HERBAL ACTIVES

terpenes and terpenoids

functions and signaling actions
of the isoprenoid plant compounds

Lesson #2

a very large group

Terpenes, also known as terpenoids when modified by oxygen, are the largest and most diverse group of naturally occurring compounds in nature, formed primarily in plants.

Terpenes have a wide range of medicinal uses, including antiviral, antimicrobial, anti-inflammatory, antioxidant, anticancer, antiseptic, astringent, digestive, and diuretic properties.

Because they play a significant role in the therapeutic constituents of plants and plant oils, we will examine the group as a whole to lay the groundwork to study individual compounds commonly found in healing herbs and plants.

terpenes

Much of the recent research on terpenes is for the cannabis industry because of the powerful healing potential; however, this is just a small aspect of their power and use in herbalism.

Found in all parts of nature, including plants, animals, humans, and bacteria, they exhibit a range of active properties that vary by size and differ from one another.

Built up of isoprene units, two, three, four, six, and eight isoprene units are the molecular root of all terpenes.

The diterpenes, tri-terpenes, and tetra-terpenes in the accompanying chart provide an overview of the relationships between the isoprene compounds.

isoprene

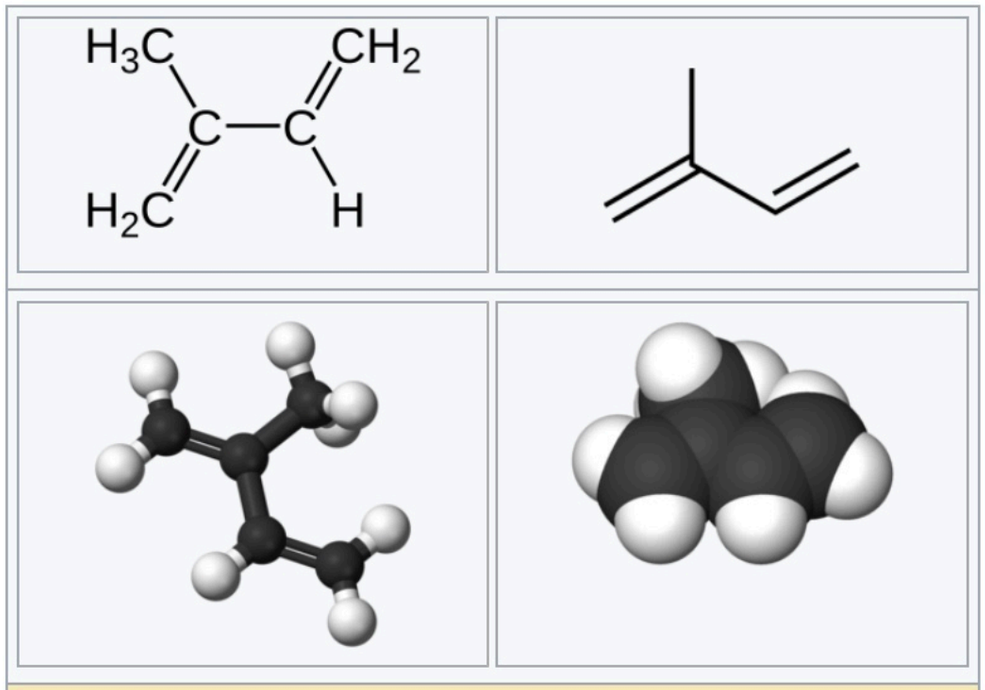
Isoprene is a common volatile organic compound that is colorless and is the root of the isoprenoid family of compounds.

An isoprene has a basic formula of C5H8, and can be known as a terpene or a terpenoid.

These isoprene units of five carbon atoms combine and form from one up to eight isoprene units, each with differing characteristics.

The smallest, two and three-isoprene units, are truly volatile and found in the essential oils, while the larger combinations, four, six, and eight, become resins, lipids, and oil-soluble vitamins, and are non-volatile.

Isoprene



Names	
IUPAC name	Isoprene
Preferred IUPAC name	2-Methylbuta-1,3-diene
Other names	2-Methyl-1,3-butadiene
Identifiers	
CAS Number	78-79-5 ✓

Terpenes & Terpenoids

- Both terpenes (CH) and terpenoids (CH+O2) are **present in ALL parts of the plant.**
- Built from repeating isoprene units consisting of five hydrocarbons (C5H8).
- Terpenes can be highly aromatic, the smaller volatile ones making up the essential oils while larger ones are found in the fixed oils.

Small volatile compounds:

Isoprene unit **1 isoprene unit** 5 carbon atoms basic unit 5C - (C5H8)

Monoterpenes **2 isoprene units** 10 carbon atoms essential oils, limonene, geraniol, thymoquinone, pinene, myrcene, linalool, camphene,

Sesquiterpenes **3 isoprene units** 15 carbon atoms essential oils, farnesol, bisabolol, caryophyllene, cedrene, zingiberene, farnesene

Larger non-volatile compounds:

Diterpenes **4 isoprene units** 20 carbon atoms (neutral color) Resins, Retinol (vitamin A_1), Retinal, Retinoic acid, Retinyl esters, Carnosic acid, Pine resin, Abietic acid, Phytol, Cafestol, Kahweol, Taxodione

Triterpenes **6 isoprene units** 30 carbon atoms (clear, waxy, or white) **Squalene**, Ursolic acid, Oleanolic acid, Betulin, Betulinic acid, Asiaticoside, Faradiol esters, Madecassoside, α & b-Amyrin, Taraxasterol, Shottenol, Spinasterol, Cycloartenol, Lupeol, Saponins, **Phytosterols**: Stigmasterol, β-Sitosterol, Campesterol, Brassicasterol, Δ5-Avenasterol, Δ7-Stigmastenol

Tetraterpenes **8 isoprene units** 40 carbon atoms (brightly pigmented, red, orange) **Carotenoids, β-Carotene, Lutein, Lycopene, Astaxanthin, (pro-vitamin A)** Tocotrienols, Abscisic acid (ABA), Strigolactones, Bixin and Norbixin, Crocetin, Corcins

terpenes to terpenoids

A terpene is a pure hydrocarbon, consisting of only carbon and hydrogen. Shown is a simple hydrocarbon, CH4. Squalene is also a hydrocarbon.

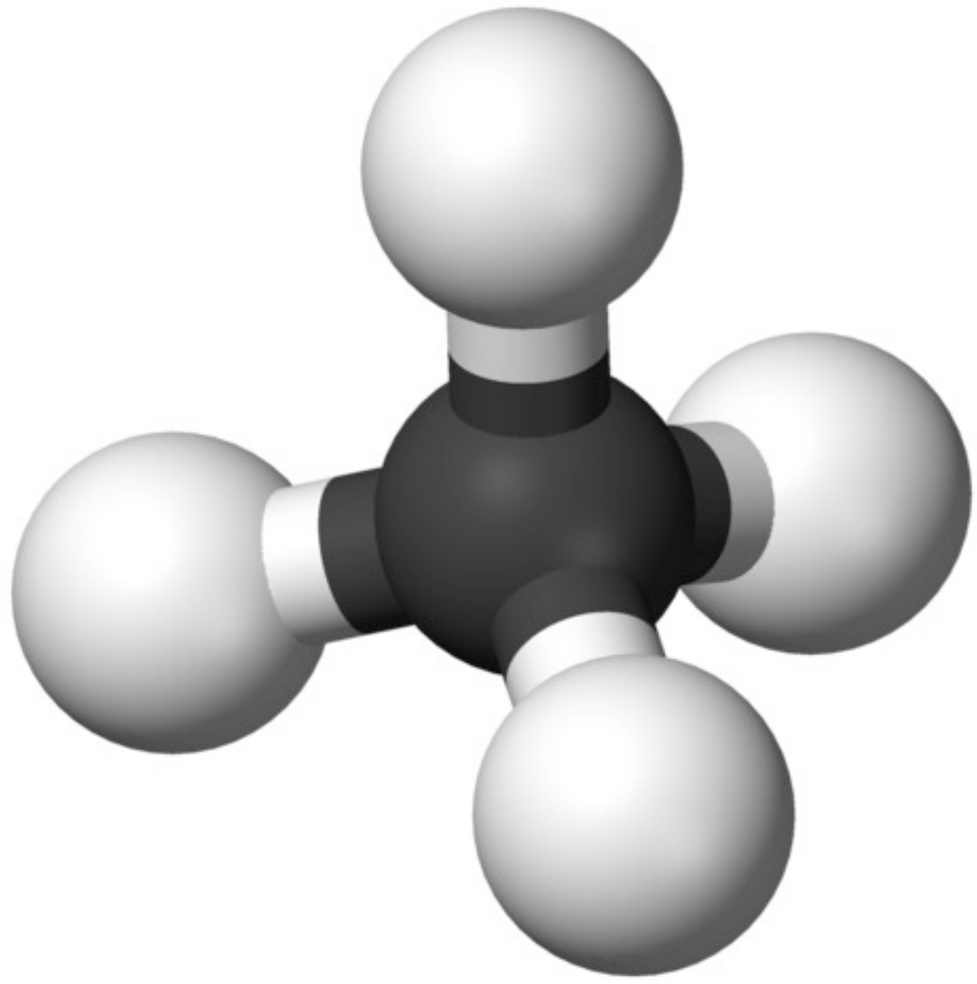
Terpenes transform into terpenoids when the compound has been modified by adding an **oxygen-containing** functional group, such as alcohols, aldehydes, ketones, epoxides, or acids; the suffix "oid" is added to indicate this modification.

–OH (Hydroxyl, alcohol)

–COOH (carboxylic acid)

C=O (carbonyl)

Adding **oxygen** transforms a volatile terpene into a functional bioactive molecule, as seen with carotene becoming a carotenoid.



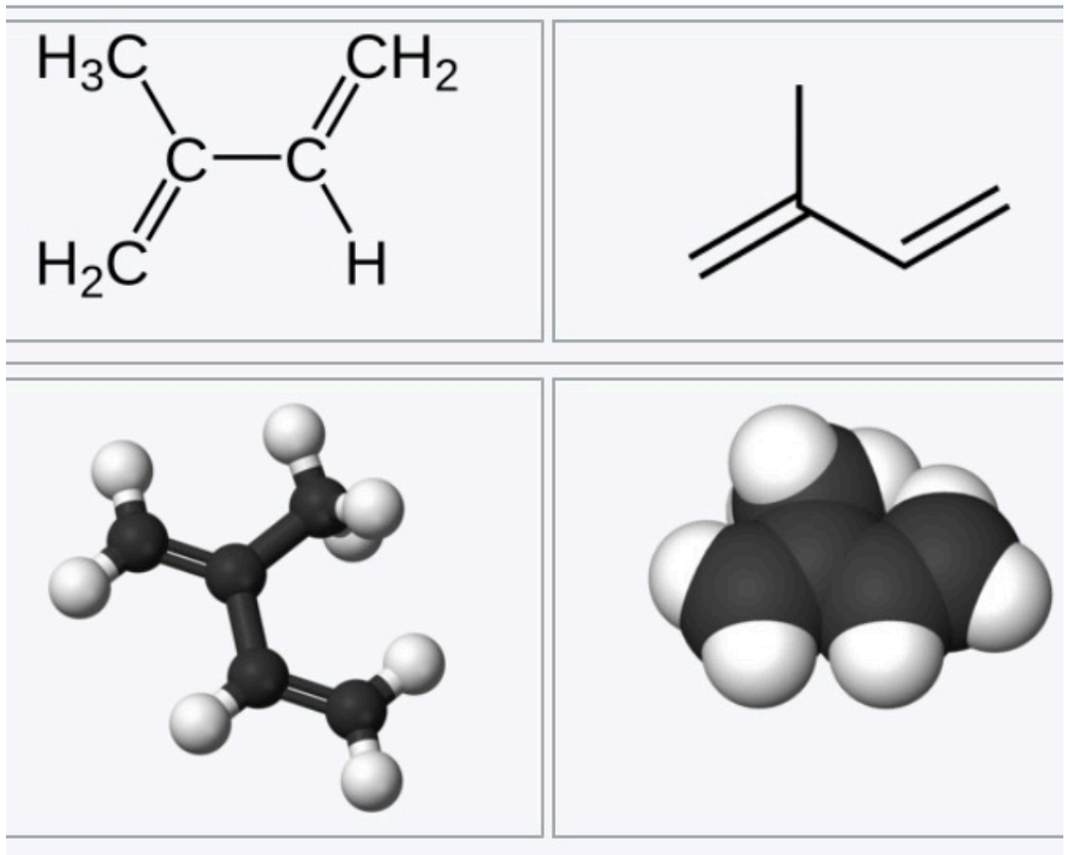
molecule size

Isoprene units, C5H8, consist of five carbon atoms, eight hydrogen atoms, and two double bonds.

These units join together to form larger molecules, each with slightly different actions and size differences, ranging from small and volatile to larger, semi-volatile and resinous, to larger, waxy, and fully non-volatile.

The previous chart divides the smallest mono and sesquiterpenes, which are fully volatile evaporative essential oils, from the larger units of di, tri, and tetraterpenes.

The larger compounds of increasing isoprene units have physical substance that are non-volatile and make up the compounds in plants and oils that benefit the skin.



diterpenes

Of the three larger terpene classes, diterpenes are the smallest, made up of four isoprene units of 20 carbon atoms and include physiologically active groups such as vitamin A.

They act as first responders in the plants, fighting microbes, reducing acute inflammation, and supporting regeneration.

Cafestol and kahweol, found in coffee and coffee oils, are diterpene alcohols.

Their relatively smaller size and semi-volatility allow them to act quickly within plant tissues and penetrate biological membranes more easily.

Semi-volatile diterpenes are neutral in color and do not alter the feel of the oils that carry them.

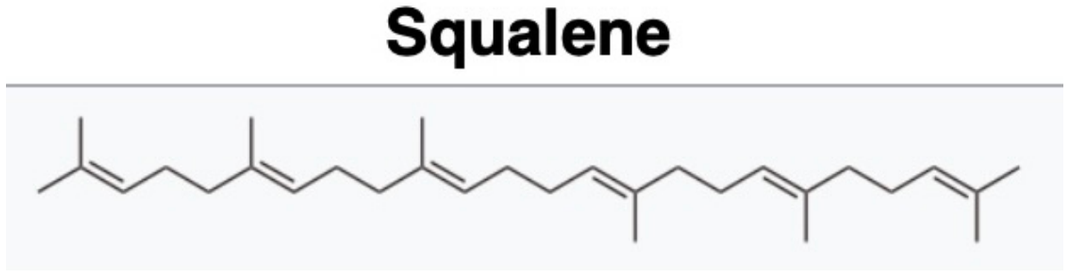
They indirectly support collagen health, barrier repair, and are photo-protective.

triterpenes

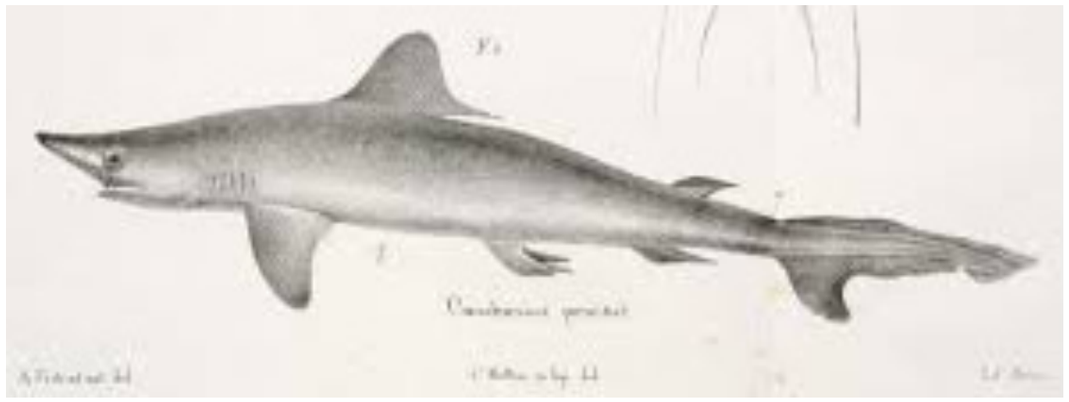
The next terpene class is the triterpenes, consisting of six isoprene units and thirty carbon atoms, and produced by animals, plants, and fungi.

Squalene is the biological precursor of all triterpenes, leading to steroids and sterols. As it is foundational to all of the triterpenes, it has a lesson of its own.

Structurally, triterpenes regenerate tissue, modulate the immune system, and maintain structures.



They play a direct role in collagen support, rebuilding lipid structures in the skin, and controlling damaging inflammation.



Triterpenes are neutral or pale in color and can affect the texture and feel of some oils and butters.

Saponin glycosides are triterpenes found in many medicinal plants and known for being anti-inflammatory, adaptogenic, and for their cleansing properties.

phyto-sterols are triterpenes

The phytosterols, plant sterols, and cholesterol counterpart are a large portion of the **triterpenes** and have a profound impact on skin health.

We see them in plant oils and in the plants to infuse: Stigmasterol, β-Sitosterol, Campesterol, Brassicasterol, and Δ5-Avenasterol.

These steroidal compounds are synthesized from the triterpene precursor squalene and play key structural roles in plant cell membranes, much like cholesterol does in animals.

As a group, they help maintain and restore the skin's lipid barrier, reducing redness caused by inflammation and itching, supporting collagen health, and modulating the skin's immune system.

Rice bran oil is rich in phytosterols

tetra-terpenes

The final class in this group is the tetraterpenes, constructed from eight isoprene units totaling forty carbon atoms.

These compounds are synthesized primarily by plants, algae, and fungi, where they serve as pigments, antioxidants, and signaling molecules.

Tetraterpenes include the carotenoids, including β-carotene, lutein, zeaxanthin, and lycopene, and so are known for their intense pigmentation, yellows, oranges, and reds—colors commonly found in fruits, flowers, and leaves.

On the skin, tetraterpenes act as potent antioxidants, absorbing UV radiation, quenching singlet oxygen, and reducing oxidative stress.

In skincare, they have roles in photo-protection, barrier support, and anti-aging protection.

Carotenoids

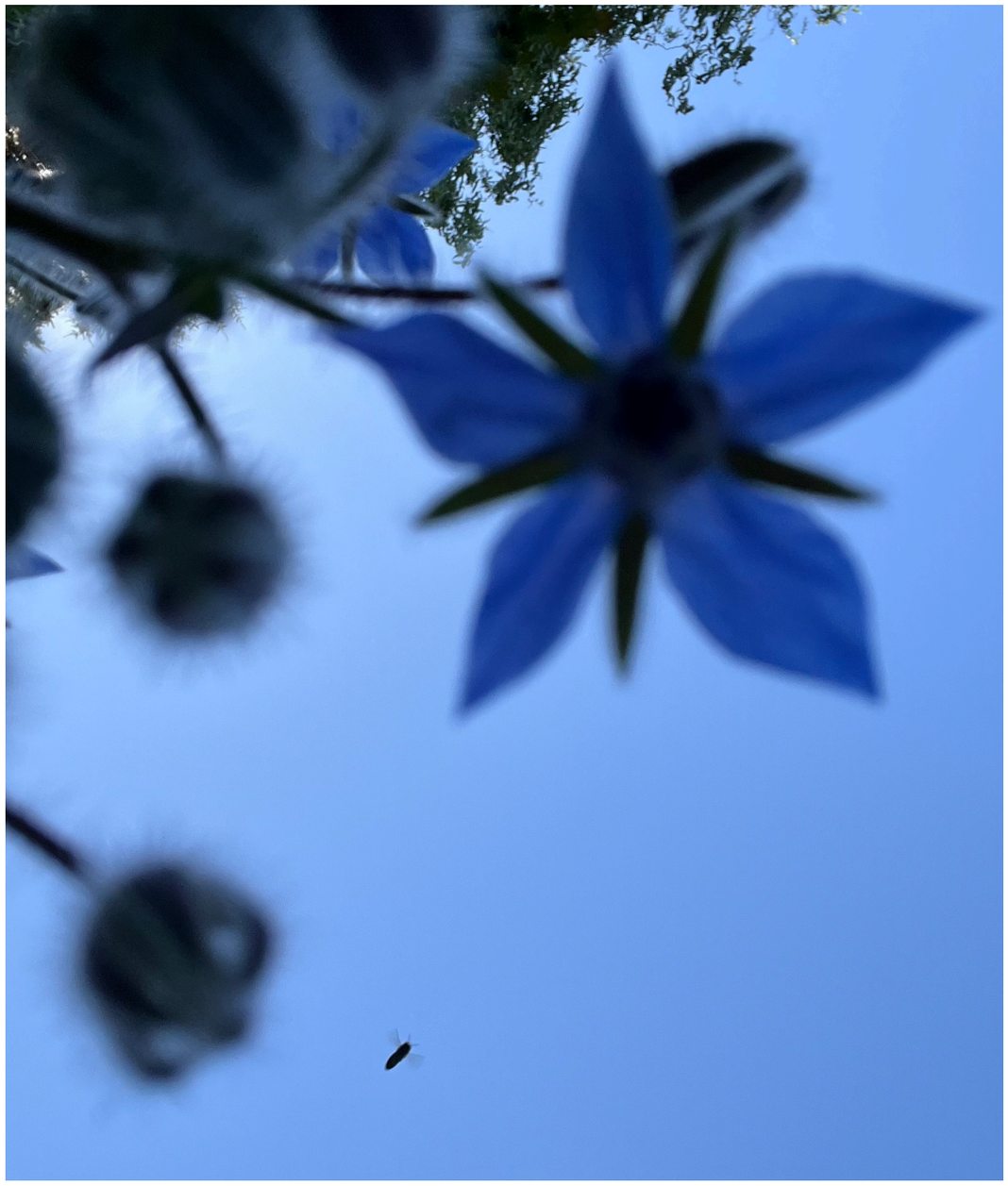
signaling

Each of these terpene groups has strengths that help our skin maintain and heal, with the most profound being the ability to regulate complex biological processes.

Specifically, **diterpenes** act as rapid responders, **triterpenes** maintain our skin and body structures, and **tetraterpenes** modulate and protect against damage from excess light.

These compounds possess the ability to be responsive, coordinate behaviors; retinoids regulate over 500 retinoic acid receptors, while steroids control metabolism, inflammation, skin repair, and carotenoids modulate immune responses, and convert to retinoids, β-carotene.

Our skin is perfectly capable of functioning and maintaining itself without direct intervention on our part, such as in collagen health and the regeneration of the skin barrier function.



signaling is communication

Complex organisms communicate across their "bodies" by subtle signaling molecules and cell receptors.

Communication is a large part of the ability of complex organisms to function, maintaining each part to further the health of the whole.

I am particularly interested in how the skin communicates with its deeper layers and even the body as a whole.

When we apply an oil or herb to the epidermis, we experience the influence on the deeper layers, including the collagen and hormonal processes of the body.

We don't need to target the collagen structure directly; instead, by using plants, oils, and compounds that can signal to collagen, we can harness the body's intelligence to impact the regenerative actions and other targeted regions effectively.

cytokines & communication

Cytokines are a group of proteins that act as signals and mediators of communication between cells, particularly within the immune system.

They are messengers that help regulate various biological processes, including inflammation, immune response to invasion, and cellular growth.

They help cell-to-cell communication by transmitting signals to influence the action and behavior of other cells.

The signaling cytokines modulated by terpenes suppress excess inflammatory functions and upregulate healing as needed for balancing and healing.

The triterpenes modulate cytokine activity through signaling pathways, improving barrier recovery and collagen production, among other effects.

terpene actions

On the skin, terpenes can influence the behavior of skin keratinocytes, calm inflammation, and restore a damaged lipid-based barrier function.

They can also affect the collagen and regulation of skin melanin, which affects the coloration of the skin.

Retinoic acid signals the skin to proliferate and differentiate, thereby rewriting the skin's processes.

Triterpenes, such as ursolic acid, stimulate genes that repair and protect against oxidative damage.

They work together to maintain the necessary functions that enable the skin to perform its job.

saponins

Terpenoid glycosides, which include the saponins, are the exceptions to the oil solubility of the group, as their sugar groups add water solubility.

The triterpenoid saponins, such as oleanolic acid, ursolic acid, betulinic acid, and others, possess a terpenoid backbone with specific functional groups that make them active on the skin.

Betulinic acid, specifically, stimulates collagen production and skin-repairing properties crucial for maintaining the skin's firmness and elasticity.

Even with the increase of hydrophilic properties, saponins can contribute to oil infusions through a process known as hydrophilic-lipophilic interaction, covered in a later lesson.

infusing process

Triterpenoids are often concentrated in the epidermal waxes of leaves, which are called Cuticular waxes. These are composed primarily of lipophilic compounds that will migrate into the infusing oil.

What helps the transference of compounds into oil is a long maceration period, warm infusion methods, or solvent-assisted extraction.

More on infusing techniques will be covered when we discuss hydrophilic compounds like the polyphenols.