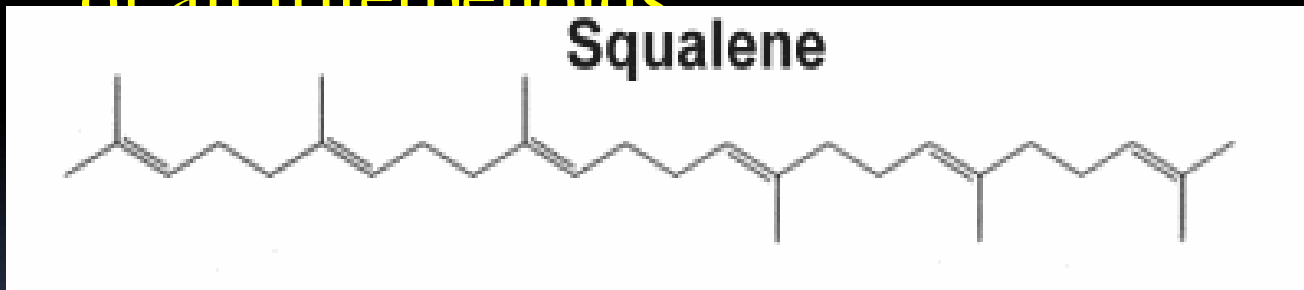


- ❖ Various unsaturated and branched sesterpenes, known as **Haslenes**, were found in species of diatomaceous algae.
- ❖ They are widely distributed and abundant in marine sediments, and were shown to have cytostatic properties.
- ❖ One of them is shown below.

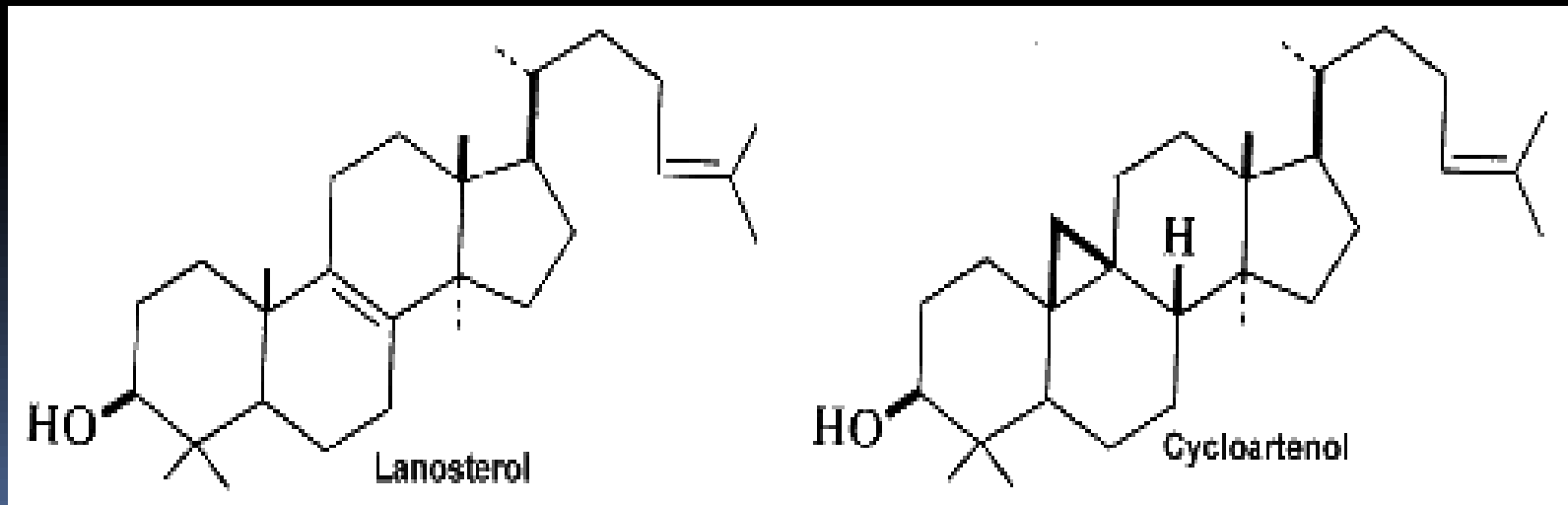
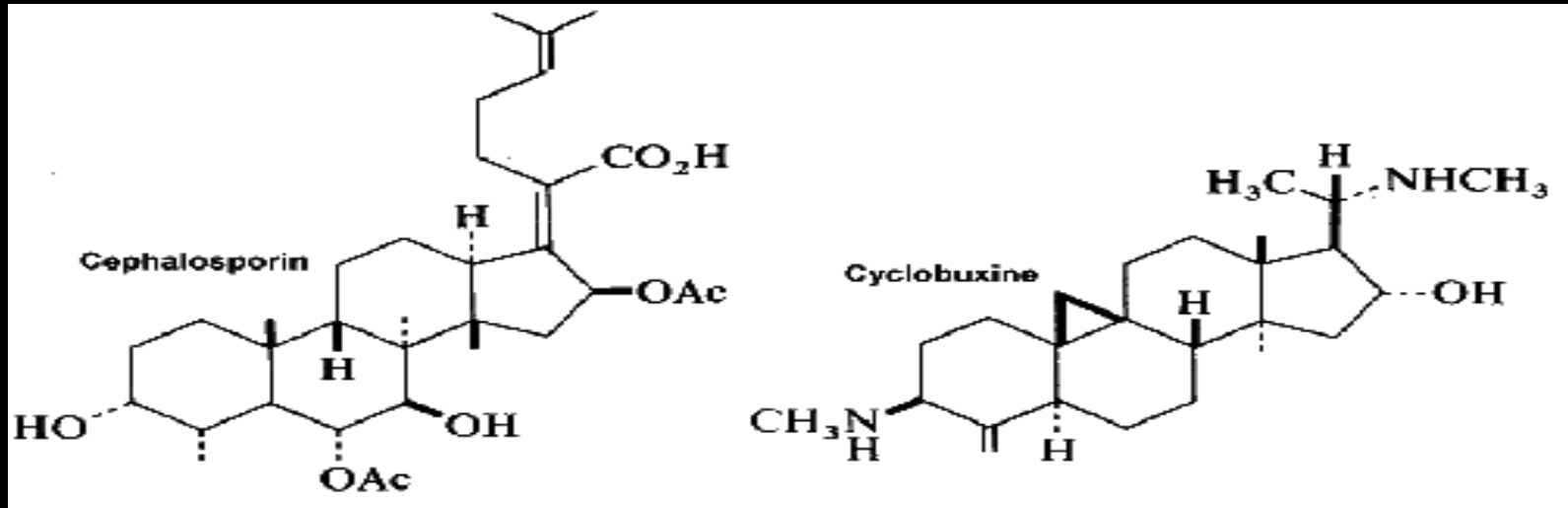


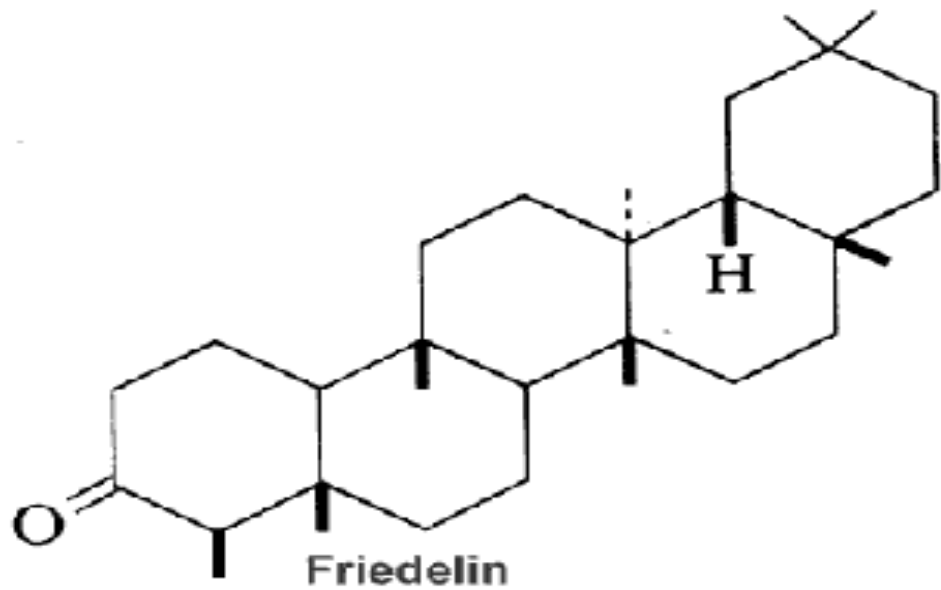
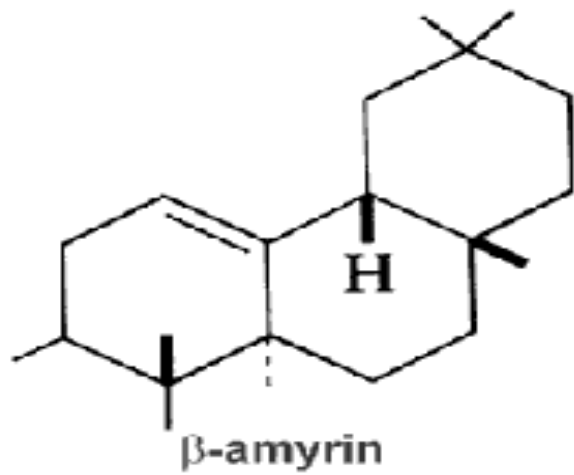
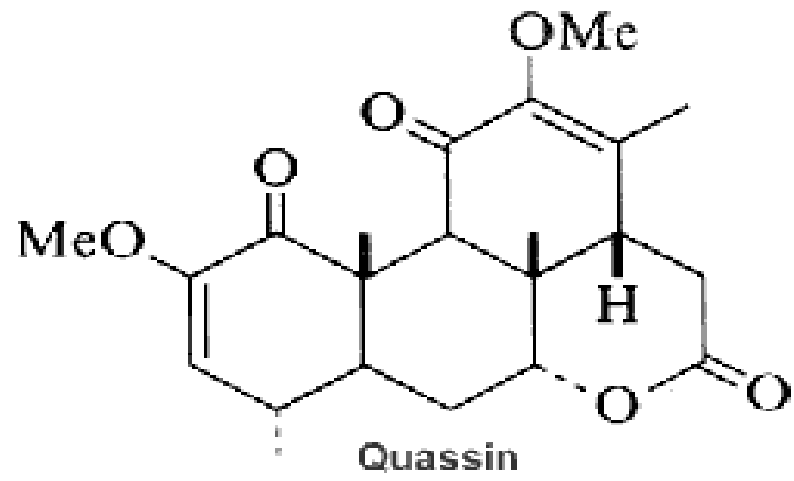
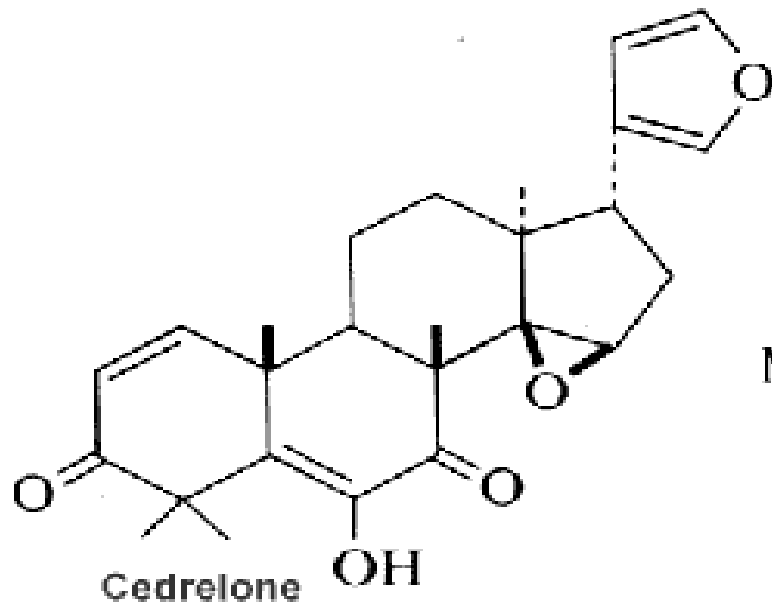
TRITERPENOIDS

- They form a large group of natural substances which includes steroids and consequently sterols.
- Squalene is the immediate biological precursor of all triterpenoids

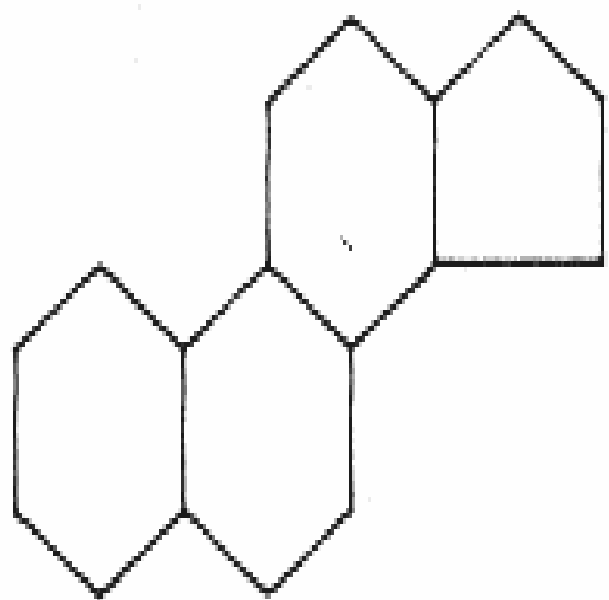


Among the large number of triterpenoid structures, some of them are shown below.

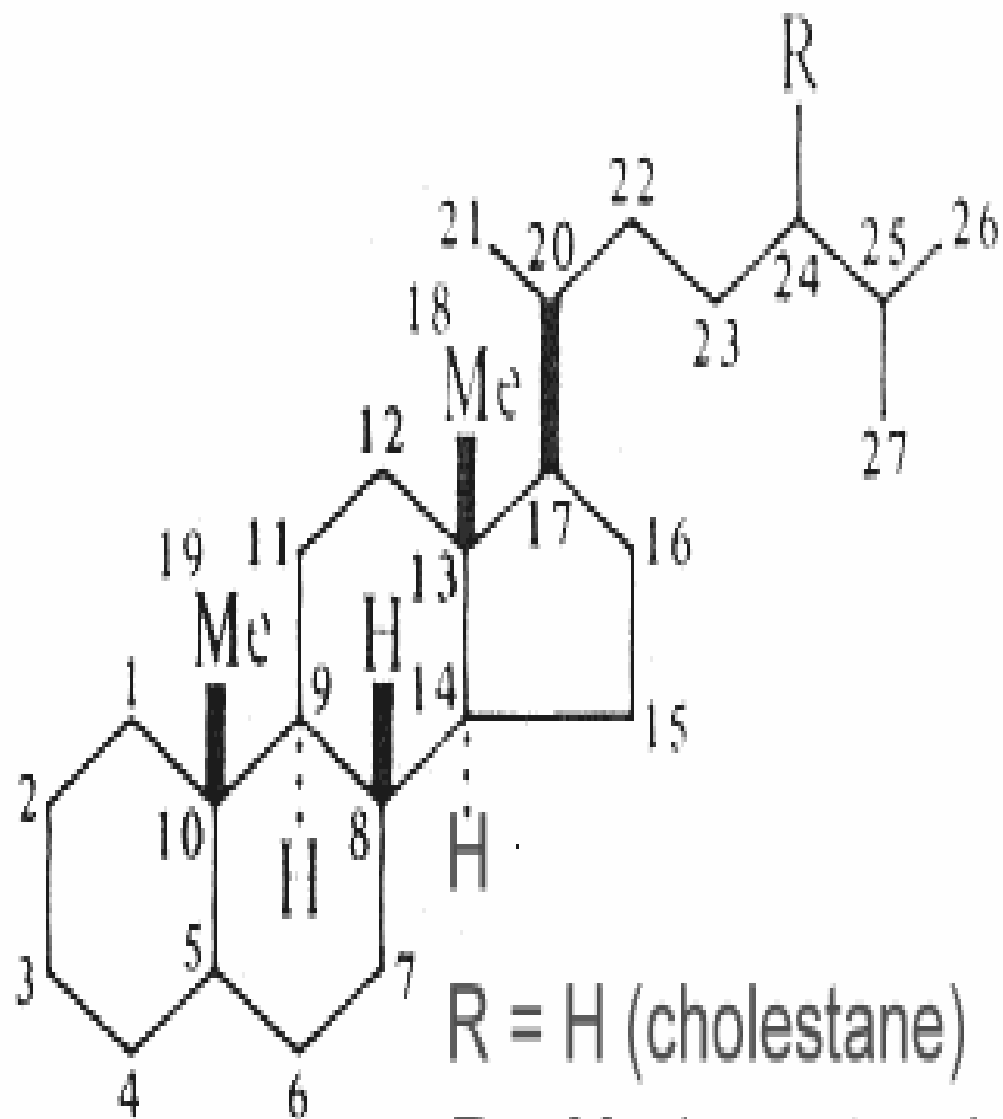




- ❖ **Steroids** are modified triterpenes which derived also from squalene by cyclization, unsaturation and substitution.
- ❖ The nucleus of all steroids is the tetracyclic C17 hydrocarbon 1,2-cyclopentanoperhydrophenanthrene (gonane or sterane) substituted by methyl groups at C10 and C13, as well as an alkyl side-chain at C17.
- ❖ Steroids may possess a nucleus derived from the former one by one or more C-C bond scissions or ring expansions or contractions. Gonane and three examples of basic unsubstituted steroids are shown below.



Gonane

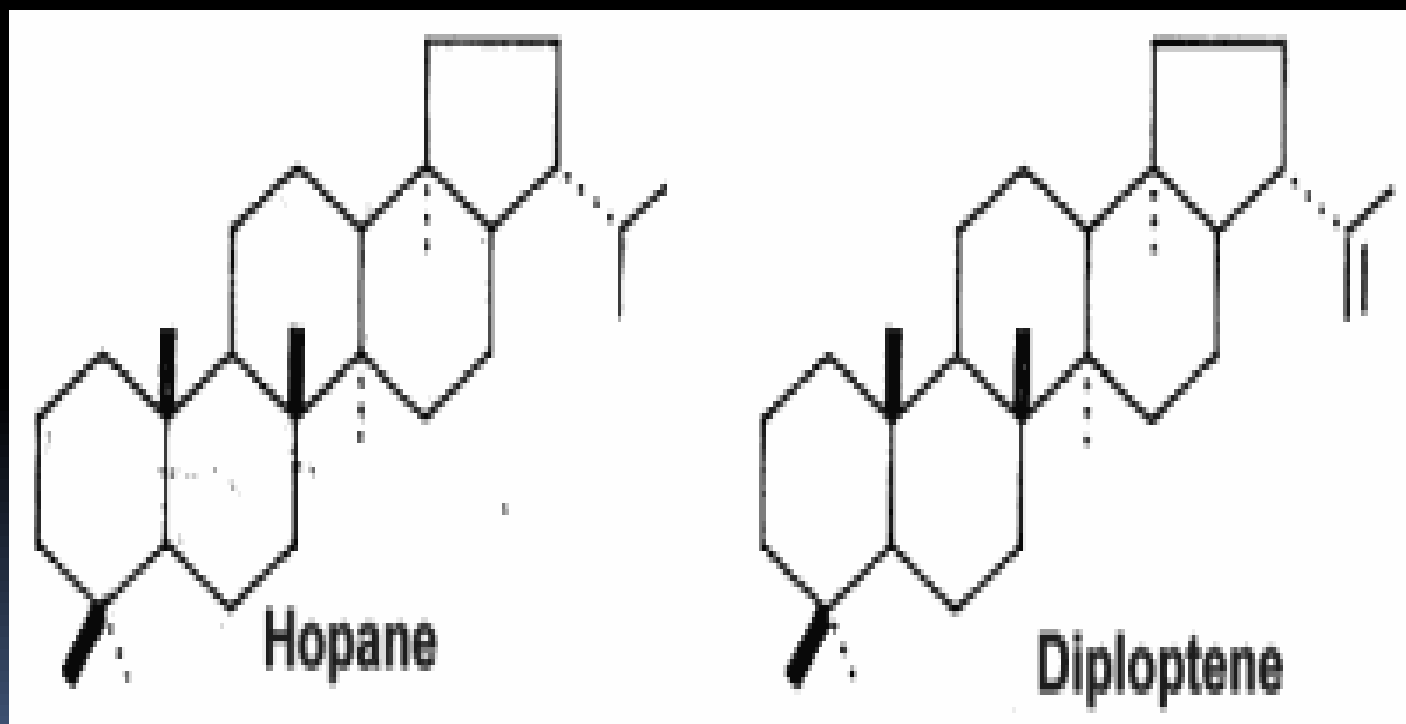


R = H (cholestane)

R = Me (ergostane)

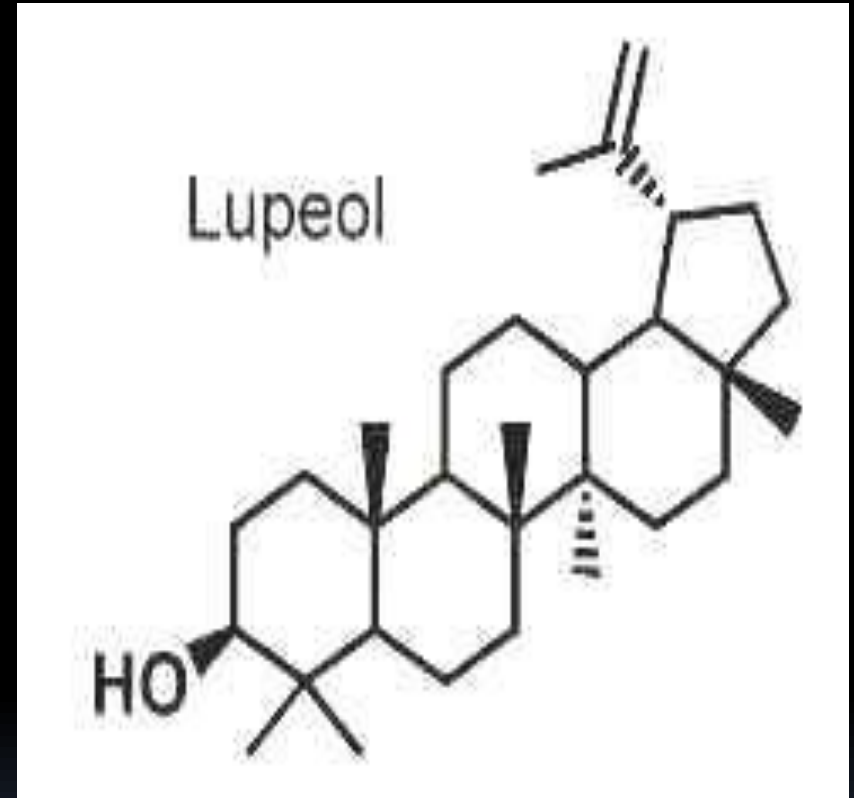
R = Et (stigmastane)

- ❖ The **hopanoids** are **pentacyclic triterpenoids** based on the **hopane** skeleton (with a five-membered ring E)
- ❖ The simplest C₃₀ hopanoid is **diploptene**.



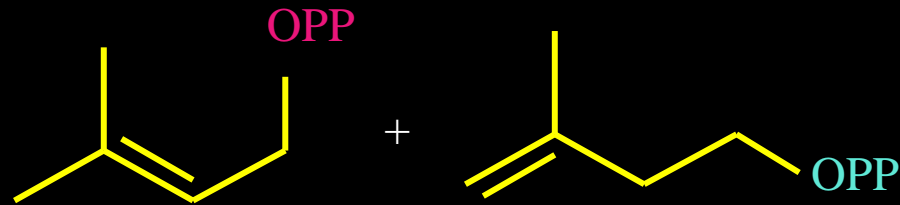
✘ Other pentacyclic triterpenoids based on the **lupane** skeleton include a very large number of naturally occurring members with different functional groups which are found in vegetables and fruit.

✘ Among them, **lupeol** is one of the most ubiquitous compounds.



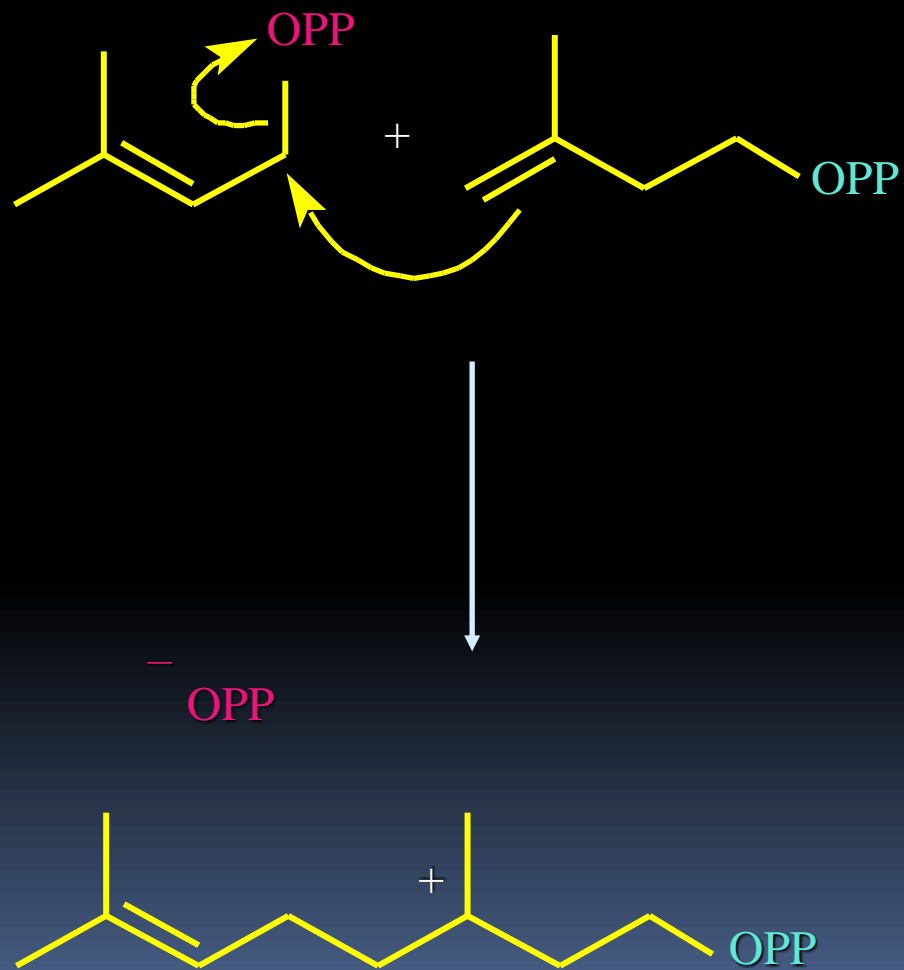
Terpene Biosynthesis

Carbon-Carbon Bond Formation

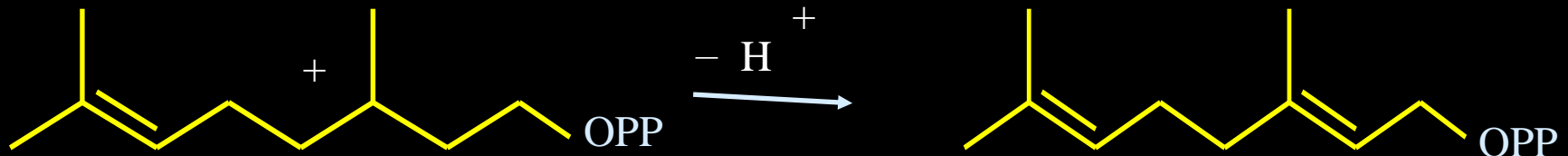


- The key process involves the double bond of isopentenyl pyrophosphate acting as a nucleophile toward the allylic carbon of dimethylallyl pyrophosphate.

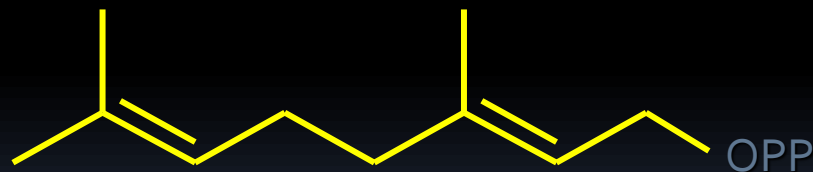
Carbon-Carbon Bond Formation



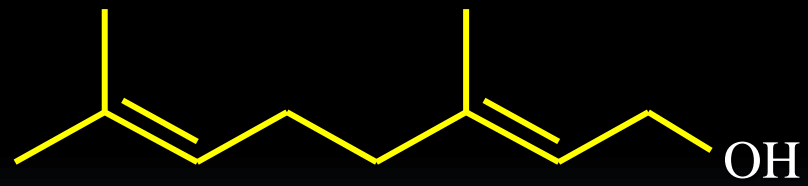
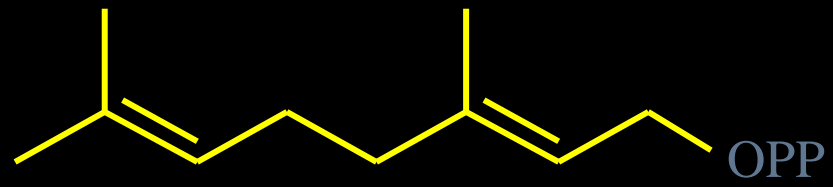
After C—C Bond Formation...



The carbocation loses a proton to give a double bond.

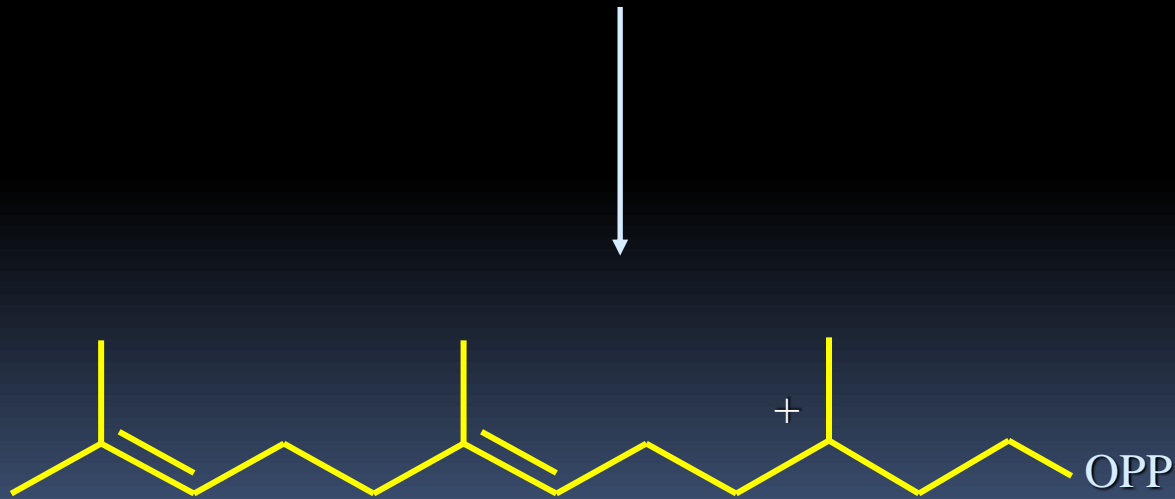
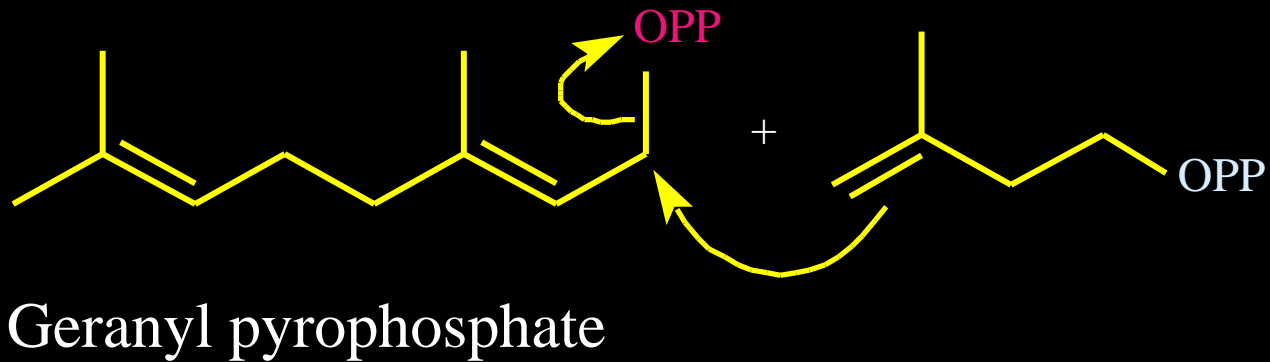


Geranyl pyrophosphate formed after loss of proton can undergo hydrolysis to give geraniol (rose oil).

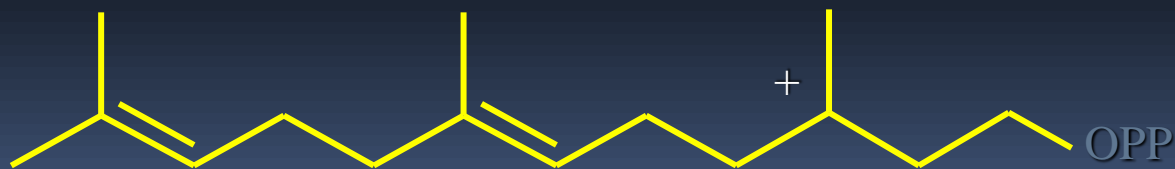
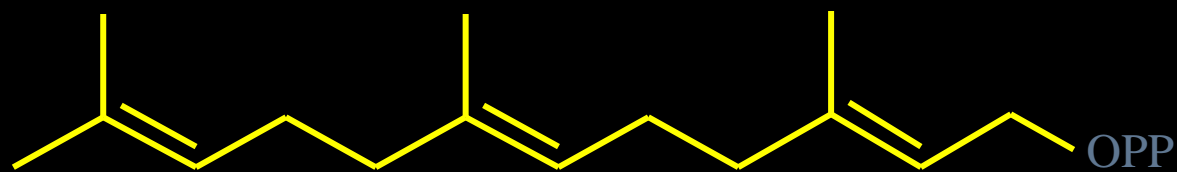


Geraniol

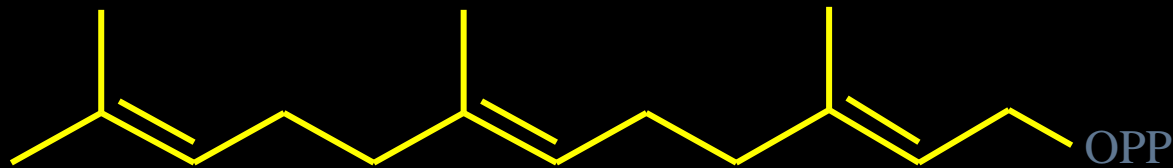
From 10C to 15 C



From 10 Carbons to 15

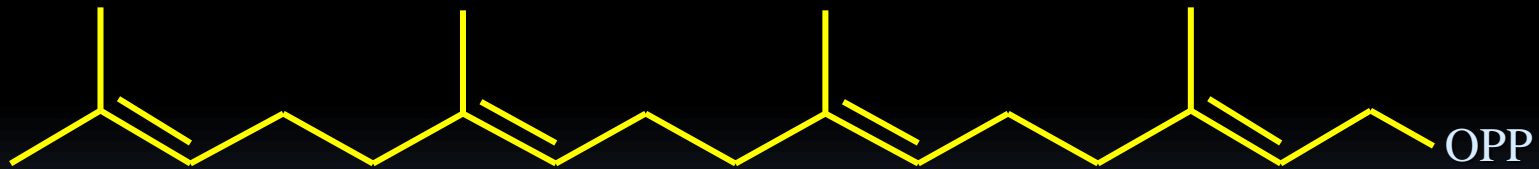
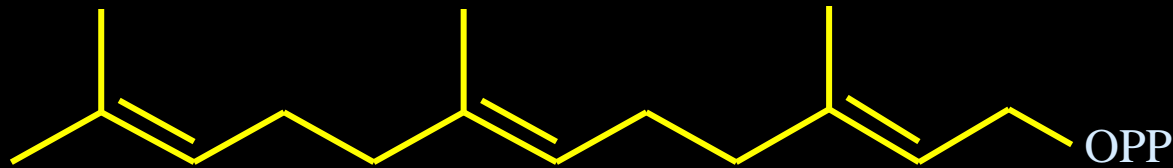


From 10 Carbons to 15



- This compound is called farnesyl pyrophosphate.
- Hydrolysis of the pyrophosphate ester gives the alcohol farnesol .

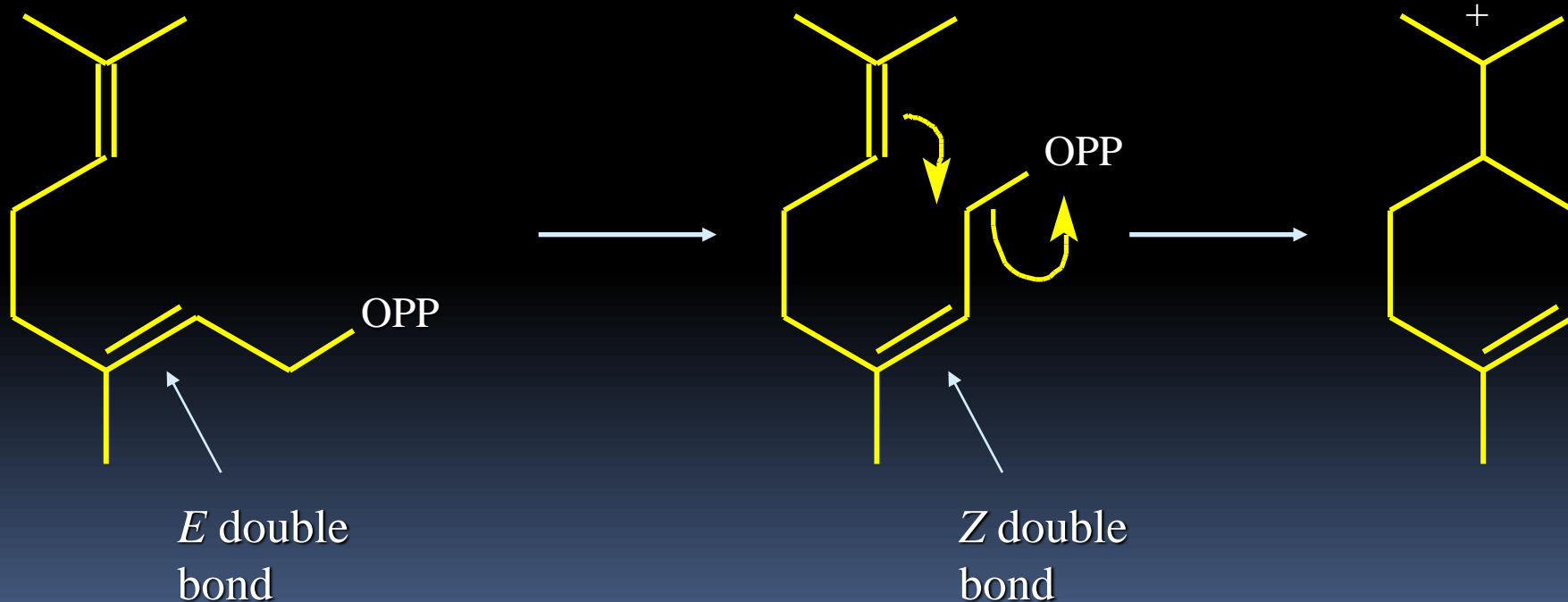
From 15 Carbons to 20



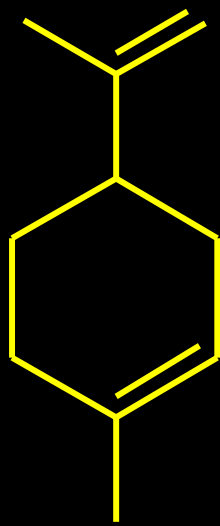
Farnesyl pyrophosphate is extended by another isoprene unit by reaction with isopentenyl pyrophosphate.

Cyclization

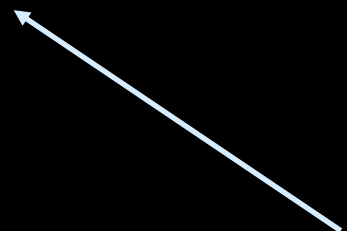
Rings are formed by intramolecular carbon-carbon bond formation.



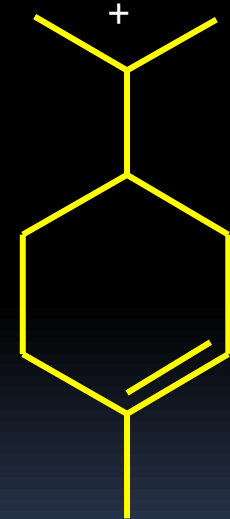
Limonene



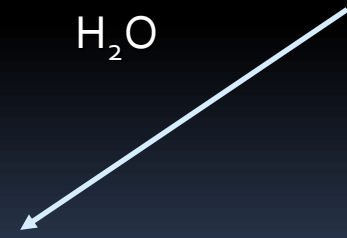
- H⁺



+



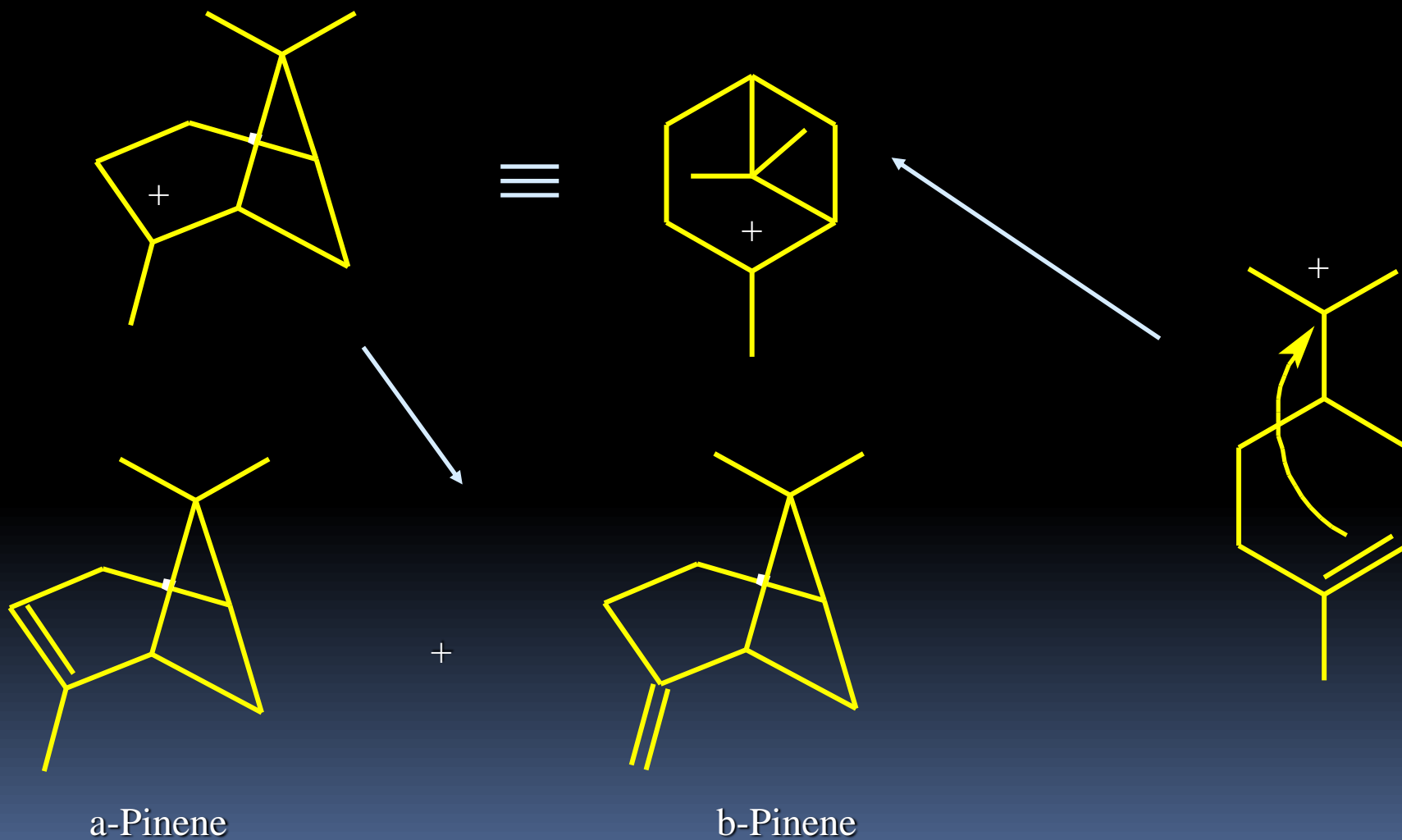
H₂O



α -Terpineol



Bicyclic Terpenes



Continued.....