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1. Terpenes and terpenoids

Natural products are the compounds which isolate from different natural sources such as plants, animals, microbes, insects, plant pathogens, and endophytes and marine. These are known as secondary metabolites since they are formed due to the enzymatic resections of primary metabolites (amino acids, sugars, vitamins, etc.). Terpenes belong to the biggest

![Classification of terpenes](image-url)

**Figure 1.** Classification of terpenes.
class of secondary metabolites and basically consist of five carbon isoprene units which are assembled to each other (many isoprene units) by thousands of ways. Terpenes are simple hydrocarbons, while terpenoids are modified class of terpenes with different functional groups and oxidized methyl group moved or removed at various positions. Terpenoids are divided into monoterpenes, sesquiterpenes, diterpenes, sesterpenes, and triterpenes depending on its carbon units (Figure 1). Most of the terpenoids with the variation in their structures are biologically active and are used worldwide for the treatment of many diseases. Many terpenoids inhibited different human cancer cells and are used as anticancer drugs such as Taxol and its derivatives. Many flavorings and nice fragrances are consisting on terpenes because of its nice aroma. Terpenes and its derivatives are used as antimalarial drugs such as artemisinin and related compounds. Meanwhile, terpenoids play a diverse role in the field of foods, drugs, cosmetics, hormones, vitamins, and so on. This chapter provides introduction and information on the bioactive terpenes isolated currently from different natural sources.

2. Monoterpenes

Monoterpenes consist of 10 carbon atoms with two isoprene units and molecular formula C<sub>10</sub>H<sub>16</sub>. These are naturally present in the essential and fixed oils of plants and related sources. Monoterpenes are structurally divided into the acyclic, monocyclic, and bicyclic type of

<table>
<thead>
<tr>
<th>Names</th>
<th>Plant source</th>
<th>Activity</th>
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</tr>
</thead>
<tbody>
<tr>
<td>9-OH-isoegomaketone [(2E)-1-(3-furanyl)-4-OH-4-Me-2-penten-1-one]</td>
<td>Leaves of Perilla frutescens var. crispa</td>
<td>It exhibited inhibitory activity on nitric oxide (NO) production in lipopolysaccharide (LPS)-activated RAW264.7 cells with an IC&lt;sub&gt;50&lt;/sub&gt; value of 14.4 μM. Compounds in the SC-CO&lt;sub&gt;2&lt;/sub&gt; extracts of the radiation mutant cultivar and the original plant were quantified by high-performance liquid chromatography with diode array detection.</td>
<td>[2]</td>
</tr>
</tbody>
</table>

Table 1. Source and biological activities of some monoterpenes.

![Figure 2. Structure of monoterpenes.](https://example.com/monoterpenes.png)
The compounds belong to this class usually have strong aroma and odor and are used in many pharmaceutical companies. Mixture of different monoterpene-based oils is used as fragrances for making perfumes and in other cosmetics. Most of the monoterpenes are active biologically with strong antibacterial activities. Several studies have shown in vitro and in vivo antitumor activity of many essential oils obtained from plants. The antitumor activity of essential oils of many species has been related to the presence of monoterpenes in their composition [1]. Herein, we are discussing some of the recently published active monoterpenes (Table 1, Figure 2).

### 3. Sesquiterpenes

Sesquiterpenes are the class of secondary metabolites consisting of three isoprene units (C₁₅H₂₄) and found in linear, cyclic, bicyclic, and tricyclic forms. Sesquiterpenes are also found in the form of lactone ring (Table 2). Many of the latex in latex-producing plants contain sesquiterpene, and these are potent antimicrobial and anti-insecticidal agent. Artemisinin, a sesquiterpene lactone, one of the most active compounds in *Artemisia annua* shoots and roots (Figure 3).

<table>
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</thead>
<tbody>
<tr>
<td>Arvestolides H and I</td>
<td><em>Artemisia vestita</em></td>
<td>H and I showed inhibitory effects on nitric oxide production in BV-2 cells induced by lipopolysaccharide with IC₅₀ values of 43.2 and 39.9 μM, respectively.</td>
<td>[3]</td>
</tr>
<tr>
<td>Drimenin</td>
<td>Canelo tree <em>Drimys winteri</em></td>
<td>Potency for drimenin at the hα4β2 AChR (0.97 μM) is several folds higher than that for other clinically used antidepressants using the same method. It could be used as a molecular scaffold for the development of more potent inhibitors with higher selectivity for the hα4β2 AChR.</td>
<td>[4]</td>
</tr>
<tr>
<td>Artefreynic acid B, C, and G</td>
<td><em>Artemisia freyniana</em></td>
<td>B, C, and G exhibited inhibitory effects against LPS-stimulated nitric oxide (NO) production in RAW 264.7 macrophage cells with IC₅₀ values of 10.8, 12.6, and 11.7 μM, respectively.</td>
<td>[5]</td>
</tr>
<tr>
<td>Chrysanthemulide A</td>
<td><em>Chrysanthemum indicum</em></td>
<td>Mechanistic study revealed that the potential anti-inflammatory activity of A appears to be mediated via suppression of an LPS-induced NF-κB pathway and downregulation of MAPK activation.</td>
<td>[6]</td>
</tr>
<tr>
<td>14-O-Acetylinsulicolide A, 6β,9α-dihydroxy-14-p-nitrobenzoylcinnamolide, insulicolide A</td>
<td>Marine-derived <em>Aspergillus ochraceus</em> fungus</td>
<td>These compounds were evaluated for their cytotoxicities against three renal carcinoma cell lines, ACHN, OS-RC-2, and 786-O cells, and it displayed activities with IC₅₀ values of 0.89–8.2 μM. Further studies indicated that it arrested the cell cycle at the G0/G1 phase at a concentration of 1 μM and induced late apoptosis at a concentration of 2 μM after a 72 h treatment of 786-O cells.</td>
<td>[7]</td>
</tr>
</tbody>
</table>
Santhemoidin A was the most active compound found in this study, with IC_{50} values of 0.10 μM against *Trypanosoma brucei rhodesiense* trypomastigotes and selectivity indices of 20.5, respectively. [8]

Table 2. Source and biological activities of some sesquiterpenes.

<table>
<thead>
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<th>Ref.</th>
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</thead>
<tbody>
<tr>
<td>Santhemoidin A</td>
<td><em>Tarchonanthus camphoratus</em> and <em>Schkuhria pinnata</em></td>
<td>A was the most active compound found in this study, with IC_{50} values of 0.10 μM against <em>Trypanosoma brucei rhodesiense</em> trypomastigotes and selectivity indices of 20.5, respectively.</td>
<td>[8]</td>
</tr>
</tbody>
</table>

Figure 3. Structures of sesquiterpenes.
4. Diterpenes

Diterpenoids belong to a versatile class of chemical constituents found in different natural sources having $\text{C}_{20}\text{H}_{32}$ molecular formula and four isoprene units (Figure 4). This class of compounds showed significant biological activities including anti-inflammatory, antimicrobial,
anticancer, and antifungal activities. Some of the diterpenes also have cardiovascular activity, such as grayanotoxin, forskolin, eleganolone, marrubenol, and 14-deoxyandrographolide. Kaurane and pimarane-type diterpenes are also biologically active metabolites isolated from the roots and leaves of different plants (Table 3).

### 5. Sesterpenes

Sesterpenes consist of 25 carbon atoms with 5 isoprene units and molecular formula $\text{C}_{25}\text{H}_{40}$ (Figure 5). These are naturally present in the fungus, marine organism, insects, sponges, lichens, and protective waxes of insects. These types of compounds are biologically active having anti-inflammatory, anticancer, antimicrobial, and antifungal activities (Table 4).
Figure 5. Structures of sesterpenes.

<table>
<thead>
<tr>
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<tbody>
<tr>
<td>Cybastacines A and B</td>
<td>Nostoc sp. Cyanobacterium</td>
<td>A and B showed moderate in vitro antibiotic activities. Sesterterpenes are rare among microbial secondary metabolites, with only one report of a previous alkaloid—sesterterpene found in cyanobacteria. This discovery represents a significant addition to the novel chemical structures active against resistant bacterial strains.</td>
<td>[15]</td>
</tr>
<tr>
<td>Scalarane sesterterpenes</td>
<td>Mushroom species, <em>Pleurotus ostreatus</em> and <em>Scleroderma areolatum</em></td>
<td>This compound exhibited moderate micromolar activity against <em>P. falciparum</em> 3D7 and <em>T. cruzi Tulahuen C4</em> parasites. It showed &lt;50% inhibition at 25 μM, when incubated with the tumoral liver cell line, HepG2 (HB-8065) for 72 h.</td>
<td>[16]</td>
</tr>
</tbody>
</table>

Table 4. Source and biological activities of some sesterpenes.
6. Triterpenes

A major class of secondary metabolites are known as triterpenes and it usually contains 30 carbon atoms consisting of 6 isoprene units (Figure 6). It is derived from the squalene biosynthetic pathway. Triterpenes have many methyl groups and it can be oxidized into alcohols, aldehydes, and carboxylic acids, which make it complex and differentiate it biologically. Triterpenes have many active sites for the glycosylation which converts it into another big class of compounds, namely, saponins (triterpene glycoside). Herein, we are discussing some recently published bioactive triterpenes (Table 5).
Meroterpenes are the secondary metabolites with partial terpenoid skeleton. Meroterpenoids were partially derived from mevalonic acid pathways and widely derived from animals, plants, and microorganisms. They exhibit various biological activities, including cytotoxicity against cancer cell lines. Here are some examples:

<table>
<thead>
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<tbody>
<tr>
<td>Polyporenic acid B</td>
<td>Fruiting bodies of Fomitopsis palustris</td>
<td>It showed strong cytotoxicity against the HCT116, A549, and HepG2 cell lines with IC₅₀ values of 8.4, 12.1, and 12.2 μM, respectively.</td>
<td>[17]</td>
</tr>
<tr>
<td>Pardinol B</td>
<td>Tricholoma pardinum</td>
<td>Compound showed strong cytotoxicity against HL-60 SMMC-7721 A-549 MCF-7 SW480, 8.3, 15.0, 14.4, 12.7, 15.0 μM, respectively.</td>
<td>[18]</td>
</tr>
<tr>
<td>Pardinol E</td>
<td>T. pardinum</td>
<td>E exhibited strong cytotoxicity against HL-60 SMMC-7721 A-549 MCF-7 SW480, 9.8, 11.7, 9.8 11.9, 15.6, μM, respectively.</td>
<td>[18]</td>
</tr>
<tr>
<td>Pardinol F</td>
<td>T. pardinum</td>
<td>F showed strong cytotoxicity against HL-60 SMMC-7721 A-549 MCF-7 SW480, 11.2, 15.6, 12.6, 10.5, 14.1 μM, respectively.</td>
<td>[18]</td>
</tr>
<tr>
<td>Xuedanencins G</td>
<td>Tubers of Hemsleya pensianensis</td>
<td>G and H were evaluated for cytotoxic activity against the Hela human cancer cell line and compounds showed significant cytotoxicity with IC₅₀ value at 1.82 and 2.45 μM, respectively.</td>
<td>[19]</td>
</tr>
<tr>
<td>and H</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cyclocariols A, B, and H</td>
<td>Leaves of Cyclocarya paliurus</td>
<td>A, B, and H were tested against human colon tumor (HCT-116) cell lines, exhibited good activities with IC₅₀ values of 6.53, 4.94, and 6.48 μM, respectively.</td>
<td>[20]</td>
</tr>
</tbody>
</table>

Table 5. Source and biological activities of some triterpenes.

7. Meroterpenes

Meroterpenes are the secondary metabolites with partial terpenoid skeleton. Meroterpenoids were partially derived from mevalonic acid pathways and widely derived from animals, plants,
bacteria, and fungi [21] (Figure 7). Meroterpene biosynthesis expands the diversity available to isoprenoid pathways alone and allows for the assembly of natural products with highly unique structural attributes. Organisms belonging to the fungal kingdom have become proficient at exploiting this broad chemical synthesis platform for complex metabolite production. Herein, we are discussing some of the recently published bioactive meroterpenes (Table 6).

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**References**


