

INTRODUCTION TO NATURAL PRODUCTS

CHAPTER

05

Kajal Chakraborty, Shubhajit Dhara, Shilpa K Pai, & Anoop P Vijay

Marine Biotechnology Fish Nutrition and Health Division,

Central Marine Fisheries Research Institute,

Post Box No. 1603, Ernakulam North P.O., Kochi-682 018

ABSTRACT

Natural products are a rich source of bioactives with significant potential. This potential stems from their classification into primary and secondary metabolites based on their roles. Primary metabolites, including carbohydrates, proteins, lipids, nucleic acids, amino acids, enzymes, vitamins, and minerals, are integral to energy storage, metabolism, and genetic information transfer. Secondary metabolites, such as terpenoids, alkaloids, flavonoids, and steroids, serve external functions like defense, competition, and attraction. Both primary and secondary metabolites play crucial roles in maintaining the health and functioning of ecosystems.

Keywords: Primary metabolite, Secondary metabolite

INTRODUCTION

Natural products refer to chemical compounds or substances that are derived from living organisms, such as plants, animals, fungi, and microorganisms. These products have been used by humans for various purposes, including food, medicine, cosmetics, and industrial applications, for centuries. Natural products have played a crucial role in the development of traditional medicine and continue to be important sources of new drugs and therapeutic agents (Yuan et al., 2016). Albrecht Kossel's classification of natural products into primary and secondary metabolites has been widely adopted and remains a fundamental concept in the field of biochemistry and natural product research.

1. PRIMARY METABOLITES:

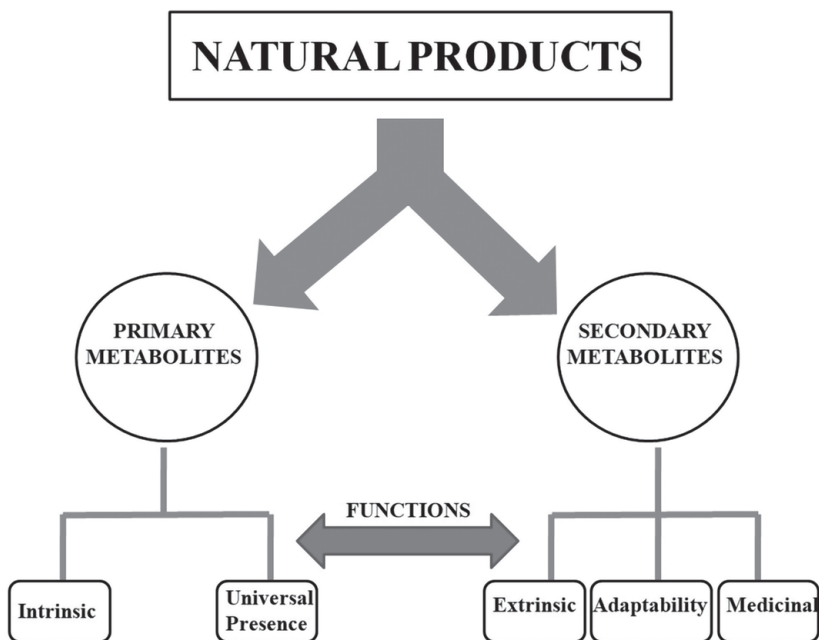
- a) **Intrinsic Function:** Primary metabolites are compounds produced by an organism that serve essential roles in its basic metabolic processes and are crucial for its survival and growth. These include fundamental biomolecules such as carbohydrates, proteins, nucleic acids, and lipids.
- b) **Universal Presence:** Primary metabolites are commonly found in all living organisms, as they are necessary for fundamental cellular functions. They play roles in energy production, cell structure, and basic biochemical pathways.



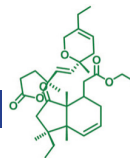
2. SECONDARY METABOLITES:

- a) **Extrinsic Function:** Secondary metabolites are not directly involved in the primary metabolic processes necessary for the organism's growth and development. Instead, they often serve external or extrinsic functions, such as defense against predators, competition for resources, or attraction of pollinators.
- b) **Adaptive Advantage:** While secondary metabolites are not essential for survival, they can provide adaptive advantages to the organism. For example, certain secondary metabolites act as natural pesticides, antibiotics, or signaling molecules that help the organism respond to environmental challenges.
- c) **Medicinal Properties:** Some secondary metabolites have been found to possess medicinal properties. These compounds often interact with biological systems in ways that make them valuable for medical applications.

The pharmaceutical industry has taken advantage of secondary metabolites in drug discovery, recognizing their diverse bioactivities. Many important drugs, such as antibiotics and anticancer agents, have been derived from secondary metabolites produced by various organisms (Wink, 2015).



Natural products: Classification & Function



CLASSIFICATION OF PRIMARY METABOLITES

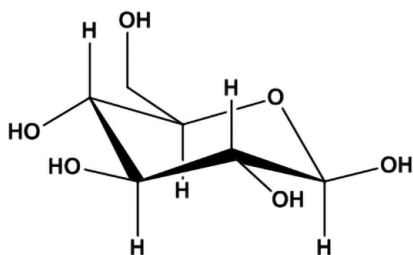
Primary metabolites can be classified into 5 major categories-

1. CARBOHYDRATES:

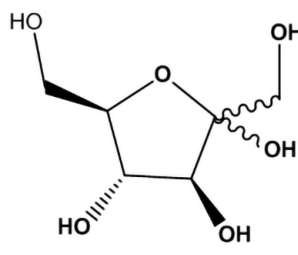
Carbohydrates stand out as the predominant primary metabolites within living organisms. Within this realm, insoluble carbohydrate polymers take on crucial roles as structural and defensive components in the cell walls of bacteria and plants, as well as in the connective tissues of animals. Additionally, certain carbohydrate polymers function in lubricating skeletal joints and facilitating recognition and adhesion between cells. Further complexity arises with more intricate carbohydrate polymers, which become covalently bonded to proteins or lipids, thereby serving as signals that dictate the intracellular positioning or metabolic destiny of these hybrid molecules, which are referred to as glycoconjugates.

Carbohydrates are compounds characterized by their polyhydroxy aldehyde or ketone functional groups, or they can be substances that break down into these compounds upon hydrolysis. While the majority of carbohydrates follow the empirical formula $(\text{CH}_2\text{O})_n$, indicating a ratio of carbon, hydrogen, and oxygen atoms, it's important to note that certain carbohydrates may also incorporate nitrogen, phosphorus, or sulfur into their structures. Carbohydrates are classified based on the number of saccharide units they contain:

a) Monosaccharides: These are single polyhydroxy aldehyde or ketone units. Examples include D-glucose and D-mannose. Depending on the location of the carbonyl functional group within the carbon chain, a monosaccharide is again classified as either an aldose, characterized by the presence of an aldehyde group at the end of the carbon chain, or a ketose, where the carbonyl group is situated at any other position within the chain, typically within a ketone group.



D-Glucose

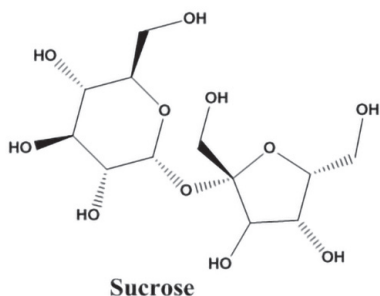


D-Fructose

Haworth projection of D-Glucose and D-Fructose

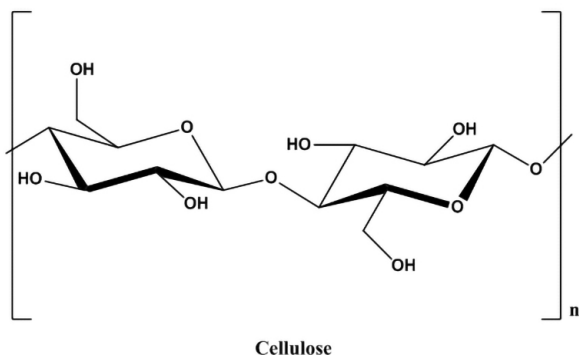


b) Oligosaccharides: This category includes disaccharides, which consist of two monosaccharide units. A common example is sucrose (cane sugar), which comprises the six-carbon sugars D-glucose and D-fructose.



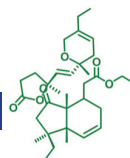
Haworth projection of Sucrose

c) Polysaccharides: These are sugar polymers with more than 20 monosaccharide units, and some can have hundreds or thousands of units. Polysaccharides like cellulose form linear chains, while others like glycogen are branched. Despite both consisting of recurring units of D-glucose, polysaccharides like glycogen and cellulose differ in their glycosidic linkage types, leading to distinct properties and biological roles.



Structure of Cellulose

Specific molecules containing carbohydrates play essential roles in cell-cell recognition and various biological processes. These molecules, termed glycoconjugates, are involved in functions such as adhesion, cell migration during development, blood clotting, immune responses, and wound healing. In most of these cases, the informational carbohydrate is covalently joined to a protein or a lipid to form a glycoconjugate, which is the biologically active molecule. Glycoconjugates can be further elaborated as



- Proteoglycans are large molecules found on the cell surface or within the extracellular matrix. They consist of one or more glycosaminoglycan chains covalently linked to either a membrane protein or a secreted protein. The glycosaminoglycan component typically constitutes the majority of the proteoglycan molecule's mass, shapes its structure, and frequently serves as the primary site of biological activity. Proteoglycans play significant roles as integral components of connective tissue, particularly in structures like cartilage. Through numerous noncovalent interactions with other proteoglycans, proteins, and glycosaminoglycans, they contribute to the tissue's strength and resilience.
- Glycoproteins consist of one or multiple oligosaccharides, which vary in complexity, covalently attached to a protein. Unlike the relatively uniform glycosaminoglycan chains found in proteoglycans, the oligosaccharide components of glycoproteins exhibit greater diversity. Rich in information, these oligosaccharides create highly specific sites for recognition and facilitate high-affinity binding by other proteins.
- Glycolipids are a type of membrane lipid characterized by having oligosaccharide hydrophilic head groups. Similar to glycoproteins, these oligosaccharide head groups serve as specific recognition sites for carbohydrate-binding proteins (Chawla, 2017; Nelson, & Cox, 2013).

a) **PROTEINS:**

Proteins are constructed from chains of amino acids linked by peptide bonds, formed through dehydration reactions between the α -carboxyl group of one amino acid and the α -amino group of another. These complex molecules are essential for maintaining overall health and performing vital biological functions within organisms.

- **Structural Components:** Proteins provide structural support to cells and tissues. For example, collagen is a fibrous protein that forms the framework of connective tissues like skin, bones, and tendons.
- **Hormones and Signaling Molecules:** Certain proteins, such as insulin, serve as hormones that regulate physiological processes like glucose metabolism. Signaling proteins relay messages within and between cells, coordinating various cellular activities.
- **Transport Proteins:** Proteins facilitate the transport of molecules across cell membranes or within the bloodstream. Hemoglobin, for instance, transports oxygen in red blood cells.
- **Defense and Immunity:** Antibodies are proteins produced by the immune system to recognize and neutralize foreign substances like bacteria and viruses.
- **Regulatory Proteins:** Proteins play roles in gene expression and regulation, controlling when and how genes are activated. Transcription factors are proteins that bind to DNA and



influence the transcription of specific genes.

- Muscle Contraction: Proteins such as actin and myosin are responsible for the contraction of muscle fibers, enabling movement (Whitford, 2013).

b) LIPIDS:

Fats and oils serve as the primary stored energy reserves in many organisms. Additionally, phospholipids and sterols play vital roles as major structural components of biological membranes. Despite their smaller quantities, other lipids are essential in various biological functions, acting as enzyme cofactors, electron carriers, light-absorbing pigments, hydrophobic anchors for proteins, facilitators in membrane protein folding, emulsifying agents in the digestive tract, as well as serving roles in hormone regulation and intracellular signaling. Fatty acids serve as the predominant source of stored energy in living organisms through their transformation into fats and oils.

Fatty acids, distinguished by their carboxylic acid groups and hydrocarbon chains ranging from 4 to 36 carbon atoms (C4 to C36), display structural diversity. Some feature straight, saturated chains devoid of double bonds, while others contain one or more double bonds.

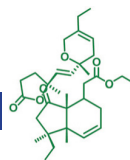
NOMENCLATURE

Simplified nomenclature of compounds involves length of fatty acid chain and number of double bonds

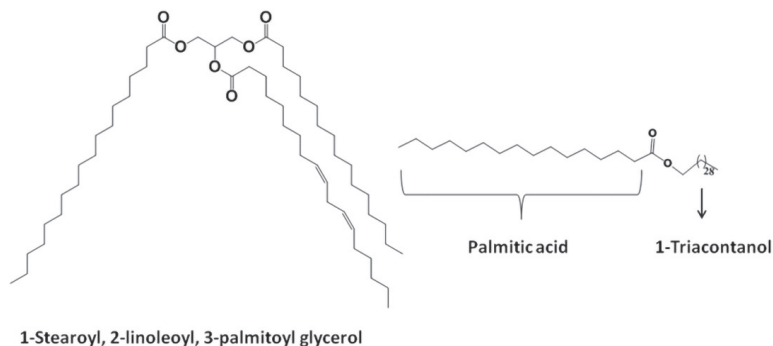
- 16-carbon saturated palmitic acid is abbreviated 16:0
- 18-carbon oleic acid, with one double bond, is 18:1
- The double bonds are specified by superscript following Δ (delta) symbol. A 20 carbon chain fatty acid with double bond at position 9 and 12 is 20:2 ($\Delta^9, 12$)

Generally, polyunsaturated fatty acids exhibit a distinct structural pattern where their double bonds are typically not conjugated (alternating single and double bonds, as in $-\text{CH}=\text{CH}-\text{CH}=\text{CH}-$) but rather separated by a methylene group ($-\text{CH}=\text{CH}-\text{CH}_2-\text{CH}=\text{CH}-$). Additionally, in the majority of naturally found unsaturated fatty acids, these double bonds are in the *cis* configuration.

- The most basic fatty acids derived from lipids are triglycerides, also known as triglycerols, fats, or neutral fats. They are formed through an esterification reaction between glycerol and fatty acids. Triglycerides play a vital role in energy storage and provide insulation against external impacts.

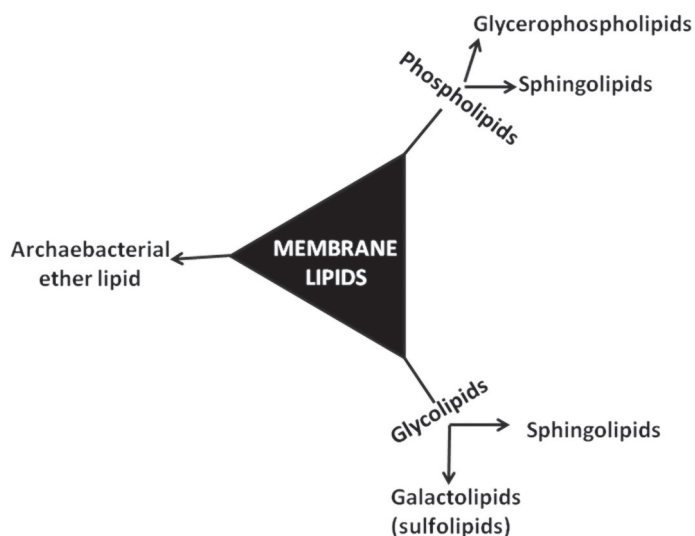


- Waxes consist of esters formed from saturated and unsaturated fatty acids ranging from C14 to C36, combined with long-chain alcohols spanning from C16 to C30. These compounds serve as primary metabolic fuels for free-floating microorganisms, supporting their essential biological functions.



Fatty acid and waxes

- Structural lipids comprising the double-layered cell membrane play a pivotal role in facilitating ion transfer across cellular boundaries. These lipids, classified into phospholipids, glycolipids, and archebacterial ether lipids based on their attached functional groups, serve as crucial components in maintaining cellular integrity and regulating ion passage (Burge & Calder, 2015).



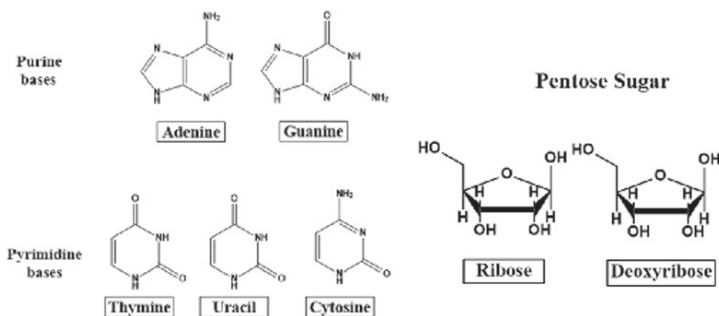
Classification of membrane lipids



a) NUCLEIC ACIDS:

Deoxyribonucleic acid (DNA) and ribonucleic acid (RNA) are the molecular repositories of genetic information. The arrangement of each protein, and consequently, every biomolecule and cellular element, is a result of the information encoded in the nucleotide sequence of a cell's nucleic acids. The fundamental prerequisite for life lies in the capacity to store and pass on genetic information from one generation to the next. Nucleic acids consist of nucleotides, serving as the energy currency in metabolic transactions, crucial chemical connectors in cells' response to hormones and external stimuli, and forming the structural foundation for various enzyme cofactors and metabolic intermediates. Nucleotides have 3 characteristic components.

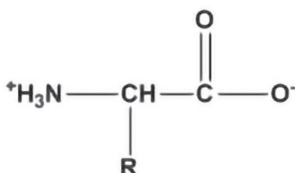
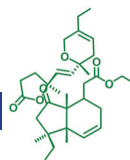
- A nitrogenous base- The nitrogenous bases are derivatives of two parent compounds pyrimidine and purine bases.
- A pentose sugar- The sugar component in DNA is called deoxyribose whereas in RNA it is ribose.
- Phosphate group- The phosphodiester bond is formed when the phosphate group of one nucleotide reacts with the hydroxyl group on the 3' carbon of the sugar molecule of another nucleotide. This reaction releases a molecule of water and forms a covalent bond between the phosphate and sugar, creating a continuous nucleic acid chain (Minchin & Lodge, 2019).



Arrangement of Various Nitrogenous Bases and Pentose Sugars in Nucleic acids

b) AMINO ACIDS:

Amino acids are building blocks of peptides and proteins. All 20 amino acids are made up of α -amino acids with carboxyl group and amino acid group attached to same carbon atom. Amino acid varies with size and structure of side chain attached.



General representation of amino acids

Amino acids into five main classes based on the properties of their R groups in particular, their polarity, or tendency to interact with water at biological pH.

- **Nonpolar, Aliphatic R Groups:** The amino acids in this category possess nonpolar and hydrophobic R groups. Within proteins, the side chains of alanine, valine, leucine, and isoleucine have a tendency to aggregate, contributing to the stabilization of protein structure through hydrophobic interactions. Glycine possesses the simplest structure among amino acids. While it is formally nonpolar, its extremely small side chain does not significantly contribute to hydrophobic interactions. Methionine, one of the two sulfur-containing amino acids, features a nonpolar thioether group in its side chain. Proline is characterized by an aliphatic side chain with a distinctive cyclic structure. The secondary amino (imino) group of proline residues is constrained in a rigid conformation, which diminishes the structural flexibility of polypeptide regions containing proline.
- **Aromatic R Groups:** Phenylalanine, tyrosine, and tryptophan are relatively nonpolar (hydrophobic) due to their aromatic side chains. All of these amino acids can engage in hydrophobic interactions.
- **Polar, Uncharged R Groups:** The R groups of these amino acids exhibit higher solubility in water, or are more hydrophilic, compared to nonpolar amino acids. This is due to the presence of functional groups that can form hydrogen bonds with water molecules. This category includes serine, threonine, cysteine, asparagine, and glutamine. The polarity of serine and threonine is attributed to their hydroxyl groups, while cysteine's polarity arises from its sulfhydryl group. Asparagine and glutamine exhibit polarity due to their amide groups.
- **Positively Charged (Basic) R Groups:** The R groups that are either positively or negatively charged are considered the most hydrophilic. Amino acids with R groups exhibiting significant positive charge at pH 7.0 include lysine, characterized by a second primary amino group at the ϵ position on its aliphatic chain; arginine, featuring a positively charged guanidino group; and histidine, which possesses an imidazole group.
- **Negatively Charged (Acidic) R Groups:** The two amino acids with R groups carrying a net negative charge at pH 7.0 are aspartate and glutamate, both of which feature a second carboxyl group (Nelson, & Cox, 2013).



VITAMINS & MINERALS:

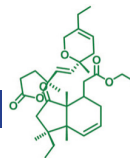
Vitamins and minerals are essential nutrients required for healthy functioning of body.

Table 1. Vitamins, Minerals and their functions

Nutrient	Function
Vitamin A (Retinol)	Vision, Immune function, skin health and cell division
Vitamin B	Energy metabolism, Nerve function, formation of RBC and maintaining skin, hear and eye
Vitamin C (Ascorbic acid)	Antioxidant, Supports immune system, Collagen formation for skin, Absorption of Iron
Vitamin D (Calciferol)	Bone health, Immunoregulation
Vitamin E (Tocopherol)	Antioxidant, Cytoprotective effect
Vitamin K (Menadione, Phylloquinone)	Blood clotting and Bone health
Calcium	Bone and teeth formation, Blood clotting, Muscle function
Iron	Heamoglobin production
Magnesium	Muscle and nerve function, Blood sugar regulation, Bone health
Phosphorus	Energy metabolism, Bone health
Potassium	Fluid balance, Nerve signals, Muscle contractions
Sodium	Fluid balance, Nerve function, Muscle contractions
Zinc	Immune function, Wound healing, DNA synthesis
Selenium	Antioxidant, regulation of thyroid
Copper	Iron metabolism, Collagen formation, Nerve function

a) ENZYMES:

Enzymes play a fundamental role in these metabolic pathways by facilitating and catalyzing biochemical reactions. Enzymes are proteins that act as catalysts, speeding up chemical reactions without being consumed in the process. They are involved in a wide range of metabolic processes, such as the breakdown of nutrients, synthesis of biomolecules, and regulation of cellular activities. Structurally they are linear chain of amino acids arranged in



a 3-Dimensional fashion, catalytic behaviour depends upon the the sequence of amino acid chain. Enzyme names often reflect the substrate or the type of reaction they catalyze, and they typically end with the suffix “-ase.” This convention makes it easier to identify the function of an enzyme based on its name.

- Oxidoreductase- Catalyses redox reactions. Eg:- Peroxiredoxin (PRDX) and thioredoxin (TXN) are thiol-disulphide oxidoreductase which link receptors to oxidative stress initiating immune regulation
- Transferase-Transfer a functional group. Eg:- Glutathione S-transferases (GSTs) promotes pro-inflammatory signalling during brain inflammation.
- Hydrolases- Cleavage of bonds through hydrolysis. Eg:- Leukotriene A4 hydrolase (LTA4H) catalyses hydrolysis of Leukotriene A4 which is involved in achidionic acid metabolism pathway.
- Lyases- Cleavage of bonds by means other than hydrolysis and oxidation. Eg:- Phosphosulfolactate synthase facilitates Michael addition of sulphide group to phosphoenolpyruvate.
- Isomerases- Catalyses isomerisation. Eg:- Beta-carotene isomerase catalyses isomerisation of all-trans-beta carotene to 9-cis-beta carotene.
- Ligases- Join two covalent bonds. Eg:- Acetyl-CoA carboxylase converts irreversible carboxylation of acetyl-CoA to produce malonyl-CoA.
- Translocases- Catalyses movement of ions or molecules across membrane or their separation within membrane. Eg:- ADP/ATP translocase (ANT) transfers adenosine diphosphate from cytosol and exports ATP from mitochondrial matrix

SECONDARY METABOLITES FROM NATURAL PRODUCTS:

Secondary metabolites are organic compounds produced by living organisms that are not directly involved in the growth, development, or reproduction of the organism. Unlike primary metabolites, which are essential for basic life processes, secondary metabolites often serve specialized functions, such as defense mechanisms, communication, or adaptation to environmental challenges. Many secondary metabolites have been identified in natural products derived from plants, microorganisms, and other organisms, showcasing their diverse chemical structures and biological activities.

Classification of Natural Products:

The classification of natural products, though somewhat arbitrary, typically centers on secondary metabolites. This discussion focuses on several prominent classes, including:



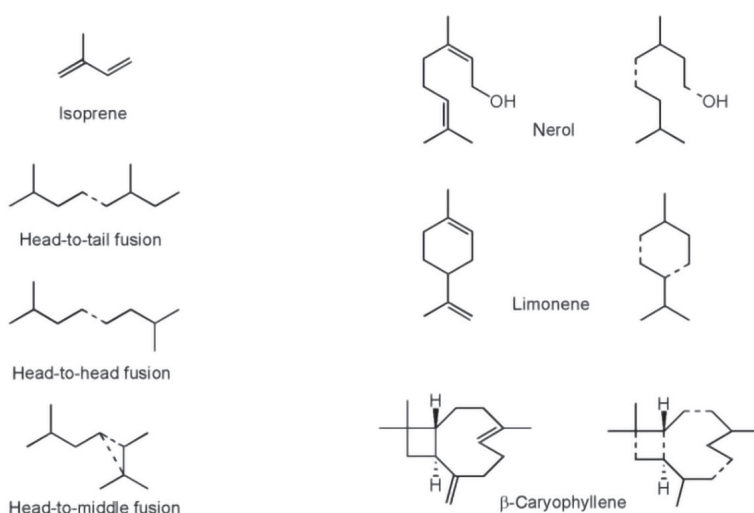
1. Terpenes
2. Alkaloids
3. Fatty Acid Derivatives
4. Flavonoids

TERPENES/ TERPENOIDS

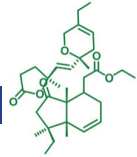
Terpenoids, also referred to as isoprenoids, constitute a vast and structurally diverse category of natural compounds. The term “terpene” was initially associated with the hydrocarbons found in turpentine, with the suffix “ene” indicating the presence of olefinic bonds.

The classification of terpenoids is based on the number and structural organization of carbons, which result from the linear arrangement of isoprene units, followed by cyclization and rearrangements of the carbon skeleton, guided by the isoprene rule. Isoprene, serving as the fundamental “building block” of terpenoids, is represented by 2-methylbuta-1,3-diene (C_5H_8). The simplest class of terpenoids, hemiterpenoids, is derived from a single isoprene unit. Table 2 illustrates the names of various terpenoid groups.

The isoprene rule stipulates that all terpenoids originate from the ordered, head-to-tail connection of isoprene units. While head-to-tail fusion is the most prevalent, nonhead-to-tail condensation of isoprene units can also occur. Head-to-head fusions are common in triterpenoids and carotenoids, and some compounds form through head-to-middle fusions, such as irregular monoterpene. The following figure depicts the most typical fusions of isoprene units, illustrating how these units and the original backbone can be traced in three



Head-to-tail coupling of isoprene units, and isoprene units in some terpenoid backbones.



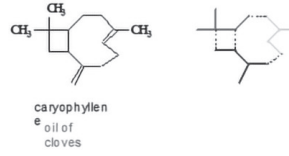
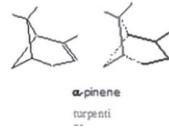
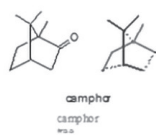
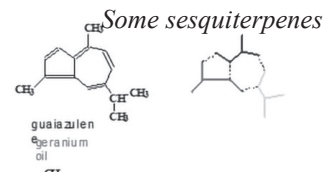
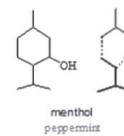
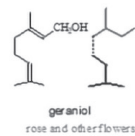
sample terpenoids.

Table 2 Classification of Terpenoids

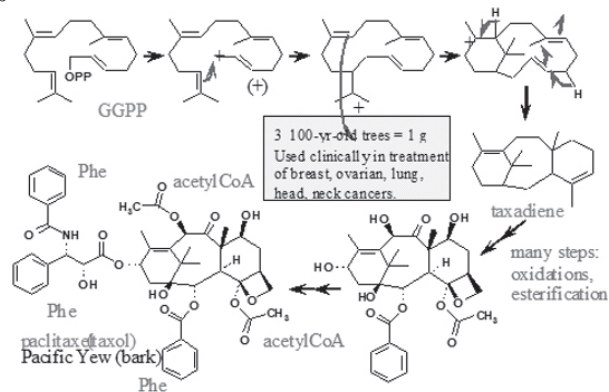
Name	No. of Isoprene Units	No. of Carbon Atoms	General Formula
Hemiterpenoids	1	5	C_5H_8
Monoterpenoids	2	10	$C_{10}H_{16}$
Sesquiterpenoids	3	15	$C_{15}H_{24}$
Diterpenoids	4	20	$C_{20}H_{32}$
Sesterterpenoids	5	25	$C_{25}H_{40}$
Tetraterpenoids (carotenoids)	8	40	$C_{40}H_{64}$
Polyterpenoids	8	40	$(C_5H_8)_n$

Bicyclic and tricyclic: a few classes – ambrein, malabricane

Examples of monoterpenes



Examples of diterpenes



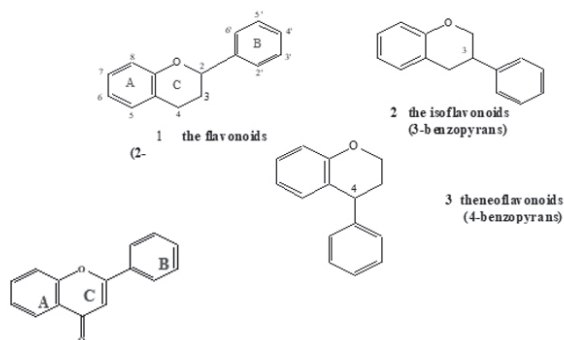


FLAVONOIDS

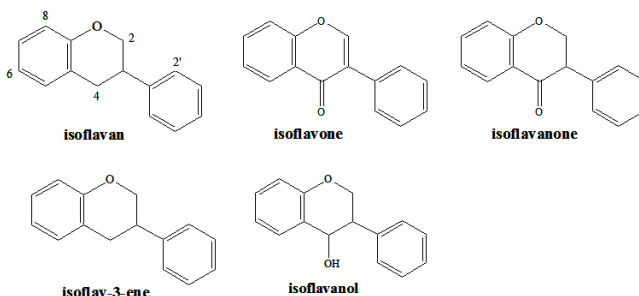
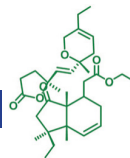
Flavonoids, a class of water-soluble pigments, stand out as a highly researched category of phenolics with over 3000 distinct compounds described. Their prevalence in nature and potential health benefits make them a focal point of scientific inquiry. These compounds exhibit a diverse array of biological functions, and their significance is underscored by reported effects such as antioxidant, antimicrobial, anti-carcinogenic, and cardio-protective properties. Flavonoids comprise a diverse set of compounds and perform a wide range of functions. Specific flavonoids can also function to protect plants against UV-B irradiation. The flavonoids consist of various groups of plant metabolites which include chalcones, aurones, flavanones, isoflavonoids, flavones, flavonols, leucoanthocyanidins, catechins, and anthocyanins.

The nomenclature of flavonoids is characterized by its straight forward approach. The aromatic ring A is condensed to the heterocyclic ring C, and the aromatic ring B is typically attached at the C2 position. The nomenclature further involves the listing of substituents for both the A and C rings, with primed numbers assigned to the B ring. It is worth noting that the numbering for the aromatic rings of the open-chained precursor chalcones follows a reversed pattern.

ISOFLAVONOIDS (3-BENZOPYRANS)



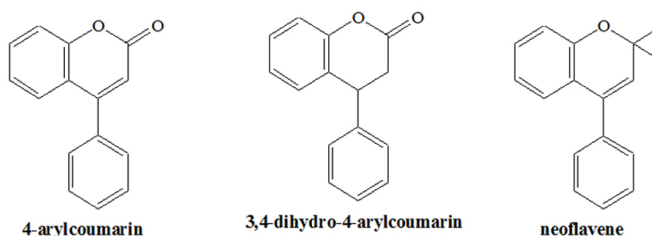
Isoflavonoids are a subclass of flavonoids, which are a type of polyphenolic compounds found in plants. Isoflavonoids specifically exhibit a structure similar to flavonoids but with a unique arrangement of the B ring. They are commonly found in leguminous plants, particularly soybeans and other members of the Fabaceae family. Isoflavonoids possess a 3-phenylchroman skeleton that is biogenetically derived by 1,2-aryl migration in a 2-phenylchroman precursor. They have drawn attention for their potential health benefits and estrogenic activity. Some well-known isoflavonoids include genistein, daidzein, and glycitein, which are frequently present in soy-based foods.



NEOFLAVONOIDS (4-BENZOPYRANS)

Neoflavonoids are a group of natural compounds that belong to the larger family of flavonoids. Similar to isoflavonoids, they share a basic flavonoid structure but have distinct differences, particularly in the arrangement of their B ring. Neoflavonoids are known for their occurrence in certain plants and have drawn attention due to their potential pharmacological activities.

These compounds have been studied for various biological properties, including antioxidant, anti-inflammatory, and antimicrobial activities. Neoflavonoids are not as extensively researched or as commonly found in nature as other flavonoids, but their unique chemical structures make them interesting subjects for scientific investigation. Like many flavonoids, neoflavonoids contribute to the diverse array of natural compounds found in plants, offering potential applications in medicine, nutrition, and other fields.



COUMARINS AND STILBENES

Coumarins belong to a widespread family of plant metabolites called the benzopyranones, with more than 1500 representative in more than 800 species. In plants these compounds can occur in seed coats, fruits, flowers, roots, leaves, stems, although in general the greatest concentration are found in fruits and flowers. Their roles in plants appear to be mainly defence-related, given their antimicrobial antifectant, UV-screening and germination inhibitor

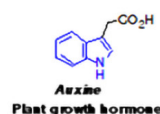
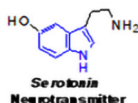
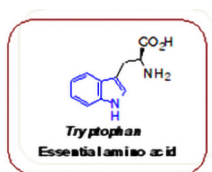


properties. Stilbenes are present in bryophytes, pteridophyte, gymnosperms and angiosperms, with more than 300 different stilbenoids known today. The stilbenes play important roles in plants, particularly in heartwood protection and also have significance in pharmacology and human health. Due to their large biological activities, plant secondary metabolites have been used for centuries in traditional medicine. Nowadays, they correspond to valuable compounds such as pharmaceuticals, cosmetics, fine chemicals, or more recently nutraceuticals. Recent surveys have established that in western countries, where chemistry is the backbone of the pharmaceutical industry, 25% of the molecules used are of natural plant origin.

ALKALOIDS

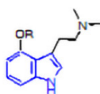
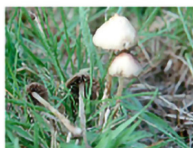
Alkaloids, a diverse class of compounds derived from amino acids with a nitrogen atom in the heterocyclic ring, play a significant role in plant-based secondary metabolites, constituting about 20% of them. Coined by German chemist Carl F. W. Meissner in 1819, the term “alkaloids” is rooted in the Arabic name al-qali, associated with the plant source of the first isolated soda. These compounds have historical importance due to their wide-ranging physiological effects and pharmacological properties, serving as antibiotics, anticancer agents, narcotics, poisons, and stimulants. Approximately 12,000 alkaloids have been isolated from various plant genera, each categorized based on biosynthetic precursors and heterocyclic ring systems.

Indole alkaloids, exemplified by serotonin, include about 2,000 compounds, with members like vincamine and vincristine widely explored for their biological and pharmacological properties. Tropane alkaloids, found in families like Erythroxylaceae, Convolvulaceae, and Solanaceae, with key members such as scopolamine and atropine, have legitimate medicinal uses and exhibit anticholinergic activities.



Indole alkaloids

Psilocybesemilanceata

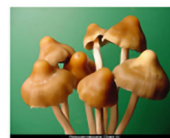


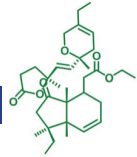
Hallecinogens from *Psilocybe* mushrooms

R=H: *Psilocin*
R=PO₃H: *Psilocybin* } *in vivo*

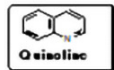
Serotonin agonists,
not broken down in the body
strong, continuous nerve impulse

Psilocybe Mexicana

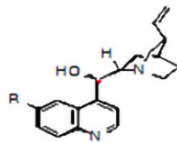




Quinoline and isoquinoline alkaloids, resulting from the fusion of benzene and pyridine rings, include important compounds like quinine with diverse biological activities, ranging from antimalarial to analgesic properties. Purine alkaloids, derived from adenine and guanine, encompass caffeine, theobromine, and theophylline, offering antioxidant and anti-inflammatory benefits.

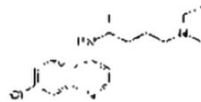


Cinchona pubescens (Kina tree) from South America

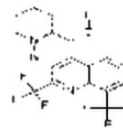


R=OMe: Quinine
R=H: Quinidine

Quinidine: Antiarrhythmic
Quinine: Antimalarial

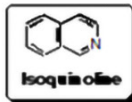


Chloroquine –
synthetic analog



Mefloquine is used to
prevent malaria (malaria
prophylaxis)

Quinoline alkaloids



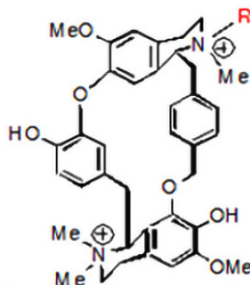
Curare - Poison - Southamerican Indians

Mixt. of alkaloids

Several sources i.e. *Chondodendrontomentosum*



Ex. *Mimacurium klorid*
Muscle relax, anesthesia



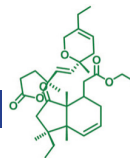
R=H: Tubocurarin

Isoquinoline alkaloids



CONCLUSION

In conclusion, natural products encompass a diverse array of chemical compounds derived from living organisms, including plants, animals, fungi, and microorganisms. These compounds can be classified into primary and secondary metabolites based on their roles and functions within organisms. Primary metabolites are essential for basic metabolic processes and include carbohydrates, proteins, lipids, nucleic acids, amino acids, enzymes, vitamins, and minerals. They are ubiquitous in all living organisms and play critical roles in energy production, cell structure, genetic information transfer, and other fundamental biochemical pathways. Secondary metabolites, on the other hand, are not directly involved in primary metabolic processes but often serve external functions such as defense, competition, or attraction. They are produced by organisms as a response to environmental challenges and can have medicinal properties. Secondary metabolites include terpenoids, alkaloids, flavonoids, and steroids, among others. The pharmaceutical industry has recognized the significant potential of natural products, particularly secondary metabolites, in drug discovery and development. Many important drugs, including antibiotics and anticancer agents, have been derived from natural sources. Overall, the study of natural products is essential not only for understanding the complexity of biological systems but also for discovering new therapeutic agents and advancing medical science. Continued research in this field holds promise for addressing various health challenges and improving human well-being.



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