

Definition: **C₁₀ and C₁₅ are volatile organic compounds derived from plants.** Terpenes are generally associated with characteristic fragrances. Some terpenes are alcohols (e.g., menthol from peppermint oil) and some terpenes are aldehydes (e.g., citronellal). Terpenes are made up of isoprene (C₅) units.

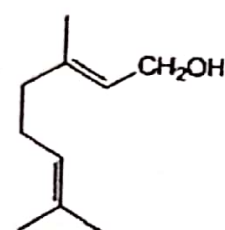
Examples: nepetalactone from catnip, limonene from lemon oil, zingiberene from ginger

Classification of Terpenes

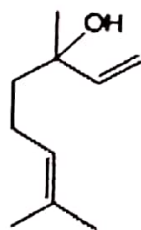
Terpenes classification is based on number of isoprene units linked together in a head to tail fashion. They are classified [8] as monoterpenes, sesquiterpenes, diterpenes, triterpenes, tetraterpenes, polyterpenes etc. prefix represents the number of isoprene unit present in a molecule.

Monoterpenes

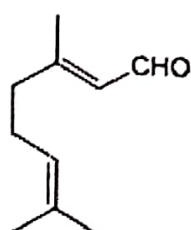
They consist of two isoprene units and have the molecular formula $C_{10}H_{16}$. They are volatile natural products found in higher plants as essential oils and are widely used in perfumery and flavoring industries. For example, geraniol is a main constituent of geranium oil (*Pelargonium graveolens*) and its isomer linalool is found in the oil of a garden herb, clary sage. Citral, a lemon oil component, is extracted from lemon grass oil (*Cymbopogon flexuosus*). Menthol is isolated from *Mentha arvensis*. It has significant commercial values and is widely used to flavor sweets, tobacco and toothpaste. It is also used for local anaesthetic and refreshing effects.



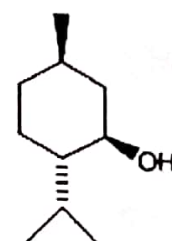
Geraniol



linalool

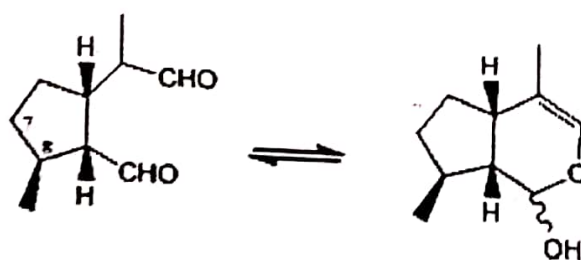


Citral



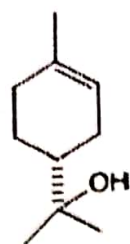
Menthol

Moreover, highly oxygenated monoterpenoids such as iridodial are found in ants and exist in equilibrium with its hemiacetal form [9].



iridodial

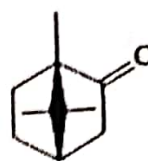
The pine oil (turpentine) contains two monoterpenes viz. terpineol and α -pinene. Camphor was extracted from camphor tree, *Cinnanomum camphora*. It is used to protect cloths from moths. At present, α -pinene is a raw material for the commercial synthesis of camphor. Some of the other examples such as myrcene, limonene, citronellal, are also monoterpenes.



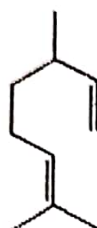
terpineol



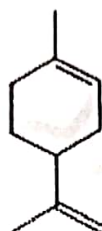
α - Pinene



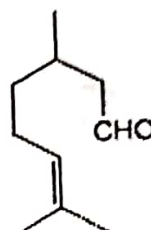
camphor



myrcene



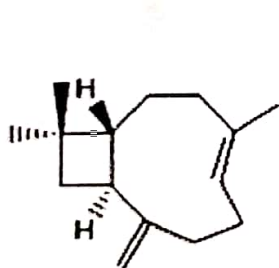
limonene



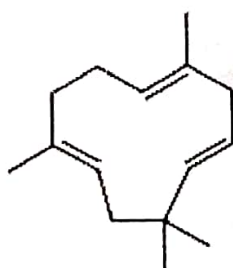
citronellal

Sesquiterpenes

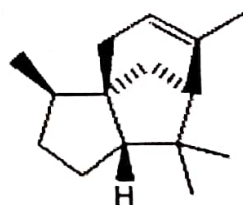
Sesquiterpens are also generally obtained from the essential oils but from higher boiling point fractions. It contains three isoprene units and has molecular formula $C_{15}H_{24}$. For example Caryophyllene from oil of cloves, humulene from oil of hops, cedrene from cedar wood oil and longifolane from Indian turpentine oil (*Pinus ponderosa*).



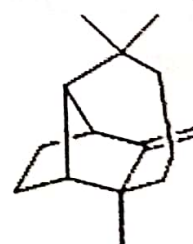
caryophyllene



humulene

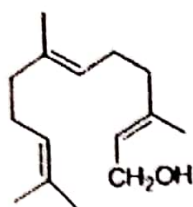


cedrene

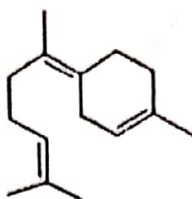


longifolane

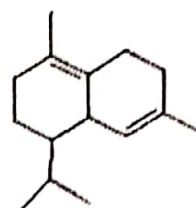
There are some other examples of sesquiterpenes such as farnesol, bisabolene, cadinene, selinene, vetivone, and antibiotic pentalenolactone etc.



farnesol

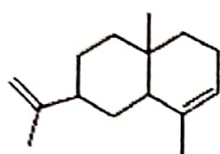


bisabolene

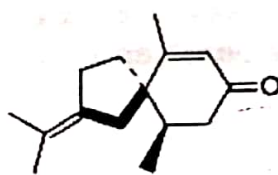


cadinene

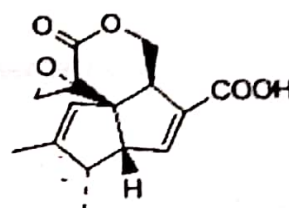
α - Terpinolene
(Bingele)



selinene

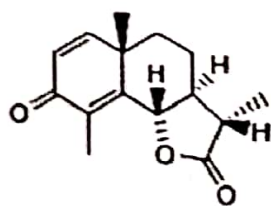


vetivone

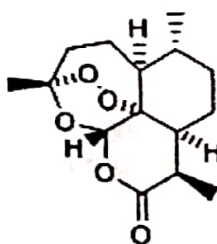


pentalenolactone

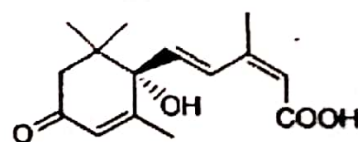
Sesquiterpenoid lactones such as santonin from *Artemisia maritima* (warm wood) and artemisinin obtained from *Artemisia annua* are commonly used as medicine. Absciscic acid, a plant hormone is also an example of sesquiterpenoid. It stimulates leaf fall and dormancy in plants.



santonin



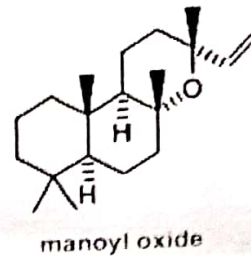
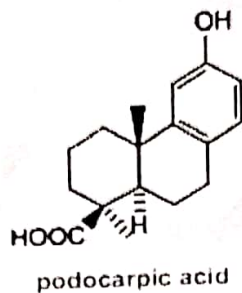
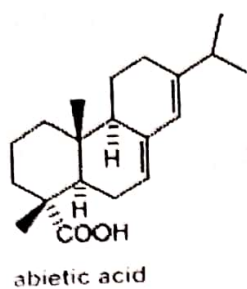
artemisinin



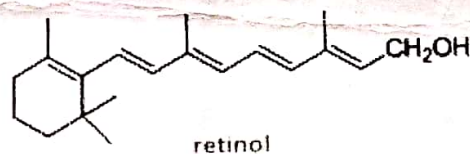
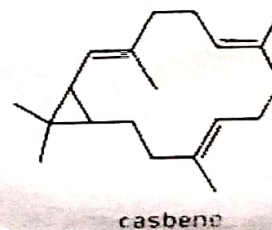
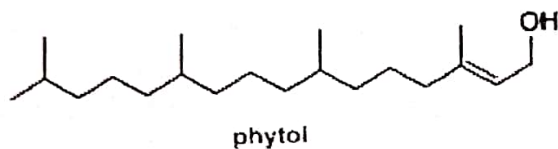
Absciscic acid

Diterpenes

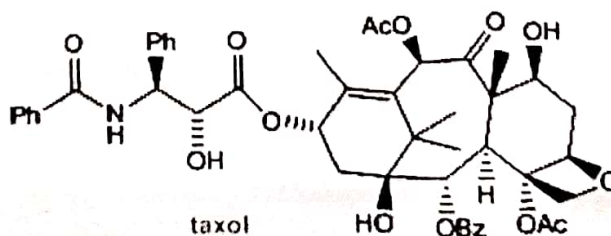
Diterpenes are composed of four isoprene units having general molecular formula $C_{20}H_{32}$. Some of the diterpenes are wood resin product. For example, abietic acid (from *Pinus* and *Abies* species), podocarpic acid (from *Podocarpus cupressinum*) and neutral resin manoyl oxide.



Biologically active compounds such as phytol, vitamin A (Retinol) and casbene (phytoalexin) can also be considered as diterpenes.

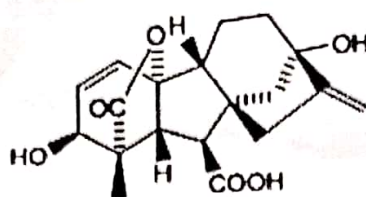


Taxol or paclitaxel is a diterpenoid, which was first isolated from the bark of the Pacific yew, *Taxus brevifolia* [10]. It is widely used in the treatment of breast and ovarian cancer.



Plant hormone, gibberellic acid is a diterpenoid which is synthesized as a phytotoxin by the fungus *Gibberella fujikuroi*. It is used in the malting step in

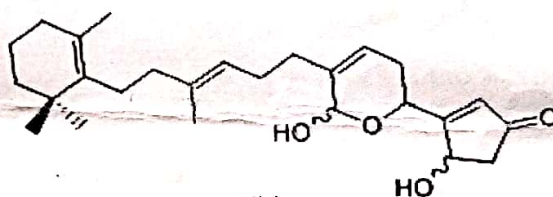
beer manufacture to increase α -amylase production and also for growing of seedless grapes.



gibberellic acid

Sesterterpenes

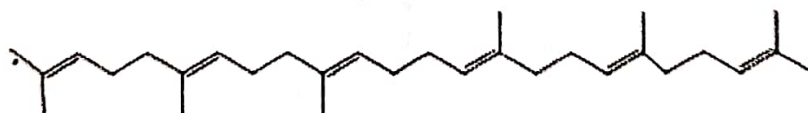
It contains five isoprene units and it has molecular formula $C_{25}H_{40}$. Sesterterpenes are most abundant in marine sponges. Manoalide was first discovered in 1980 by Scheuer from the marine sponge *Luffariella variabilis* [11]. It showed antibacterial activity against *Streptomyces pyogenes* and *Staphylococcus aureus*.



manoalide

Triterpenes

Triterpenes contain six isoprene units having molecular formula $C_{30}H_{48}$. Squalene is a simple linear triterpene which was first isolated from fish liver oil.

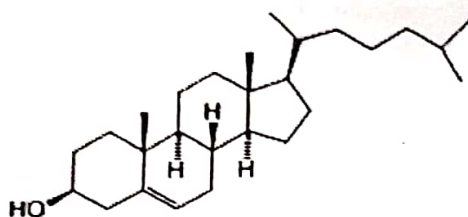


Squalene

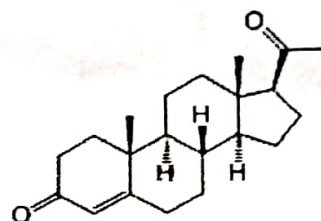
Subsequently, it is been reported from plant oils, and mammalian fats. Most of the members of this category contain tetracyclic structure.

The cyclopentaperhydrophenanthrene backbone is common skeleton of all

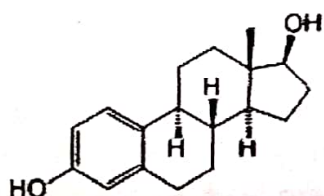
steroids which belongs to the category of tetracyclic triterpens. Cholesterol is an important constituent of lipid membranes. Female steroid hormones such as progesterone, estradiol and male hormone testosterone also belongs to triterpenes.



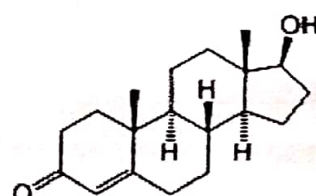
cholesterol



progesterone

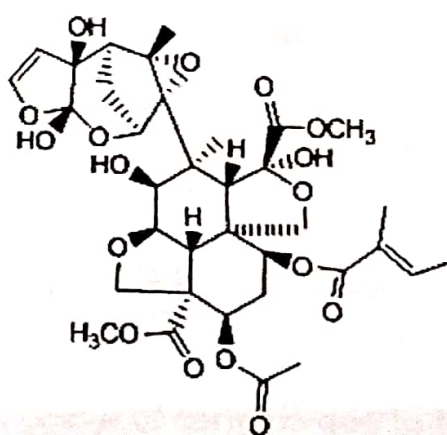


estradiol



testosterone

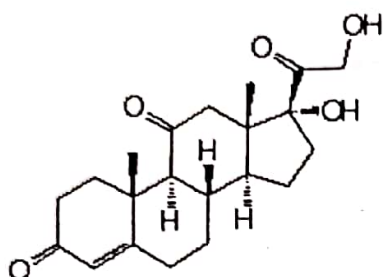
Azadirachtin from *Neem* tree is highly oxidized tetranortriterpenoid which shows strong insect anti-feedant and growth inhibitor activity [12].



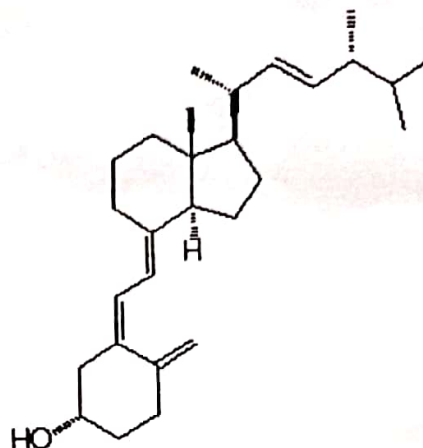
azadirachtin

Moreover, cortical steroids (e.g. cortisone) are also triterpenes which have an immunosuppressive activity and reduce inflammation. They are used in

the treatment of asthma, rheumatoid arthritis etc. Vitamin D helps in the absorption of calcium and phosphate from gastrointestinal.

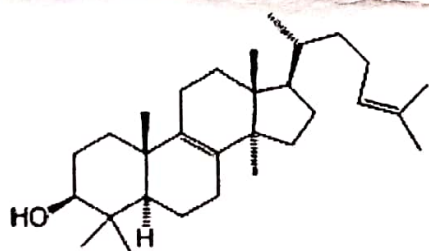


cortisone

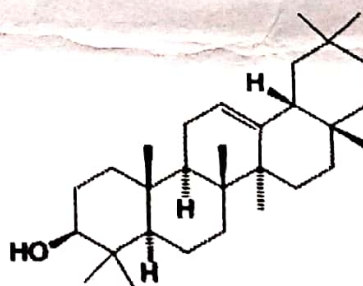


vitamin D

Lanosterol, a tetracyclic triperene is present in wool fat and its ester are present in lanolin cream while the α - and β -amyrins are commonly found in wood resins and the bark of many trees.



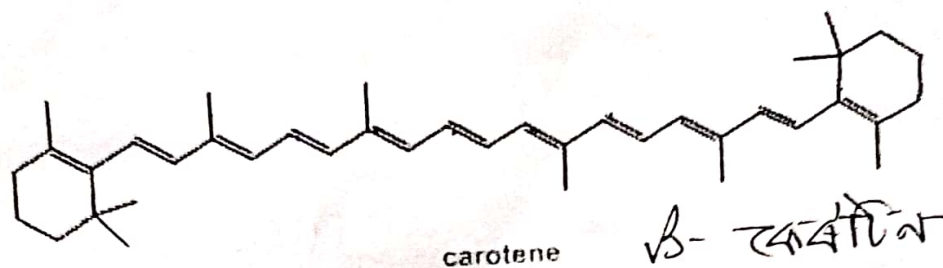
lanosterol



β - amyrin

Tetraterpenes

It is composed of eight isoprene units having molecular formula $C_{40}H_{56}$. Some of the biologically active compounds like lycopene, monocyclic γ -carotene and bicyclic α and β -carotenes are common examples of tetraterpenes. Thus, the red colour of carrot is due to the presence of β -carotene while the deep-red pigment of tomato is due to the presence of lycopene. The carotenoids possess anti-oxidants properties. Moreover, carotenoids are precursors of vitamin A, which has vital role in vision process.



Polyterpenes

Polyterpenes are polymer in which several isoprene units are joined through head-to-tail fashion. Natural rubber (*Heva brasiliensis*) is best known example of this series.

