Review

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Constituents from Chloranthaceae plants and their biological activities

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Abstract: The Chloranthaceae is a small family with only four genera (*Ascarina, Chloranthus, Hedyosmum*, *Sarcandra*), of which nearly 70 species are distributed around the world. Chemical constituents in Chloranthaceae plants, especially sesquiterpenes, have attracted a great deal of attention in recent 5 years. Many characteristic constituents of this family may be responsible for anti-microbial, anti-tumor and other activities. In order to provide information for the future research, the structures and biological activities of the known constituents from the plants of Chloranthaceae have been reviewed in this article.

Keywords: biological activities; chemical constituents; Chloranthaceae; plants.

Introduction

The Chloranthaceae is a small family with only four genera (*Ascarina*, *Chloranthus*, *Hedyosmum*, *Sarcandra*), nearly 70 species which are distributed throughout tropics and subtropical zones of South America, East Asia and Pacific. Genus *Ascarina* consists of about 12 species, found in the Australian region, the Pacific Islands and Madagascar. The genus *Chloranthus* consists of 15 species, mainly distributed in eastern Asia, and all species can be found in China. Genus *Hedyosmum* is mainly distributed in tropical America, and consists of 41 species. The last genus *Sarcandra* consists of three species. Of those plants in Chloranthaceae family, there are three genera (*Chloranthus*, *Hedyosmum*, *Sarcandra*), 16 species and five varieties distributed in China. Many species of Chloranthaceae have been used as herbal medicines which show varied medicinal features. In order to provide information for the further research work, this article reviews the structures and biological activities of the known constituents from the plants of Chloranthaceae.

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Chemical constituents

Of over 70 Chloranthaceae species, there are 21 species have been studied about chemical constituents. In the genus of *Ascarina*, only one species *Ascarina lucida* was reported about the isolation of 15 flavonoids. Plants in genus *Chloranthus* have achieved wide and deep studies. Among the 15 species, 14 have been investigated for their chemical constituents as follows, *Chloranthus japonicus*, 63 compounds isolated and elucidated; *Chloranthus serratus*, 48 compounds; *Chloranthus henryi*, 48 compounds; *Chloranthus multistachys*, 46 compounds; *Chloranthus spicatus*, 41 compounds; *Chloranthus anhuiensis*, 22 compounds; *Chloranthus elatior*, 18 compounds; *Chloranthus sessilifolius*, 17 compounds; *Chloranthus fortune*, 13 compounds; *Chloranthus angustifolius*, eight compounds; *Chloranthus glaber*, seven compounds; *Chloranthus holostegius*, six compounds; *Chloranthus tianmushanensis*, two compounds; and *Chloranthus erectus*, one compound. Of the 41 species of genus *Hedyosmum*, only

four species have been studied for chemical constituents. These are *Hedyosmum orientale* from which nine compounds have been isolated; *Hedyosmum brasiliense*, seven compounds; *Hedyosmum angustifolium*, four compounds; and *Hedyosmum arborescens*, one compound isolated. The species *Sarcandra glabra* and *Sarcandra hannanensis* have been analyzed. *S. glabra* is used as traditional herbal medicine in China for the remedy of influenza, pneumonia, rheumatoid arthritis and bacillary dysentery. In total, 100 constituents have been isolated from the whole plants of *S. glabra* during the period of 2005–2015. It ranks the first in the numbers of isolated compounds in all 21 species of Chloranthaceae. *S. hannanensis* is the unique species only distributed in the province of Hainan, China. There are 18 compounds isolated from this species to date.

The chemical constituents of Chloranthaceae plants include terpenoids, coumarins, lignans, flavonoids and some other compounds. Their structures (compounds **1–504**) are shown in Figures 1–7, and their names and the corresponding plant sources are collected in Tables 1–7. Possible biogenetic pathway of selected sesquiterpenes in the plants of Chloranthaceae are shown in Schemes 1–3.

Sesquiterpenoids

Plants of Chloranthaceae are rich in sesquiterpenes of eudesmane, lindenane, guaiane, germacrane, cadinane, and aromadendrane-type compounds.

Eudesmanes

Eudesmanes are the main constituents in the genus of *Chloranthus*, mainly found in the species *C. serratus* (**1–17**), *C. spicatus* (**18–30**), *C. Henryi* (**31–42**), *C. elatior* (**43–55**), *C. japonicus* (**56–66**), *C. multistachy* (**75–81**), *C. anhuiensis* (**82–86**), *C. angustifolius* (**87–89**), *C. glaber* (**90**), *C. fortunei* (**91**), and *C. erectus* (**92**). In the genus of *Sarcandra*, eight eudesmanes (**67–74**) have been isolated from *S. glabra*. As for the genus of *Hedyosmum*, only two eudesmanes (**93** and **94**) have been found, one in *H. orientale* and second in *H. brasiliense*. Totally 94 eudesmanes have been reported to date. In 1985, the first three eudesmanes **1–3** were isolated from the roots of *C. serratus* [1]. Compounds **4–7** [2], **8–15** [3] and **16–17** [4] were isolated from the whole plants of *C. serratus*. Compound **4** possesses a nitro group at C-1 which is an uncommon substituent of eudesmane-type sesquiterpenes. Compound **8**, named serralactone A, was first isolated from the whole plants of *C. serratus* in 2009. But in 2010 it was isolated again from the whole plants of *S. glabra*, mistakenly reported as a new sesquiterpene and named sarcandralactone B [5]. Thus, serralactone A and sarcandralactone B show virtually identical HR-MS, ^{1}H-NMR and ^{13}C-NMR spectra.

Chloranthus spicatus plants grown in Vietnam mainly produce flowers for scenting tea. Phytochemical investigation of this plant have led to compounds **2** and **18**, which have been isolated for the first time as minor constituents of the essential oil from the flowers of *C. spicatus* [6]. Compounds **19–23** have been isolated from a polar extract of the aerial parts of *C. spicatus* [7]. Among them, compounds **19** and **20** differ in absolute stereochemistry at C-4, and compound **23** is a cycloeudesmane-type sesquiterpene. Compounds **24–27** have been isolated from the roots of *C. spicatus* [8]. Compound **25** has an eudesmane-type backbone with the same substitution pattern as compound **24**, but differs in the stereochemistry of the H-C fragment (R = H), as shown in Figure 1. Compound **26** was first isolated from the roots of *C. spicatus* in 2010 and, mistakenly, also reported as a new compound from the whole plants of *C. multistachys* in 2012 [9] and named multislactone A. Compound **27** is an *O*-methylated derivative of **26**. In 2012, Yang and co-workers re-examined the data of *C. spicatus* in order to explore the chemical differences between aerial parts and whole plants. As a result, two new compounds **28**, **29**, and one known compound **30** were isolated [10]. Compound **29** was reported as a new sesquiterpenoid both in the whole plants of *C. spicatus* and *C. elaior* in the same year [11].

The species *C. henryi* has long been used as a folk medicine for dispelling pathogenic wind, removing dampness, and for promoting blood circulation. In 2005, compounds **31–32** were isolated from the roots of *C. henryi* for the first time [12] and compounds **33** [13] and **34** [14] were isolated from leaves and stems of *C. henryi*. The structure of **33** was elucidated by spectroscopic methods. Compound **34** has an uncertain configuration at C-11. Compounds **5**, **35** and **36** have been isolated from leaves and stems of *C. henryi* [15]. Compounds **37–39** have been isolated from roots of *C. henryi* [16]. Compounds **40–42** have been isolated from the whole plant of *C. henryi* [17]. Compound **41** shows a significant anti-neuroinflammatory effect by inhibiting nitric-oxide (NO) production in lipopolysaccharide (LPS)-stimulated murine BV-2 microglial cells with relatively low cytotoxicity.

The species *C. elatior* is a perennial plant that grows in the Southwest of China. In 2012, two compounds **43** and **44** were isolated from the whole plants of *C. elatior* [11]. Six 2-oxoeudesm-7(11)-en-12,8-olide derivatives, named chlorantholides A–F (**45–50**), were isolated from

Table 1 Sesquiterpenes.

No.	Name	Part	Source	References
	Eudesmanes			
1	Neoacolamone	*Roots*	*C. serratus*	[1]
2	7α-Hydroxy-neoacolamone (7α-Hydroxy-eudesm-4-en-6-one)	*Roots*	*C. serratus*	[1]
		Flowers	*C. spicatus*	[6]
3	Ccolamone	*Roots*	*C. serratus*	[1]
4	Chlorantene B	*Whole plants*	*C. serratus*	[2]
5	Chlorantene C (4β-Hydroxy-8,12-epoxyeudesma-7,11-diene-1,6-dione)	*Whole plants*	*C. serratus*	[2]
		Leaves and stems	*C. henryi*	[15]
		Whole plants	*C. multistachys*	[36]
6	Chlorantene D	*Whole plants*	*C. serratus*	[2]
		Whole plants	*C. multistachys*	[36]
7	Chlorantene G	*Whole plants*	*C. serratus*	[2]
8	Serralactone A (Sarcandralactone B) (1β-Hydroxyeudesma-3,7(11)-dien-12,8α-olide)	*Whole plants*	*C. serratus*	[3]
		Whole plants	*S. glabra*	[5]
9	Serralactone B	*Whole plants*	*C. serratus*	[3]
10	Serralactone C	*Whole plants*	*C. serratus*	[3]
11	Serralactone D	*Whole plants*	*C. serratus*	[3]
12	Neolitacumone B	*Whole plants*	*C. serratus*	[3]
		Whole plants	*C. japonicus*	[28]
		Whole plants	*C. elatior*	[11]
		Whole plants	*C. spicatus*	[10]
		Whole plants	*S. glabra*	[5]
13	Cyperusol C	*Whole plants*	*C. serratus*	[3]
14	Eudesm-4(15)-ene-1β,7,11-triol	*Whole plants*	*C. serratus*	[3]
15	Eudesm-3-ene-1β,7,11-triol	*Whole plants*	*C. serratus*	[3]
		Whole plants	*S. glabra*	[5]
16	4β-Hydroxy-5α,8β(*H*)-eudesm-7(11)-en-8,12-olide	*Whole plants*	*C. serratus*	[4]
17	4β,8β-Dihydroxy-5α(*H*)-eudesm-7(11)-en-8,12-olide	*Whole plants*	*C. serratus*	[4]
		Whole plants	*C. elatior*	[11]
18	Eudesma-4(15),7(11),9-trien-12-olide	*Flowers*	*C. spicatus*	[6]
19	1β,4β-Dihydroxy-5α,8β(H)-eudesm-7(11)*Z*-en-8,12-olide	*Aerial part*	*C. spicatus*	[7]
		Whole plants	*C. multistachys*	[115]
		Aerial part	*C. elatior*	[19]
20	1β,4α-Dihydroxy-5α,8β(H)-eudesm-7(11)*Z*-en-8,12-olide	*Aerial part*	*C. spicatus*	[7]
		Whole plant	*C. multistachys*	[115]
		Aerial part	*C. elatior*	[19]
21	Homalomenol A	*Aerial part*	*C. spicatus*	[7]
22	Oplodiol	*Aerial part*	*C. spicatus*	[7]
		Whole plants	*C. serratus*	[3]
23	5α,7α (H)-6,8-Cycloeudesma-1β,4β-diol	*Aerial part*	*C. spicatus*	[7]
		Whole plants	*C. spicatus*	[10]
24	4α-Hydroxy-5α,8β(*H*)-eudesm-7(11)-en-8,12-olide	*Roots*	*C. spicatus*	[8]
		Whole plants	*C. elatior*	[11]
		Whole plants	*C. serratus*	[4]
25	4α-Hydroxy-5α,8α(*H*)-eudesm-7(11)-en-8,12-olide	*Roots*	*C. spicatus*	[8]
		Whole plants	*C. elatior*	[11]
26	4α,8β-Dihydroxy-5α(*H*)-eudesm-7(11)-en-8,12-olide (multislactone A)	*Roots*	*C. spicatus*	[8]
		Whole plants	*C. elatior*	[11]
		Whole plants	*C. serratus*	[4]
		Whole plants	*C. multistachys*	[9]
		Roots	*C. angustifolius*	[41]
		Aerial part	*C. angustifolius*	[42]
27	4α-Hydroxy-5α(H)-8β-methoxy-eudesm-7(11)-en-8,12-olide	*Roots*	*C. spicatus*	[8]

Table 1 (continued)

No.	Name	Part	Source	References
28	Chlospicate A	*Whole plants*	*C. spicatus*	[10]
29	Chlospicate B (chlorelactone A)	*Whole plants*	*C. spicatus*	[10]
		Whole plants	*C. elatior*	[11]
30	5-Eudesmene-1β,4α-diol	*Whole plants*	*C. spicatus*	[10]
		Aerial part	*C. elatior*	[19]
31	Curcolonol	*Roots*	*C. henryi*	[12]
		Whole plants	*C. multistachys*	[90]
		Roots	*C. anhuiensis*	[39]
		Roots	*C. angustifolius*	[41]
32	Zedoarofuran	*Roots*	*C. henryi*	[12]
		Whole plants	*C. multistachys*	[36]
33	1α-Hydroxy-8,12-epoxyeudesma-4,7,11-triene-6,9-dione	*Leaves and stems*	*C. henryi*	[13]
34	7α-8-Oxoeudesm-4(14)-en-12-oic acid	*Leaves and stems*	*C. henryi*	[14]
35	1α-Methoxy-8,12-epoxyeudesma-4,7,11-trien-6-one	*Leaves and stems*	*C. henryi*	[3]
36	11,12,13-Trihydroxyeudesma-4(15),8-dien-9-one	*Leaves and stems*	*C. henryi*	[3]
37	1α-Hydroxy-8,12-epoxyeudesma-4,7,11-triene-3,6-dione	*Roots*	*C. henryi*	[16]
38	Curcolone	*Roots*	*C. henryi*	[16]
39	Endesm-4(15)-en-7α,11-diol	*Roots*	*C. henryi*	[16]
40	(5*S*,6*R*,8*S*,10*R*)-6-Hydroxyeudesma-4(15),7(11)-diene-12,8-olide	*Whole plant*	*C. henryi*	[17]
41	6α-Hydroxyeudesma-4(15),7(11),8(9)-triene-12,8-olide	*Whole plant*	*C. henryi*	[17]
42	8,12-Epoxy-1β-hydroxyeudesma-4(15),7,11-trien-6-one	*Whole plant*	*C. henryi*	[17]
43	Chlorelactone B (9α-Hydroxy-5α,8β(H)-2-oxoeudesma-3,7(11)-dien-12,8α-olide)	*Whole plants*	*C. elatior*	[11]
44	Chloranthalic acid	*Whole plants*	*C. elatior*	[11]
45	Chlorantholide A (2-Oxoeudesma-3,7(11),8-trien-12,8-olide)	*Whole plants*	*C. elatior*	[18]
46	Chlorantholide B (2-Oxoeudesma-3,7(11)-dien-12,8α-olide)	*Whole plants*	*C. elatior*	[18]
47	Chlorantholide C (2-Oxoeudesma-3,7(11)-dien-12,8β-olide)	*Whole plants*	*C. elatior*	[18]
48	Chlorantholide D (8β-Hydroxy-2-oxoeudesma-3,7(11)-dien-12,8-olide)	*Whole plants*	*C. elatior*	[18]
49	Chlorantholide E (8β,9α-Dihydroxy-2-oxoeudesma-3,7(11)-dien-12,8-olide)	*Whole plants*	*C. elatior*	[18]
50	Chlorantholide F (5α,8β-Dihydroxy-2-oxoeudesma-3,7(11)-dien-12,8-olide)	*Whole plants*	*C. elatior*	[18]
51	(1*R*,4*R*,5*R*,8*S*,10*R*)-1-Hydroxy-4-methoxy-eudesm-7(11)-en-12,8-olide	*Aerial parts*	*C. elatior*	[19]
52	Chloranthone A	*Aerial parts*	*C. elatior*	[20]
53	Chloranthone B	*Aerial parts*	*C. elatior*	[20]
54	Chloranthone C	*Aerial parts*	*C. elatior*	[20]
55	Chloranthone D	*Aerial parts*	*C. elatior*	[20]
56	8β-Hydroxyeudesma-4(15),7(11)-dien-12,8-olide (codonolactone, atractylenolide III, atractylenolide β)	*Whole plants*	*C. japonicus*	[21]
		Roots	*C. henryi*	[13]
		Roots	*C. anhuiensis*	[39]
		Roots	*C. fortunei*	[44]
		Leaves	*C. tianmushanensis*	[86]
		Whole plants	*C. multistachys*	[9]
		Whole plants	*C. spicatus*	[10]
		Whole plants	*C. serratus*	[4]
		Whole plants	*S. glabra*	[31]
57	Shizukafuranol	*Whole plants*	*C. japonicus*	[22]
58	Shizukolidol	*Whole plants*	*C. japonicus*	[22]
		Whole plants	*C. henryi*	[23]
		Roots	*C. spicatus*	[8]
		Whole plants	*C. elatior*	[18]
59	5α-(Cinnamoyloxy)-8,12-epoxy-3-methoxy-7β*H*,8α*H*-eudesma-3,11-dien-6-one	*Roots*	*C. japonicus*	[24]
60	8β-(Cinnamoyloxy)eudesma-4(14),7(11)-dien-12,8-olide	*Roots*	*C. japonicus*	[24]

Table 1 (continued)

No.	Name	Part	Source	References
61	8,12-Epoxy-1α-hydroxy-4α*H*,5α*H*-eudesma-7,11-diene-6,9-dione	*Roots*	*C. japonicus*	[24]
62	8,12-Epoxy-1α-methoxy-4α*H*,5α*H*-eudesma-7,11-diene-6,9-dione	*Roots*	*C. japonicus*	[24]
63	Chlorajapolide I (4β-Hydroxy-8β-ethyoxyl-7(11)-eneudesm-8,12-olide)	*Aerial part*	*C. japonicus*	[25]
64	3,4,8α-Trimethyl-4α,7,8,8α-tetrahydro-4a-naphto [2,3-b] furan-9-one	*Aerial part*	*C. japonicus*	[26]
65	Chloraeudolide	*Whole plants*	*C. japonicus*	[27]
		Whole plants	*C. multistachys*	[38]
66	Chlojaponilactone A (8β-Droxyeudesm-3, 7(11)-dien-12, 8α-olide)	*Whole plants*	*C. japonicus*	[28]
67	Sarcaglaboside A (1β,5α,8β*H*-Eudesman-4(15),7(11)-dien-8α,12-olide-1-*O*-β-D-glucopyranoside)	*Whole plants*	*S. glabra*	[29]
		Whole plants	*C. spicatus*	[72]
		Whole plants	*C. japonicus*	[52]
68	Sarcaglaboside B (1β,5α,8β*H*-Eudesman-2,4(15),7(11)-trien-8α,12-olide-1-*O*-β-D-glucopyranoside)	*Whole plants*	*S. glabra*	[29]
69	Sarcaglaboside H (4α-Hydroxy-5α,8βH-eudesman-7(11)-en-8α,12-olide-15-*O*-β-D-glucopyranoside)	*Whole plants*	*S. glabra*	[30]
70	8β,9α-Dihydroxyeudesman-4(15),7(11)-dien-8α,12-olide	*Whole plants*	*S. glabra*	[31]
71	Glabranol B (1β,4α,7β,11-Tetrahydroxyeudesmane)	*Aerial parts*	*S. glabra*	[32]
72	1α,8α,9α-Trihydroxyeudesman-3(4),7(11)-dien-8β,12-olide	*Whole plants*	*S. glabra*	[33]
73	Atractylenolide IV	*Whole plants*	*S. glabra*	[34]
74	Sarcandralactone E	*Whole plants*	*S. glabra*	[35]
75	Chlomultin B	*Whole plants*	*C. multistachys*	[36]
		Whole plant	*C. henryi*	[17]
76	1β,8β-Dihydroxyeudesman-3,7(11)-dien-8α,12-olide	*Whole plants*	*C. multistachys*	[36]
77	Lasianthuslactone A	*Whole plants*	*C. multistachys*	[9]
		Whole plants	*C. serratus*	[4]
78	*ent*-(3*R*)-3-Hydroxyatractylenolide III	*Whole plants*	*C. multistachys*	[38]
79	Multistalactone A (4*R*,5*R*,6*S*,8*R*,10*S*)-6,8-Dihydroxy-4,15-epoxy-eudes-7(11)-en-12,8-olide)	*Whole plants*	*C. multistachys*	[38]
80	Multistalactone B (4*S*,5*R*,8*R*,10*R*)-4-Hydroxy-1-oxoeudesm-7(11)-en-12,8-olide)	*Whole plants*	*C. multistachys*	[38]
81	Multistalactone C (4*R*,5*R*,8*S*,10*R*)-4-Hydroxy-1-oxoeudesm-7(11)-en-12,8-olide	*Whole plants*	*C. multistachys*	[38]
82	(3*R*)-3-Hydroxyatractylenolide III	*Roots*	*C. anhuiensis*	[39]
83	8β-Hydroxy-1-oxoeudesma-3,7(11)-dien-12,8α-olide	*Roots*	*C. anhuiensis*	[39]
84	5α-Hydroxyeudesma-4(15),7(11),8(9)-trien-8,12-olide	*Roots*	*C. anhuiensis*	[39]
85	1-Oxoeudesm-7(11)-en-8,12-olide	*Roots*	*C. anhuiensis*	[39]
		Whole plants	*C. henryi*	[17]
86	Anhuienoside A	*Leaves*	*C. anhuiensis*	[40]
87	9α-Hydroxycurcolonol	*Roots*	*C. angustifolius*	[41]
88	3α-Hydroxy-4-deoxy-5-dehydrocurcolonol	*Roots*	*C. angustifolius*	[41]
89	4β,7β,11-Enantioeudesmantriol	*Aerial parts*	*C. angustifolius*	[42]
90	Atractylenolide II (8βH-Eudesma-4(14),7(11)-dien-12,8-olide)	*Leaves*	*C. glaber*	[43]
		Leaves and stems	*C. henryi*	[13]
91	Atractylenolactam	*Roots*	*C. fortunei*	[44]
92	Chloranerectuslactone V	*Leaves*	*C. erectus*	[45]
93	9α-Hydroxyasterolide	*Aerial part*	*H. orientale*	[37]
94	1α-Acetoxyeudesma-3,7(11)-dien-8,12-olide	*Leaves*	*H. brasiliense*	[46]
	Lindenranes			
95	Shizukanolide A (Shizukanolide)	*Aerial parts*	*C. japonicus*	[48]
		Roots	*C. japonicus*	[65]
		Roots	*C. glaber*	[56]
		Whole plants	*C. henryi*	[23]
		Whole plants	*S. glabra*	[93]
96	Chloranthalactone C (13-deoxyshizukanolide H)	*Whole plants*	*C. japonicus*	[21]

Table 1 (continued)

No.	Name	Part	Source	References
		Roots	*C. holostegius*	[95]
		Roots	*C. serratus*	[1]
		Roots	*C. fortunei*	[44]
		Aerial part	*C. fortunei*	[57]
97	Chloranthalactone D	*Whole plants*	*C. japonicus*	[21]
98	Chloranthalactone E	*Whole plants*	*C. japonicus*	[21]
		Leaves	*C. glaber*	[43]
		Whole plants	*S. glabra*	[31]
		Roots	*C. japonicus*	[49]
99	Shizukanolide C	*Roots*	*C. japonicus*	[49]
		Whole plants	*C. japonicus*	[28]
		Aerial part	*C. fortunei*	[57]
		Whole plants	*C. spicatus*	[72]
100	Shizukanolide D	*Roots*	*C. japonicus*	[50]
101	9-Hydroxy heterogorgiolide	*Aerial part*	*C. japonicus*	[51]
		Leaves	*C. erectus*	[45]
		Whole plants	*S. glabra*	[30]
102	Yinxiancaoside A (Sarcaglaboside G)	*Whole plants*	*C. japonicus*	[52]
		Whole plants	*S. glabra*	[30]
103	Chlorajapolide A ((1α,3α,6β,8β)-6-Hydroxy-15-al-1*H*-lindan-4,7(11)-dien-12,8α-olide)	*Whole plants*	*C. japonicus*	[27]
104	Chlorajapolide B ((1α,3α,6β,8β)-6,15-Epoxy-15-hydroxy-1*H*-lindan-4,7(11)-dien-12,8α-olide)	*Whole plants*	*C. japonicus*	[27]
105	Chlorajapolide C ((1α,3α,8β)-15-Hydroxy-1*H*-lindan-4,7(11)-dien-12,8α-olide)	*Whole plants*	*C. japonicus*	[27]
106	Chlorajapolide D ((1α,3α,5α,8β)-4α,15-Dihydroxy-1*H*-lindan-4,7(11)-dien-12,8α-olide)	*Whole plants*	*C. japonicus*	[27]
107	Chlorajapolide E ((1α,3α,4β,9β)-8β-Methoxy-9α-hydroxy-15-acetyl-1*H*-lindan-4,7(11)-dien-12,8α-olide)	*Whole plants*	*C. japonicus*	[27]
108	Chlorajaposide ((1α,3α-8β-Glucopyranosyl-1*H*-lindan-4(15),7(11)-dien-12,8α-olide)	*Whole plants*	*C. japonicus*	[27]
109	Chlorajapolide F	*Aerial part*	*C. japonicus*	[25]
110	Chlorajapolide G (chlojaponilactone E)	*Aerial part*	*C. japonicus*	[25]
		Whole plants	*C. japonicus*	[53]
111	Chlorajapolide H	*Aerial part*	*C. japonicus*	[25]
112	Chlojaponilactone B	*Whole plants*	*C. japonicus*	[53]
113	Chlojaponilactone C	*Whole plants*	*C. japonicus*	[53]
114	Chlojaponilactone D	*Whole plants*	*C. japonicus*	[53]
115	Chloranthalactone E 8-*O*-β-D-glucopyranoside (8β,9α-Dihydroxy-5α,9β*H*-lindan-4(15),7(13)-dien-8α,12-olide-8β-*O*-β-D-glucopyranoside)	*Whole plants*	*S. glabra*	[29]
116	8β,9α-Dihydroxylindan-4(5),7(11)-dien-8α,12-olide	*Whole plants*	*S. glabra*	[31]
117	Sarcaglaboside F (8β,9β-Epoxy-4α-hydroxy-5αH-lindan-7(11)-en-8α,12-olide-15-O-β-D-glucopyranoside)	*Whole plants*	*S. glabra*	[30]
118	Sarcandralactone A	*Whole plants*	*S. glabra*	[5]
119	Glabranol A (8α,9α,15-Trihydroxylinden-4,7(11)-dien-12,8β-olide)	*Whole plants*	*S. glabra*	[32]
120	4α-Hydroxy-5αH-lindan-8 (9)-en-8, 12-olide	*Whole plants*	*S. glabra*	[54]
121	Sarcandralactone C	*Whole plants*	*S. glabra*	[35]
122	Sarcandralactone D	*Whole plants*	*S. glabra*	[35]
123	Chloranthalactone A = shizukanolide B (Dehydro-shizukanolide, 8,9-Dehydroshizukanolide)	*Roots*	*C. glaber*	[55]
		Aerial parts	*C. japonicus*	[48]
		Leaves	*C. glaber*	[43]
		Flowers	*C. spicatus*	[6]
		Whole plants	*C. henryi*	[23]
		Roots	*C. japonicus*	[65]

Table 1 (continued)

No.	Name	Part	Source	References
		Leaves	*C. tianmushanensis*	[86]
		barks	*H. angustifolium*	[60]
124	Chloranthalactone B	*Roots*	*C. glaber*	[55]
		Leaves	*C. glaber*	[43]
		Whole plants	*C. japonicus*	[21]
		Whole plants	*S. glabra*	[30]
		Aerial part	*C. japonicus*	[25]
		Leaves	*C. erectus*	[45]
125	Chloranthalactone F	*Leaves*	*C. glaber*	[43]
126	Chloranoside A (Shizukanolide E 15-*O*-β-glucoside)	*Whole plants*	*C. glaber*	[56]
		Whole plants	*C. japonicus*	[52]
		Aerial part	*C. fortunei*	[57]
		Whole plants	*C. spicatus*	[72]
		Whole plants	*S. glabra*	[29]
127	Chloranoside B (Shizukanolide F 15-*O*-β-glucoside)	*Whole plants*	*C. glaber*	[56]
128	Shizukanolide G	*Aerial part*	*C. fortunei*	[57]
129	Shizukanolide H	*Aerial part*	*C. fortunei*	[57]
		Whole plants	*C. japonicus*	[28]
		Whole plants	*S. glabra*	[35]
130	Chlorafortulide	*Whole plants*	*C. fortunei*	[58]
131	Shizukanolide E	*Roots*	*C. serratus*	[50]
		Roots	*C. henryi*	[12]
		Whole plants	*S. glabra*	[100]
132	Shizukanolide F	*Roots*	*C. serratus*	[50]
		Aerial part	*C. fortunei*	[57]
		Whole plants	*C. spicatus*	[72]
		Whole plants	*S. glabra*	[34]
133	13-Hydroxy-8,9-dehydroshizukanolide (onoseriolide)	*Stems and Leaves*	*H. brasiliense*	[59]
		Aerial part	*H. orientale*	[37]
		barks	*H. angustifolium*	[60]
		Leaves	*H. brasiliense*	[46]
134	Oxyonoseriolide	*barks*	*H. angustifolium*	[60]
135	Hedyosmone	*barks*	*H. angustifolium*	[60]
	Guaianes			
136	Hedyosumin A (7α,10α-Epoxy-3-oxo-1αH-guaia-4(5),11(13)-dien-8α,12-olide)	*Aerial part*	*H. orientale*	[37]
137	Hedyosumin B (7α,10α-Epoxy-3-oxo-1,11αH-guaia-4(5)-en-8α,12-olide)	*Aerial part*	*H. orientale*	[37]
138	Hedyosumin C (3β-Hydroxy-7α,10α-epoxy-1,11αH-guaia-4(5)-en-8α,12-olide)	*Aerial part*	*H. orientale*	[37]
139	Hedyosumin D (13-Acetoxy-1α,5αH-guaia-3,7(11),10(15)-trien-8α,12-olide)	*Aerial part*	*H. orientale*	[37]
140	Hedyosumin E (1α,5α,8βH-Guaia-3,7(11)-dien-8,12-olide-10-*O*-β-D-glucopyranoside)	*Aerial part*	*H. orientale*	[37]
141	10α-Hydroxy-1,5αH-guaia-3,7(11)-dien-8α,12-olide	*Aerial part*	*H. orientale*	[37]
142	Hedyosmum F	*Aerial part*	*H. orientale*	[61]
143	Chlomultin A	*Whole plants*	*C. multistachys*	[36]
144	(1*R*,4*S*,5*R*,8*S*,10*S*)-Zedoalactone A	*Whole plants*	*C. multistachys*	[38]
145	Multistalactone D (chlospicate C)	*Whole plants*	*C. multistachys*	[38]
		Whole plants	*C. spicatus*	[10]
146	Multistalactone E	*Whole plants*	*C. multistachys*	[38]
147	Multistalactone F	*Whole plants*	*C. multistachys*	[38]
148	Podoandin	*Leaves*	*H. brasiliense*	[62]
149	1,2-Epoxy-10α-hydroxy-podoandin	*Leaves*	*H. brasiliense*	[62]
150	1-Hydroxy-10,15-methylenepodoandin	*Leaves*	*H. brasiliense*	[62]
151	7,10-Epoxy-1,5-guaia-3,11-dien-8,12-olide (7,10-Epoxy-hedyosminolide)	*Leaves*	*H. arborescens*	[63]

Table 1 (continued)

No.	Name	Part	Source	References
		Aerial part	*H. orientale*	[61]
152	Chlorantene A	*Whole plants*	*C. serratus*	[2]
153	(1*S*,4*S*,5*S*,8*R*,10*S*)-4,10-Dihydroxyguai-7(11)-en-12,8-olide (zedoalactone A)	*Whole plants*	*C. serratus*	[3]
		Aerial part	*C. elatior*	[19]
154	12-Oxochloraniolide A	*Whole plants*	*C. henryi*	[17]
155	(7*S*,1(10)*Z*)-4,5-Secoguaia-1(10),11-diene-4,5-dione	*Whole plants*	*C. henryi*	[17]
156	Chloraniolide A	*Roots*	*C. anhuiensis*	[39]
157	Chlospicate D	*Whole plants*	*C. spicatus*	[10]
158	Zedoalactone E (1βH,5βH,8βH-4α,10α-Dihydroxyguai-7(11)-en-12,8-olide)	*Aerial part*	*C. elatior*	[19]
	Germacranes			
159	Acoragermacrone	*Roots*	*C. serratus*	[1]
160	Aederone	*Roots*	*C. serratus*	[1]
161	Furanodienone	*Roots*	*C. serratus*	[1]
		Whole plants	*C. japonicus*	[22]
		Roots	*C. angustifolius.*	[41]
		Whole plants	*S. glabra*	[93]
162	Chlorantene E	*Whole plants*	*C. serratus*	[2]
163	(1*E*,4*Z*)-8-Hydroxy-6-oxogermacra-1(10),4,7(11)-trieno-12,8-lactone	*Leaves and stems*	*C. henryi*	[3]
164	8-Methoxy-6-oxogermacra-1(10),4,7(11)-trieno-12,8-lactone	*Leaves and stems*	*C. henryi*	[3]
165	15-Hydroxy-11βH-8-oxogermacra-1(10),4-dieno-12,6α-lacton	*Leaves and stems*	*C. henryi*	[3]
166	Zederone epoxide	*Whole plants*	*C. henryi*	[17]
167	(1*S*,4*S*,5*S*,10*S*)-1,10 : 4,5-Diepoxygermacrone	*Whole plants*	*C. henryi*	[17]
168	Germacra-5*E*,10(14)-dien-1β,4β-diol	*Whole plants*	*C. spicatus*	[10]
169	4α,5α-Epoxy-1(10),7(11)-Dienegermacr-8α,12-olide	*Whole plants*	*C. spicatus*	[10]
170	Isofuranodiene	*Roots*	*C. japonicus*	[65]
		Roots	*C. serratus*	[1]
		Leaves	*C. tianmushanensis*	[86]
171	Glechomanolide	*Roots*	*C. japonicus*	[65]
		Leaves	*C. tianmushanensis*	[86]
		Whole plants	*C. serratus*	[3]
172	Chloranthatone	*Roots*	*C. fortunei*	[44]
173	1β,10α,4α,5β-Diepoxy-6β-hydroxyglechoman-8α,12-olide	*Whole plants*	*C. multistachys*	[122]
174	Sarcaglaboside E (1*E*,4*Z*)-8β*H*-Germacra-1,4,7(11)-trien-8α,12-olide-15-*O*-[β-D-apiofuranosyl-(1→6)-*O*-β-D-glucopyranoside]	*Whole plants*	*S. glabra*	[29]
	Cadinanes			
175	(11β)-8,11-Dihydroxycadina-6,8,10-trien-12-oic acid γ-lactone	*Leaves and stems*	*C. henryi*	[14]
		Whole plants	*C. henryi*	[17]
176	(4α,11β)-8,11-Dihydroxycadina-6,8,10-trien-12-oic acid γ-lactone	*Leaves and stems*	*C. henryi*	[14]
		Whole plants	*C. henryi*	[17]
177	(8α)-6,8-Dihydroxycadina-7(11),10(15)-dien-12-oic acid γ-lactone	*Leaves and stems*	*C. henryi*	[14]
178	(4α)-8-Hydroxy-12-norcardina-6,8,10-trien-11-one	*Whole plants*	*C. henryi*	[17]
179	(-)-Dihydropyrocurzerenone	*Whole plants*	*C. serratus*	[66]
180	Pyrocurzerenone	*Whole plants*	*C. serratus*	[66]
181	6α,8α,10α-Trihydroxycardina-4(15),7(11)-dien-12-oic acid γ-lactone	*Whole plants*	*C. serratus*	[4]
182	Chlomultin C	*Whole plants*	*C. multistachys*	[36]
183	Chlomultin D	*Whole plants*	*C. multistachys*	[36]
184	Furanocadina-1(10),6,8-triene-4-ol	*Whole plants*	*C. multistachys*	[36]
		Whole plants	*C. serratus*	[4]
	Eremophilanes			
185	(-)-Istanbulin A	*Leaves*	*S. glabra*	[67]
186	(3*R*,4*S*,5*R*,10*S*,11*S*)-3-Hydroxy-8-oxo-6-eremophilen-12-oic acid	*Leaves*	*C. anhuiensis*	[40]

Table 1 (continued)

No.	Name	Part	Source	References
187	Anhuienol	*Leaves*	*C. anhuiensis*	[40]
188	(3*R*,4*S*,5*R*,6*R*,8*R*,10*S*)-3,6,8-Trihydroxy-7(11)-eremophilen-12,8-olide	*Leaves*	*C. anhuiensis*	[40]
189	3α,6α-Dihydroxy-8αH-7(11)-eremophilen-12,8-olide	*Leaves*	*C. anhuiensis*	[40]
190	6αH,8αH-7(11)-Eremophilen-12,8:15,6-diolide	*Leaves*	*C. anhuiensis*	[40]
191	Istanbulin F (1β,8-Dihydroxyeremophila-3,7(11)-dien-8,12-olide)	*Roots*	*C. anhuiensis*	[39]
192	10α-Hydroxy-1-oxoeremophila-7(11),8(9)-diene-8,12-olide	*Whole plants*	*C. japonicus*	[28]
193	Tsoongianolide D	*Whole plants*	*C. japonicus*	[53]
194	Tsoongianolide E	*Whole plants*	*C. japonicus*	[53]
	Aromadendranes			
195	Aromadendrane-4α,10β-diol	*Leaves*	*C. glaber*	[43]
196	4β,10α-Dihydroxyaromadendrane ((+)-Alloromadendrane-4β,10α-diol)	*Aerial part*	*C. spicatus*	[7]
		Whole plants	*C. spicatus*	[10]
		Aerial part	*C. elatior*	[19]
197	Spathulenol	*Aerial part*	*C. spicatus*	[7]
		Aerial part	*H. orientale*	[37]
		Barks	*H. angustifolium*	[60]
		Whole plants	*S. glabra*	[5]
		Whole plants	*C. elatior*	[11]
198	Aromadendrane-4β,10β-diol	*Aerial part*	*H. orientale*	[37]
199	1αH,5βH,6αH,7αH-4β,10β,15-Trihydroxyaromadendrane	*Aerial part*	*C. elatior*	[19]
200	Aromadendrane-4β,10α,15-triol	*Aerial part*	*C. elatior*	[19]
	Elemanes			
201	Isogermafurenolide	*Flowers*	*C. spicatus*	[6]
202	Sarcaglaboside C (5α,8β*H*-Eleman-1,3,7(11)-trien-8α,12-olide-15-*O*-β-D-glucopyranoside)	*Whole plants*	*S. glabra*	[29]
203	Sarcaglaboside D (5α,8β*H*-Eleman-1,3,7(11)-trien-8α,12-olide-15-*O*-[β-D-apiofuranosyl-(1→6)-*O*-β-D-glucopyranoside]	*Whole plants*	*S. glabra*	[29]
204	Chlorantene F	*Whole plants*	*C. serratus*	[2]
205	15-Hydroxy-isogermafurenolide	*Leaves*	*H. brasiliense*	[46]
	Other sesquiterpenes			
206	Shizukaacoradienol	*Whole plants*	*C. japonicus*	[22]
		Roots	*C. fortunei*	[44]
207	Oplopanone	*Aerial parts*	*C. spicatus*	[7]
		Whole plants	*C. spicatus*	[10]
208	Dayejijiol	*Whole plants*	*C. henryi*	[23]
209	Pisumionoside (3*S*,5*S*,6*R*,7*E*)-3,5,6-Trihydroxy-9-oxo-megastigm-7-ene-3-*O*-β-glucopyranoside)	*Whole plants*	*C. japonicus*	[52]
210	Yinxiancaoside B (3β,5α,6β,7*E*)-3-*O*-β-Glucopyranosyl-3,5,6,9-tetrahydroxymegastigm-7-ene-9-*O*-β-glucopyranoside	*Whole plants*	*C. japonicus*	[52]
211	11-Hydroxydrim-8,12-en-14-oic acid	*Roots*	*C. henryi*	[16]
212	Acrostalic acid	*Roots*	*C. anhuiensis*	[39]
213	Chlospicate E	*Whole plants*	*C. spicatus*	[10]
214	Homalomenol C	*Whole plants*	*C. spicatus*	[10]
215	(1*S*,4*S*,5*S*,6*R*,7*R*,10*S*)-1,4-Dihydroxymaaliane	*Aerial part*	*C. elatior*	[19]
	Sesquiterpene polymers			
216	Shizukaol A	*Roots*	*C. japonicus*	[68]
		Roots	*C. serratus*	[81]
		Roots	*C. fortunei*	[83]
217	Shizukaol E	*Roots*	*C. japonicus*	[69]
		Whole plants	*C. spicatus*	[72]
		Roots	*C. fortunei*	[83]
		Whole plants	*S. glabra*	[5]

Table 1 (continued)

No.	Name	Part	Source	References
218	Shizukaol F	*Roots*	*C. japonicus*	[69]
		Whole plants	*C. multistachys*	[90]
		Aerial part	*C. fortunei*	[57]
		Roots	*C. spicatus*	[76]
		Roots	*C. fortunei*	[83]
		Aerial part	*C. angustifolius*	[42]
219	Shizukaol G	*Roots*	*C. japonicus*	[69]
		Roots	*C. spicatus*	[8]
		Whole plants	*S. glabra*	[5]
		Whole plants	*C. fortunei*	[58]
		Seeds	*S. glabra*	[87]
220	Shizukaol H	*Roots*	*C. japonicus*	[69]
		Whole plants	*C. spicatus*	[10]
		Whole plants	*S. glabra*	[35]
221	Shizukaol I	*Roots*	*C. japonicus*	[69]
		Roots	*C. fortunei*	[83]
222	Tishizukaol A	*Roots*	*C. japonicus*	[70]
223	Shizukaol J	*Roots*	*C. japonicus*	[70]
		Roots	*C. fortunei*	[83]
224	Yinxiancaol	*Roots*	*C. japonicus*	[24]
		Aerial part	*C. fortunei*	[57]
225	Chlorajaponol	*Whole plants*	*C. japonicus*	[27]
226	Chlorajaponilide A	*Whole plants*	*C. japonicus*	[71]
227	Chlorajaponilide B	*Whole plants*	*C. japonicus*	[71]
228	Chlorajaponilide C	*Whole plants*	*C. japonicus*	[71]
229	Chlorajaponilide D	*Whole plants*	*C. japonicus*	[71]
230	Chlorajaponilide E	*Whole plants*	*C. japonicus*	[71]
		Whole plants	*S. glabra*	[35]
231	Chloramultilide B	*Whole plants*	*C. spicatus*	[72]
		Aerial part	*C. fortunei*	[57]
232	Chloramultilide C (henriol A)	*Whole plants*	*C. spicatus*	[72]
		Roots	*C. henryi*	[73]
		Whole plants	*C. multistachys*	[79]
		Whole plants	*C. elatior*	[11]
		Whole plants	*C. serratus*	[4]
		Roots	*C. angustifolius*	[41]
		Aerial part	*C. angustifolius*	[42]
233	Chloramultilide D (henriol B)	*Whole plants*	*C. spicatus*	[72]
		Roots	*C. henryi*	[73]
		Whole plants	*C. multistachys*	[79]
234	Spicachlorantin A	*Roots*	*C. spicatus*	[74]
		Whole plants	*C. serratus*	[4]
		Whole plants	*C. henryi*	[17]
		Roots	*C. angustifolius.*	[41]
235	Spicachlorantin B	*Roots*	*C. spicatus*	[74]
		Whole plants	*C. multistachys*	[79]
		Whole plants	*C. japonicus*	[71]
		Whole plants	*C. henryi*	[17]
		Aerial part	*C. angustifolius*	[42]
236	Spicachlorantin C	*Roots*	*C. spicatus*	[75]
		Whole plants	*C. serratus*	[4]
237	Spicachlorantin D	*Roots*	*C. spicatus*	[75]
238	Spicachlorantin E	*Roots*	*C. spicatus*	[75]
239	Spicachlorantin F	*Roots*	*C. spicatus*	[75]
		Whole plants	*S. glabra*	[35]
240	Spicachlorantin G	*Roots*	*C. spicatus*	[76]

Table 1 (continued)

No.	Name	Part	Source	References
		Whole plants	*C. henryi*	[17]
241	Spicachlorantin H	*Roots*	*C. spicatus*	[76]
242	Spicachlorantin I	*Roots*	*C. spicatus*	[76]
243	Spicachlorantin J	*Roots*	*C. spicatus*	[76]
244	Chloramultilide A	*Whole plants*	*C. multistachys*	[77]
		Whole plants	*C. spicatus*	[72]
		Roots	*C. spicatus*	[74]
		Whole plants	*C. serratus*	[4]
		Whole plants	*C. henryi*	[17]
		Roots	*C. angustifolius.*	[41]
245	Multistalide A	*Whole plants*	*C. multistachys*	[78]
246	Multistalide B	*Whole plants*	*C. multistachys*	[78]
247	Chloramultiol A	*Whole plants*	*C. multistachys*	[79]
248	Chloramultiol B	*Whole plants*	*C. multistachys*	[79]
249	Chloramultiol C	*Whole plants*	*C. multistachys*	[79]
250	Chloramultiol D	*Whole plants*	*C. multistachys*	[79]
251	Chloramultiol E	*Whole plants*	*C. multistachys*	[79]
252	Chloramultiol F	*Whole plants*	*C. multistachys*	[79]
253	Chloramultiol G	*Whole plants*	*C. multistachys*	[38]
254	Shizukaol B (henriol C)	*Roots*	*C. serratus*	[80]
		Roots	*C. japonicus*	[24]
		Aerial part	*C. japonicus*	[25]
		Roots	*C. henryi*	[73]
		Roots	*C. fortunei*	[83]
		Roots	*C. spicatus*	[8]
		Whole plants	*C. spicatus*	[10]
		Whole plants	*S. glabra*	[5]
		Roots	*C. angustifolius*	[41]
		Aerial part	*C. angustifolius*	[42]
		Seeds	*S. glabra*	[87]
255	Shizukaol C	*Roots*	*C. serratus*	[80]
		Roots	*C. henryi*	[73]
		Whole plants	*C. multistachys*	[79]
		Roots	*C. spicatus*	[8]
		Whole plants	*C. spicatus*	[10]
		Whole plants	*S. glabra*	[5]
		Whole plants	*C. fortunei*	[58]
		Aerial part	*C. japonicus*	[25]
		Seeds	*S. glabra*	[87]
		Aerial part	*C. angustifolius*	[42]
256	Shizukaol D	*Roots*	*C. serratus*	[80]
		Roots	*C. fortunei*	[83]
		Whole plants	*C. multistachys*	[79]
		Roots	*C. spicatus*	[76]
		Aerial part	*C. japonicus*	[25]
		Whole plants	*S. glabra*	[35]
257	Cycloshizukaol A	*Roots*	*C. serratus*	[81]
		Whole plants	*C. multistachys*	[90]
		Aerial part	*C. fortunei*	[57]
		Roots	*C. spicatus*	[8]
		Roots	*C. japonicus*	[124]
		Whole plants	*C. japonicus*	[71]
		Whole plants	*S. glabra*	[5]
258	Serratustones A	*Whole plants*	*C. serratus*	[82]
259	Serratustones B	*Whole plants*	*C. serratus*	[82]
260	8α-Ethoxy-spicachlorantin A	*Whole plants*	*C. serratus*	[4]

Table 1 (continued)

No.	Name	Part	Source	References
261	8α-Hydroxy-chloramultiol F	*Whole plants*	*C. serratus*	[4]
262	Shizukaol K	*Roots*	*C. fortunei*	[83]
263	Shizukaol L	*Roots*	*C. fortunei*	[83]
264	Shizukaol M	*Roots*	*C. fortunei*	[83]
265	Shizukaol N	*Roots*	*C. fortunei*	[83]
		Seeds	*S. glabra*	[87]
266	Shizukaol O	*Roots*	*C. fortunei*	[83]
		Whole plants	*C. fortunei*	[58]
		Aerial part	*C. japonicus*	[25]
267	13′-Acetylshizukaol C (chloraholide D, henriol D)	*Roots*	*C. fortunei*	[83]
		Whole plants	*C. fortunei*	[58]
		Whole plants	*C. holostegius*	[85]
		Roots	*C. henryi*	[73]
		Stems and Roots	*C. henryi*	[118]
		Roots	*C. spicatus*	[8]
		Whole plants	*S. glabra*	[35]
268	Shizukaol P	*Aerial part*	*C. fortunei*	[57]
		Roots	*C. spicatus*	[76]
269	9-*O*-β-Glucopyranosylcycloshizukaol A	*Aerial part*	*C. fortunei*	[57]
270	Chloraholide A	*Whole plants*	*C. holostegius*	[84]
271	Chloraholide B	*Whole plants*	*C. holostegius*	[84]
		Whole plants	*C. spicatus*	[72]
		Whole plants	*C. japonicus*	[71]
272	Chloraholide C	*Whole plants*	*C. holostegius*	[85]
		Whole plants	*C. japonicus*	[71]
273	Chloraholide E	*Whole plants*	*C. holostegius*	[85]
274	Chloraholide F	*Whole plants*	*C. holostegius*	[85]
		Whole plants	*S. glabra*	[5]
275	Tianmushanol	*Leaves*	*C. tianmushanensis*	[86]
		Roots	*C. angustifolius*	[41]
276	8-*O*-Methyltianmushanol	*Leaves*	*C. tianmushanensis*	[86]
		Roots	*C. angustifolius*	[41]
277	Sarcandrolide A (13′-deoxyshizukaol C)	*Whole plants*	*S. glabra*	[5]
		Seeds	*S. glabra*	[87]
278	Sarcandrolide B	*Whole plants*	*S. glabra*	[5]
279	Sarcandrolide C (2‴-*O*-acetylshizukaol G)	*Whole plants*	*S. glabra*	[5]
280	Sarcandrolide D	*Whole plants*	*S. glabra*	[5]
281	Sarcandrolide E	*Whole plants*	*S. glabra*	[5]
282	Sarcandrolide F	*Whole plants*	*S. glabra*	[35]
283	Sarcandrolide G	*Whole plants*	*S. glabra*	[35]
284	Sarcandrolide H	*Whole plants*	*S. glabra*	[35]
285	Sarcandrolide I	*Whole plants*	*S. glabra*	[35]
286	Sarcandrolide J	*Whole plants*	*S. glabra*	[35]
287	Sarglabolide A	*Seeds*	*S. glabra*	[87]
288	Sarglabolide B	*Seeds*	*S. glabra*	[87]
289	Sarglabolide C	*Seeds*	*S. glabra*	[87]
290	Sarglabolide D	*Seeds*	*S. glabra*	[87]
291	Sarglabolide E	*Seeds*	*S. glabra*	[87]
292	Sarglabolide F	*Seeds*	*S. glabra*	[87]
293	Sarglabolide G	*Seeds*	*S. glabra*	[87]
294	Sarglabolide H	*Seeds*	*S. glabra*	[87]
295	Sarglabolide I	*Seeds*	*S. glabra*	[87]
296	Sarglabolide J	*Seeds*	*S. glabra*	[87]
297	Sarglabolide K	*Seeds*	*S. glabra*	[87]
298	Sarcanolide A	*Whole plants*	*S. hainanensis*	[88]
299	Sarcanolide B	*Whole plants*	*S. hainanensis*	[88]

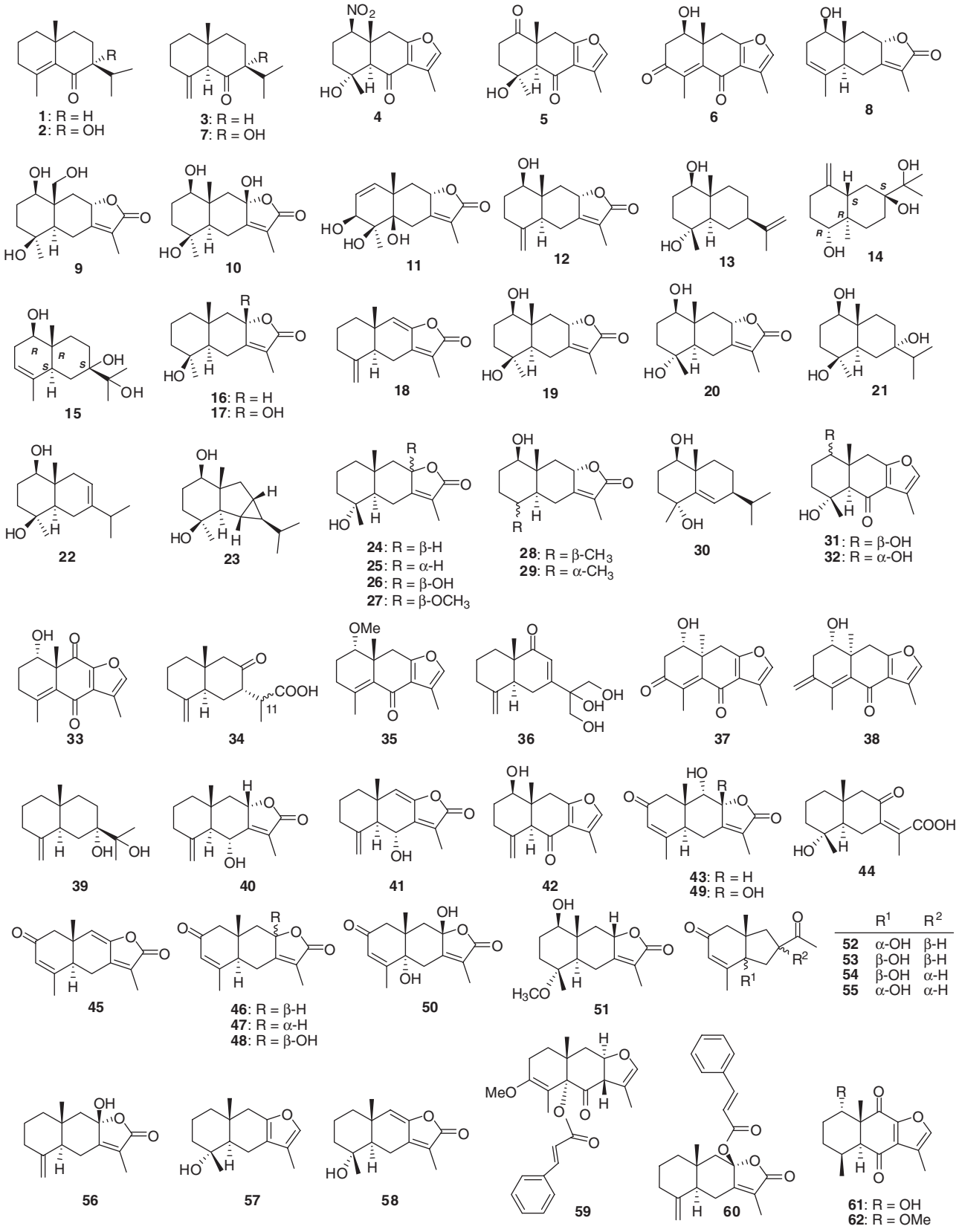


Figure 1 Sesquiterpenoid structures.

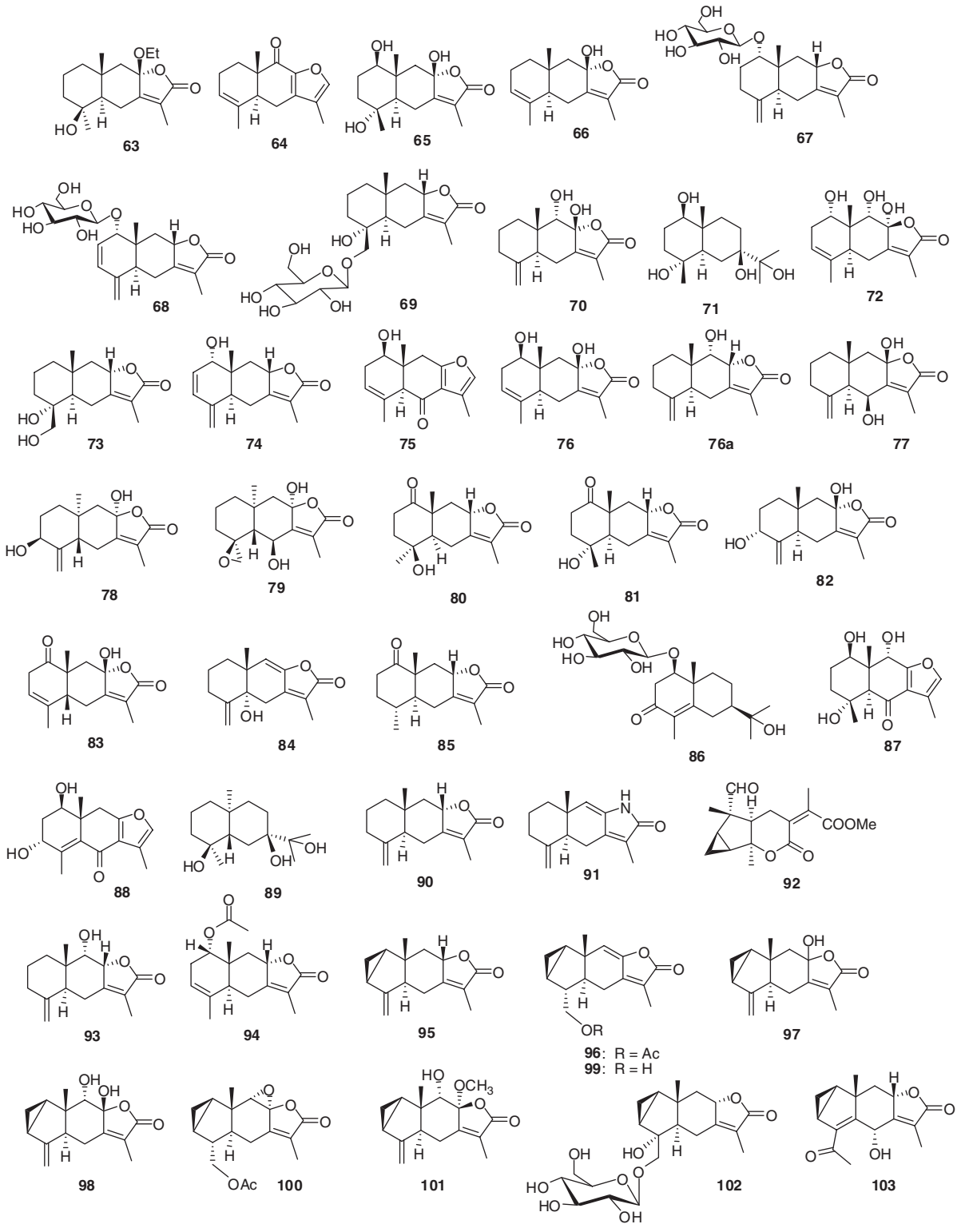


Figure 1 (continued)

the ethanol extract of *C. Elatior* [18]. These six new compounds all have an α,β-unsaturated carbonyl group at C-2 position, and their ^{13}C NMR chemical shifts are in the range of δ_C 196.8–198.6, which are quite different from the chemical shift of C-12 at about δ_C 170.6–174.2. The structure of **83** (chlorantholide D) was also revised in this report. In 2013,

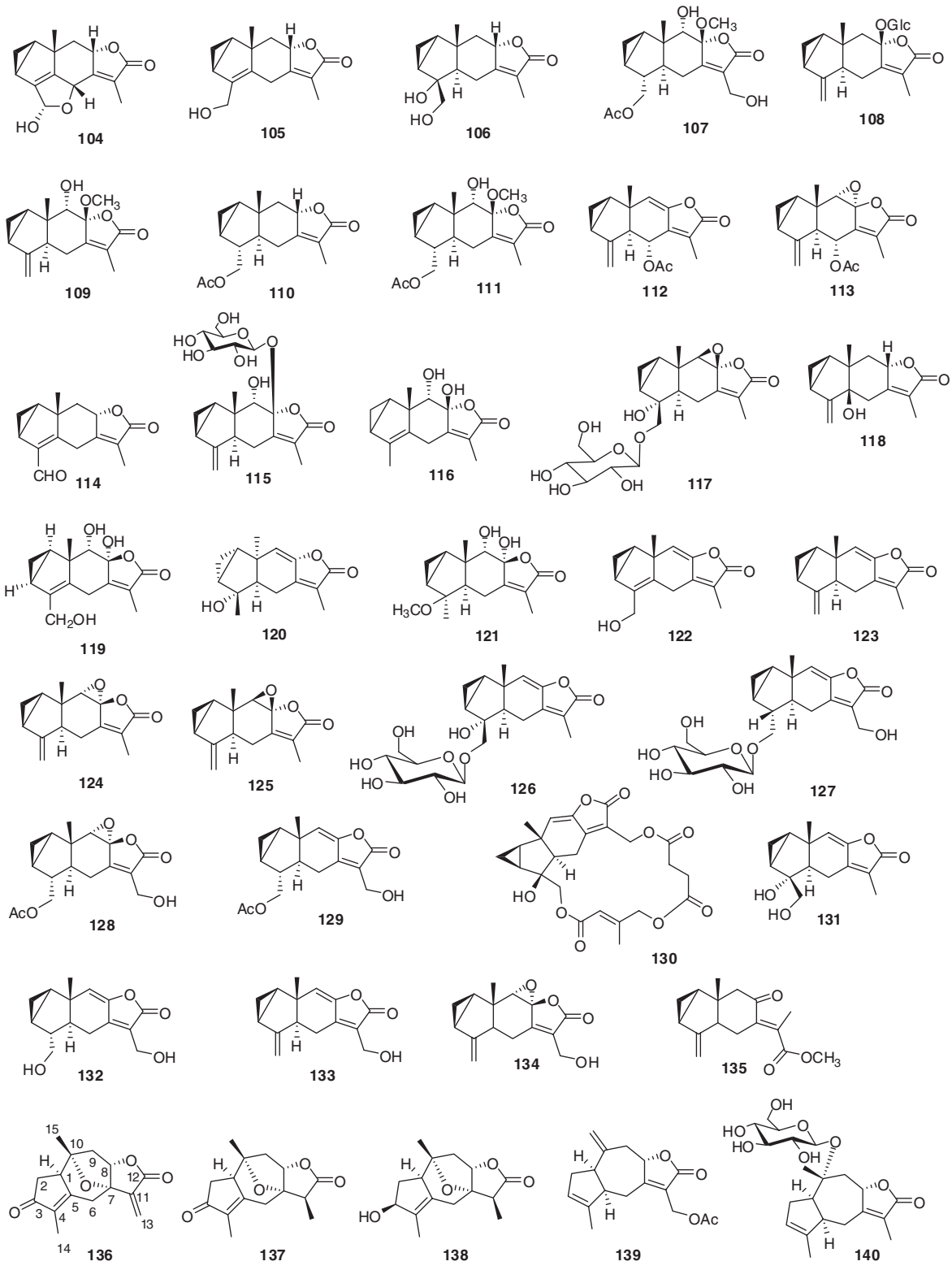


Figure 1 (continued)

compound **51** with a methoxy group rather than a tertiary hydroxy group at C-4 was isolated from the ethanol extract of the aerial parts of *C. elatior* [19]. In 2014, four novel naturally occurring diastereoisomers of dinor-eudesmenes with a degraded five-membered ring B, compounds **52–55**, were isolated from the aerial parts of *C. elatior*.

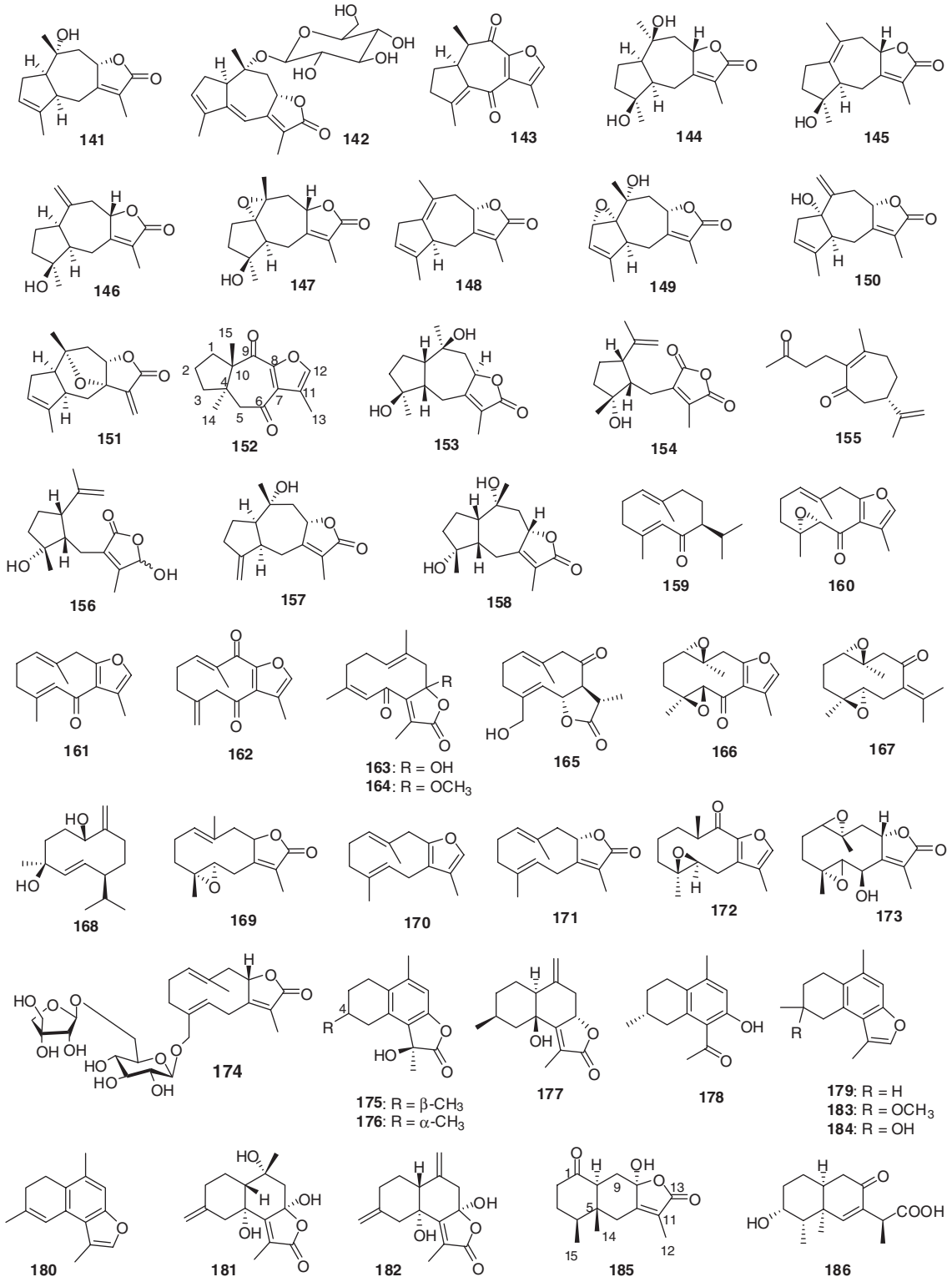


Figure 1 (continued)

Their biosynthesis apparently involves a series of oxidation, degradation, and rearrangement reactions [20].

To date, 14 eudesmane-type sesquiterpenes have been isolated from *C. japonicus*. The first one, compound **56**, was isolated from the whole plants of *C. japonicus* in 1980 [21]. Two additional compounds **57** and **58** were isolated in 1984 [22, 23]. Chemical investigation of the roots of *C. japonicus* have resulted in the isolation and

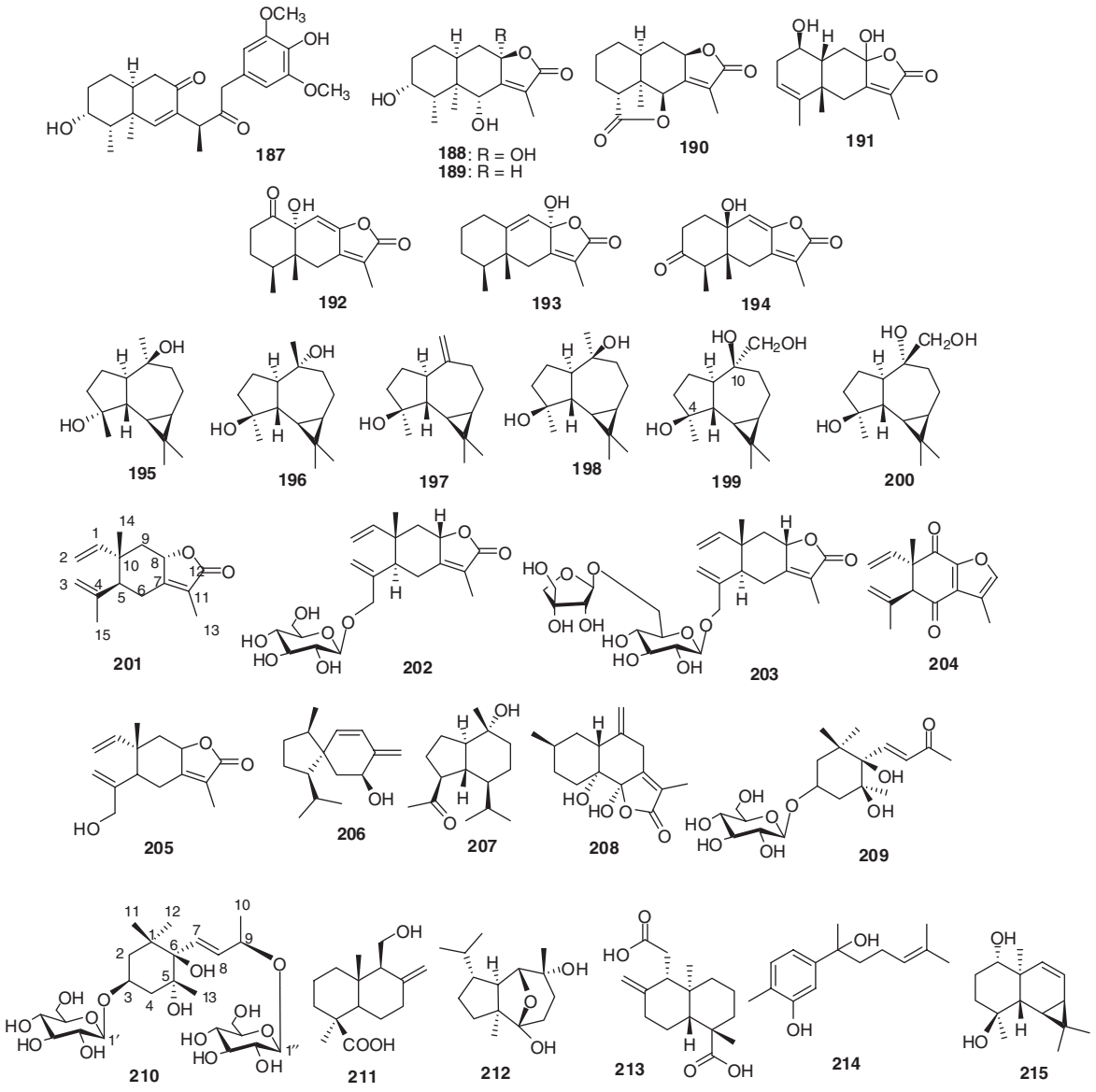


Figure 1 (continued)

characterization of four new eudesmane-type sesquiterpenes **59–62** including two new sesquiterpene cinnamates [24]. The structure elucidation of **59–62** has been conducted by using spectroscopic methods including comparison of the ^{1}H- and ^{13}C-NMR data of **59** with those of other eudesmane-type sesquiterpenes. The ^{13}C-atom signal at δ 169.3 in the ^{13}C-NMR spectrum of **59** has been assigned to the carbonyl of the cinnamoyl group. The (*E*)-configuration of the cinnamoyl group is fully consistent with the coupling constant of 16.2 Hz observed in the doublets for the two olefinic H-atoms at δ 8.09 and δ 6.95. Compounds **63** and **64** have been isolated from the aerial parts of *C. japonicus* [25]. Compound **64**, a novel sesquiterpene furan compound, shows antifungal activity [26]. A new sesquiterpene lactone **65** has been isolated from an ethyl acetate-soluble partition of the ethanol extract of the whole plants of *C. japonicus* [27]. Compound **66** is a new eudesmane-type sesquiterpenoid lactone isolated from the whole plant of *C. japonicus* [28].

The species *Sarcandra glabra*, belonging to the genus *Sarcandra* of Chloranthaceae, grows mainly in the southern part of China and Japan. The whole plant has been used as an antibacterial and antitumor agent in China. The first three new eudesmanolide glycosides, **67**, **68** [29] and **69** [30], have been isolated from the whole plant of *S. glabra*; their sugar moiety has been determined as D-glucose. A new sesquiterpene lactone **70** has been isolated from the whole plant of *S. glabra* [31]. Phytochemical study of the ethanol extract of *S. glabra* has resulted in the isolation of a

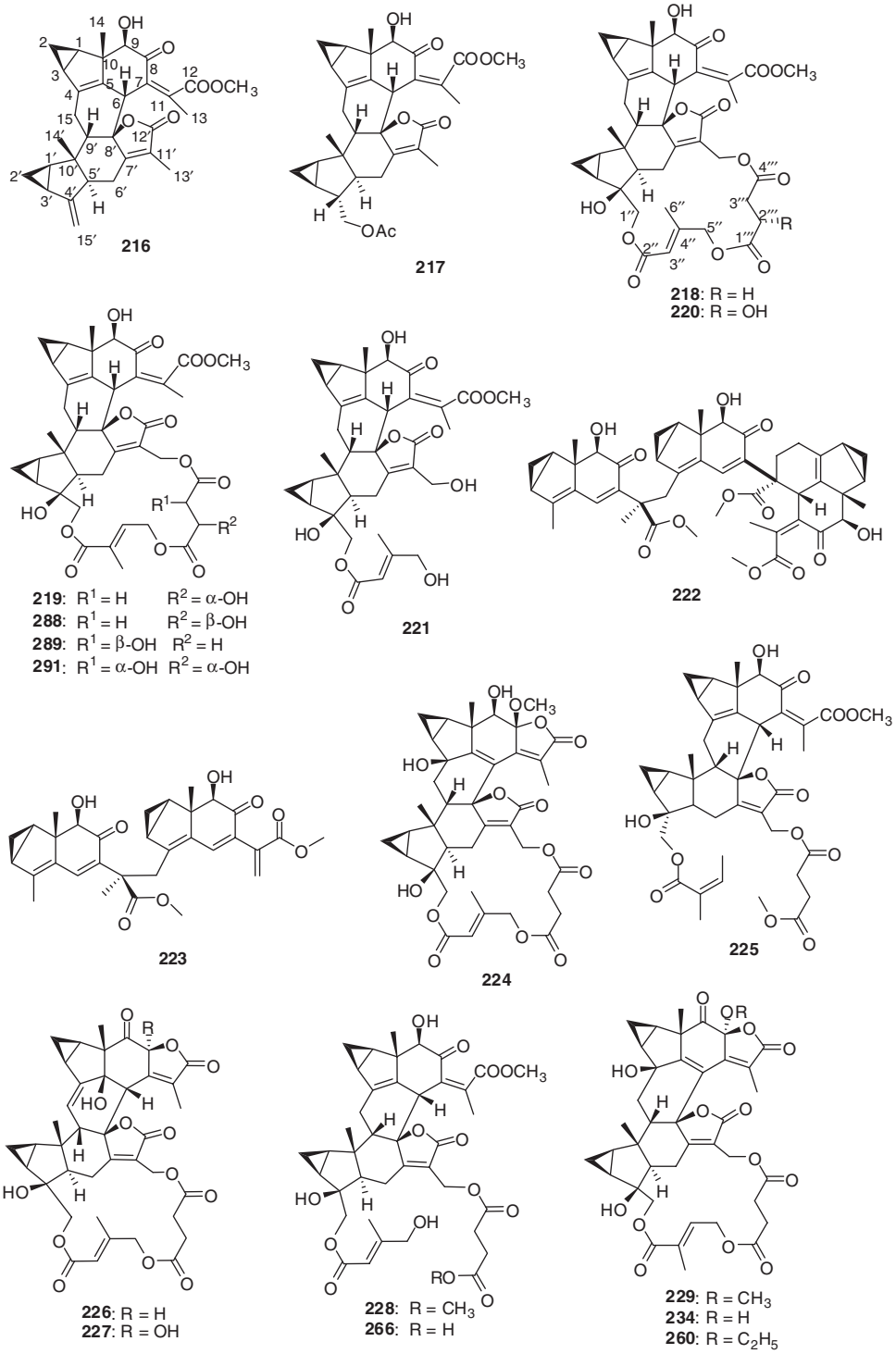


Figure 1 (continued)

new sesquiterpene **71** [32]. In 2012, as a continuation of the chemical investigation of *S. glabra* in the search for hepatoprotective substances, a new sesquiterpene lactone **72** was isolated [33]. Compound **73** has been isolated from the 70% aqueous acetone extract of the whole plant of *S. glabra* and, by far, it is the only eudesmane with a hydroxymethyl substitutent at C-4 found in plants of Chloranthaceae. In the MTT assay, compound **73** has shown little cytotoxic activity against Hela, HCT-8 and MCF-7 cancer cell lines with $IC_{50} > 50$ μg mL^{-1} [34]. A new sesquiterpenoid monomer **74** has been isolated from the whole plants of *S. glabra* [35].

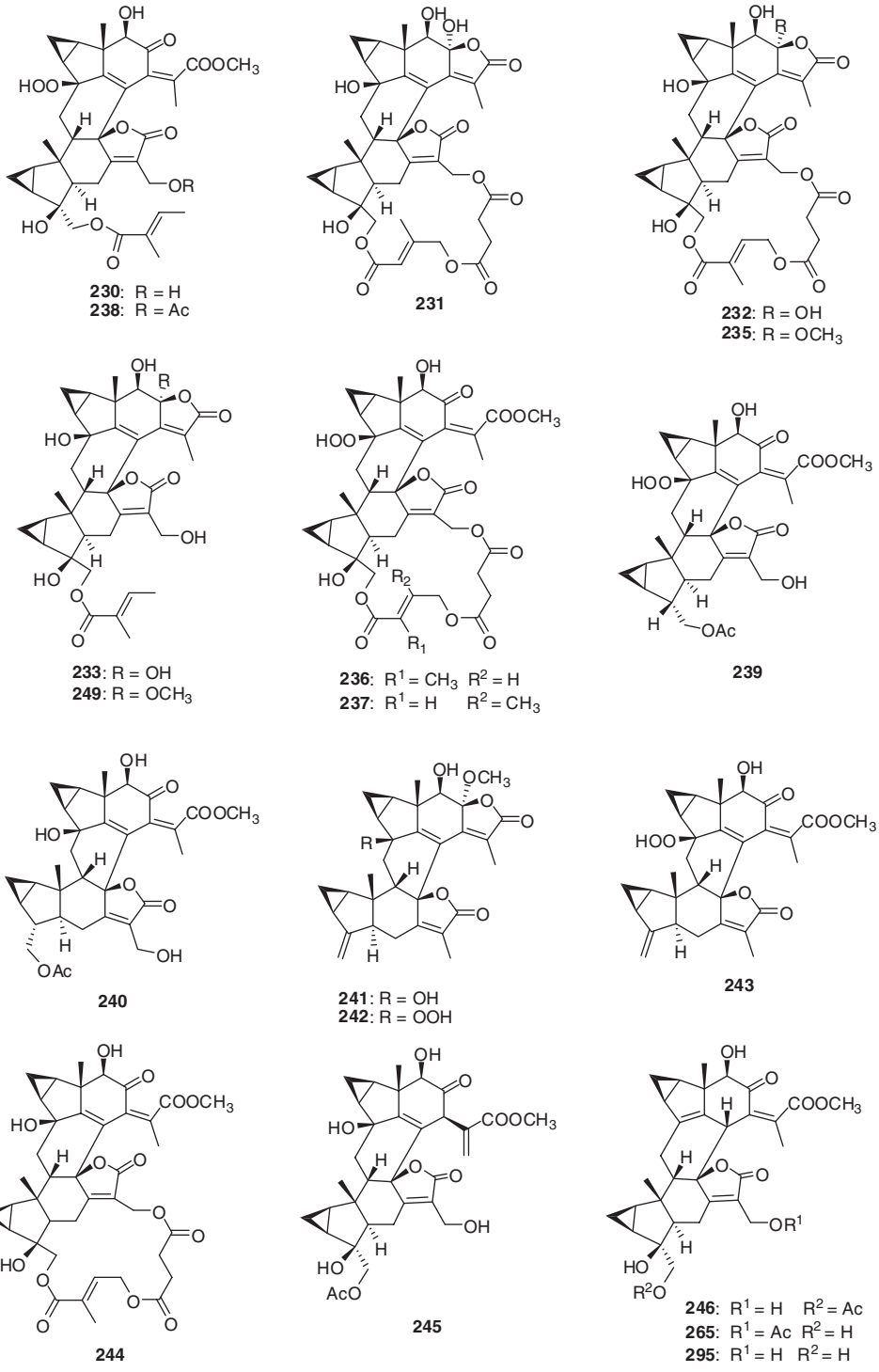


Figure 1 (continued)

The plant *Chloranthus multistachys* is a perennial herb distributed in wet areas of eastern Asia. Compounds **75**, **76** [36] and **77** [9] have been isolated from the whole plant of *C. multistachys*. The structure of **76** given in the literature [36] is wrong, and the actual structure must be **76a** (9α-hydroxyasterolide) [37] (Figure 1). In 2013, compounds **78–81** were isolated from the whole plant of *C. multistachys* [38]. Compound **79** is the only eudesmane sesquiterpenoid with an epoxide ring located between C-4 and C-15 in compounds of the Chloranthaceae family. *Chloranthus anhuiensis* is a species endemic to Anhui Province of China, and its chemical constituents were

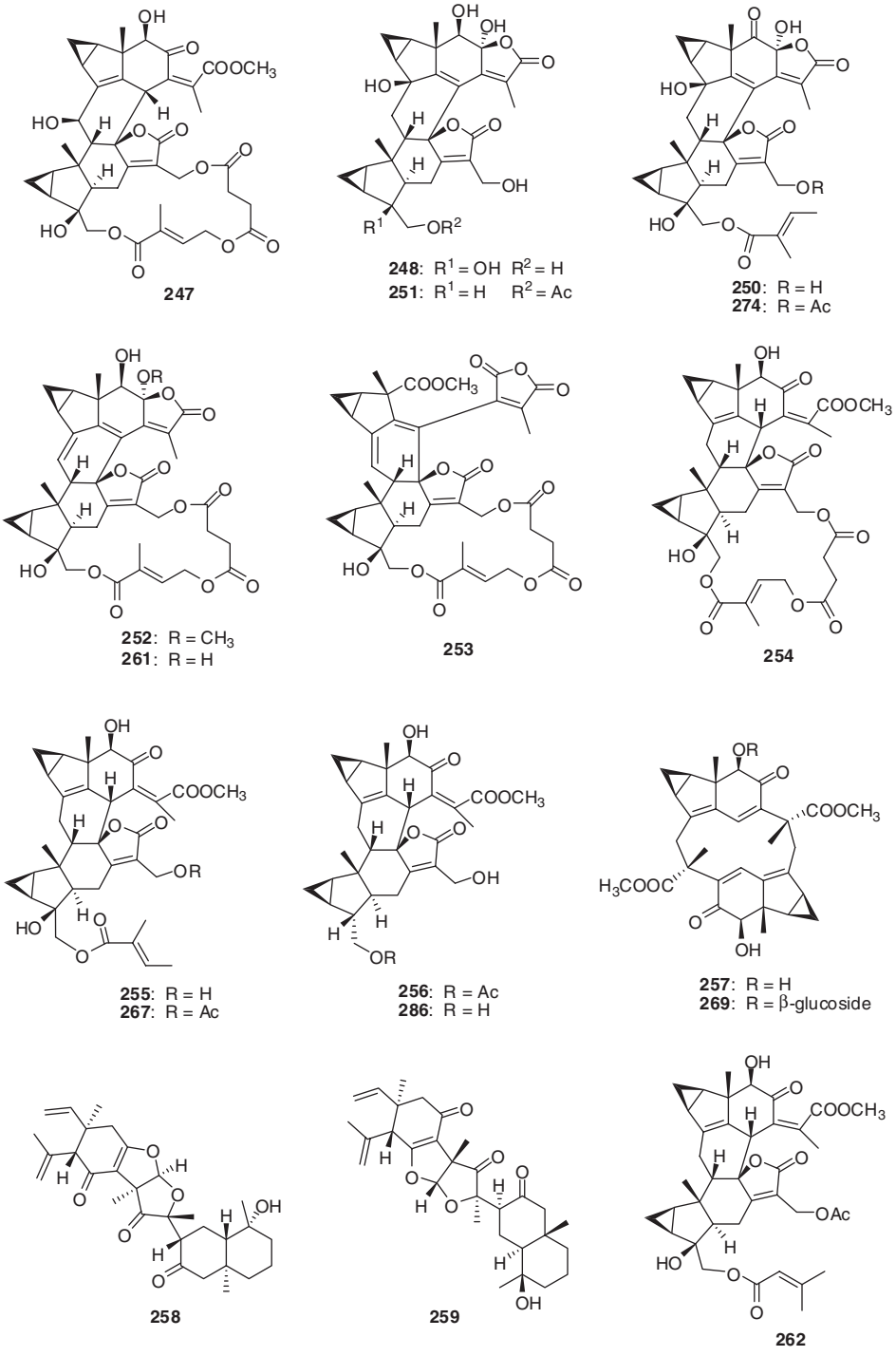


Figure 1 (continued)

not investigated until 2010 when four compounds **82–85** were isolated from the roots of this plant (compound **83** was revised as **48** in 2012 [18]). Antifungal screening of the compounds conducted with the NCCLS M27-A method have showed that the compounds exhibit weak antifungal activities [39]. Compound **86** is produced as phytoalexin in the fresh leaves of *C. anhuiensis* in response to abiotic stress elicitation by $CuCl_2$, and it is the fourth eudesmane glycoside isolated from plants of Chloranthaceae [40].

Plant *Chloranthus angustifolius* is an endemic species found in Sichuan and Hubei provinces of China. There are few reports about its chemical constituents. In 2014, two new eudesmane-type sesquiterpenes, compounds **87** and **88**, were isolated from the roots of *C. angustifolius* [41].

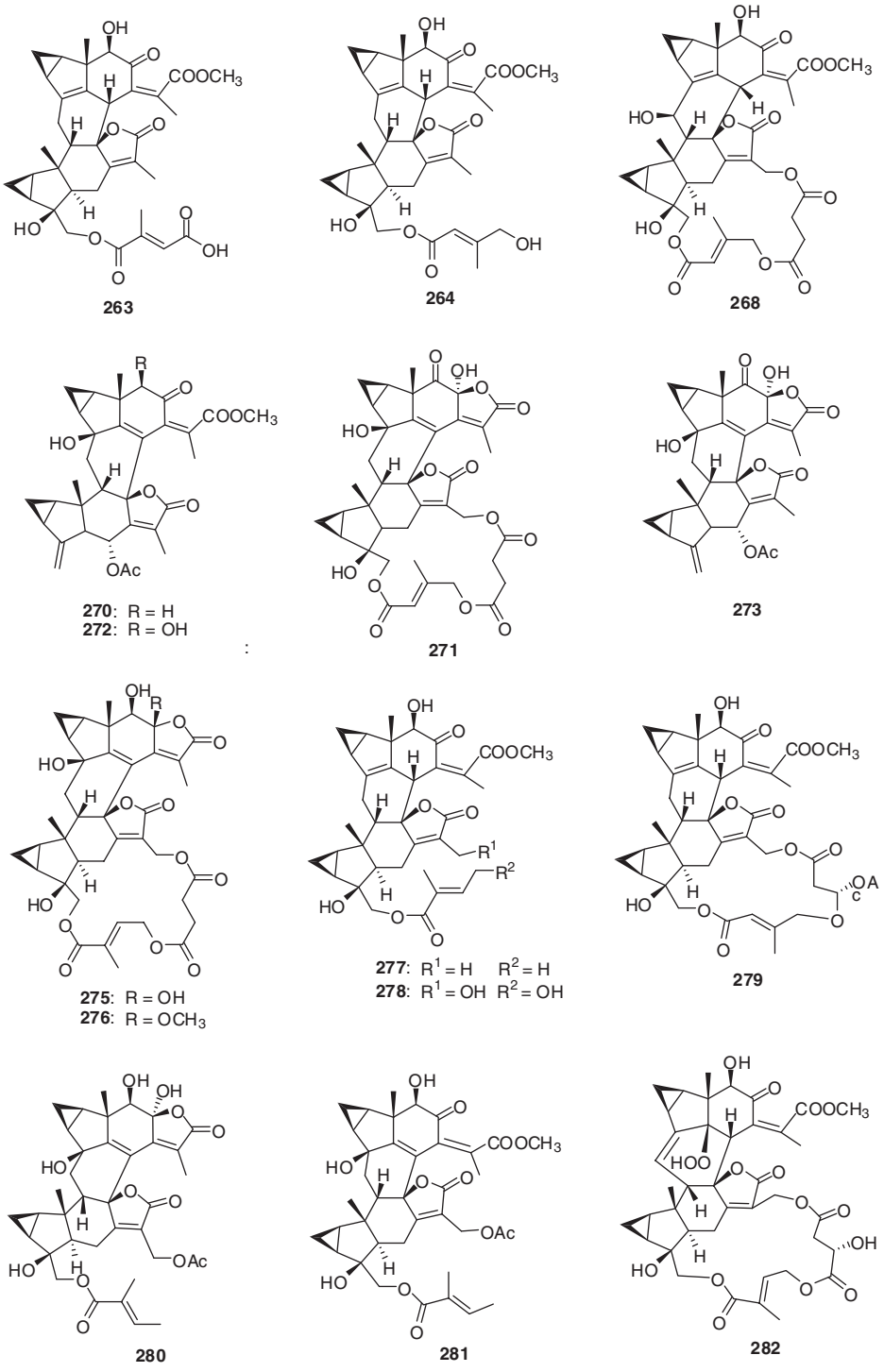


Figure 1 (continued)

The following year, compound **89** was isolated from the aerial parts of this plant [42]. Compound **89** can be used to differentiate *C. angustifolius* from other species of *Chloranthus* because of the fact that it has not been isolated from other species of this genus so far. The eudesmanolide **90** has been isolated from leaves of *C. glaber* [43]. Compound **91** has been isolated from the roots of *C. fortune* [44] and, for the first time, from the genus of *Chloranthus*. From the leaves of *C. erectus*, a new secoeudesmanolide **92** has been isolated. It has been suggested that compound **92** is formed by a series of consecutive transformations of chloranthalactone B (**124**) as shown in Scheme 1 [45].

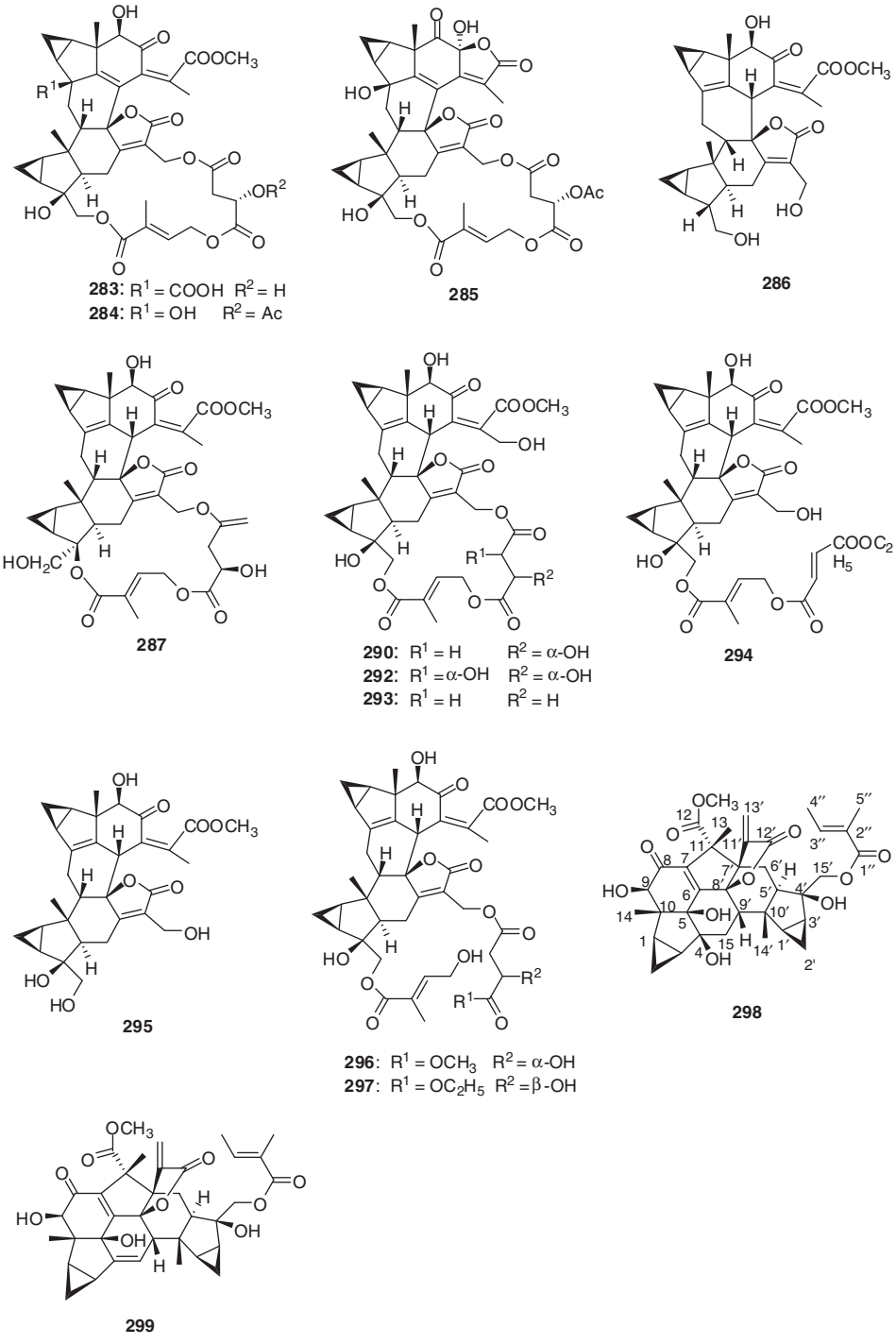
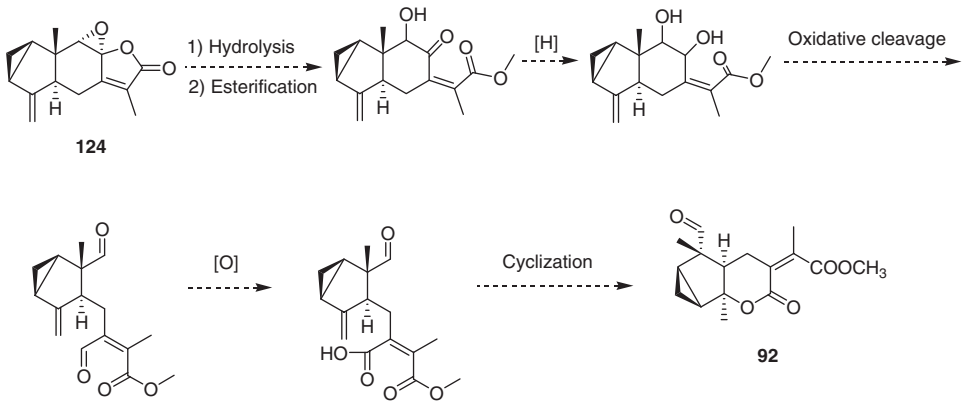


Figure 1 (continued)

Plants of the *Hedyosmum* genus (Chloranthaceae) are mainly distributed in the tropical area of America, and only one species, *H. orientale*, grows in China. Compound **93** has been isolated from the aerial parts of *H. orientale*. It shows moderate activities against A-549 and HL-60 tumor cell lines with the IC_{50} values of 3.1 and 8.8 μM, respectively [37]. The plant *H. brasiliense* is an aromatic and dioecious neotropical shrub endemic to Brazil; compound **94** has been isolated from its leaves for the first time [46].

Lindenanes

The distribution of lindenane sesquiterpenes in natural sources is limited, but Chloranthaceous plants have been



Scheme 1 Plausible transformation of **124** into **92**.

found to be rich in unusual sesquiterpene lactones having a lindenane skeleton. These derivatives are named shizukanolides and chloranthalactones. In total, 41 compounds have been reported to date. They are mainly found in species *C. japonicus* (**95–114**), *S. glabra* (**115–122**), *C. glaber* (**123–127**), *C. fortunei* (**128–130**), *C. serratus* (**131–132**), *H. brasiliense* (**133**) and *H. angustifolium* (**134** and **135**). Because of its special 3/5/6 linear cyclic system, lindenanolides can be regarded as characteristic constituents of some Chloranthaceae plants and might be used as chemotaxonomical markers [47].

Lindenanolide **95** was isolated for the first time in 1979 from plants of Chloranthaceae from aerial parts of *C. japonicus* [48]. Compounds **96–98** have been found in the whole plants of *C. japonicus*. Compound **98** contain two hydroxy groups in addition to a lactone ring [21]. The cytotoxicities of these three lactones against mouse lymphosarcoma L-5178Y cells have been evaluated in comparison with that of helenalin. These lactones are moderately cytotoxic. In 1981, a 15-hydroxylindenanolide **99** was isolated from roots of *C. japonicus*. The compound does not show antifungal activity against *Mucor griseocyanus* AHU 6044 compared with that of chloranthalactone A, which is known to be highly active [49]. A highly oxygenated lindenanolide **100** has also been isolated from roots of *C. japonicus*. The compound has a relatively unique γ,δ-epoxy-α,β-unsaturated-γ-lactone moiety, which has been rarely found in natural products [50]. Compound **101**, the structure of which has been revised to the eight-epimer in the literature [25], has been isolated from the aerial parts of *C. japonicus*. It shows mild inhibitory effects on collagen, U45519, AA and epinephrine induced platelet aggregation [51]. The third lindenane sesquiterpene glucoside **102**, found in Chloranthaceae plants, has been isolated from the whole plant of *C. japonicus* [52]. This compound has also been reported as a new constituent of *S. glabra* [30]. Six new lindenanolides **103–108** have been isolated from an ethyl acetate-soluble partition of the ethanol extract of the whole plants of *C. japonicus* [27]. In 2012, three new compounds **109–111** were isolated from the aerial part of *C. japonicus* [25]. Compound **110**, named chlorajapolide G, was also reported as a new lindenane-type sesquiterpenoid lactone, named chlojaponilactone E, identified in the same plant in 2013. Four lindenanoids **110** and **112–114** have been isolated from AcOEt-soluble part of the EtOH extract of whole plants of *C. japonicus* [53]. Compounds **112** and **113** are the only two lindenanoids with an OAc group at the C-6 position.

The lindenanoid glucosides **115** and **117** have been isolated from the whole plant of *S. glabra* [29, 30]. Compound **115** shows pronounced hepatoprotective activity against D-galactosamine-induced toxicity in WB-F344 rat hepatic epithelial stem-like cells. Compound **116** has also been isolated from the whole plant of *S. glabra* [31]. Biologically inactive sesquiterpenes **118** [5], **119** [32], **120** [54] and **121**, **122** [35] have also been isolated from the whole plants of *S. glabra*.

In 1978, the first two lindenanes **123** and **124** were isolated from roots of *C. glaber* [55]. From the leaves of *C. glaber*, a new lindenane **125** was isolated [43]. Then, in 1994, the first two lindenane C-15 glycosides **126** and **127** were isolated [56].

In 2009, two new sesquiterpenes, **128** and **129**, were isolated from the aerial part of *C. fortune* [57]. A novel lindenane sesquiterpene with an unprecedented 18-membered triester ring **130** was isolated from the whole plant of *C. fortune* [58].

Only two highly oxygenated lindenanilides **131** and **132** have been isolated from the roots of *C. serratus* [50]. Compound **132** is the first entry to 13-hydroxylated lindenanes in the Chloranthaceae. By now, three lindenanilides have been found in the genus of *Hedyosmum*. Compound

133 has been isolated from the extract of *H. brasiliense* [59]. The anti-leishmanial compounds **134** and **135** have been isolated from the ethyl acetate extracts of the bark of *H. angustifolium* [60].

Guaianes

In the Chloranthaceae family, the 8,12-guaianolides are mainly secondary metabolites. The biological activities of this type of guaianes can be correlated with the presence of an α,β methylene function conjugated to a γ-lactone. They are mainly found in the genera *Chloranthus* and *Hedyosmum* as constituents of *H. orientale* (**136–142**), *C. multistachys* (**143–147**), *H. brasiliense* (**148–150**), *H. arborescens* (**151**), *C. serratus* (**152** and **153**), *C. henryi* (**154** and **155**), *C. anhuiensis* (**156**), *C. spicatus* (**157**), and *C. elatior* (**158**). This class of compounds maybe used as chemotaxonomical markers of the above species.

Seven guaiane-type sesquiterpenoids **136–141** [37] and **142** [61] have been isolated from the aerial parts of *H. orientale*. Compounds **140** and **142** are the only two guaiane 10-glucosides found in Chloranthaceae plants.

There are five guaianes, **143** [36] and **144–147** [38], isolated from the whole plant of *C. multistachys*. Compound **145** was reported for the first time as a constituent in the whole plant of *C. spicatus* in 2012 [10].

From leaves of *H. brasiliense*, the only representative of the Chloranthaceae in Brazil, three compounds **148–150** have been isolated. These compounds do not show anti-mycobacterial activity against isoniazid-sensitive *M. tuberculosis* at concentrations of 1–30 μM [62].

The first 7,10-epoxy-guaianolide constituent **151** of Chloranthaceae was isolated from the leaves of *H. arborescens* in 2005 [63]. Together with compounds **136–138**, there are four 7,10-epoxy-guaianolides identified in Chloranthaceae plants to date. The absolute configuration of this class of guaianolides, with unusual 7,10-epoxy group, has been unambiguously established by analysis of the calculated and experimental VCD spectra [64].

Compound **152** [2], a guaiane with a unique C-4 and C-10 linkage, and its analogue **153** [3], have been isolated from the whole plants of *C. serratus*. Isolation of three secoguaienes, **154** and **155** from the whole plant of *C. henryi* [17] and **156** from the roots of *C. anhuiensis* [39], has been reported. In 2012, two new 12,8-guaianolide-type compounds **145** and **157** were isolated from the whole plant of *C. spicatus* [10]. Compound **158** has been isolated from the EtOH extract of the aerial parts of *C. elatior* [19].

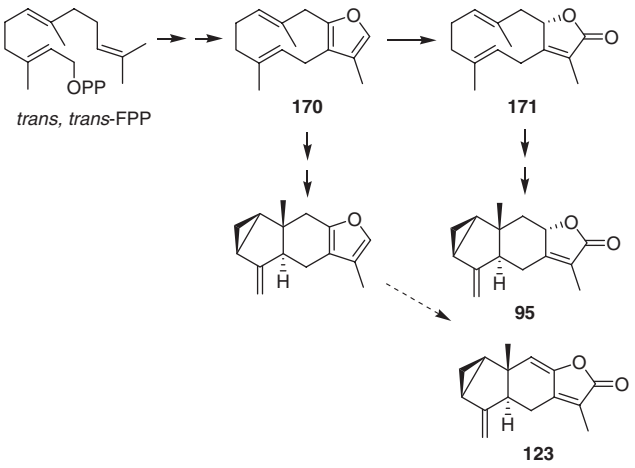
Germacranes

A total of 16 germacrane-sesquiterpene compounds (**159–174**) have been isolated from Chloranthaceae plants. They have been found in the species of *C. serratus* (**159–162**), *C. henryi* (**163–167**), *C. spicatus* (**168** and **169**), *C. japonicus* (**170** and **171**), *C. fortunei* (**172**), *C. multistachys* (**173**), and *S. glabra* (**174**). The characteristic feature of this class of compounds is a macro-ten-membered ring system that is sometimes fused to a furan ring.

Compounds **159–161** have been isolated from roots of *C. serratus* [1]. Compound **161**, present in the amount of about 0.1% in fresh roots of this herb, has been speculated to be partially responsible for the insecticidal activity of this plant. Compound **162** has been isolated from the whole plants of *C. serratus* [2]. Compounds **163–165** have been isolated from leaves and stems of *C. henryi* [15] and **166** and **167** from the whole plants of *C. henryi* [17]. Compounds **168** and **169** have been isolated from the whole plants of *C. spicatus* [10]. Compounds **170** and **171**, isolated from roots of *C. aponicas* [65], were the first two germacrane-sesquiterpene reported from Chloranthaceae plants in 1981. Their possible biogenetic pathway is shown in Scheme 2. Compound **172** has been isolated from roots of *C. fortune* [44] and **173** from the whole plants of *C. multistachys* [38]. In 2006, in the search for hepatoprotective compounds from *S. glabra*, a new germacrane glycoside **174** was isolated [29].

Cadinanes

Ten cadinanes (**175–184**) have been reported to date. These are compounds **175–178** from *C. henryi* [14, 17], compounds



Scheme 2 Possible biogenetic pathway of shizukanolides.

179–181 [4, 66] from *C. serratus* and compounds **182–184** from the whole plant of *C. multistachys* [36].

By using the MTT colorimetric method, compound **177** shows antitumor activity against the Hela, A549, MCF, and K562 human-tumor cell lines, with IC_{50} values of 4.7, 8.9, 9.6, and 11.8 μg/mL, respectively. Compound **181** [4] is a Chinese folk medicine for the treatment of bruises, bone fractures, and rheumatoid arthritis.

Eremophilanes

In 1988, a new sesquiterpene lactone **185**, the enantiomer of istanbulin A, was obtained from *S. glabra* leaves [67]. Some six-eremophilene derivatives **186–190** [40] and **191** [39] are produced as phytoalexin in the fresh leaves of *C. anhuiensis*, in response to abiotic stress elicitation by $CuCl_2$. These are the first reports of eremophilane-type sesquiterpenes in *C. anhuiensis*. From the whole plants of *C. japonicus*, three eremophilanes **192–194** have been repored. Compound **192** has been isolated from this species for the first time [28]. Reinvestigation of the AcOEt-soluble part of the EtOH extract of whole plants of *C. japonicus* have afforded compounds **193** and **194** [53].

Aromadendranes

The first aromadendrane-type sesquiterpene isolated from Chloranthaceae plants was compound **195** which was found in the leaves of *C. glaber* in 1993 [43]. Compounds **196** and **197** were isolated from a polar extracts of the aerial parts of *C. spicatus* [7]. Compound **196** is the C-4, C-10 epimer of **195**. From *H. orientale*, the only one species of *Hedyosmum* genus growing in China, a non-cytotoxic compound **198** has been isolated [37]. It is the C-4 epimer of compound **195** and C-10 epimer of **196**. Investigation to the ethanol extract of the aerial parts of *C. elatior* has resulted in finding two aromadendranes **199** and **200**. Compound **199** is the C-10 epimer of **200** [19].

Elemanes

Five elemane-type sesquiterpenes, **201–205**, have been reported as constituents of Chloranthaceae plants. Compound **201** has been isolated for the first from the essential oil of the flowers of *C. spicatus* [6]. Two new elemanolide glycosides **202** and **203** have been isolated from the whole plant of *S. glabra* [29]. Hepatoprotective activity against D-galactosamine-induced toxicity of these two new compounds have been examined in WB-F344 cells. This has been the first report of hepatoprotective activity from a *Sarcandra* species. In 2008, compound **204** was isolated from the whole plants of *C. serratus* as a new sesquiterpenoid [2]. It shows moderate activity against *Helicobacter pylori*-SS1 in 13 microorganisms with MICs of 25–50 μg/mL. In the course of study of the hot tea infusion from the fresh leaves of *H. brasiliense*, a new secondary metabolite **205** has been identified [46].

Other sesquiterpenes

At present, only compound **206** with acorane skeleton has been found in Chloranthaceae plants. It has been isolated from the whole plants of *C. japonicus* [22]. Compound **207**, isolated from aerial parts of *C. spicatus*, has a special skeleton with a *trans* 5/6 connectivity [7]. A new sesquiterpene with a novel bicarbocyclic framework **208** has been isolated from *C. henryi*. This compound exhibits anti-tumor activitiy against Hela and K562 human tumor cell lines [23]. Two sesquiterpene glucosides **209** and **210** have been isolated from the whole plant of *C. japonicus* [52]. Compound **210** is a rare bidesmosidic megastigmane sesquiterpene glucoside. The cytotoxic activities of compounds **209** and **210** have been tested by a MTT method but the results have showed marginal cytotoxic activities against Hepg-2, OV420, and MCF-7 cell lines. Compounds **211** from *C. henryi* [16] and **212** from *C. anhuiensis* [39] have been reported. In 2012, a new sesquiterpenoid **213**, along with a known sesquiterpenoid **214**, were isolated from the whole plant of *C. spicatus* [10]. Compound **215** is a new naturally occurring maaliane-type sesquiterpenoid isolated from the ethanol extract of the aerial parts of *C. elatior* [19].

Sesquiterpene polymers

Sesquiterpene polymers are characteristic constituents of the chloranthaceous plants. More than 80 sesquiterpene dimers have been isolated from this family. Excepting **258** and **259**, most of them comprise the same scaffold constructed from two lindenane moieties via a [4+2] cycloaddition reaction.

The dimeric sesquiterpenes **216–299** have been isolated from genera *Chloranthus* and *Sarcandra*. The distribution of these compounds in plants is as follows, *C. japonicus* (**216–230**), *C. spicatus* (**231–243**), *C. multistachys* (**244–253**), *C. serratus* (**254–261**), *C. fortunei*

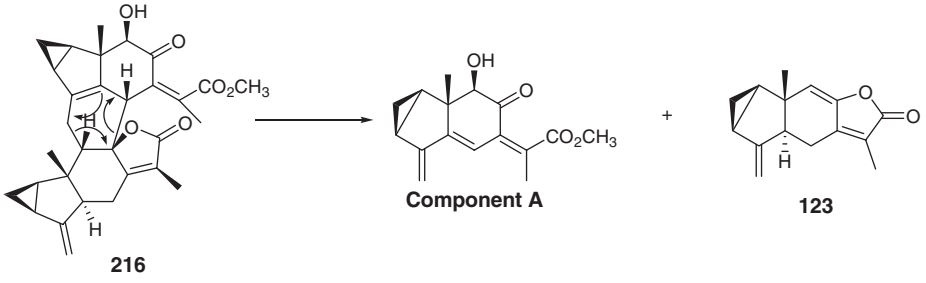
(**262–269**), *C. holostegius* (**270–274**), *C. tianmushanensis* (**275** and **276**), *S. glabra* (**277–297**), and *S. hainanensis* (**298** and **299**).

Kawabata and co-workers have searched for sesquiterpenes in plants of the Chloranthaceae and they have found a series of unusual sesquiterpene lactones having a lindenane skeleton (**216–223**) in the roots of *C. japonicus*. In 1990, the first dimeric sesquiterpene **216** consisting of two lindenane units was isolated. These two lindenane units can be obtained by pyrolysis of **216** (Scheme 3) [68]. The presence of **216** in the fresh extracts suggests that this kind of dimer is natural. Its molecular formula has been deduced as $C_{31}H_{34}O_6$ by EI-HR-MS. The spectrum shows a molecular ion peak at *m/z* 502 and two fragment ion peaks at *m/z* 274 and *m/z* 228 for the fragments discussed above. This result suggests that **216** is easily dissociated into its two components shown in Scheme 3.

In 1995, five novel lindenane dimers **217–221** were isolated from roots of *C. japonicus* [69]. In 1997, further investigation of the chemical constituents of *C. japonicus* yielded a novel lindenane trimer **222** along with a structurally related dimer **223**. This is the first and the only trimeric lindenane sesquiterpene isolated from chloranthaceous plants [70]. These two compounds correspond to a basic lindenatriene which is a component of all shizukaols. In 2008 a new sesquiterpene dimer **224** with a macrocyclic tris-lactone unit attached at C-13′ and C-15′ was reported. Related compounds **225–230** were isolated in 2011 from the whole plants of *C. japonicus*. The MTT assay has been used to determine the cytotoxicity of **225** against a panel of eight cancer cell lines. However, this compound does not show any marked activity [27]. Experiments to find compounds with anti-HIV-1 activities from *C. japonicus* have led to the isolation of five new lindenane dimers **226–230** [71]. Compounds **226** and **227** represent the first examples of lindenane dimers with a C-5 hydroxy group and a C-4–C-15 double bond. Compound **230** is a rare lindenane disesquiterpenoid containing a hydroperoxy group at C-4.

Totally 13 lindenane dimers **231–243** were isolated from the whole plants and roots of *C. spicatus*. In 2007, an investigation on the whole plant of *C. spicatus* revealed three new dimeric sesquiterpenoids **231–233** [72]. Among them, **232** (named chloramultilide C) and **233** (named chloramultilide D), were also reported as new compounds, named henriol A and B, that were isolated from the roots of *C. henryi* in 2008 [73]. They all contain a 4-hydroxy substitution. The same year the Kim group examined the methanol extracts from the roots of *C. spicatus*, and isolated two new lindenane sesquiterpene dimers **234** and **235** which can be considered the products of a Diels-Alder cycloaddition involving a macrocyclic trilactone consisting of a 4-hydroxy-2-methyl-but-2-enoyl group and a succinyl group by ester linkages [74]. Compounds **236–239**, new lindenane-sesquiterpene dimers possessing a hydroperoxy group, have been isolated from the roots of *C. spicatus*. These compounds can be considered to be biogenetic precursors for the corresponding hydroxy derivatives of dimeric lindenane sesquiterpenes distributed in *Chloranthus* plants [75]. Further study of the roots of *C. spicatus* have resulted in the isolation of four new lindenane sesquiterpenoid dimers **240–243**, the absolute configurations of which have been determined by CD spectroscopic analysis [76].

Compounds **244–253** have been isolated from whole plant of *C. multistachys*. In 2006, a highly complex sesquiterpenoid dimer **244** was found [77]. In 2010, two novel sesquiterpenoid dimers **245** and **246** were isolated from the whole plant of *C. multistachys* [78]. Six complex lindenane-type sesquiterpenoid dimers **247–252** have been isolated from the whole plant of *C. multistachys* [79]. Compounds **247** and **252** contain a unique 18-membered macrocyclic triester system. In 2013, an 8,9-seco-lindenane disesquiterpenoid **253** was isolated from whole plant tissues of *C. multistachys* [38]. This compound seems to be derived from the enzymatic *endo*-Diels-Alder cyclo-addition of two lindenanes and an enzymatic Baeyer-Villiger oxidation.



Scheme 3 Pyrolysis of compound **216**.

Chemical constituents investigation of roots and the whole plants of *C. serratus*, has revealed the presence of **254–261**. In 1992, three novel dimeric sesquiterpenes **254–256** named shizukaol B, C and D, were isolated from the roots of *C. serratus* [80]. These compounds consist of two lindenane (modified eudesmane) units. Among them, compound **254** (named shizukaol B) was also reported as a new compound, named henriol C, isolated from the roots of *C. henryi* in 2008 [73]. In 1993, a novel dimeric sesquiterpene **257**, having a C_2-symmetric structure and the unique 12-membered ring system, was isolated from the roots of *C. serratus* [81]. In 2012, two dimeric sesquiterpenes, named serratustones A (**258**) and B (**259**) were isolated from the whole plants of *C. serratus* [82]. Serratustones A and B represent a new carbon skeleton that is formed by dimerization of an elemane and an eudesmane, and they are the first examples of nonlindenane-type sesquiterpenoid dimers from the Chloranthaceae family [82]. Compounds **260** and **261** have been isolated from the whole plant of *C. serratus* [4].

Compounds **262–269** have been isolated from roots and aerial part of *C. fortunei*. The respective dimers **262–266** are named shizukaols K-O. A previously known sesquiterpene dimer **267** has also been isolated from the roots of *C. fortune* [83]. In the original literature, the proposed structure of compound **265** was incorrect. The revised structure of compound **265** is given in this review. In 2009, a sesquiterpene dimer **268** and a sesquiterpene glycoside **269** were isolated from the aerial part of *C. fortune* [57]. In all lindenane-type sesquiterpenoid dimers reported from Chloranthaceae family to date, only two compounds have a hydroxy group at C-15, one is compound **268** and the other is **247**. Compound **269** is the 9-*O*-β-glucoside of **257**. The initially proposed structure of **269** has been revised in this review.

Two highly complex sesquiterpenoid dimers **270** and **271** have been isolated from *C. holostegius* and the biogenetic pathway to **270** has been proposed in the literature [84]. Further analysis of *C. holostegius* has revealed the presence of four additional sesquiterpenoid dimers **267** and **272–274**. A suggested biogenetic pathway to **272** and **273** can be found in the original literature [85].

Investigation of the leaves of *C. tianmushanensis* have resulted in the isolation and characterization of two new sesquiterpene dimers **275** and **276** with a rare 18-membered triester ring system. Their proposed biogenetic pathway is described in the original literature [86].

Twenty three novel lindenane-type sesquiterpenoid dimers have been found in the genus of *Sarcandra*. Three species in the *Sarcandra* genus of the Chloranthaceae family, which are mainly distributed in the southeast of Asia, and two of them, *Sarcandra glabra* and *S. hainanensis*, have been found to contain lindenane-type sesquiterpenoid dimers. In 2010, five new dimeric sesquiterpenoids, sarcandrolides A-E (**277–281**), were isolated from the whole plants of *S. glabra* [5]. In 2013, five new sesquiterpenoid dimers, sarcandrolides F-J (**282–286**), were isolated from the whole plants of *S. glabra* [35]. Compound **282** represents the first example of a lindenane-type sesquiterpenoid dimer bearing a hydroperoxy group at C-5. In 2015, 11 new sesquiterpene dimers, (**287–297**), were isolated from the seeds of *S. glabra* [87]. Compound **287** possesses a 17-membered macrocyclic ester system, which is different from the 18-membered rings present in other reported analogues. Two novel lindenane-type sesquiterpenoid dimers **298** and **299** have been isolated from the whole plants of *S. hainanensis* [88]. These two compounds feature a new nonacyclic scaffold in which the bond of C-11–C-7′ imposes the five-membered lactone ring in a full β-direction [88].

Diterpenoids, triterpenoids and other terpenoids

Labdanes

Thirty six labdane-type diperpenoids have been isolated from Chloranthaceae family. These compounds are distributed in the genus of *Chloranthus* as follows, *C. henryi* (**300–315**), *C. anhuiensis* (**316–321**), *C. spicatus* (**322–327**), *C. serratus* (**328–334**) and *C. elatior* (**335**). In 2006, the first two labdane-type diterpenes **300** and **301** were isolated from the roots of *C. henryi*. Compound **301** is a bis(norlandane) that exhibits antitumor activity against Hela and K562 human tumor cell lines [13]. Its analogues **302** and **303** isolated from *C. henryi* are biologically inactive [14, 23]. Further investigation of *C. henryi* by bioactivity-guided fractionation has led to isolation of three new diterpenoids **304–306** and three known labdane diterpenes **307–309** [73]. Among them, compounds **304** and **307** show hepatoprotective activity against D-galactosamine-induced toxicity in WB-F344 rat hepatic epithelial stem-like cells. In search for new anti-rheumatoid agents, four new diterpenoids **310–313** and two known diterpenoids **314–315** have been isolated from the roots of *C. henryi* [16].

In 2010, the first phytochemical investigation of the roots of *C. anhuiensis* led to the isolation two new labdane-type diterpenes **316** and **317** and four known compounds **318–321** [39]. In 2010, compounds **322–326** were isolated from the roots of *C. spicatus* [8] and compound **327** was isolated from the whole plants of *C. spicatus* [10].

There are seven labdane-type diterpenes isolated from the whole plant of *C. serratus*. In 2012, two new norditerpenoids **328** and **329** were isolated [4]. In 2013,

Table 2 Diterpenoids and triterpenoids.

No.	Name	Part	Source	References
	Labdanes			
300	12,15-Epoxy-5αH,9βH-labda-8(17),13-dien-19-oic acid	*Leaves and stems*	*C. henryi*	[13]
301	14-Methoxy-15,16-dinor-5αH,9αH-labda-13(*E*),8(17)-dien-12-one	*Leaves and stems*	*C. henryi*	[13]
302	(13*S*)-13-Hydroxy-19-methoxy-5αH-8(17),14-labdadien	*Leaves and stems*	*C. henryi*	[23]
303	12,15-Epoxylabda-8(20),13-dien-18-oic acid	*Leaves and stems*	*C. henryi*	[14]
304	Henrilabdane A (12 (*R*),15-Dihydroxylabda-8(17),13*E*-dien-19-oic acid)	*Roots*	*C. henryi*	[73]
		Roots	*C. henryi*	[16]
		Roots	*C. anhuiensis*	[39]
		Whole plants	*C. multistachys*	[9]
305	Henrilabdane B (9*S*,14,15-Dihydroxylabda-8(17),12*E*-dien-19-oic acid)	*Roots*	*C. henryi*	[73]
306	Henrilabdane C (12-oxo-15-Hydroxylabda-8(17),13*E*-dien-19-oic acid)	*Roots*	*C. henryi*	[73]
		Roots	*C. henryi*	[16]
		Roots	*C. anhuiensis*	[39]
		Whole plants	*C. multistachys*	[9]
307	12(*S*),15-Dihydroxylabda-8(17),13*E*-dien-19-oic acid	*Roots*	*C. henryi*	[73]
		Roots	*C. anhuiensis*	[39]
		Whole plants	*C. multistachys*	[9]
308	12(*R*),13(*S*)-Dihydroxylabda-8(17),14-dien-19-oic acid	*Roots*	*C. henryi*	[73]
309	12(*R*),13(*R*)-Dihydroxylabda-8(17),14-dien-19-oic acid	*Roots*	*C. henryi*	[73]
310	7β,12α-Dihydroxy-13-epi-manoyl oxide	*Roots*	*C. henryi*	[16]
311	7β,12α-Dihydroxymanoyl oxide	*Roots*	*C. henryi*	[16]
312	(12*R*)-Labda-8(17),13*E*-dien-12,15,19-triol	*Roots*	*C. henryi*	[16]
313	15-Nor-14-oxolabda-8(17),12*E*-dien-19-ol	*Roots*	*C. henryi*	[16]
314	13-Epitorulosol	*Roots*	*C. henryi*	[16]
315	15-Nor-14-xolabda-8(17),12*E*-dien-19-oic acid	*Roots*	*C. henryi*	[16]
316	(12*R*,13*E*)-15-Acetoxy-12-hydroxylabda-8(20),13-dien-19-oic acid	*Roots*	*C. anhuiensis*	[39]
317	(12*S*,13*E*)-15-Acetoxy-12-hydroxylabda-8(20),13-dien-19-oic acid	*Roots*	*C. anhuiensis*	[39]
318	3β,13-Dihydroxylabda-8(20),14-dien-19-oic acid	*Roots*	*C. anhuiensis*	[39]
319	(12*E*)-15-Norlabda-8(20),12-dien-13,19-dioic acid	*Roots*	*C. anhuiensis*	[39]
320	13,14-Dihydrogen-isocupressic acid	*Roots*	*C. anhuiensis*	[39]
321	(12*E*,14*R*)-14,15-Dihydroxylabda-8(20),12-dien-19-oic acid	*Roots*	*C. anhuiensis*	[39]
322	(12*S**,13*E*)-12-Hydroxy-15-methoxylabda-8(17),13-dien-18-oic acid	*Roots*	*C. spicatus*	[8]
323	Labdan-8(17),12,14-trien-18-oic acid	*Roots*	*C. spicatus*	[8]
324	Labdan-8(17),12,14-trien-18-ol	*Roots*	*C. spicatus*	[8]
325	(12*E*)-15-Nor-14-oxolabda-8(17),12-diene-18-oic acid	*Roots*	*C. spicatus*	[8]
326	13β-Hydroxylabda-8(17),14-dien-18-oic acid methyl ester	*Roots*	*C. spicatus*	[8]
327	15-Norlabda-8(20),12*E*-diene-14-carboxalde-19-oic acid	*Whole plants*	*C. spicatus*	[10]
328	3β-Hydroxy-15-nor-14-oxo-8(17),12-labdadien-14-al	*Whole plants*	*C. serratus*	[4]
329	3β,6β-Dihydroxy-15-nor-14-oxo-8(17),12-labdadien-14-al	*Whole plants*	*C. serratus*	[4]
330	Serralabdane A	*Whole plants*	*C. serratus*	[89]
331	Serralabdane B	*Whole plants*	*C. serratus*	[89]
332	Serralabdane C	*Whole plants*	*C. serratus*	[89]
333	Serralabdane D	*Whole plants*	*C. serratus*	[89]
334	Serralabdane E	*Whole plants*	*C. serratus*	[89]
335	Elatiorlabdane	*Whole plants*	*C. elatior*	[11]
	Kauranes			
336	*ent*-17-Hydroxyl-16β-methoxyl-kauran-3-one	*Whole plants*	*C. multistachys*	[90]
337	*ent*-17-Acetoxyl-16β-methoxyl-kauran-3-one	*Whole plants*	*C. multistachys*	[90]
338	*ent*-17-Hydroxyl-kaur-15-en-3-one	*Whole plants*	*C. multistachys*	[90]
339	*ent*-3β-Acetoxyl-kaur-15-en-16β, 17-diol	*Whole plants*	*C. multistachys*	[90]
340	*ent*-Kauran-3β, 16β, 17-triol	*Whole plants*	*C. multistachys*	[90]
341	*ent*-3β-Acetoxyl-kauran-16β, 17-diol	*Whole plants*	*C. multistachys*	[90]
342	*ent*-Kauran-16β, 17-diol	*Whole plants*	*C. multistachys*	[90]

Table 2 (continued)

No.	Name	Part	Source	References
343	Abbeokutone	*Whole plants*	*C. multistachys*	[90]
344	*ent*-17α-Acetyl-16β-hydroxyl-kauran-3-one	*Whole plants*	*C. multistachys*	[90]
	***Ent*-abietanes**			
345	Sessilifol A	*Whole plants*	*C. sessilifolius*	[91]
346	Sessilifol B	*Whole plants*	*C. sessilifolius*	[91]
347	Sessilifol C	*Whole plants*	*C. sessilifolius*	[91]
348	Sessilifol D	*Whole plants*	*C. sessilifolius*	[91]
349	Sessilifol E	*Whole plants*	*C. sessilifolius*	[91]
350	Sessilifol F	*Whole plants*	*C. sessilifolius*	[91]
351	Sessilifol G	*Whole plants*	*C. sessilifolius*	[91]
352	Sessilifol H	*Whole plants*	*C. sessilifolius*	[91]
353	Sessilifol I	*Whole plants*	*C. sessilifolius*	[91]
354	Sessilifol J	*Whole plants*	*C. sessilifolius*	[91]
355	Sessilifol K	*Whole plants*	*C. sessilifolius*	[91]
356	Sessilifol L	*Whole plants*	*C. sessilifolius*	[91]
357	Sessilifol M	*Whole plants*	*C. sessilifolius*	[91]
358	Sessilifol N	*Whole plants*	*C. sessilifolius*	[91]
	Norditerpenoids			
359	Sessilifol O	*Whole plants*	*C. sessilifolius*	[91]
360	Sessilifol P	*Whole plants*	*C. sessilifolius*	[91]
361	Sessilifol Q	*Whole plants*	*C. sessilifolius*	[91]
	Triterpenoids and other terpenoids			
362	Sarcandroside A (3β,19α,20β-Trihydroxyurs-11,13(18)-diene-28,20β-lactone-3-*O*-β-D-glucopyranosyl (1→3)-[α-L-rhamnopyranosyl (1→2)]-β-D-xylopyranoside)	*Whole plants*	*S. glabra*	[92]
363	Sarcandroside B (3-*O*-β-D-Glucopyranosyl (1→3)-[α-L-rhamnopyranosyl (1→2)]-β-D-xylopyranosyl-pomolic acid 28-*O*-β-D-glucopyranosyl ester)	*Whole plants*	*S. glabra*	[92]
364	Lupeol	*Whole plants*	*S. glabra*	[93]
365	24-Hydroxylupeol	*Whole plants*	*S. glabra*	[93]
366	28-Hydroxyolean-12-ene-3,11-dione	*Leaves and stems*	*C. henryi*	[14]
367	Bolivianine	*trunk bark*	*H. angustifolium*	[94]
368	Isobolivianine	*trunk bark*	*H. angustifolium*	[94]
369	Loliolide	*Aerial part*	*C. japonicus*	[25]

five new biologically inactive [89] labdane diterpenes **330–334**, named serralabdanes A–E, were isolated. The absolute configuration of the 12,13-diol moiety in serralabdane C (**332**) has been determined by using the induced circular dichroism after the addition of dimolybdenum teracetate in DMSO solution (Snatzke's method). One new labdane-type diterpenoid, named elatiorlabdane (**335**) has been found in the whole plants of *C. elatior* [11].

Kauranes

In 2008, two new kaurane-type diterpenoids, **336** and **337**, along with seven known compounds **338–344**, were isolated from the whole plants of *C. multistachys* [90]. This is the only report on the isolation of kaurane-type diterpenoids from Chloranthaceae family.

Ent-abietanes

To date, 14 *ent*-abietane-type diterpenoids have been isolated from *C. sessilifolius*. In 2015, sessilifols A–N (**345–358**), were isolated from the whole plants of *C. sessilifolius* [91]. Sessilifols A (**345**) and B (**346**) possess an uncommon five-membered C-ring formed by oxidative cleavage of the C-13/C-14 bond in abieta-7,13-diene followed by the formation of a new C-C bond between C-12 and C-14. Sessilifol C (**347**) is a rare 7,8-seco-9-spiro-fused *ent*-abietane.

Norditerpenoids

Three new norditerpenoids **359–361** have been isolated from *C. sessilifolius* [91]. Sessilifol O (**359**) represents the

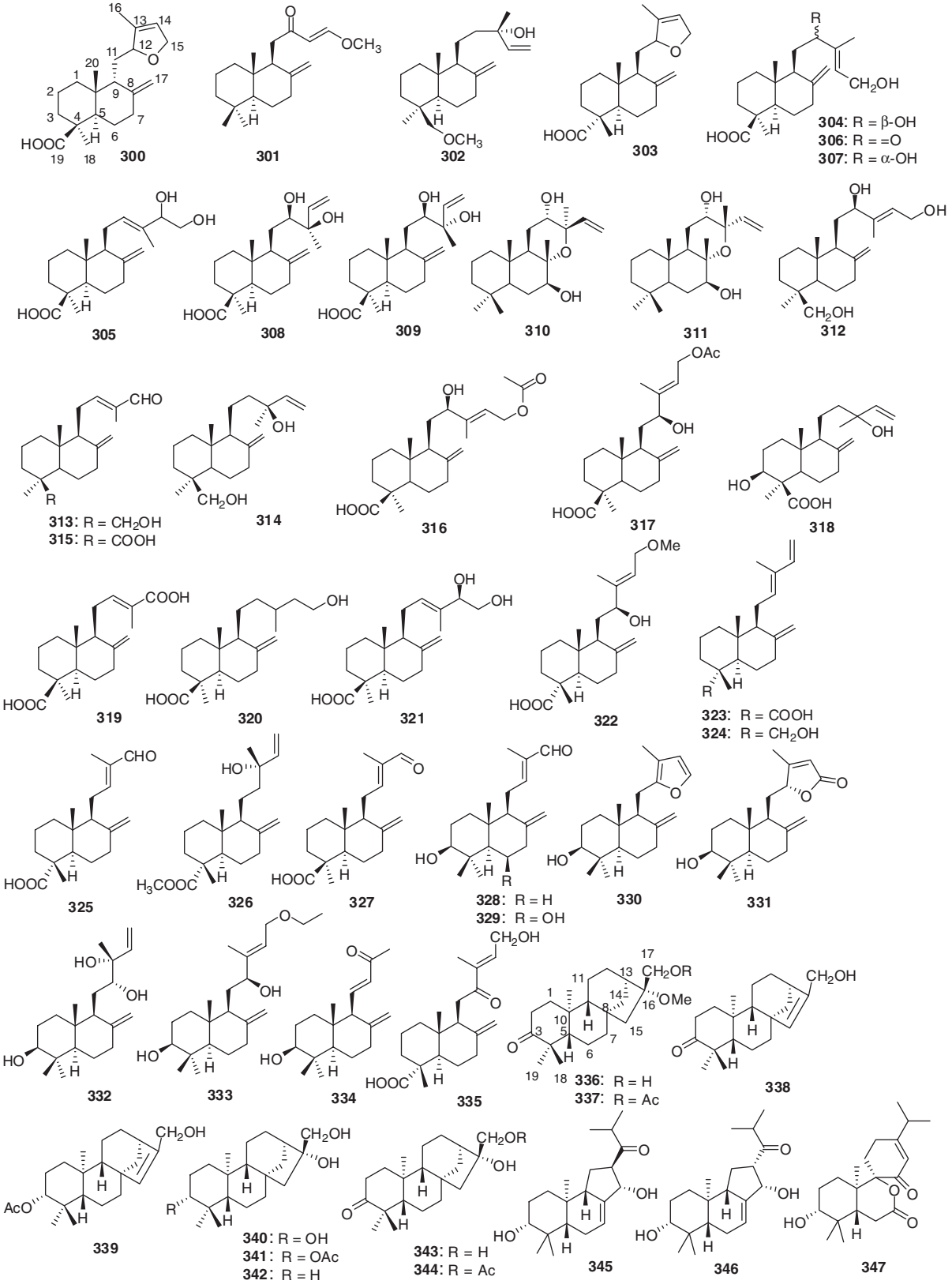


Figure 2 Diterpenoid and triterpenoid structures.

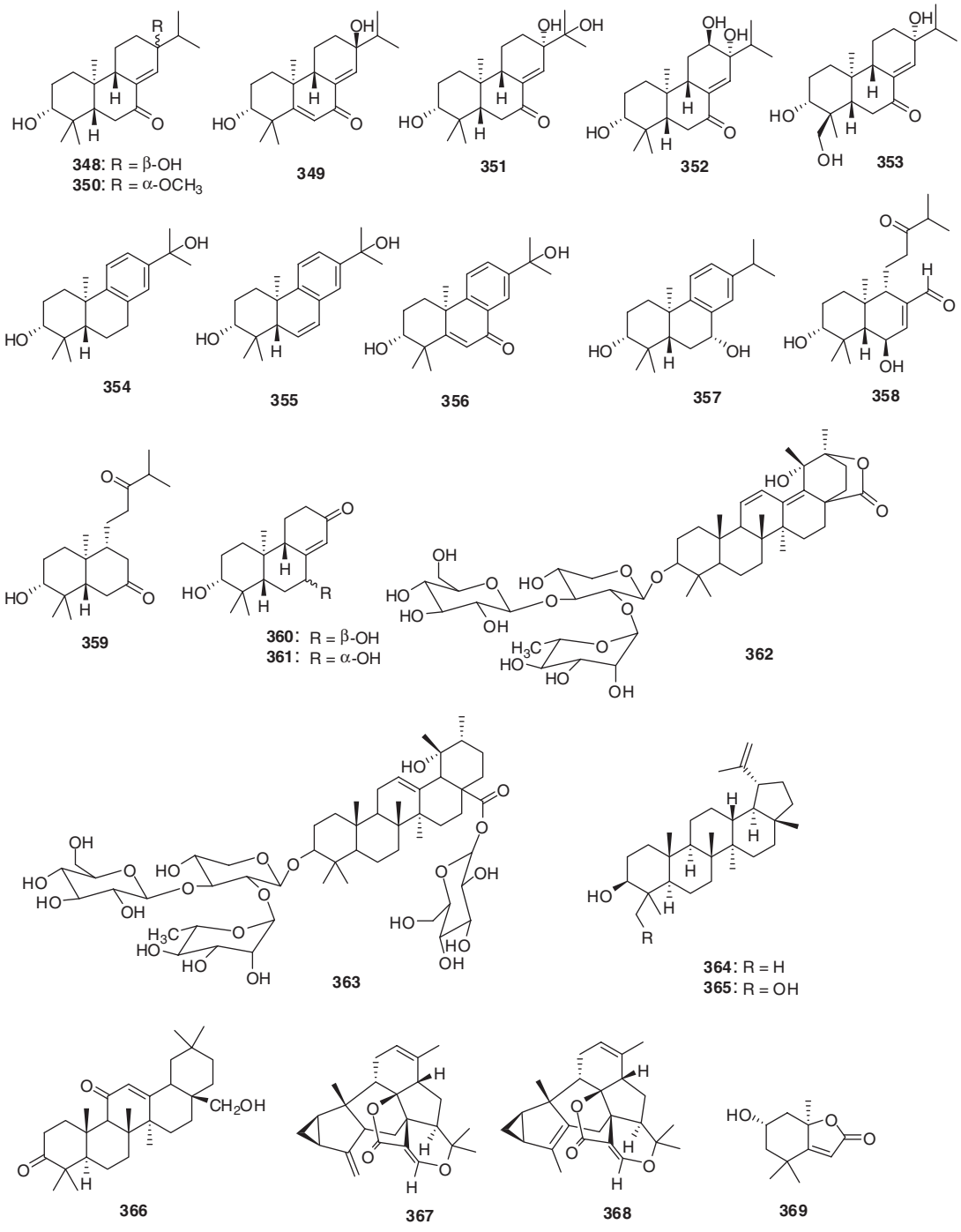


Figure 2 (continued)

first example of a naturally occurring 14-norabietane-type diterpenoid. Only five triterpenoids have been reported in the plants of Chloranthaceae family, and four of them have been isolated from *S. glabra*. In 2005, two new triterpenoid saponins **362–363** [92] and two known triterpenoids **364–365** [93] were isolated from the whole plants of *S. glabra*. A biologically inactive triterpenoid **366** has been isolated from the leaves and stems of *C. henryi* [14]. In 2007, a novel sesterpene **367** with an unprecedented skeleton was isolated from the trunk bark of *H. angustifolium* [94]. Under acidic conditions this compound undergoes isomerization to **368**. A biologically inactive monoterpene **369** has been isolated from the aerial part of *C. japonicus* [25].

Coumarins

Fourteen coumarin derivatives have been reported to date. Their distribution in plants is as follows, *C. Japonicus* (**370**, **371**, **383**), *C. holostegius* (**372**), *C. henryi* (**373–375**), *S. glabra* (**376–382**). In 1984, compounds **370** and **371** were isolated from *C. Japonicus* [22]. In 1987, a coumarin glucoside **372** was found in the roots of *C. holostegius* [95]. In 2005, during the study of the chemical constituents of the roots of *C. henryi*, three coumarin glucosides **373–375** were obtained [12], along with a new compound **132** of a different class. Chemical investigation to the whole plants of *S. glabra* has led to the isolation of compounds **376** [93], **377** [96], **378–381** [97] and **382** [98]. In 2009, a new coumarinolignan glucoside **329** was isolated from the whole plant of *C. japonicus*. This compound is marginally cytotoxic against human hepatoma (Hepg-2), ovarian carcinoma (OV420), and breast cancer (MCF-7) cells [99].

Lignans

To date, only ten lignans **384–393** have been isolated from Chloranthaceae family, mainly found in *C. japonicus* and *S. glabra*. Compounds **384–388** belong to eupomatenoid benzofuran-type neolignans isolated from the whole

Table 3 Coumarins.

No.	Name	Part	Source	References
370	Scopoletin	*Whole plants*	*C. Japonicus*	[22]
		Whole plants	*S. glabra*	[7]
		Aerial parts	*H. brasiliense*	[62]
371	Isoscopoletin	*Whole plants*	*C. Japonicus*	[22]
		Whole plants	*S. glabra*	[100]
372	Fraxidin-8-O-β-D-glucoside	*Roots*	*C. holostegius*	[95]
373	Skimmin (isofraxidin-7-*O*-β-*D*-glucoside)	*Roots*	*C. henryi*	[12]
		Whole plants	*S. glabra*	[109]
		Whole plants	*S. hainanensis*	[111]
374	Calucanthoside (Umbelliferone 7-*O*-β-*D*-glucoside)	*Roots*	*C. henryi*	[12]
375	Chloracoumarin (6,8-Gimethoxy-7-*O*-[β-D-apiofunanosyl(1→3)-β-D-glucopyranosyl]-2H-benzopyran-2-one)	*Roots*	*C. henryi*	[12]
376	Eleutheroside B1 (Isofraxidin 7-*O*-α-D-glucopyranoside)	*Whole plants*	*S. glabra*	[93]
377	Isofraxidin	*Whole plants*	*S. glabra*	[96]
378	4, 4′-Biisofraxidin	*Whole plants*	*S. glabra*	[97]
379	Esculetin	*Whole plants*	*S. glabra*	[97]
380	Fraxitin	*Whole plants*	*S. glabra*	[97]
381	Scoparone	*Whole plants*	*S. glabra*	[97]
382	Hemidesmin-1	*Whole plants*	*S. glabra*	[98]
383	Yinxiancaoside C (Cleomiscosin C-4-*O*-β-D-glucopyranoside)	*Whole plants*	*C. japonicus*	[99]

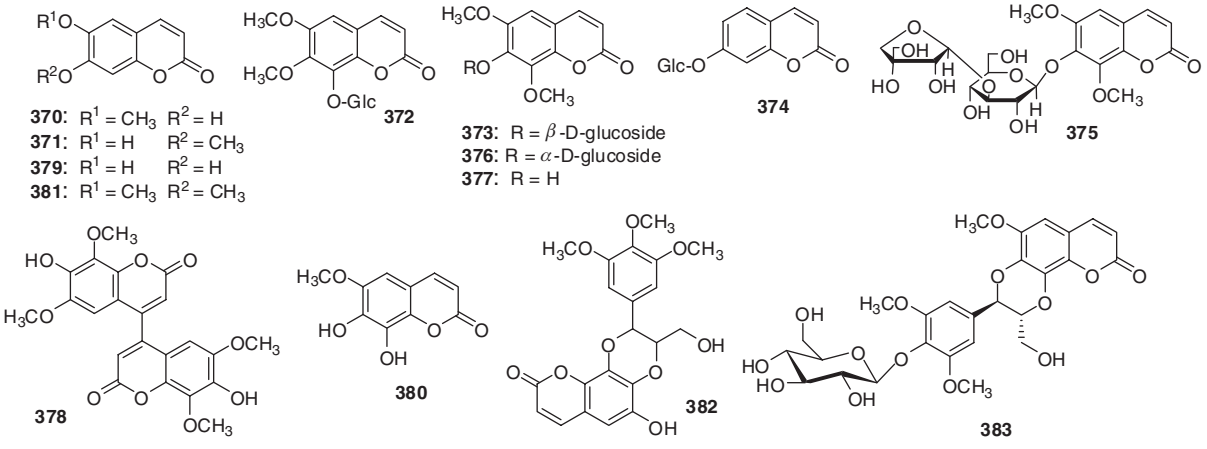


Figure 3 Coumarin structures.

Table 4 Lignans.

No.	Name	Part	Source	References
384	(7*S*, 8*R*)-Dihydrodehydrodiconiferyl alcohol	*Whole plants*	*C. japonicus*	[99]
		Whole plants	*C. multistachys*	[115]
		Whole plants	*S. glabra*	[98]
385	(7*S*, 8*R*)-Urolignoside	*Whole plants*	*C. japonicus*	[99]
		Leaves	*H. brasiliense*	[46]
386	(7*S*, 8*R*)-Dihydrodehydrodiconiferyl alcohol-9-O-β-D-glu copyranoside	*Whole plants*	*C. japonicus*	[99]
387	(7*S*, 8*R*)-Dihydrodehydrodiconiferyl alcohol-9′-O-β-D-glu copyranoside	*Whole plants*	*C. japonicus*	[99]
388	(7*S*, 8*R*)-5-Methoxydihydrodehydrodiconiferyl alcohol-4-O-β-D-glucopyranoside	*Whole plants*	*C. japonicus*	[99]
		Whole plant	*S. glabra*	[101]
		Leaves	*H. brasiliense*	[46]
389	Syringaresinol monoside	*Whole plants*	*S. glabra*	[100]
390	Styraxjaponoside B	*Whole plants*	*S. glabra*	[100]
391	(-)-(7*S*, 8*R*)-Dihydrodehydrodiconiferyl alcohol 9-O-α-D-glucopyranoside	*Whole plant*	*S. glabra*	[101]
392	(-)-(7*S*, 8*R*)-Dihydrodehydrodiconiferyl alcohol 9′-O-α-D-glucopyranoside	*Whole plant*	*S. glabra*	[101]
393	(-)-(7*S*, 8*R*)-Dihydrodehydrodiconiferyl alcohol 4-O-α-D-glucopyranoside	*Whole plant*	*S. glabra*	[101]

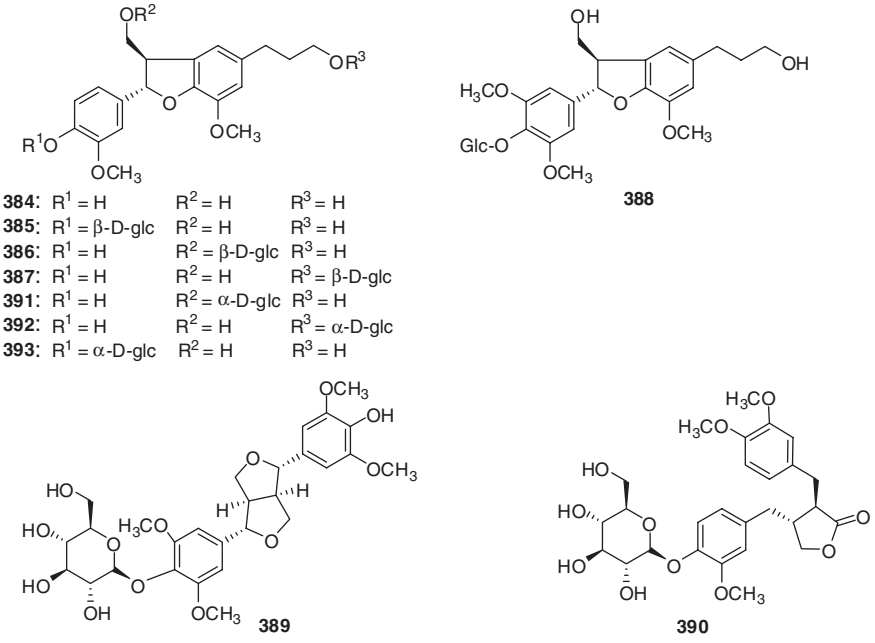


Figure 4 Lignan structures.

plants of *C. japonicus* [99]. Compounds **389**, **390** [100] and **391–393** [101] have been isolated from the whole plants of *S. glabra*.

Phenylpropionic acids and other phenylpropanoids

A total of 24 phenylpropionic acid and phenylpropanoids have been reported. They are mainly distributed in plants of *S. glabra* (**394–406**, **411–414**), *C. anhuiensis* (**407**), *C. multistachys* (**408**, **409**, **417**), *H. brasiliense* (**410**), and *C. serratus* (**415** and **416**).

Phenylpropionic acids **394** [96], **395** [102], **396** [98], **397–400** [103], **401** [100], **402** [104] and **403–406** [105] have been isolated from the whole plants of *S. glabra*. In 2010, one new caffeoyl phenylethanoid diglycoside with an unusual cyclic structure, anhuienoside B (**407**), was isolated in the fresh leaves of *C. anhuiensis* [40]. Compounds **408** and **409** were isolated from the whole plants of *C. multistachys* [38]. Studies in 2015 led to the isolation of compound **410** from the fresh leaves of

Table 5 Phenylpropionic acids and other phenylpropanoids.

No.	Name	Part	Source	References
394	Caffeic acid	*Whole plants*	*S. glabra*	[96]
395	5-*O*-Caffeoyl quinic acid Me ester	*Whole plants*	*S. glabra*	[102]
396	Ethyl rosmarinate	*Whole plants*	*S. glabra*	[98]
397	3-*O*-Caffeoylquinic acid (chlorogenic acid)	*Whole plants*	*S. glabra*	[103]
398	3-*O*-Caffeoylquinic acid Me ester	*Whole plants*	*S. glabra*	[103]
399	4-*O*-Caffeoylquinic acid	*Whole plants*	*S. glabra*	[103]
400	4-*O*-Caffeoylquinic acid Me ester	*Whole plants*	*S. glabra*	[103]
401	5-*O*-Caffeoyl shikimic acid	*Whole plants*	*S. glabra*	[100]
402	Rosmarinic acid-4-*O*-glucoside	*Whole plants*	*S. glabra*	[104]
403	4-*O*-Caffeoylshikimic acid	*Whole plants*	*S. glabra*	[105]
404	3-*O*-Caffeoylshikimic acid	*Whole plants*	*S. glabra*	[105]
405	5-*O*-Caffeoylquinic acid	*Whole plants*	*S. glabra*	[105]
406	Caffeic acid ethyl ester	*Whole plants*	*S. glabra*	[105]
407	Anhuienoside B	*Leaves*	*C. anhuiensis*	[40]
408	Rosmarinic acid	*Whole plants*	*C. multistachys*	[38]
		Whole plants	*S. glabra*	[96]
		Leaves	*H. brasiliense*	[46]
409	Methyl rosmarinate (Rosmarinic acid Me ester)	*Whole plants*	*C. multistachys*	[38]
		Whole plants	*S. glabra*	[96]
410	Isorinic acid	*Leaves*	*H. brasiliense*	[46]
411	Methyl 3, 4-dihydroxyphenyllactate	*Whole plants*	*S. glabra*	[96]
412	β-Hydroxypropiovanillone	*Whole plants*	*S. glabra*	[104]
413	Caryophyllic acid	*Whole plants*	*S. glabra*	[105]
414	Vinyl caffeate	*Whole plants*	*S. glabra*	[105]
415	*Threo*-1-(1-methoxy-2-hydroxypropyl)-2-methoxy-4,5-methylenedioxybenzene	*Whole plants*	*C. serratus*	[2]
416	*Erythro*-1-(1-methoxy-2-hydroxypropyl)-2-methoxy-4,5-methylenedioxybenzene	*Whole plants*	*C. serratus*	[2]
417	Citrusin C	*Whole plants*	*C. multistachys*	[38]

H. brasiliense [46]. Phenylpropanoids **411** [96], **412** [104] and **413**, **414** [105] have been isolated from the whole plants of *S. glabra*. Two new phenylpropanoids **415** and **416**, a pair of stereoisomers, have been isolated from the whole plants of *C. serratus* [2]. Compound **417**, a glucoside of **413**, has been isolated from whole plants of *C. multistachys* [38].

Flavonoids

Forty seven flavonoids have been isolated from Chloranthaceae family since 1982. They are mainly distributed in plants of *A. lucida* (**418–432**), *S. glabra* (**433–451**), *S. hainanensis* (**452–463**), and *C. multistachys* (**464**). The earliest report on the isolation of flavonoids from Chloranthaceae plants was in 1982 with four flavone C-glycosides **418–420**, some flavonoid aglycones and their 3-*O*-mono and diglycosides **421–432** described as constituents of the leaves of *A. lucida* [106]. This is also the only report about chemical investigation of plants in genus *Ascarina* to date.

Most flavonoids **433–463** isolated from Chloranthaceae plants are mainly distributed in the plants of genus *Sarcandra*. Flavonoids **433–451** have been isolated from the whole plants of *S. glabra*. Two flavanones **433**, **434** and a dihydrochalcone **435** have been obtained from the whole plants of *S. glabra* [93]. Compound **436**, a novel phenylpropanoid-substituted catechin glycoside, and compound **437** with a rare phenylpropanoid-substituted dihydrochalcone have also been isolated from *S. glabra* [107]. Flavonoid **438** and chalcone **439** are two compound isolated for the first time from *S. glabra* [108]. In 2008, five flavonoid glycosides including **440–443** and a flavonone 3-*O*-glycoside **444** were isolated from the whole plants of *S. glabra* [102]. In the same year, a flavonone 6-C-glycoside **445** [109] and a rare flavonone **446** [98] without a 4′-substituent were isolated. Compounds **447–449**, that differ in the absolute configuration at C-2 and C-3, were also isolated from *S. glabra* [100]. In 2012, two additional phenylpropanoid-substituted catechin glycosides **450** and **451** were isolated from the whole plant [33]. Flavonoids **452–463** have been obtained from the whole plants of

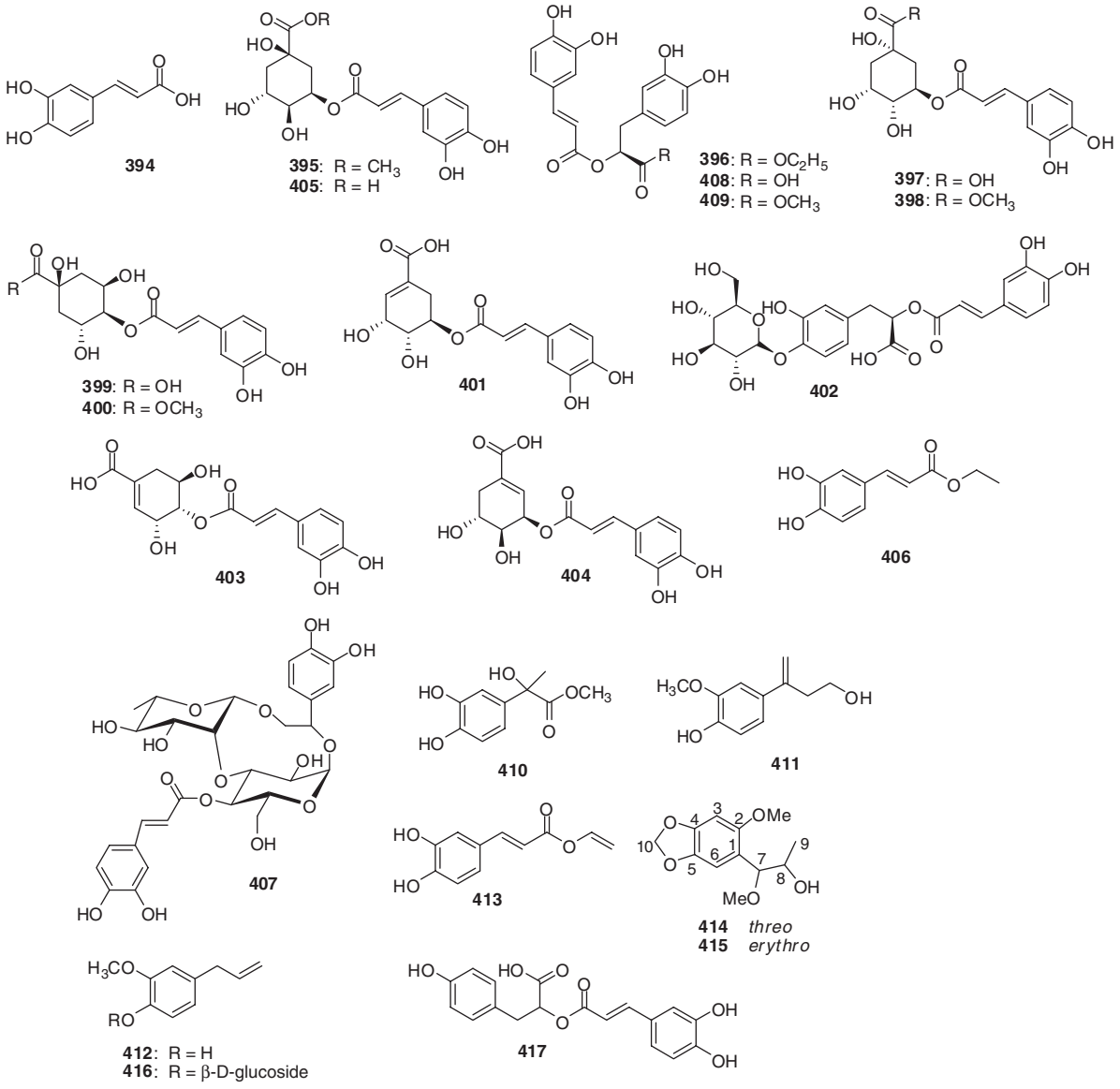


Figure 5 Phenylpropionic acid and other phenylpropanoid structures.

S. hainanensis [110–112]. The chalcone **464**, found in genus *Chloranthus*, has been isolated from whole plant tissues of *C. multistachys* [38].

Other compounds

Several amides **465–473** have been isolated from the genus of *Chloranthus* and *Sarcandra*. They are distributed in the species *C. serratus* [113], *S. glabra* [98], *C. anhuiensis* [40] and *C. angustifolius* [42]. These amide derivatives in *Chloranthus* and *Sarcandra* may serve as specific fingerprint markers for distinguishing between species within the genus.

Six steroids **474–479** are distributed in two kinds of plants, namely *C. henryi* and *C. multistachys* [38]. Compounds **480–487** are derivatives of benzoic acid. Compounds **480** [93], **481** [104], **482** and **483** [114], **484** [105] and **485** [96] have been found in the whole plants of *S. glabra*. The esters **486** [38] and **487** [115] have been isolated from the whole plants of *C. multistachys*. Other carboxylic acids and alcohols, **488** [93], **489–492** [110], **493** [114] and **494** [108] have been isolated from the whole plants of *S. glabra* and *S. hainanensis*. Monosaccharides **495** and **496** have been isolated from the whole plants of *S. glabra* [108]. Two anthraquinones **497** and **498** found in the whole plants of *S. hainanensis* [110] are the only anthraquinones in Chloranthaceae plants. The glycoside **499**

Table 6 Flavonoids.

No.	Name	Part	Source	References
418	Vitexin (apigenin 8-*C*-β-D-glucoside)	*Leaves*	*A. lucida*	[106]
419	Isovitexin (apigenin 6-*C*-β-D-glucoside)	*Leaves*	*A. lucida*	[106]
420	Orientin	*Leaves*	*A. lucida*	[106]
421	Isoorientin	*Leaves*	*A. lucida*	[106]
422	Kaempferol	*Leaves*	*A. lucida*	[106]
		Whole plants	*S. glabra*	[109]
		Whole plants	*S. hainanensis*	[112]
423	Kaempferol 3-*O*-β-D-glucoside	*Leaves*	*A. lucida*	[106]
		Whole plants	*S. hainanensis*	[112]
424	Kaempferol 3-*O*-β-D-galactoside	*Leaves*	*A. lucida*	[106]
425	Kaempferol 3-*O*-β-D-xyloside	*Leaves*	*A. lucida*	[106]
426	Kaempferol 3-*O*-*a*-L-rhamnoside	*Leaves*	*A. lucida*	[106]
427	Kaempferol 3-*O*-rutinoside	*Leaves*	*A. lucida*	[106]
428	Quercetin 3-*O*-β-D-glucoside	*Leaves*	*A. lucida*	[106]
429	Quercetin 3-*O*-β-D-galactoside	*Leaves*	*A. lucida*	[106]
430	Quercetin 3-*O*-β-D-xyloside	*Leaves*	*A. lucida*	[106]
431	Quercetin 3-*O*-*a*-L-rhamnoside	*Leaves*	*A. lucida*	[106]
		Whole plants	*S. glabra*	[114]
432	Quercetin 3-*O*-β-D-rutinoside (Rutin)	*Leaves*	*A. lucida*	[106]
		Whole plants	*S. glabra*	[114]
433	Pinostrobin	*Whole plants*	*S. glabra*	[93]
		Whole plants	*S. hainanensis*	[111]
434	7-Methylnaringenin	*Whole plants*	*S. glabra*	[93]
435	2′,6′-Dihydroxy-4′-methoxydihydrochalcone	*Whole plants*	*S. glabra*	[93]
436	Glabraoside A	*Whole plants*	*S. glabra*	[107]
437	3′-(7″-Allylphrnyl)-2′,4′,4″-trihydroxy-6′-methoxydihydrochalcone	*Whole plants*	*S. glabra*	[107]
438	Quercetin	*Whole plants*	*S. glabra*	[108]
439	Isoliquiritigenin	*Whole plants*	*S. glabra*	[108]
440	Kaempferol-3-*O*-β-D-glucuronide	*Whole plants*	*S. glabra*	[102]
		Leaves	*H. brasiliense*	[46]
441	Quercetin-3-*O*-α-D-glucuronide	*Whole plants*	*S. glabra*	[102]
442	Quercetin-3-*O*-β-D-glucuronopyranoside Me ester	*Whole plants*	*S. glabra*	[102]
443	5, 7, 4′-Trihydroxy-8-C-β-D-glucopyranosyl flavanone	*Whole plants*	*S. glabra*	[102]
444	Neoastilbin	*Whole plants*	*S. glabra*	[102]
445	5, 7, 3′, 4′-Tetrahydroxy-6-C-β-D-glucopyranosyl flavanone	*Whole plants*	*S. glabra*	[109]
446	(+)-3,3′,5,5′,7-Pentahydroxyflavanone	*Whole plants*	*S. glabra*	[98]
447	Isoastilbin	*Whole plants*	*S. glabra*	[100]
448	Neoisoastilbin	*Whole plants*	*S. glabra*	[100]
449	Astilbin	*Whole plants*	*S. glabra*	[100]
450	Glabraoside C	*Whole plants*	*S. glabra*	[33]
451	Glabraoside D	*Whole plants*	*S. glabra*	[33]
452	2′,3′-Dihydroxy-4′,6′-dimethoxychalcone	*Whole plants*	*S. hainanensis*	[110]
453	2′-Hydroxy-4′,6′-dimethoxychalcone	*Whole plants*	*S. hainanensis*	[110]
454	Cardamonin	*Whole plants*	*S. hainanensis*	[110]
455	Sarcandrone A	*Whole plants*	*S. hainanensis*	[111]
456	Sarcandrone B	*Whole plants*	*S. hainanensis*	[111]
457	Sarcandrone C	*Whole plants*	*S. hainanensis*	[112]
458	Sarcandrone D	*Whole plants*	*S. hainanensis*	[112]
459	7-Hydroxy-5,8-dimethoxyflavanone	*Whole plants*	*S. hainanensis*	[111]
460	7-Hydroxy-5,6-dimethoxyflavanone	*Whole plants*	*S. hainanensis*	[112]
461	7-Hydroxy-5-methoxyflavanone	*Whole plants*	*S. hainanensis*	[112]
462	Naringenin-4′,7-dimethyl ether	*Whole plants*	*S. hainanensis*	[112]
463	3,4′,5,7-Tetrahydroxyflavanone-3-O-glucoside	*Whole plants*	*S. hainanensis*	[112]
464	2-Hydroxy-4,4′,6′-trimethoxychalcone	*Whole plants*	*C. multistachys*	[38]

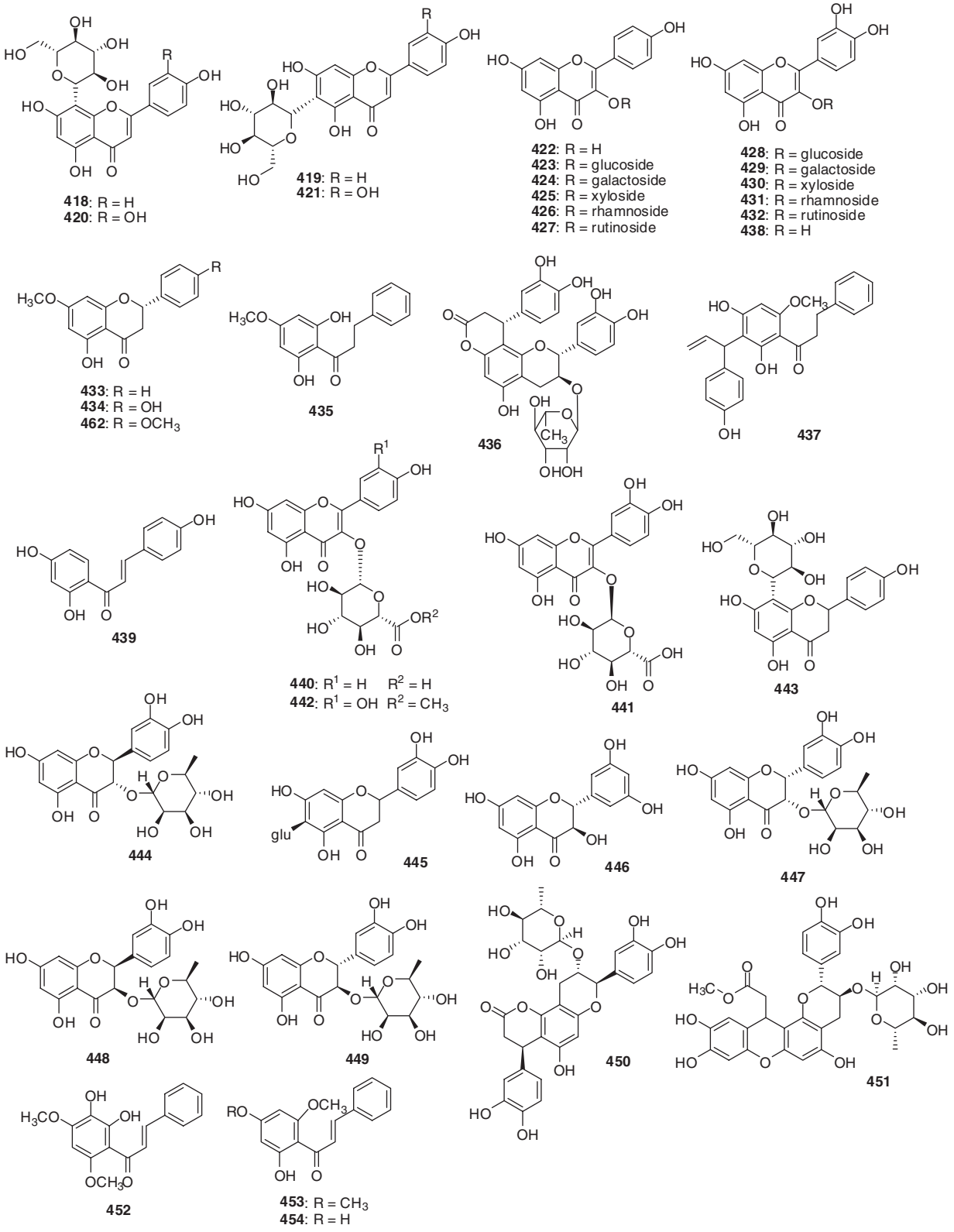


Figure 6 Flavonoid structures.

[30] and its aglycone **500** [116] have been isolated from *S. glabra*. In 2010, a new tetrahydrophenanthrene named henryin A (**501**) was isolated from the leaves of *C. henryi* [117] and a benzaldehyde derivative **502** was isolated from the leaves of *C. anhuiensis* [40]. In 2012, from the whole plant of *S. glabra*, a new glycoside **503** was isolated [101].

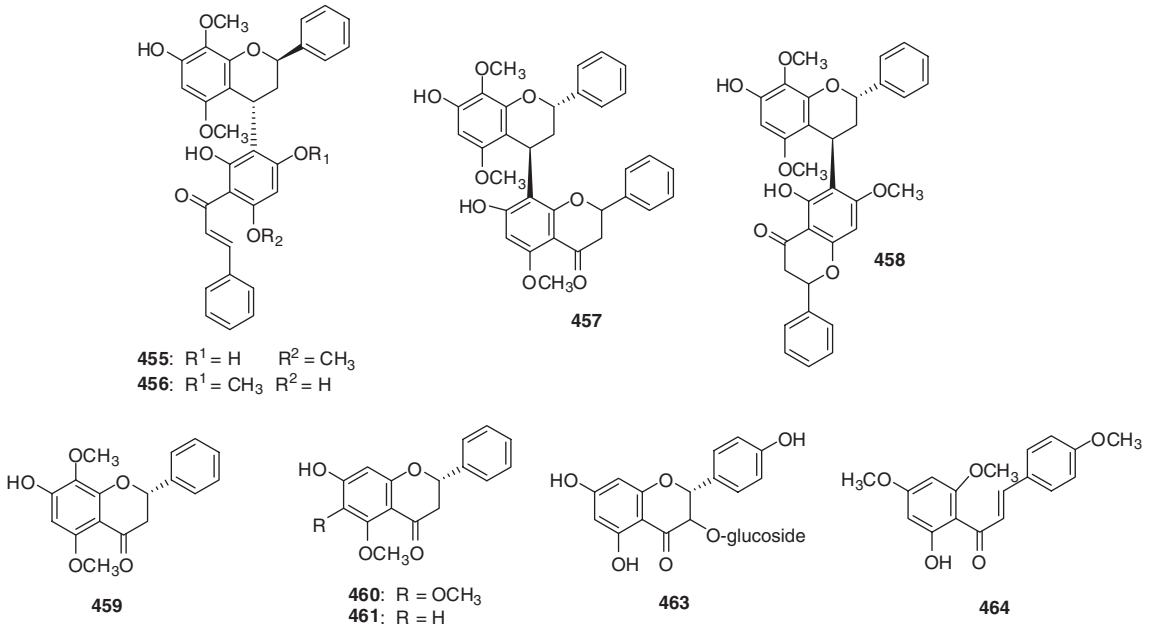


Figure 6 (continued)

The phenylethanoid glycoside **504** has been isolated from *C. multistachys* [38].

Biological activities

Antimicrobial activity

Compounds **4–7** have been tested for antimicrobial activity against 13 microorganisms *in vitro* but only compounds **6** and **7** show moderate activity against *Helicobacter pylori*-SS1 with MICs of 25–50 μg/mL [2]. Compounds **26**, **31**, **87**, **88**, **161**, **232**, **234**, **244**, **254**, **275** and **276** have been evaluated for antimicrobial activity against five bacterial strains including *Staphylococcus aureus* (Sa, ATCC 29213), *Escherichia coli* (Ec, ATCC 25922), *Salmonella typhimurium* (St, ATCC 13311), *Pseudomonas aeruginosa* (Pa, ATCC 27853), and *Klebsiella pneumoniae* (Kp, ATCC 18433), as well as six fungal strains including *Candida albicans* (Ca, ATCC 90028), *Cryptococcus neoformans* (Cn, ATCC 22402), *Candida glabrata* (Cg, ATCC 90030), *Candida krusei* (Ck, ATCC 6258), *Candida parapsilosis* (Cp, ATCC 22019), and *Aspergillus sp*. (As, ATCC 293) *in vitro* by using a microdilution assay. Sesquiterpene dimers **232**, **234**, **244**, **254**, **275** and **276** show remarkable antifungal activity against *C. albicans* with MIC values ranging from 4 to 8 μg/mL. Sesquiterpenes **26**, **31**, **87** and **88**, show moderate inhibitory activity against *C. albicans* with MIC values ranging from 16 to 32 μg/mL. The fungus *C. neoformans* is most sensitive to sesquiterpene dimer **254** with a MIC value of 8 μg/mL. These results suggest that the sesquiterpenes may be the chemical constituents responsible for the known anti-ringworm effect of *C. angustifolius* [41].

Compound **64** is a specific inhibitor of chitin synthase 2 of *S. cerevisiae*. It also exhibits antifungal activities against various human and phytopathogenic fungi such as *C. albicans*, *Cryptococcus neoformans*, *Alternaria kikuchiana*, *Colletotrichum lagenarium*, *Fusarium oxysporum*, *Magnaporthe grisea*, *Botrytis cineria*, *Pythium ultimum* and *Rhizoctonia solani* with MIC values of 50–100 μg/mL [26].

Compound **231** is an antifungal agent against *Candida albicans* and *C. parapsilosis* with an MIC value of 0.068 μM [72]. Specific inhibitors of chitin synthases might serve as interesting lead compounds for the development of effective antifungal agents. Sesquiterpenes **254**, **256** and **260**, have been evaluated for their inhibitory effects on the release of NO from macrophages using LPS-induced RAW264.7 cells as a model system, with the respective IC_{50} values of 0.22, 0.15, and 7.22 μM [4]. Compound **267** is an antifungal agent with MICs of 1–32 μg/mL *in vitro* against *Alternaria kikuchiana*, *Botrytis cinerea*, *Colletotrichum lagenarium*, *Magnaporthe grisea*, *Pythium ultimum* and *Phytophthora infestans*. The disease-control activity of compound **267** is stronger than that of the commercially available fungicide chlorothalonil, but weaker

Table 7 Other compounds.

No.	Name	Part	Source	References
465	N-β-phenethyl-3-(3,4-methylenedioxyphenyl) propenamide	*Whole plants*	*C. serratus*	[113]
466	N-β-phenethyl-3-(3,4-dimethoxyphenyl) propenamide	*Whole plants*	*C. serratus*	[113]
467	N-*trans*-feruloyltyramine	*Whole plants*	*S. glabra*	[98]
		Aerial parts	*C. angustifolius*	[42]
468	N-acetyltyramine 1-*O*-β-D-glucoside	*Leaves*	*C. anhuiensis*	[40]
469	N-*p-trans*-coumaroyltyramine	*Aerial parts*	*C. angustifolius*	[42]
470	Cannabisin G	*Aerial parts*	*C. angustifolius*	[42]
471	Thoreliamide A	*Aerial parts*	*C. angustifolius*	[42]
472	Cannabisin F	*Aerial parts*	*C. angustifolius*	[42]
473	Aurantiamide acetate	*Aerial parts*	*C. angustifolius*	[42]
474	β-Sitosterol	*Roots*	*C. henryi*	[12]
		Whole plants	*S. glabra*	[93]
		Whole plants	*S. hainanensis*	[110]
475	Daucosterol	*Roots*	*C. henryi*	[12]
		Whole plants	*S. glabra*	[108]
476	β-Ecdysterone	*Whole plants*	*C. multistachys*	[38]
477	Ajugasterone C-20,22-acetonide	*Whole plants*	*C. multistachys*	[38]
478	24-*Epi*-pterosterone-2,3,20,22-diacetonide	*Whole plants*	*C. multistachys*	[38]
479	20-Hydroxyecdysterone-2,3:20,22-diacetonide	*Whole plants*	*C. multistachys*	[38]
480	3,4-Dihydroxybenzonic acid (protocatechuic acid)	*Whole plants*	*S. glabra*	[93]
481	Isovanillic acid	*Whole plants*	*S. glabra*	[104]
482	*p*-Hydroxybenzoic acid	*Whole plants*	*S. glabra*	[114]
483	*o*-Phthalic acid	*Whole plants*	*S. glabra*	[114]
484	3-Methoxy-4-hydroxybenzoic acid	*Whole plants*	*S. glabra*	[105]
485	Dibutyl phthalate	*Whole plants*	*S. glabra*	[96]
486	3,4-*O*-Isopropylidene shikimic acid	*Whole plants*	*C. multistachys*	[38]
487	Syringic acid-4-*O*-α-L-rhamnopyranoside	*Whole plants*	*C. multistachys*	[115]
488	Palmitic acid	*Whole plants*	*S. glabra*	[93]
		Whole plants	*S. hainanensis*	[110]
489	Icosanoic acid	*Whole plants*	*S. hainanensis*	[110]
490	Octadecanoic acid	*Whole plants*	*S. hainanensis*	[110]
491	Docosanoic acid	*Whole plants*	*S. glabra*	[114]
492	Tetracosanoic acid	*Whole plants*	*S. glabra*	[114]
493	Succinic acid	*Whole plants*	*S. glabra*	[114]
494	Hexacosanol	*Whole plants*	*S. glabra*	[108]
495	Glucose	*Whole plants*	*S. glabra*	[108]
496	Hexitol	*Whole plants*	*S. glabra*	[108]
497	Chrysophanol	*Whole plants*	*S. hainanensis*	[110]
498	Emodin	*Whole plants*	*S. hainanensis*	[110]
499	Dihydrovomifoliol-*O*-β-D-glucopyranoside	*Whole plants*	*S. glabra*	[30]
500	Dihydrovomifoliol	*Whole plants*	*S. glabra*	[34]
501	Henryin A ((S)-4,6,9-Trimethyl-5,6,7,8-tetrahydrophenan-threne-1,2-diol)	*Leaves*	*C. henryi*	[117]
502	3,4,5-Trimethoxybenzaldehyde	*Leaves*	*C. anhuiensis*	[40]
503	Benzyl 2-β-glucopyranosyloxybenzoate	*Whole plants*	*S. glabra*	[101]
504	Phenethyl-8-*O*-β-D-glucopyranoside	*Whole plants*	*C. multistachys*	[38]

than that of dimethomorph. Therefore, compound **267** might be an interesting lead compound to develop effective antifungal agents [118]. Essential oils from *C. japonicus* and *C. multistachys* show strong antimicrobial activity against most tested microorganisms. For both species, minimum values for inhibitory and bactericidal concentrations are 0.39–12.50 mg/mL and 0.78–50.00 mg/mL, respectively. These essential oils may be natural sources of potent antimicrobial agents for the medicinal and pharmaceutical industries [119].

Anti-inflammatory activity

Compounds **26** and **306** have been evaluated for anti-inflammatory activities by measuring the inhibition

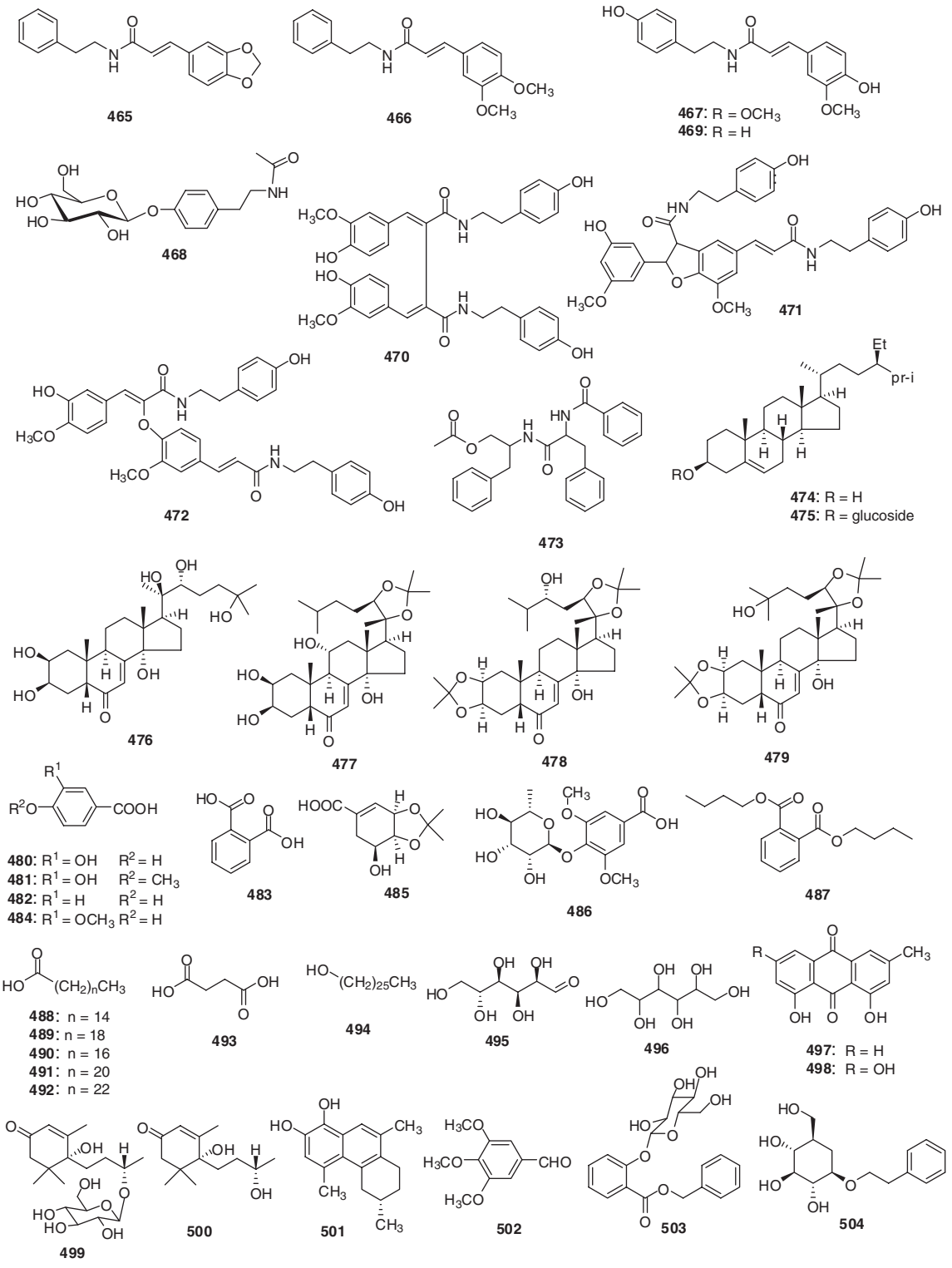


Figure 7 Structures of other compounds.

of the PAF induced release of β-glucuronidase from rat PMNs *in vitro*. These compounds inhibit the release of β-glucuronidase from rat PMNs induced by PAF [9]. Compounds **41**, **166**, **235**, **240**, **244** and **254** have been assayed for their inhibitory effects on NO production in LPS-activated BV-2 cells. These compounds decrease NO production with IC_{50} values 79.0, 68.1, 79.4, 70.4, 47.9, and 31.1 μM, respectively, without cytotoxicity [17]. Compounds

350 and **353** show moderate antineuroinflammatory activities, with IC_{50} values of 8.3 and 7.4 μM, respectively [91]. This is the first report on the antineuroinflammatory activity of naturally occurring *ent*-abietanes [91]. In 2012, compounds **96**, **130**, **217**, **219**, **254–257**, **264**, **266** and **267**, were tested for their inhibitory effects on LPS-induced nitric oxide production in RAW264.7 cells. Shizukaols E (**217**), G (**219**), M (**264**), O (**266**), and henriol D (**267**) show significant anti-inflammatory activities with IC_{50} values of 1.90, 3.68, 1.95, 7.01, and 1.95 μM, respectively [58]. Serralabdanes A-E (**330–334**) have also been investigated using the same assay. Compared with IC_{50} values of the reference compound dexamethasone at 1.08 ± 0.15 μM, the five compounds display weak activities with IC_{50} values of 38.45 ± 1.02, 29.78 ± 0.92, 44.37 ± 0.58, 53.68 ± 1.52, and 47.31 ± 1.26, respectively [89]. Dimers **219**, **254** and **287** can significantly inhibit NO production in LPS-induced macrophages with IC50 values at, 4.65, 2.33 and 3.04 μmol/L, respectively [87]. The pretreatment with coumarin **377** increases the survival rate following LPS stimulation in mice. The effect involves regulation of NF-κB signal which, in turn, regulates production of inflammatory cytokine TNF-α, suggesting that IF may have a therapeutic effect against LPS-induced inflammatory disease [120]. Further research has suggested that compound **377** has a protective effect against LPS-induced acute lung injury (serious lung inflammation and increased capillary permeability) [121].

Anti-tumor activity

Compound **33** shows moderate antitumor activity against human cervical squamous carcinoma (Hela) cells (IC_{50} = 22.2 μM) and human erythroleukemia (K562) cells (IC_{50} = 21.8 μM) and weak antitumor activity against Hela cells (IC_{50} = 89.3 μM) and K562 cells (IC_{50} = 78.5 μM). Compound **301** is highly active against Hela cells (IC_{50} = 5.6 μM) and K562 cells (IC_{50} = 5.9 μM) [13]. Codonolactone **56** inhibits invasion and migration of breast cancer cells *in vitro*. The mechanism of its inhibitory effects has been investigated and results suggest that **56** inhibits the binding of Runx2 to sequences of the mmp-13 promoter [122]. Compound **208** shows strong anti-tumor activity against Hela (IC_{50} = 5.6 μg/mL), and K562 (IC_{50} = 5.0 μg/mL). Compound **95** demonstrates moderate anti-tumor activity against Hela (IC_{50} = 17.2 μg/mL, and K562 (IC_{50} = 21.6 μg/mL) [23]. Compounds **282** and **284** exhibit cytotoxicity against the HL-60 cell line with IC_{50} values of 0.03 and 1.2 μM, respectively [35]. Compound **93** shows moderate activity against A549 and HL-60 with IC_{50} values of 3.1 and 8.8 μM, respectively [37]. Compound **177** shows remarkable antitumor activity against the Hela, A549, MCF, and K562 human-tumor cell lines, with IC_{50} values of 4.7, 8.9, 9.6, and 11.8 μg/mL, respectively [14]. Crude extracts of *C. japonicus* and some isolates have been tested for their cytotoxicity against NCI-H460 (human large cell lung cancer cell line) and SMMC-7721 (hepatocellular carcinoma) cell lines. Among them, the methanol extract, ethyl acetate fraction, and isolated shizukaols B, C, D, and O (**254, 256** and **266**) show marked cytotoxicities with IC_{50} value from 32.5 to 36.79 μM against NCI-H460, and 13.71 to 37.39 μM against SMMC-7721. Sesquiterpene dimers are presumably responsible for the cytotoxicities exhibited by *C. japonicus* [25]. Compound **254** derived from the ethanol extract of the roots of *C. henryi* exhibits cytotoxic activities against BEL-7402 and BGC-823 cell lines (IC_{50} = 1.4 and 3.2 μg/mL, respectively). Compound **304** shows moderate cytotoxic activities against BEL-7402, HCT-8, and BGC-823 cell lines (IC_{50} = 17.0, 0.54, and 5.76 μg/mL, respectively) [73]. Compounds **254, 257** and **218**, isolated from *C. japonicus*, are potential cell adhesion inhibitors. They inhibit PMA-induced homotypic aggregation of HL-60 cells with MIC values of 34.1 nM (**254**), 0.9 μM (**257**) and 27.3 nM (**218**). All three compounds significantly inhibit ICAM-1 expression in HL-60 cells in a dose-dependent manner. It can be suggested that compounds **254, 257** and **218** prevent monocyte adhesion to HUVEC through the inhibition of cell adhesion molecules expression stimulated by TNF-α [123]. Sesquiterpene polymers **277–279** show inhibitory activities against the HL-60 (human leukemia) cell line with IC_{50} values of 3.1, 8.4, and 8.5 μM, respectively. Compounds **277** and **279** show inhibitory activities against the A-549 cell line with the respective IC_{50} values of 7.2 and 4.7 μM. Eleutheroside B_1 (**376**) exhibits potent activity against BGC-823 and A2780 cancer cell lines with the IC_{50} value of 2.53 and 1.85 μM, respectively [101].

Anti-HIV activity

Fifteen disesquiterpenoids (**216**, **218**, **220**, **224**, **226–229**, **235**, **254–257**, **271** and **272**) have been tested for their activity against HIV-1 replication. Compounds **218**, **220**, **254** and **255** show inhibitory effects on HIV-1 replication (C_{50} in the range from 0.11 to 4.05 μM) for wild-type HIV-1 and two non-nucleoside reverse transcriptase inhibitor resistant HIV-1 strains ($HIV_{RT\text{-}K103N}$ and $HIV_{RT\text{-}Y181C}$). Among the tested compounds, shizukaol B (**254**) exhibits remarkable activity against HIVwt, $HIV_{RT\text{-}K103N}$, and $HIV_{RT\text{-}K103N}$ (EC_{50} = 0.22, 0.47, and 0.50 μM, respectively). Compounds **218**, **220**, **254** and **255** show significant cytotoxity against C8166 cell line

(CC_{50} = 0.047, 0.022, 0.020 and 0.089, respectively), and inhibitory activities against HIV-1 (EC_{50} = 0.0043, 0.0033, 0.0014 and 0.016 μM, respectively) [71].

Compounds **455** and **456** have been assayed for their HIV-1 integrase (IN) inhibition activities with a microplate screening method using magnetic beads. The reference drug has been baicalein (IC_{50} = 1.06 μM). They exhibit weak activities with IC_{50} values of 18.05 and 25.27 μM, respectively [111].

Additional biological activity

In the search for compounds with hepatoprotective activity from *S. glabra*, compounds **67**, **68**, **115**, **126**, **174**, **202** and **203** have been found to be active at 10^{-4} M *in vitro*, without any obvious cytotoxic effects [29]. This is the first report of hepatoprotective activity of compounds derived from a *Sarcandra* species [29]. Compounds **232** and **304**–**306** show moderate hepatoprotective activities with IC_{50} values of 0.19, 0.66, 0.09 and 0.18 μM, respectively [73].

The hydroalcoholic extract (HE) from *H. brosiliense* and compound **133** show activity in many assays of pain, such as abdominal constriction response caused by intraperitoneal injection of acetic acid, formalin-induced licking, capsaicin-induced licking, hot-plate test, and tail-flick test. HE produces remarkable inhibition of acetic acid-induced abdominal constriction in mice (ID_{50} = 12.7 mg/kg). In the assay of formalin-induced licking, HE inhibits the first and second phase (ID_{50} = 31.1 and 21.7 mg/kg, respectively). HE also has an effect on capsaicin-induced neurogenic pain (ID_{50} = 69.0 mg/kg). Compound **133** shows graded antinociception against acetic acid writhing and capsaicin-induced neurogenic pain [59].

The search for anti-leishmanial agents from *H. angustifolium* has led to the isolation of compounds **123**, **133**–**135**, and **197**. Compound **133** exhibits significant activity against *L. amazonensis* and *L. infantum* with a value of IC_{50} of 19.8 and 20.9 μM, respectively. This is the first time of anti-leishmanial activity finding for a lindenane sesquiterpene [60].

Tyrosinase is a key enzyme for melanin biosynthesis in plants and animals. Tyrosinase inhibitors, therefore, can be clinically useful for the treatment of some dermatological disorders associated with melanin hyperpigmentation. Compounds **163** and **164** inhibit the enzyme tyrosinase with the IC_{50} values of 325 and 269 μM, respectively, compared to the standard tyrosinase inhibitor kojic acid (IC_{50} = 211 μM) [15]. Similar values have been found for **275** and **276** [86].

Six novel sesquiterpenoid dimers isolated from *C. holostegius* have been tested their inhibition on the delayed rectifier $(I_K)K^+$ current. Chloraholides A (**270**) and B (**271**), exhibit potent and selective inhibition with IC_{50} of 10.9 and 18.6 μM, respectively, and are 56- and 96-fold more potent than the positive control, tetraethylammonium chloride (IC_{50} = 1.05 μM), a classical blocker of the delayed rectifier $(I_K)K^+$ current [84]. Chloraholides C-F (**272**, **267**, **273** and **274**), show potent and selective inhibition on the delayed rectifier $(I_K)K^+$ current with the IC_{50} values of 3.6 ± 10.1, 2.7 ± 0.3, 27.5 ± 5.1 and 57.5 ± 6.1 μM, respectively [85].

Shizukaol D (**256**) can activate AMP-activated protein kinase (AMPK), which is a key sensor and regulator of intracellular energy metabolism, leading to a decrease in triglyceride and cholesterol levels in HepG2 cells. Compound **256** can also induce mitochondrial dysfunction by depolarizing the mitochondrial membrane and suppressing energy production, which may result in AMPK activation. This research suggested that **256** might be used to treat metabolic syndrome [124].

Conclusions

In total, 299 sesquiterpenes have been isolated from plants of Chloranthaceae. Eudesmanes, lindenranes and sesquiterpene polymers are present in large numbers. The lindenrane-type sesquiterpene dimers can be used as chemotaxonomical markers of genera *Chloranthus* and *Sarcandra*. Since cadinane-type sesquiterpenes have been found only in three species, *C. henryi*, *C. serratus* and *C. multistachys* of genus *Chloranthus*, this class of compounds may be explored as the chemotaxonomical markers of the above three species or genus *Chloranthus*. Many species have been used by local people as traditional herbal medicines. Some components isolated from the herbal medicines exhibit significant bioactivities. For example, chloraholides C-F (**272–274**) represent a new class of potassium channel blockers, and their potent and selective inhibition on the delayed rectifier (I_K) K^+ current suggest that further investigation into this structural class is warranted [85]. On the other hand, additional work is warranted to investigate mechanisms of these interesting bioactivities. There are also many species, such as plants of genus *Hedyosmum* and *Ascarina*, that have received no or little attention from the viewpoints of chemical and biological properties.

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