# Plant Chemistry

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**College of Science/University of Diyala**
**Fourth Year**
**Second Semester**
**2025/2026**

# Lect.1: Introduction to Plant chemistry

Plant chemistry or phytochemistry, is the study of the chemical compounds and processes that occur within plants. This branch of chemistry is crucial for understanding the complex interactions between plants and their environment, including their roles in ecosystems, their medicinal properties, and their uses in agriculture and industry.

Plant chemistry takes into account the structural compositions of these metabolites, the biosynthetic pathway, functions, mechanisms of actions in the living system.

The proper understanding of phytochemical is essential for drug discovery and for the development of novel therapeutic agents against major diseases.

Phytochemistry can be classified into several categories based on the types of compounds and their functions. Here are the main classifications:

1. Primary Metabolites

These are essential for the growth and development of plants. They include:

- Carbohydrates: Energy sources and structural components (e.g., glucose, starch).
- Proteins: Enzymes and structural proteins.
- Lipids: Fats and oils that serve as energy reserves and structural components of cell membranes.

2. Secondary Metabolites

These compounds are not essential for basic growth but play significant ecological roles. They are further divided into several groups:

- Alkaloids
- Terpenoids

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# Lect.2: Secondary Metabolites

**Secondary metabolites:** are organic compounds produced by an organism but play no role in its normal development. Secondary metabolites frequently play a crucial role in plant defense. They are not essential for the immediate survival of the organism, in contrast to primary metabolites, which actively participate in photosynthesis and respiration. **Kossel** is credited with introducing the idea of secondary metabolite to the field of biology. He pioneered the concept of secondary metabolites as distinct from primary ones. These secondary metabolites quickly became characterized by their low quantity compared to the primary molecules produced by plants, often less than 1 % of the total carbon, or by a storage mechanism that typically takes place in specialized cells or organs.

The producer organism of secondary metabolites can grow without their synthesis, suggesting that secondary metabolism is unnecessary, at least for short-term survival. Secondary metabolism is an essential component of cellular biology and metabolism; it depends on primary metabolism to supply the necessary enzymes, energy, substrates, and cellular machinery and aids in the producer's long-term survival. These metabolites protect plants from biotic or abiotic stress. Secondary metabolites can be induced by stress. Primary metabolites support nutrition and reproduction. Secondary metabolites employed as medications, flavours, perfumes, pesticides, and colours have high commercial value. Such developments will broaden and improve the utilization of higher plants as chemical sources, especially for medicines. The investigation of biological processes and the structure of secondary metabolites is crucial since it has allowed applications in numerous fields. Numerous secondary metabolites are employed as flavour enhancers, insecticides, resins, gums, scents, and herbicides. Ongoing and increasing work in this field should lead to the biotechnological production of specialized, valuable, and undiscovered plant compounds.

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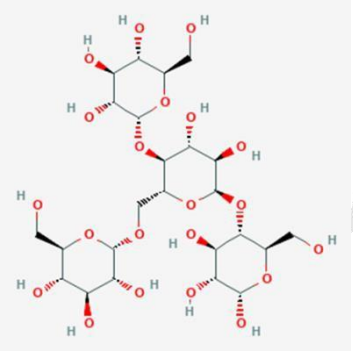
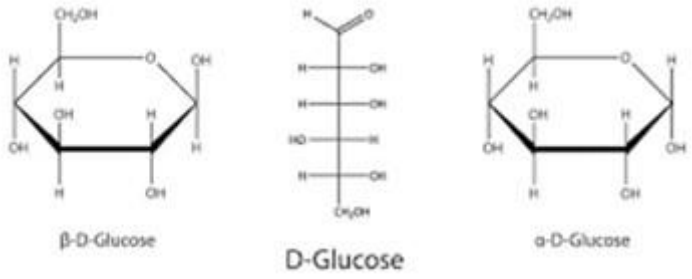
# Lect.3: Carbohydrates

Carbohydrates are the primary fuel for our muscles and the brain. Eating a high carbohydrate diet will ensure maintenance of muscle and liver glycogen (storage forms of carbohydrate), improve performance and delay fatigue.



The word carbohydrate means 'hydrate of carbon'. Thus, carbohydrates are a group of polyhydroxy aldehydes, ketones or acids or their derivatives, together with linear and cyclic polyols. Most of these compounds are in the form $CnH_2nOn$ or $Cn(H_2O)n$, for example glucose, $C_6H_{12}O_6$ or $C_6(H_2O)_6$. Sometimes, carbohydrates are referred to simply as sugars and their derivatives.




Carbohydrates are found abundantly in nature, both in plants and animals, and are essential constituents of all living matter. Photosynthesis is the means by which plants produce sugars from CO2 and water.

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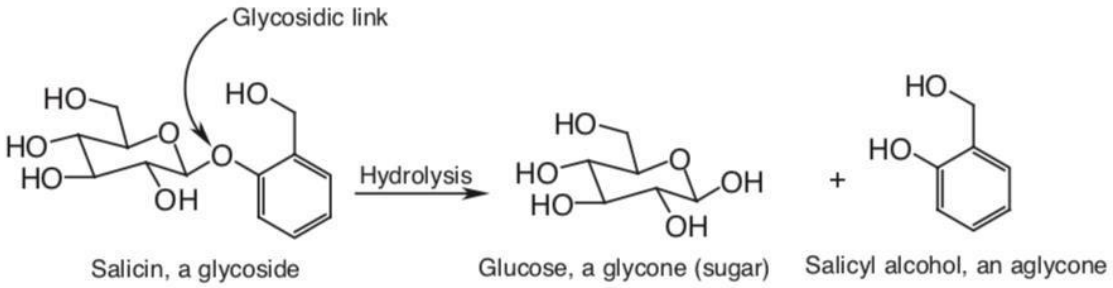
# Lect.4: Glycosides

- Glycosides Compounds that yield one or more sugars upon hydrolysis. **A glycoside** is composed of two moieties: sugar portion (glycone) and non-sugar portion (aglycone or genin). For example, the hydrolysis of salicin produces a glucose unit and salicyl alcohol.




- Glycosides of many different aglycones are extensively found in the plant kingdom. Many of these glycosides are formed from phenols, polyphenols, steroidal and terpenoidal alcohols through glycosidic attachment to sugars. Among the sugars found in natural glycosides, D-glucose is the most prevalent one, but L-rhamnose, D- and L-fructose and L-arabinose also occur quite frequently. Of the pentoses, L-arabinose is more common than D-xylose and the sugars often occur as oligosaccharides.
- The sugar moiety of a glycoside can be joined to the aglycone in various ways, the most common being via an oxygen atom (O-glycoside). However, this bridging atom can also be a carbon (C-glycoside), a nitrogen (N-glycoside) or a sulphur atom (S-glycoside). By virtue of the aglycone and/or sugar, glycosides are extremely important pharmaceutically and medicinally. For example, digitoxin is a cardiac glycoside found in the foxglove plant (*Digitalis purpurea*).

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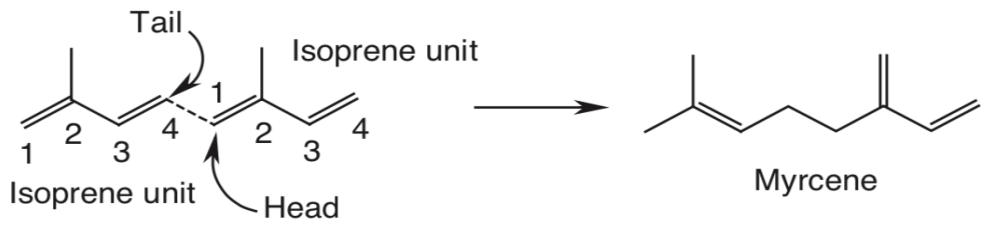
# Lect.5: Terpenoids & Steroids

Terpenoids are compounds derived from a combination of two or more isoprene units. Isoprene is a five-carbon unit, chemically known as 2-methyl-1,3-butadiene. According to the isoprene rule proposed by Leopold Ruzicka, terpenoids arise from head-to-tail joining of isoprene units. Carbon 1 is called the 'head' and carbon 4 is the 'tail'. For example, myrcene is a simple 10-carbon-containing terpenoid formed from the head- to-tail union of two isoprene units as follows.




## Classification of Terpenoids:

Terpenoids are classified according to the number of isoprene units involved in the formation of these compounds.

| Types of terpenoids | Number of carbon Atoms | Number of isoprene units | Examples |
|---|---|---|---|
| Monoterpene | 10 | 2 | Limonene |
| Sesquiterpene | 15 | 3 | Artemisinin |
| Diterpene | 20 | 4 | Forskolin |
| Triterpene | 30 | 6 | a-amyrin |
| Tetraterpene | 40 | 8 | b-carotene |
| Polymeric terpenoid | Several | Several | Rubber |

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# Lect.6: Phenolic Compounds

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# Lect.7 Plant Pigments

## What are Pigments?

✤Pigments are molecules that absorb specific wavelength (energies) of light and reflect all others.

✤Pigments are coloured.

✤The colour we see is the net effect of all the light reflecting back at us…!

✤They are the substances produced by living organisms that have a colour resulting from selective colour absorption.

## The Principal pigments in plants are:

1. Chlorophyll
2. Carotenoids
3. Xanthophylls
4. Anthocyanins
5. Betalains

## Primary function of pigments in plants:

- Primary Function : Photosynthesis
- Uses green pigment chlorophyll along with several red and yellow pigments.
- Help to capture as much light as possible.
- Other functions include attracting insects to flowers to encourage pollination.

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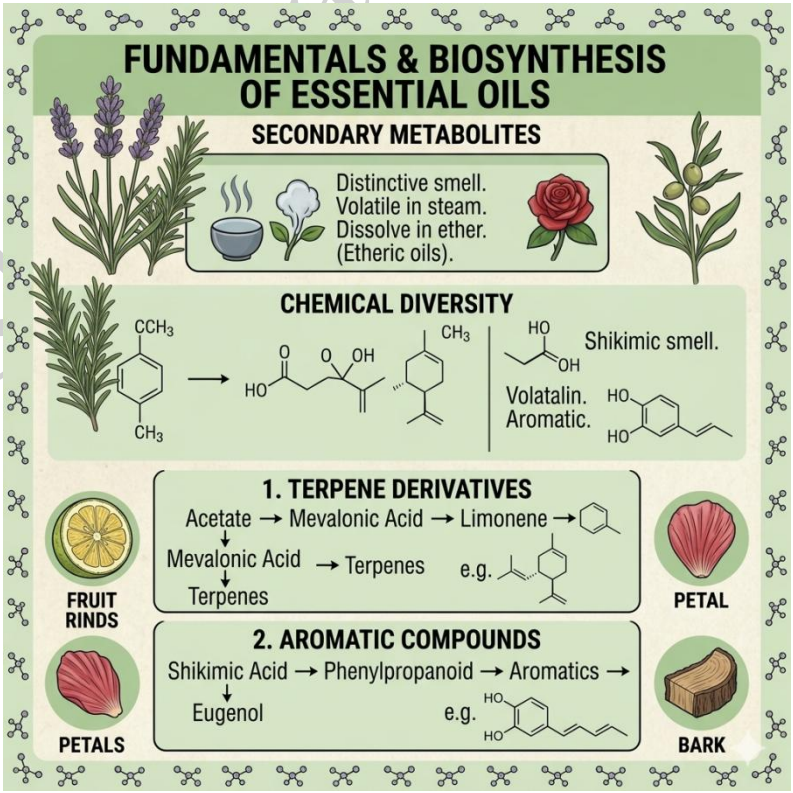
# Lect.8: Essential oils

## Essential oils

Volatile oils are secondary metabolic products which are generally complex in composition.

Volatile or essential oils, as their name implies, are volatile in steam. They are called aromatic oils for their distinctive smell, are also called etheric oils. Because of its ability to dissolve in ether, and also called volatile oils because it is characterized by being volatile at high temperatures and does not decompose, unlike fixed oils that do not volatilize, but rather decompose at high temperatures. They differ entirely in both chemical and physical properties from fixed oils. They are liquids that come from plants. The oils are distilled from the flower, leaves, stems, roots, bark, and resins of plants or they are cold-pressed from the rinds of citrus fruits.

Think of them as the "immune system" of the plant: everything the plant needed to grow, thrive, and survive is what is extracted.



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# Lect.9: Poisonous compounds in plants

## Introduction:

Toxicity from herbs is a common issue we encounter in our daily lives. The severity of this toxicity has become a critical problem because many people struggle to distinguish between beneficial plants and toxic ones or to understand how to use them safely. Currently, toxicity can stem not only from harmful plants but also from those that are generally considered safe. This can happen due to overdosing or even as a result of an immunological response, such as allergies triggered by certain substances in plants, which can lead to conditions like asthma or allergic rhinitis.

### *Viola odorata*

**Scientific classification**

Family: Violacae

Genus: Viola

Species: *Viola odorata*

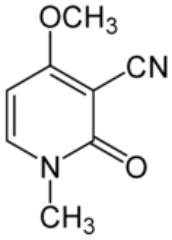
البنفسج العطري

**Characteristics**

- The flowers are aromatic and normally either dark violet or white,
- The leaves and flowers are all in a basal rosette (الوردة القاعدية)
- The leaf stalks have hairs which point downwards, and the plant spreads with stolons (above-ground shoots).

**Uses**: Several cultivars have been selected for garden use

**Medicinal uses:** Respiratory ailments**,** Insomnia and skin disorders.




**Toxicity:** *Viola odorata* is not a poisonous plant but toxicity in improper use or taken in higher doses than recommended and this toxicity is due to the high content of saponin in the root.

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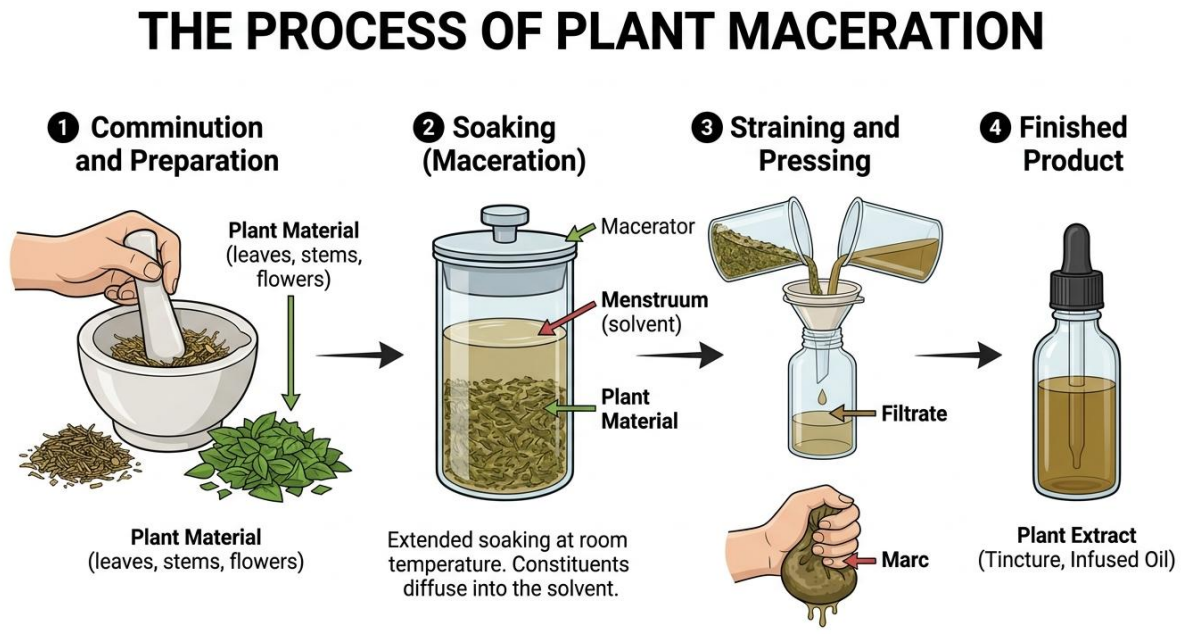
# Lect.10: Methods of extraction

Modern extraction methods in plant chemistry represent advanced techniques designed to efficiently isolate bioactive compounds while minimizing time, solvent consumption, and environmental impact.

- It is defined as the process of isolation of soluble material from an insoluble residue, which may be liquid or solid, by treatment with a solvent.
- The crude drug contains the active constituents which can be isolated from these drugs by various methods of extraction and separation.
- Extraction methods are classified in to two categories (Small scale extraction processes are like maceration and percolation. This processes are slow and time consuming while Large scale extraction is modified soxhlet extractor, this extraction is easily with the help of attachments).

## 1. Maceration

Maceration process involves the separation of medicinally active portions of the crude drugs. It is based on immersion of the crude drugs in a bulk of the solvent or menstrum. Stoppered container is filled with solid drug material with about 750ml of the menstrum. Allwed it upto three to seven days in warm place with frequent shaking. The mixture of crude drug containing solvent is filtered until most of liquid drain off. The filtrate and washing are combined to produce 1000ml of solution.



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# Lect.11: Purification Techniques in Natural Product Isolation

Purification represents a critical stage in the isolation of plant-derived compounds and is a fundamental aspect of both Plant chemistry. Following extraction and fractionation, crude plant extracts typically contain a complex mixture of compounds, including pigments, lipids, and a wide range of secondary metabolites. Therefore, purification is essential to isolate individual chemical constituents in a pure form, which is necessary for accurate structural identification and reliable evaluation of biological activity.

## Chromatographic techniques

- Mikhail Tsvet (1872–1919) was a Russian-Italian botanist recognized as the father of chromatography.
- He separated plant pigments (1906)
- Colorful separation of plant pigments was done using a column of calcium carbonate (chalk)
- the new technique was called chromatography because the result of the analysis was written in color.(Chroma means color and graphein means to write)

# CHROMATOGRAPHY

Technique used to separate and identify the components of a mixture

PRINCIPLE: Works by allowing the molecules present in the mixture to distribute themselves between a stationary and a mobile medium.
Molecules that spend most of their time in the mobile phase are carried along faster.

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# Lect.12: Bioactive Compounds in Common Plants and Their Applications

Plants produce a wide variety of chemical compounds classified into:

- **Primary metabolites** – essential for growth and development (e.g., carbohydrates, proteins)
- **Secondary metabolites** – not directly essential for growth but important for defense, stress response, and interaction with the environment

Secondary metabolites include phenolics, alkaloids, terpenoids, glycosides, flavonoids, and essential oils, responsible for antioxidant, antimicrobial, anti-inflammatory, and therapeutic activities.

These compounds are important for human use in medicine, food, cosmetics, and agriculture. Locally available plants in Iraq provide excellent examples for study and practical applications.

## Bioactive Compounds in Common Plants

### Garlic (*Allium sativum*) – Family: Amaryllidaceae

- **Description:** Bulbous plant used worldwide as a spice and traditional medicine; native to Central Asia.
- **Active compounds:** Sulfur compounds (**allicin**)
- **Bioactivity:** Antimicrobial, antifungal, antioxidant

### Mint (*Mentha spp.*) – Family: Lamiaceae

- **Description:** Fragrant herb used in teas, culinary dishes, and medicine; cooling and soothing.
- **Active compounds:** Essential oils (**menthol**)
- **Bioactivity:** Antioxidant, antimicrobial, calming

### Chamomile (*Matricaria chamomilla*) – Family: Asteraceae

- **Description:** Flowering plant widely used in herbal teas; known for calming and anti-inflammatory effects.
- **Active compounds:** Flavonoids (**apigenin**), phenolic compounds
- **Bioactivity:** Anti-inflammatory, calming, antioxidant