Phytochemistry, Vol 22, No 5, pp 1071–1095, 1983
Printed in Great Britain

0031–9422/83/051071–25$12 50/0

REVIEW

TRITERPENOIDS

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(*Received* 20 *August* 1982)

Key Word Index—Triterpenoids, pentacyclic triterpenes, tetracyclic triterpenes, isolation, structure elucidation; natural distribution

Abstract—Triterpenoids isolated from various sources are reviewed. The newer techniques used in their isolation and structure elucidation are discussed. A compilation of the triterpenoids isolated during the period 1977–1981, along with available physical data, is included. The biological activities of the triterpenoids are also reviewed.

The classical era of triterpenoid chemistry may be said to have ended in 1949 with the structure elucidation of oleanolic acid by Bischof *et al.* [1]. With the advent of the powerful analytical methods and their subsequent developments over the years, the structure elucidation of a natural product has become, it may be said, a routine affair. As a consequence, increasing numbers of new triterpenoids, including very complex ones, are being isolated and their structures established. Earlier comprehensive reviews in the field of triterpenoids [2–6] covered the literature up to 1976. The present review incorporates new methods of isolation and structure elucidation, the new triterpenoids isolated and the biological properties of these compounds reported during the period 1977–1981.

The literature survey has revealed that investigations are not only limited to isolation and structure elucidation but also include chemotaxonomic studies on the distribution of various triterpenoids in plants [7–11]. Variation of the triterpenoid acids with ripening of fruit has been reported [12]. Also, the isolation by HPLC and characterization of the sapogenols A–C and E from soyabean plants grown in the presence of [2-^{14}C]mevalonic acid has helped in the understanding of the biosynthetic pathways of their formation [13]

ISOLATION AND IDENTIFICATION

Triterpenoids occur in nature either in the free state or as saponins. The free triterpenoids are generally isolated in the pure state by solvent extraction and CC of the extract on alumina or Si gel. Acid or enzymic hydrolysis of the saponins has to be performed before chromatographic purification of the triterpenoid moiety. However, acid hydrolysis of saponins often leads to artifacts. For example, although a number of triterpenoid sapogenols have been isolated from seeds of *Careya arborea* [14, 15], the genuine sapogenins present are 16-deoxybarringtogenol C and barringtogenol C Enzymic hydrolysis of saponins is not always wholly successful. Alternative newer techniques of cleaving the carbohydrate moiety are sometimes reported. A photochemical procedure for cleaving the arabinoside linkage of Ziyu-glycoside II leaving the acid labile aglycone unchanged has been reported [16] Lead tetra-acetate oxidation followed by treatment with alkali was found to be effective for selective cleavage of the glucuronide linkage in saponins that possess a glucuronic acid moiety directly connected to the sapogenol [17] Another technique for the cleavage of the sugar moiety containing glucuronic acid consists of anodic oxidation followed by alkali treatment [18]

Various chromatographic techniques are increasingly being used for isolation and identification of triterpenoids. Newer developments in these techniques have made the task of isolation and identification much easier.

Thin layer chromatography and gas liquid chromatography

Panaxadiol and panaxatriol on treatment with 100-fold of β-naphthoyl chloride in pyridine at room temperature give the stable β-naphthoates which are analysed by TLC dual chromatoscanners [19]. Densitometric TLC has been reported for quantitative estimation of the dammarane type of triterpenoids [20].

Separation of the methyl esters of oleanolic and ursolic acids by GC using a glass column packed with 30% OV-17 or SE-30 has been reported [21]. Soyasapogenols A–E and medicagenic acid in alfalfa were determined by GC after derivatization with *N*, *O*-bis-(trimethyl silyl)-acetamide and chlorotrimethyl silane [22]. A new GC method for the determination of ginseng sapogenins as their acetylated products using *N*-methyl imidazole as catalyst has been described [23]

High performance liquid chromatography.

HPLC methods have now been frequently used for the detection and isolation of triterpenoids. The main advantage of this method is that it does not require any derivatization of the product to be analysed. The technique has been described in a recent book by Simpson [24]. Non-aqueous reversed phase chromatography has been found to be suitable for the analysis of non-polar triterpenoid mixtures at the microgram level [25].

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Glycyrrhizin and glycyrrhetinic acid in blood plasma have effectively been determined in 10 min by HPLC using a Permaphase AAX column and a UV detector [26] Besides the isolation and detection of triterpenoids, the effect of several solvents, such as benzene, toluene, methylene chloride, hexane, cyclohexane, methylcyanide, diethyl ether, dimethyl ether and tetrahydrofuran on the rearrangement of triterpenoids has been examined by HPLC [27]

Gas chromatography/mass spectrometry

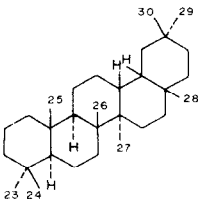
GC/MS is used for rapid detection and estimation of triterpenoids The technique is successfully being used in the determination of triterpenes of the licorice root extract [28] and the extract of *Trametes lilacinogilva* [29]

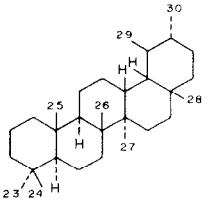
STRUCTURE ELUCIDATION

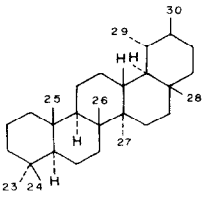
Various spectrometric methods are increasingly being used with advantage for structure elucidation of complex triterpenoids

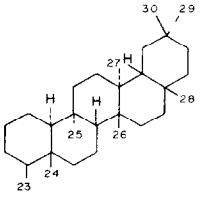
IR spectroscopy

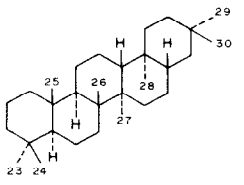
The low frequency IR spectra of some substituted hopane triterpenoids have been proved to be successful for the determination of substituted patterns of hopane-6α,7β,22- and 15α,22,24-triol [30] The newly developed FT-IR technique was found very useful for structure elucidation of two nor-triterpene ketones with the lanostane skeleton [31]

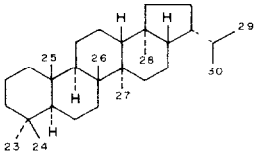

Oleanane (1)

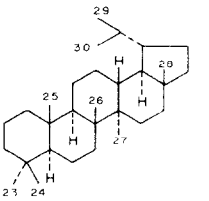

Ursane (2)


ψ-Taraxastane (3)


Friedelane (4)


Stictane (5)


Hopane (6)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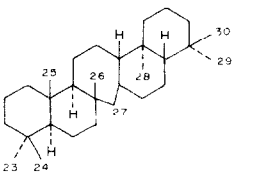
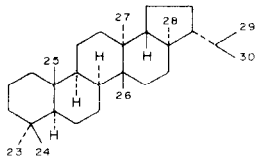
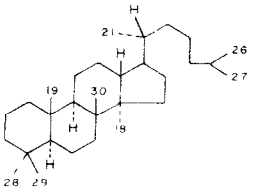
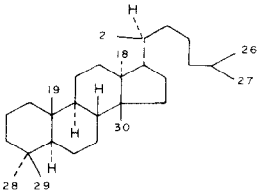

Serratane (8)


Fernane (9)


Dammarane (10)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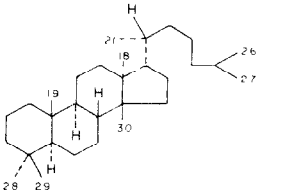
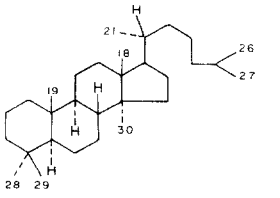
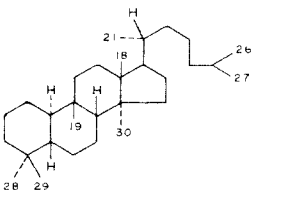
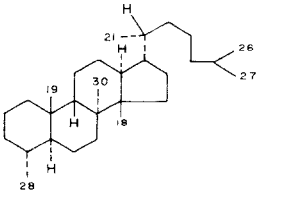

Euphane (12)


Lanostane (13)


Cucurbitane (14)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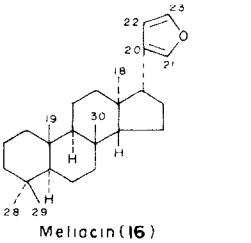
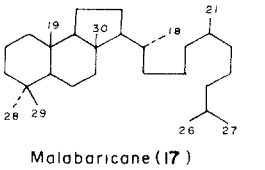
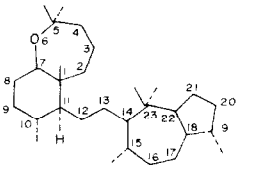
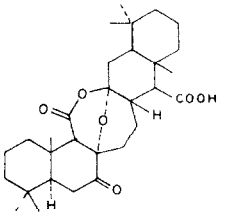

Meliacin (16)


Malabaricane (17)


Siphonane (18)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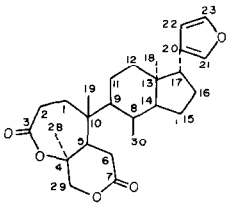

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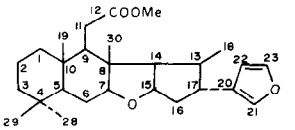

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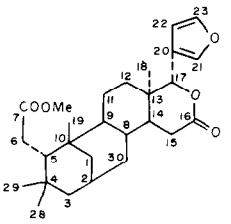

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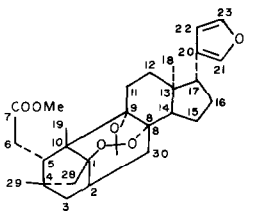

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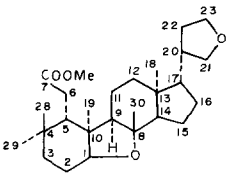

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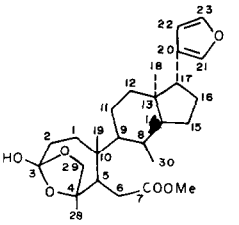

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NMR spectroscopy

NMR spectroscopy, particularly ^{13}C NMR spectroscopy is now being frequently employed in triterpenoid structure elucidation. ^{13}C NMR spectra of oleanane [32], cucurbitacin [33, 34], moronic acid [35], lupane [36, 37], hopane [37], lanostane [38] and the aglycone of holothurin glycosides [39], have been studied and the carbon signals have been assigned by using single frequency off-resonance, decoupling techniques and comparison with chemical shift data of known compounds The ^{13}C NMR data of some pentacyclic triterpenes with the 18β- and 18α-olean-12-en skeletons are reported wherein the shielding data are interpreted in terms of the different orientation of the COOMe group and change in configuration at the D/E ring junction [40]. The configuration at C-18 of six pairs of 18α- and 18β-glycyrrhetic acid derivatives was determined from the chemical shifts of C-12, C-13, C-18 and C-28. The shifts of the carbons, caused by the change of configuration of the D/E ring junction, are independent of substitution at C-3 and C-20 [41]. The structure and stereochemistry of ring A of tetrahydrocucurbitacin I and of tetrahydroisocucurbitacin I were determined by ^{13}C NMR and CD methods [42]

It has been shown that spin-lattice relaxation times (T_1) can be conveniently used as an indicator for the ^{13}C NMR assignments of the terminal *cis*- and *trans*-methyls in a 2'-methyl-1'-propenyl moiety. The T_1 of the terminal methyl groups in $Me_2C = CHR$ (R = Me, CH_2Br, COOH, COMe, CHOHMe, $(CH_2)_2COMe$, prenyl, polyprenyl) showed that T_1 for *cis*-methyl carbon atoms is always longer than T_1 for *trans*-methyl carbon atoms [43].

Internuclear double resonance (INDOR) and lanthanide induced shift (LIS) studies are frequently reported for stereochemical assignments of triterpenoids. The methyl signals of friedelin and its derivatives were assigned by using the homonuclear INDOR technique in the presence of $Pr(fod)_3$ and the results were correlated with the conformation of the D and E rings [44, 45].

Complete assignments of the carbon frequencies of 16 olean-18-en derivatives have been accomplished by means of SFORD and NORD experiments using shift reagent techniques [46]. It has also been demonstrated that the experimental shift values of C-1 and C-14 of germanicol agree reasonably well with those of calculated values [47]. The experimental and calculated ^{13}C NMR signal values of the carbons of lupeol were also found to be in good agreement [48] Moreover, the substituent effects of an equatorial hydroxyl group at C-1 and C-11 and equatorial acetoxyl or axial hydroxyl group at C-11 or C-16 have been determined, which may be useful for further studies in this field.

The ^{13}C NMR signals of 15 20-hydroxydammarane triterpenes including ginseng sapogenins and their deuterated analogs have been assigned by the use of a shift reagent. Clear differences in the C-17, C-21 and C-22 chemical shifts in pairs of C-20 epimers were observed, especially for 12-hydroxy compounds [49].

Lanthanide induced shifts (LIS), with $Eu(dpm)_3$, and aromatic solvent induced shifts (ASIS), with benzene, pyridine and hexafluorobenzene, of the ^1H NMR signals were examined for tetracyclic triterpenes containing a hydroxyl, carbonyl or acetoxyl group at C-3. The magnitude and direction of LIS or ASIS of corresponding protons were influenced by the nature of the C-3 functional group [50] The ^1H NMR spectra of 12 triterpenoids with ursane skeletons were analysed using $Eu(fod)_3$ as a shift reagent. The shielding effects of substituents on the methyl resonances were found to be additive [51]

Recently, 2D-spectroscopy (2D-J NMR) has been introduced to assign all the peaks in the complex spectra as well as to derive the structures of triterpenoids. 2D-J spectroscopy allows separation of chemical shifts and spin-coupling information in weakly spin coupled systems [52] and 2D shift correlation spectroscopy enables simultaneous aquisition of correlated ^1H–^{13}C spectra [53, 54] The homonuclear 2D-J spectroscopy has been described [55] as a variant of the classical Karr–Purcell spin-echo experiments in which the time delay between a 90° and 180° pulse is systematically varied The result, after transposition of the individual spin-echo spectra, a second Fourier transformation and a tilt of the frequency axes, is a spectrum which, in the weakly coupled case, contains only chemical shift information along one frequency axis (f_2') and homonuclear coupling constant information on the other axis (f_1). It then becomes possible to measure chemical shifts and coupling constants in a region of the spectrum which normally consists of so many overlapping multiplets that analysis is impossible. A comprehensive review of 2D-NMR covering the period up to mid-1978 has been published [56].

The structures of trichilins A and B have been established by using the 2D-J NMR technique The 6α-H/7-H coupling in trichilin A could be measured in the 2D-J spectrum but not in the 1D spectrum. Moreover, it

was possible to assign the signals for 16α-H in the 2D-J spectrum which could not be done with the 1D spectrum [57]

Mass spectroscopy

The reports on mass spectral studies of a large number of tetracyclic and pentacyclic triterpenoids are available [6] The base peaks in mass spectra of several triterpenoids have been found to be characteristic of the stereoskeleton [58] Mass spectral fragmentation patterns have been described for friedelane [59], ψ-taraxastane [60–63], dammarane [64, 65], stictane [66], allobetulin [67] and hopane [68] triterpenoids as well as pentacyclic hydrocarbons [69]

Besides electron impact mass spectra, the chemical ionization technique has also been introduced in the field of triterpenoids Thus, exact MWs of (20*S*)-protopanaxadiol and protopanaxatriol could be determined by CI-MS using Me_3CH and ammonia as ionizing gas [70]

Molecular rotation

Application of the method of molecular rotation differences in structural and stereochemical problems was introduced by Barton and Jones [71] Recently the molecular rotation data of 105 unsaturated tetracyclic and pentacyclic triterpenoid alcohols and their simple derivatives were correlated [72] All the known compounds were divided into 19 stereoskeletal types New generalizations were made on the application of this method for the elucidation of triterpenoid structures Moreover, Horeau's method [73] has been found to be useful to determine the configuration of the trisubstituted epoxide in aglaiol, a dammarane type triterpenoid [74]

Optical rotatory dispersion and circular dichroism

Stereochemical investigations by ORD and CD of a series of mono- and dicarbonyl derivatives of pentacyclic triterpenes have already been reported in the earlier review [6] The stereochemistries of 2-acetoxy-3-keto-β-amyrin and 3-acetoxy-2-keto-β-amyrin have been determined on the basis of ORD measurements [75]

As a result of the development of improved methods in measuring optical activity in the UV region, CD spectra have become more useful for molecular structure determination Electronic assignments and use of the Scott–Wrixon rules [76–78] proved useful in elucidating the finer details of molecular structure. Thus, measurement of CD spectra of several triterpenoid hydrocarbons [79] led to correlations between the relative energies of various CD bands, their signs, and the UV spectra in order to evaluate the amount and type of stress and strain in an ethylenic bond along with other structural information

X-ray crystallography

The determination of structure and absolute stereochemistry of the most complicated triterpenoids is undoubtedly a formidable task and the existing spectrometric and other methods are sometimes found inadequate for this purpose In such cases X-ray crystallographic studies are very helpful for the determination of the structure and stereochemistry During the period under review, X-ray studies have been reported for benulin [80], 3β,16β-dimethoxyolean-12-en-28,21β-olide [81], passiflonic acid methyl ester [82], meristotropate [83], lupenone [84], epifriedelinol [85], gilvanol [86], papyriogenin [87], anuserol [88], 17α-*H*,18α-*H*,21β-*H*,20,30-bisnorhopane [89], officinalic acid [90], 15-*O*-acetylacerinol, simplexyl acetate and *O*-methylcimiacerol [91], hederagenin [92], 3β,28-diacetoxy-18β,19β-epoxylupane [93], aphanastatin, amoorastatin, 12-hydroxyamoorastatin [94] and sipholenol and sipholenone [95]

The triterpenoids isolated and characterized from the plant kingdom during the period under review are listed in Table 1, along with the available mps and specific rotations, and Table 2 shows the triterpenoids isolated from other sources

BIOLOGICAL ACTIVITY

The wide occurrence in nature and structural diversity of triterpenoids have evoked considerable interest in their biological activity

Cytotoxic activity

Several cytotoxic triterpenoids have been isolated during the period 1977–1981 from different plant species A new and highly cytotoxic meliacin type triterpene, isolated from *Aphanamixis grandifolia*, is of special interest [134] A chloroform soluble fraction of the ethanol extract of the leaves of *Bursera klugii* showed activity against two test systems, the P-388 lymphocytic leucomia (3 PS) and human epidermoid carcinoma of the nasopharynx (9 KB) and the PS activity was due to the two constituents sapelins A and B [332]

The relation between chemical structure and cytotoxic effects of 35 dammarane type triterpenoids and betulin on early embryogenesis of the sea urchin was studied. Some of these compounds had a cytotoxic effect on developing sea urchin embryos Depending on their structure and concentration the glycosides caused anomalies in embryo development, arrest of egg division and blastomerelysis Panaxoside A aglycone and panaxadiol diglucoside had the highest cytotoxic activity [333] The triterpenoids pachymic acid, tumulosic acid and their 7,9(11)-dehydro derivatives, obtained from *Poria cocos*, possess cytotoxic activity *in vivo* against hepatoma [334]. Two compounds, isocucurbitacin D and 3-epi-isocucurbitacin D, isolated from *Phormium tenax*, showed tumor inhibitory properties against KB cell culture (ED_{50} = 0 024 and 0 24 μg/ml, respectively) Moreover, the latter compound was found active against P-388 lymphocytic leucomia in the mouse [335] A study on some toxic African Euphorbiaceae containing cucurbitacins has been made and it is reported that the isolated cucurbitacins at 0 1 mg/ml killed HeLa cells cultures within 3 days, inhibited mitosis in *Allium sativum* meristems and inhibited its root growth [336]

Cytostatic activity

Iguesterin and their related compounds isolated from the root bark of *Maytenus canariensis* showed powerful cytostatic activity against HeLa cells *in vitro* though no conclusive relationship was established between the activity and structure [337]

Table 1 Distribution of triterpenoids in the plant kingdom

Plant	Substance mp, $[\alpha]_D$	Structure: Basic skeleton*	Structure: Groups	Ref
Mycophyta				
(a) Fungi				
Fomes officinalis (Polyporaceae)	Officinalic acid 272°, −62°	**19**	—	[90]
Neamatoloma fasciculare (Agaricaceae)	Fasciculol A	**13**	2α,3β,24β,25-$(OH)_4$; Δ^8	[96–99]
	Fasciculol B, 230–232°, +80.5°	**13**	2α,3β,12α,24β,25-$(OH)_5$, Δ^8	—
	Fasciculol C, 242–244°, +73.78°	**13**	2α,3β,21,24β,25-$(OH)_5$, Δ^8	—
	Fasciculol D, 95–97°, +14 1°	**13**	3β,12α,24β,25-$(OH)_4$; 2α-Q, Δ^8	—
	Fasciculol E, 105–106°, +30 6°	**13**	2α,12α,21,24,25-$(OH)_5$, 2α-Q, Δ^8	—
	Fasciculol F, 102–103°, +9.9°	**13**	3β,12α,21,24,25-$(OH)_5$; 2α-Q; Δ^8	—
	Fasciculol G	**13**	2α,12α,21,24,25-$(OH)_5$, 3β-Q, Δ^8 [Q = $MeO_2CCH_2NHCOCH_2CMe(OH)CH_2COO$]	—
Polyporus officinalis (Polyporaceae)	Polyporenic acid D, 268–270°, +40°	**13**	3α-OH, $\Delta^{8,24(31)}$, 27-COOH	[100]
(b) Lichens				
Cetraria nivalis (Parmeliaceae)	Triterpene ketol, 221–222°, +105°	**5**	3-Oxo; 22α-OH	[101]
Nephroma laevigatum (Pettigeraceae)	Nephrin, 224–226°	**6**	6α,7β,22-$(OH)_3$	[102]
Pseudocyphellaria amphisticta (Stictaceae)	Amphistictinic acid, 150–152°	**6**	15α-OAc, 22-OH; 24-COOH	[103]
P berberina	Durvilldiol 283–284°	**5**	3β,22α-$(OH)_2$	[104]
	Durvillonol 216–218°	**5**	3-Oxo, 22α-OH	—
P degelii	PD-1 235–237°	**5**	22α-OH; 3,4-seco, $\Delta^{4(23)}$, 3-COOH	[105]
	PD-2	**5**	22α-OH; 3,4-seco; $\Delta^{4(23)}$, 3-CHO	—
	PD-3 88–90°	**5**	3,22α-$(OH)_2$, 3,4-seco, $\Delta^{4(23)}$	—
P. mongeotiana	Triterpene I 229°	**6**	7β,22-$(OH)_2$	[106]
	Triterpene II 249–250°	**6**	15α,22-$(OH)_2$	—
	Triterpene III 247–248°	**6**	7β-OAc; 22-OH	—
	Triterpene IV 201–202°	**6**	15α-OAc; 22-OH	—
Bryophyta				
Liverworts				
Nardia scalaris (Lophoziaceae)	Substance I	**8**	3-Oxo; 21α-OMe; Δ^{14}	[107]
Pteriodophyta				
(a) Lycopods				
Lycopodium wightianum (Lycopodiaceae)	Wightianol A, 347–350°	**8**	3β,14β,20β,21β,24-$(OH)_5$	[108]
	Wightianol B, 360°	**8**	3β,20β,21β,24-$(OH)_4$; Δ^{14}	—

Table 1 (*Contd*)

Plant	Substance mp, $[\alpha]_D$	Structure: Basic skeleton*	Structure: Groups	Ref
(b) Ferns				
Adiantum candalum (Adiantaceae)	Isoadiantone, 326–327	R	22-Oxo, 21α-H, friedo-hopane	[109]
A. monochlamys	Triterpene, 154–157°, +19.4°	R	Δ^5-Ozonide, D B-friedo-hopane	[110]
Diplazium esculentum (Athyriaceae)	Esculentic acid, 275–276°	**2**	2α,3α,23-$(OH)_3$, Δ^{12}, 28-COOH	[111]
Marsilea minuta (Marsileaceae)	Marsileagenin A, 332–333°, +48°	**1**	2α,3β,16β,21β,22α,28-$(OH)_6$, Δ^{12}	[112]
Oleandra neriifolia (Oleandraceae)	Triterpene, 179–180°, +27.16°	**6**	29-OCH_2Me	[113]
Polypodium juglandifolium (Polypodiaceae)	Compound I, 165–168°, −93°	**9**	20-Oxo, $\Delta^{9(11)}$	[114]
	Compound D, 134–136°, +34.4°	**13**	3β-OH, 9,19-cyclo, 24,24-$(Me)_2$	
	Compound A, 142–144°, +35.7°	**13**	3β-OH, 9,19-cyclo, Δ^{20}, 24,24-$(Me)_2$, 28-nor	
P. subpetiolatum	Triterpene I, 222–223°, −53°	**9**	3β-OAc, $\Delta^{9(11)}$	[115]
	Triterpene II	**9**	3β-*O*-Palmitoyl, $\Delta^{9(11)}$	
Gymnospermae				
Abies alba (Pinaceae)	Abietospiran	**13**	3α-OMe, 9,19-cyclo, 17,23-epoxy, 26→23 lactone	[116]
Pinus monticola (Pinaceae)	Substance I	**8**	3β-OMe, 21-oxo, Δ^{14}, 30-nor	[117]
	Compound I, 193–194°, +77°	**13**	3β-OMe, (24*S*), 24,25-$(OH)_2$, $\Delta^{9(11)}$	[118]
	Compound II, 214–215°, +56°	**13**	3β,24,25-$(OH)_3$, (24*S*), $\Delta^{9(11)}$	
	Compound III, 161–163°, +93°	**13**	3β-OMe, 24-oxo, $\Delta^{9(11)}$	
	Compound IV, 180–180.5°, +86	**13**	3β-OMe, 24-OH, (24*S*), $\Delta^{9(11)\,25}$	
	Compound V, 181–184°	**13**	3α,24ξ-$(OH)_2$, $\Delta^{9(11)\,25}$	-
	Compound VI, 204–205°, +92°	**13**	3β-OMe, $\Delta^{9(11)}$, 22(or 23),25-$(OH)_2$	—
	Compound VII, 161–162°, +95°	**13**	3β-OMe, 24-oxo, $\Delta^{9(11)}$, 26,27-bisnor	-
	Compound VIII, 153–155°, +85°	**13**	3β-OMe, (24*S*), 24,25-(2′-methyl-1′, 3′-dioxamethylene), $\Delta^{9(11)}$	—
	Compound IX, 101.5–103°, +48.5°	**13**	3β-OMe, $\Delta^{9(11)}$, 24,25-(2-*R*-1′,3′-dioxatrimethylene) (R = $C_{22}H_{45}O$)	- -
	Compound X 91–92 +39	**13**	3β-OMe, $\Delta^{9(11)}$, 24,25-(2′-*R*-1′,3′-dioxatrimethylene) (R = $C_{22}H_{43}$)	-
Angiospermae				
(a) Monocotyledoneae				
Muscari comosum (Liliaceae)	Compound A, −27°	**13**	3β,28,29-$(OH)_3$, 17α,23β-epoxy, 24-oxo, 27-nor, Δ^8	[119]
	Compound B, 156–158°, −33°	**13**	3,24-Dioxo, 28,29-$(OH)_2$, 17,23-epoxy, 27-nor, Δ^8	- - -
	Triterpene I	**13**	3β,29-$(OH)_2$, $\Delta^{8\,16}$, 15,23-dioxo, 27-nor, 24ξ-OMe	[120]
Vellozia stipitata (Velloziaceae)	Vellozone, 141°	**10**	3-Oxo, 20(*R*)-OH, 24-methylene	[121]
(b) Dicotyledoneae				
Acacia concinna (Leguminosae)	Acacic acid, 265–270°	**1**	3α,16α,21β-$(OH)_3$, Δ^{12}, 28-COOH	[122]

Table 1. (*Contd.*)

Plant	Substance mp, $[\alpha]_D$	Structure: Basic skeleton*	Structure: Groups	Ref
	Acacigenin B, 265–270°, +55°	1	3α,16α-$(OH)_2$, Δ^{12}, 28-COOH, 21β-OR (R = OCCMe=CH—  =CHMe)	[123]
	Acacidiol, 202–204°, +82.5°	1	3β,21β-$(OH)_2$, $\Delta^{16,18}$, 28-nor	[124]
Agauria salicifolia (Ericaceae)	Agauriasterone, 119–120°, +68.6°	13	3-Oxo, $\Delta^{8,24}$, 29-nor	[125]
Aglaia odorata (Meliaceae)	Aglaiol, 113°	10	3α-OH, 24,25-epoxy, Δ^{20}	[74]
Ailanthus excelsa (Simaroubaceae)	Triterpene-I, 174–176°, −37.2°	11	3*S*,24*S*,25-$(OH)_3$, Δ^7	[126]
A. malabarica	Malabaricol, 68–69.5°, +36.1°	17	3-Oxo, 20β-OH, 14,17-epoxy, Δ^{24}	[127]
Alnus serrulatoides (Betulaceae)	Triterpene	10	20*S*,24*R*-Epoxy, 24-Me, 3,4-seco, $\Delta^{4(28)}$, 3-COOH	[128]
	Alnuseric acid	10	3,4-Seco, 20*S*,24*R*-epoxy, $\Delta^{4(28)}$; 3-COOH	[129]
	Alnuselide	10	3,4-Seco, 20S,24*R*-epoxy, $\Delta^{24(28)}$, 3→11α-lactone	—
Alnus sieboldiana (Betulaceae)	Alnustic acid, 195–196°, +27.8°	10	3,4-Seco, 12β,20(*S*)-$(OH)_2$, 24-(=CH_2), $\Delta^{4(28)}$, 3-COOH	[130]
Antidesma menasu (Euphorbiaceae)	Antidesmanol, 277–280°, −57°	4	3-Oxo; 16α-OH	[131]
	Triterpene I, 294–295°, +67°	R	3-Oxo, 16α-OH; D C-friedo-olean; Δ^8	[132]
	Triterpene VI, 275–278°	R	3β-OH; 16-oxo, D C-friedo-olean, Δ^8	—
Aphanamixis grandifolia (Meliaceae)	Aphanastatin, 268–271°, −38.9°	16	1α,3β-$(OAc)_2$, 2α,7α,12α-$(OH)_3$, 19,28, 14β,15β-diepoxy, 28-OCOCHMeEt, 11-oxo	[133]
	12-Hydroxyamoorastatone, 279–281°, −68.2°	16	1α,7α,12α-$(OH)_3$, 3α-OAc, 11-oxo, 14β,15β-, 19,29-diepoxy; 29-OH	[134]
	Amoorastatine, 243–245°, −49.3°	16	1α,7α,28-$(OH)_3$, 3α-OAc, 11,16-dioxo, 19,29-epoxy	—
A. polystachya	Polystachin	20	11β-OCHO, 12α-$OCOCH_2CHMe_2$, 15-oxo, 1β,14β-epoxy; $\Delta^{8(30)}$	[135]
	Compound 1	16	3,4-Seco, 3→4-lactone, 7,8-seco, 7-COOMe; $\Delta^{8(30)}$; 1α,15α,29-$(OAc)_3$, 12α-$OCOCH_2CHMe_2$, 11β-OCHO, 14β-OH	[136]
	Compound 2	16	3,4-Seco, 3→4-lactone, 7,8-seco, 7-COOMe, $\Delta^{8(30)}$, 1α,15α,29-$(OAc)_3$, 12α-$OCOCHOHCHMe_2$, 11β-OCHO, 14β-OH	—
	Compound 7 239–242°, −32°	16	3,4-Seco, 3→4-lactone; 7,8-seco, 7→29-lactone, $\Delta^{1,8(30)}$, 11β-OCHO; 12α-OCOCHOHCHMeEt, 14β-OH, 15α-OAc	—
Astragalus dasyanthus (Leguminosae)	Dasyanthogenin	13	3β,6α,23-$(OH)_3$; 9,19-cyclo, 23,16-epoxy; 24,25,26,27-tetranor	[137]
A sieversianus	Cyclosiversigenin	13	3β,6α,16β,25-$(OH)_4$, 20*S*,24*R*-epoxy, 9,19-cyclo	[138]
Astrantia major (Umbelliferae)	Astrantiagenin G	1	3β-OH, Δ^{11}, 28→15-lactone	[139]
Atalantia monophylla (Rutaceae)	Atalantolide, 230–231°	16	3,4-Seco; 7β-OH; 6-oxo, 14β,15β-epoxy, $\Delta^{1,4}$; 16,17-seco, 3-COOMe, 16→17-lactone	[140]
	Atalantin, 184–185°, +84.4°	16	3,4-Seco; 7β-OH; 6-oxo, 14β,15β-, 19,4β-diepoxy, Δ^1, 16,17-seco; 16→17-lactone, 3-COOMe	
Azadirachta indica (Meliaceae)	17β-Hydroxyazadiradione, 177°, +106°	16	3,16-Dioxo, $\Delta^{1,14}$, 7α-OAc; 17β-OH	[141]
	17-Epiazadiradione, 205°, −97°	16	3,16-Dioxo, $\Delta^{1,14}$; 7α-OAc, 17α-H	—
	Nimbienen, 134°, +168°	21	1-Oxo, 6α-OAc; $\Delta^{3,13}$; 28-nor	[142]

Table 1 (*Contd*)

Plant	Substance mp, $[\alpha]_D$	Structure: Basic skeleton*	Structure: Groups	Ref
	6-Desacetylnimbinen, 141°, +132°	**21**	1-Oxo, 6α-OH, $\Delta^{3\,13}$, 28-nor	—
	Nimbandiol, 178°, +245°	**21**	1-Oxo, 4α-OH, 6α-OH, $\Delta^{2\,13}$, 28-nor	—
	6-*O*-Acetylnimbandiol, 231°, +115.8°	**21**	1-Oxo, 4α-OH, 6α-OAc, $\Delta^{2\,13}$, 28-nor	—
	1α-Methoxy,1,2-dihydro-epoxy-azadiradione, 235–236°, −14°	**16**	1α-OMe, 3,16-dioxo, 7α-OCOMe, 14β,15β-epoxy	[143]
	Diepoxyazadiradione, 110–112°, −35°	**16**	3,16-Dioxo, 7α-OCOMe, 1β,2β-, 14β,15β-diepoxy	—
	7-Acetylneotrichilenone, 208°, −21°	**16**	3,15-Dioxo, Δ^1, 7α-OCOMe	—
	7-Deacetyl-, 7-benzoyl-azadiradione, +38.8°	**16**	3,16-Dioxo, $\Delta^{1\,14}$, 7α-$OCOC_6H_5$	—
	7-Desacetyl-, 7-benzoyl-epoxyazadiradione, +81.4°	**16**	3,16-Dioxo, Δ^1, 14β,15β-epoxy, 7α-$OCOC_6H_5$	—
	7-Desacetyl, 7-benzoyl-gedulin, 278°, +10.5°	**16**	3-Oxo, 7α-$OCOC_6H_5$, 14β,15β-epoxy, 16,17-seco, 16→17-lactone	—
Bacopa monniera (Scrophulariaceae)	Psuedojujubogenin, 273–276°	**10**	3β,20ξ-$(OH)_2$, Δ^{24}, 16,30-, 16,23-diepoxy	[144]
Barringtonia acutangula (Barringtoniaceae)	Tangulic acid (diAc, 272–274°, −15°)	**1**	2α,3β,18β-$(OH)_3$, Δ^{12}, 23,28-$(COOH)_2$	[145]
	Actangulic acid 290–291°, +15°	**1**	2α,3β,18β-$(OH)_3$, Δ^{12}, 28-COOH	—
B speciosa	Barringtogenic acid, 318°	**1**	2α,3β,19α-$(OH)_3$, Δ^{12}, 24,28-$(COOH)_2$	[146]
Beyeria brevifolia (Euphorbiaceae)	Triterpene, 300–301°, +8	**7**	3β,16β,28-$(OH)_3$, $\Delta^{20(29)}$	[147]
Betula costata (Betulaceae)	Triterpene I†	**10**	3α,17α,21-$(OH)_3$, Δ^{24}	[148]
	Triterpene II†	**10**	3α,12β17α,25-$(OH)_4$, 20β,24β-epoxy	
	Triterpene III†	**10**	3β,25-$(OH)_2$, 6β-OAc, 20β,24β-epoxy	—
	Triterpene IV†	**10**	3β,6β,25-$(OH)_3$, 20β,24β-epoxy	—
B ermani	Triterpene A	**10**	3β,6α,25-$(OH)_3$; 20(*S*),24(*R*)-epoxy	[149, 150]
	Triterpene B	**10**	3β,25-$(OH)_2$, 20(*S*),24(*R*)-epoxy, 6α-OAc	—
	Triterpene C	**10**	3β,11α,25-$(OH)_3$, 20(*S*),24(*R*)-epoxy	—
	Triterpene D	**10**	3β,25-$(OH)_2$, 11α-OAc, 20(*S*),24(*R*)-epoxy	—
B lantha	Compound A	**10**	3α,11α,25-$(OH)_3$, 20(*S*), 24(*R*)-epoxy	[151]
	Compound B	**10**	3α,25-$(OH)_2$, 11α-OAc, 20(*S*),24(*R*)-epoxy	—
	Compound C	**10**	3α-OAc, 11α,25-$(OH)_2$, 20(*S*),24(*R*)-epoxy	—
	Compound D	**10**	3-Oxo, 11α,25-$(OH)_2$, 20(*S*),24(*R*)-epoxy	—
B mandschurica	Triterpene	**10**	3-Oxo, 20β,24β-$(OH)_2$, Δ^{25}	[152]
B ovalifolia	Compound I	**10**	3α,16α,25-$(OH)_3$, 21(*S*),24(*R*)-epoxy	[153]
	Compound II	**10**	3-Oxo, 16α,25-$(OH)_2$, 21(*S*),24(*R*)-epoxy	—
B papyrifera	Papyriferic acid, 203–204°, −18°	**10**	3α-$OCOCH_2COOH$, 12β-OCOMe, 2(*S*),24(*R*)-epoxy, 25-OH	[154]
Boswellia serrata (Burseraceae)	Acid G	**11**	3α-OH, $\Delta^{8\,24}$, 21-COOH	[155]
	Acid H, 198°	**11**	3β-OH, $\Delta^{8\,24}$, 21-COOH	—
	Acid E, 220°	**11**	3α-OAc, $\Delta^{8\,24}$, 21-COOH	—
Bruguiera gymnorhiza (Rhizophoraceae)	Gymnorhizol, 208–210°, −48°	**1**	3α-OH, $\Delta^{13(18)}$	[156]
Bryonia alba (Cucurbitaceae)	Iso-23,24-dihydrocucurbitacin D	**14**	2,11,22-Trioxo, 3α,16α,20,26-$(OH)_4$, Δ^5	[157]

Table 1. (*Contd*)

Plant	Substance mp, $[\alpha]_D$	Structure: Basic skeleton*	Structure: Groups	Ref.
B. diocia	Bryocoumaric acid, 143–145°	R	3α-*O*-Coumaroyl, $\Delta^{7,9(11)}$; 29-COOH, D.C-friedo-oleanane	[158]
	Isomultiflorenol, 225°	R	3β-OH, Δ^{8}, D C-friedo-oleanane	[159]
Bupleurum rotundifolium (Umbelliferae)	Rotundiogenin C, 287–289°, −30°	1	3β,16α,21α,28-$(OH)_4$, $\Delta^{11,13(18)}$	[160]
	Rotundiogenin F, 299–302°	1	3β,16α,21α,28-$(OH)_4$, $\Delta^{9(11),12}$	—
Camellia japonica (Theaceae)	Camellenodiol, 215–216.5°, +30°	1	3β,18β-$(OH)_2$, 16-oxo, Δ^{12}, 28-nor	[161]
	Camelledionol, 232–233°, +49°	1	3,16-Dioxo, 18β-OH, Δ^{12}; 28-nor	—
Canthium dicoccum (Rubiaceae)	Canthic acid (Me ester, 226°, +55 8°)	1	3β,7β-$(OH)_2$; Δ^{12}, 28-COOH	[162]
Carapa procera (Meliaceae)	Proceranolide, 192–196°	22	1-Oxo, $\Delta^{8(14)}$, 3β-OH	[163]
	Proceranone, 178–179°, +28°	16	7α-OAc, 3,4-seco, 3→4-lactone; $\Delta^{1,14}$	[164]
	Evodulone, 199–200°	16	3,4-Seco, 3→4-lactone, 7α-OAc, 16-oxo, 14β, 15β-epoxy	[165]
Careya arborea (Lecythidaceae)	Careyaborin, 257–258°	R	3β-*O*-Coumaroyl, Δ^{14}, D-friedo-oleanane	[166]
	Careyagenolide, 299° (dec)	3	2α,3β-$(OH)_2$, 28→20β-lactone	[167]
Catha cassinoides (Celastraceae)	Triterpene I, 268–269°, −15°	4	3-Oxo; 29-OH	[168]
	Triterpene II, 270–272°, −25°	4	3-Oxo, 30-OH	—
	Triterpene III, 260–262°, 0°	4	3-Oxo, 29-COOH	—
Castanopsis indica (Fagaceae)	Castanopsis, 224–228°, +28 9°	1	3β,7α-$(OH)_2$, $\Delta^{9(11),12}$	[169]
Cedrela mexicana (Meliaceae)	7α,11β-Diacetoxydihydronomilin, 262–264°	16	3,4-Seco, 16,17-seco, 14β, 15β-epoxy, 1α,7α,11β-$(OAc)_3$, 3→4-, 15→16-dilactone	[170]
Centaurea solstitialis (Compositae)	Substance A, 224–226°	3	3α-OAc, 16α-OH, $\Delta^{20(30)}$	[171]
C. squarrosa	Triterpene	2	3β-OH, $\Delta^{20(30)}$	[172]
Chisocheton paniculatus (Meliaceae)	6α-Acetoxyazadirone, 186–188°	16	6α,7α-$(OAc)_2$, 3-oxo, $\Delta^{1,14}$	[173]
	6α-Acetoxy-16-oxoazadirone, 130–132°	16	6α,7α-$(OAc)_2$, 3,16-dioxo; $\Delta^{1,14}$	—
	Compound III, 327–330°	16	6α,7α-$(OH)_2$, 3,16-dioxo, $\Delta^{1,14}$	—
Chukrasia tabularis (Meliaceae)	Chukrasin A, 190–194°, −58 ± 2°	23	2β,6ξ-$(OH)_2$, 3β,30α-$(OAc)_2$; 11α,12α-(*O*-isobutyroyl)$_2$; 15-(=COHCHMe$_2$), 16,17-seco; 16→17-lactone	[174] —
	Chukrasin B, 271–273°, −58 ± 2°	23	2β-OH; 3β-OAc, 11α,12α,30α-(-*O*-isobutyroyl)$_2$; 15-(=COHCHMe$_2$), 16,17-seco, 16→17-lactone	—
	Chukrasin C, 237–238°, −47 ± 2°	23	2β-OH, 3β,30α-OAc, 11α,12α-(*O*-isobutyroyl)$_2$, 15-(=COHCHMe$_2$), 16, 17-seco, 16→17-lactone	—
	Chukrasin D, 234–236°, −40 ± 2°	23	2β,3β,30α-$(OAc)_3$, 11α,12α-(*O*-isobutyroyl)$_2$, 15-(=COHCHMe$_2$); 16,17-seco; 16→17-lactone	—
	Chukrasin E, 212–216°, −36 ± 2°	23	2β,3β-$(OAc)_2$, 11α,12α,30α-(*O*-isobutyroyl)$_3$, 15-(=COHCHMe$_2$), 16,17-seco; 16→17-lactone	—
	Compound A, 224–228°	23	2β-OH, 3β,30α-(*O*-isobutyroyl)$_2$, 16,17-seco, 16→17-lactone	[175]

Table 1 (*Contd*)

Plant	Substance mp, $[\alpha]_D$	Structure: Basic skeleton*	Structure: Groups	Ref
	Compound B, 226–229	**23**	2β-OH, 3β,30α-(*O*-isobutyroyl)$_2$, 12-OAc, 16,17-seco, 16→17-lactone	—
	Compound C, 195–200°	**23**	2β-OH, 3β-*O*-isobutyroyl, 30α-*O*-propionyl, 16,17-seco, 16→17-lactone	—
	Compound D, 214–216°	**23**	2β-OH, 3β-*O*-isobutyroyl, 30α-*O*-propionyl, 12α-OAc, 16,17-seco, 16→17-lactone	—
Chrysanthellum procumbens (Compositae)	Caulophyllogenin	**1**	3β,16α,23-(OH)$_3$, Δ^{12}, 28-COOH	[176]
Cimicifuga simplex (Rannuculaceae)	Cimicifugenin A, 211–212°	**13**	12β-OAc, 3β,10β-, 24,25-, 16,23-, 26,23-tetraepoxy, 26ξ-OH, 9,10-seco, 9,19-cyclo, Δ^8	[177]
Citrus aurantium (Rutaceae)	Isolimonic acid	**16**	3,4-Seco, 1ξ-OH, 19,4β-, 14,15-diepoxy, 16,17-dioxo, 3-COOH	[178]
C bourgeanus	Cabraleon I	**10**	3-Oxo, 24β→20β-lactone, 25,26,27-trisnor	[179]
	3β-Cabraleadiol	**10**	3β,25α-(OH)$_2$, 24β,20β-epoxy	—
	3β-Cabraleahydroxylactone	**10**	3β-OH, 24→20-lactone, 25,26,27-trisnor	—
	Casasequic acid	**10**	3,4-Seco, 24(*S*),20(*S*)-epoxy, 25-OH, 3-COOH	—
	Donanic acid	**10**	3,4-Seco, 24(*S*),20(*S*)-lactone, 3-COOH, 25,26,27-trisnor	—
C reticulata	Methyldeacetyl nomilinate	**16**	1,4-(OH)$_2$, 3,4-seco, 3-COOMe, 7-oxo, 14β,15β-epoxy, 16,17-seco, 16→17-lactone	[180]
	Calamin, 162–165°	**16**	1,4,7-(OH)$_3$, 6-oxo, 2-Me, 14β,15β-epoxy, 16,17-seco, 16→17-lactone	
	Cyclocalamin	**16**	6,7-Dioxo, 3,4-seco, 3-COOMe, 1,4-, 14β,15β-diepoxy, 16,17-seco, 16→17-lactone	—
	Retrocalamin, 197–199°	**16**	1,7-(OH)$_2$, 3,4-seco, 3-COOMe, 1β,4β-, 14β,15β-diepoxy, 16,17-seco, 16→17-lactone, 6-oxo	—
Clausena heptaphylla (Rutaceae)	Clausenolide, 150°	**16**	A-Seco, 3-nor, 1α,11β-OH)$_2$, 1β,4β-, 14β,15β-diepoxy, 16,17-seco, 16→17-lactone, 7-oxo	[181]
Clethra barbinervis (Clethraceae)	Clethric acid, 284–287°, +50°	**2**	3α,19α,23,24-(OH)$_4$, Δ^{12}, 28-COOH	[182]
Codonopsis lanceolata (Campanulaceae)	Albegenic acid	**1**	3β,16α-(OH)$_2$, $\Delta^{13(18)}$, 28-COOH	[183]
Coleus ambionicus (Labiatae)	Triterpene	**2**	2α,3α,19α,23-(OH)$_4$, Δ^{12}, 28-COOH	[184]
Colubrina granulosa (Rhamnaceae)	Granulosic acid, 221–222°, +60°	**7**	A(1)-Nor, 3α-OH, 2α-COOH, $\Delta^{20(29)}$, 28-COOH, 25-nor	[185]
	Colubrinic acid, 173–180°, −39°	**7**	A(1)-Nor, 3α-OAc, 2β-CHO, $\Delta^{20(29)}$, 28-COOH, 25-nor	—
Cornulaca monacantha (Chenopodiaceae)	Azizic acid, 259–263°, +98°	**1**	3β,6α-(OH)$_2$, Δ^{12}, 27,28-(COOH)$_2$	[186]
	Manevalic acid, 269–272°, +58°	**1**	3β,6α-(OH)$_2$, Δ^{12}, 27-COOH	—
Cneorum tricocon (Cneoraceae)	Tricoccin S7, 202°, −40 5°	**16**	3,16-Dioxo, $\Delta^{1\,14}$, 6,7-seco, 7-COOMe, 1,8β-epoxy	[187]
	Tricoccin S8, 250°	**24**	3,16,21-Trioxo, $\Delta^{1\,14\,20(22)}$, 23ξ-OH	—
	Tricoccin S19, 259°, +1°	**24**	3,16,23-Trioxo, $\Delta^{1\,14,20(22)}$, 21ξ-OH	—
	Tricoccin S22, 197°, +51 7°	**16**	3,4-Seco, 16α,7α-(OH)$_2$, Δ^1, 14β,15β-epoxy, 3→4-lactone	[188]
	Tricoccin S32	**16**	3,4-Seco, 1α,7α,16α-(OH)$_3$, 14β,15β-epoxy, 3→4-lactone	—
Crateva nurvala (Capparidaceae)	Triterpene alcohol, 205–206°, +31°	**7**	3β-OH, $\Delta^{21\,20(29)}$	[189]
Cyamopsis tetragonolaba (Leguminosae)	3-Epikatonic acid, 283–284°, +61°	**1**	3β-OH, Δ^{12}, 29-COOH	[190]

Table 1. (*Contd.*)

Plant	Substance mp, $[\alpha]_D$	Structure: Basic skeleton*	Structure: Groups	Ref
Cymbopogon citratus (Gramineae)	Cymbopogone, 262–265°	R	3-Oxo, 18β,19α; D A-friedo-lupane	[191]
	Cymbopogonol, 265–268°	R	3β,10α-$(OH)_2$, 18β, 19α-H, $\Delta^{4(23)}$, D A-friedo-lupane	—
Daphne papyracea (Thymelaeaceae)	Taraxeric acid, 230–232°	R	D-Friedo-olean; Δ^{14}; 24-COOH	[192]
Ecballium elaterium (Cucurbitaceae)	Elatericin A	14	2,16α,20(*S*),25-$(OH)_4$, 3,11,22-trioxo, $\Delta^{1,5,23}$	[193]
	Elatericin B	14	2β,16α,20(*S*),25-$(OH)_4$, 3,11,22-trioxo; $\Delta^{5,23}$	—
Ekebergia capensis (Meliaceae)	Ekebergin, 248–250°, −37°	16	3α-OH, 15β-OAc; 7,8-seco, 7-COOMe, $\Delta^{8(30)}$, 2α-$OCOCH_2CHMe_2$; 16,17-seco, 16 → 17-lactone, 1α,14β-epoxy	[194]
Elaegia utilis (Rubiaceae)	Dammaranediol II, 198–199°, 0°	10	3β,20-$(OH)_2$, Δ^{24}, (20*S*)	[195]
	Dammaranetriol	10	3β,20,26$(OH)_3$, Δ^{24} (20*S*)	—
Elaeodendron glaucum (Celastraceae)	Elaeodendrol, 229–230°, −26.2°	4	3-Oxo, 17β-OH, 28-nor	[196]
	Elaeodendradiol, 220–222°, −24.8°	4	3-Oxo, 17β,25-$(OH)_2$, 28-nor	—
Emmenospermum pancherianum (Rhamnaceae)	Triterpene, 97–98°, +140.5°	7	18α,24-$(OH)_2$, A(1)-nor, $\Delta^{2,20(29)}$, 28-COOMe, 27 → 18α-lactone	[197]
Entandrophragma angolense (Meliaceae)	Entandrolide, 125–128°, −94°	12	A-Seco, $\Delta^{7,24}$, 3 → 5-lactone, 4,28,29-trisnor	[198]
	Isosapelin, 195–198°, −34°	11	3α,21,23-$(OH)_3$, Δ^7, 24,25-epoxy	—
Enterolobium cyclocarpum (Leguminosae)	Veracruzol	1	3ξ-OH, Δ^5, 23 or 24-nor	[199]
Epilobium hirsutum (Onagraceae)	23-Hydroxytormentic acid	1	2α,3β,19α,23-$(OH)_4$; Δ^{12}; 17-COOH	[200]
Epithelantha micromeris (Cactaceae)	Epithelenthic acid	1	3β-OH, 12-oxo, $\Delta^{9(11)}$, 28-COOH	[201]
	Methylepithelanthate, 235–235.5°	1	3α-OH, 12-oxo, $\Delta^{9(11)}$, 28-COOMe	—
Eupatorium odoratum (Compositae)	Epoxylupeol, 191–193°, +6°	7	3β-OH; 20,30-epoxy	[202]
E riparium	Taraxasteryl palmitate, 102–103°, +70°	3	3β-*O*-Palmitoyl, $\Delta^{20(30)}$	[203]
Euphorbia neriifolia (Euphorbiaceae)	Alnus-5(10)-en-1-one	R	D B-Friedo-olean, 1-oxo, $\Delta^{5(10)}$	[204]
E pulcherrima	Germanicyl tetracoasanoate	1	3β-$OCO(CH_2)_{22}Me$, Δ^{18}	[205]
	Germanicyl behenate	1	3β-$OCO(CH_2)_{20}Me$; Δ^{18}	—
E tirucalli	Euphorbinol, 111–112°, +54.5°	12	3β-OH, 24-Me, $\Delta^{8,25}$	[206]
	Cycloeuphornol	13	3β-OH, $\Delta^{20(22),25}$, 24-Me, 9,19-cyclo	[207]
Gardenia gummifera (Rubiaceae)	19α-Hydroxyerythrodiol, 245–247°, +55.9°	1	3β,19α,28-$(OH)_3$, Δ^{12}	[208]
Glochidion macrophyllum (Euphorbiaceae)	Compound I, 198°	7	1,3-Dioxo; $\Delta^{20(29)}$	[209]
	Compound II, 230–231°, +13.6°	7	1β-OH, 3α-OAc, $\Delta^{20(29)}$	—
	Compound III, 186–188°, −7.6°	7	3α-OH, 1β-OAc; $\Delta^{20(29)}$	—
Gochnatia hypoleuca (Compositae)	7421-Ghree	U	Dien, dihydroxy, dilactone	[210]
Guarea cedrata (Meliaceae)	Triterpene I	11	3,4-Seco, $\Delta^{4(28)\,7,24}$, 3,21-$(COOH)_2$	[211]

Table 1 (*Contd*)

Plant	Substance mp, $[\alpha]_D$	Structure: Basic skeleton*	Structure: Groups	Ref
	Triterpene II, 190°, +11	11	3,4-Seco, $\Delta^{4(28)\sim 24}$, 21-COOH, 3-COOMe	-
Gymnocladus dioica (Leguminosae)	2β,23-Dihydroxyacacic acid lactone, 189–192°, +16.2°	1	2β,3β,16β,23-$(OH)_4$, Δ^{12}, 18→21-lactone	[212]
Gymnosporia emarginata (Celastraceae)	3-Oxo-lup-20(29)-en-30-al, 193–194°, +30.8°	7	3-Oxo, $\Delta^{20(29)}$, 30-CHO	[213]
	3β-Hydroxy-lup-20(29)-en-30-al, 240–243°, +14.4°	7	3β-OH, $\Delta^{20(29)}$, 30-CHO	-
	30-Hydroxy-lup-20(29)-en-3-one, 186–187°, +27.2°	7	3-Oxo, 30-OH, $\Delta^{20(29)}$	—
G. wallichiana	Wallichenol (aldehyde, 240°)	7	3β,30-$(OH)_2$, $\Delta^{20(29)}$	[214]
	Gymnosporic acid, 290°, −44	7	3β-OH, (20*R*), 29-COOH	[215]
	Wallichianic acid, 280°, +28°	7	3β-OH, (20*S*), 29-COOH	—
	Wallichianol, 266°	7	3β,29-$(OH)_2$, (20*S*)	—
Gynostemma pentaphyllum (Cucurbitaceae)	Genin II, 285–288°	10	2β,3β,12β-$(OH)_3$, 20,25-epoxy	[216]
Helianthus annuus (Compositae)	Helianthriol B_0	3	3β,16β,28-$(OH)_3$, Δ^{20}	[217]
	Helianthriol B_1	3	3β,16β,28-$(OH)_3$, $\Delta^{20(30)}$	—
	Helianthriol A_1	1	3β,16β,28-$(OH)_3$, $\Delta^{13(18)}$	-
Holarrhena antidysenterica (Apocyanaceae)	Triterpene, 170°, +65.5°	7	3β-OH, $\Delta^{5\ 20(29)}$	[218]
Hoya australis (Asclepiadaceae)	Triterpene	13	3β-*O*-Cinnamoyl, 9,19-cyclo, 24-methylene	[219]
	Triterpenol	1	A-Seco, A-nor, Δ^{12}, oleanol‡	[220]
Ilex aquifolium (Aquifoliaceae)	Compound A, 161°	2	3β-OH, 27-*O*-*p*-*cis*-coumaroyl, 28-COOH, Δ^{12}	[221]
	Compound B, 203°	2	3β-OH, 27-*O*-*p*-*trans*-coumaroyl, 28-COOH, Δ^{12}	—
Jacaranda caucana (Bignoniaceae)	Jacarandic acid, 261°	2	2α,3α,19α-$(OH)_3$, Δ^{12}, 28-COOH	[222]
Jatropha acontifolia (Euphorbiaceae)	Epilupeol acetate	7	3α-OAc, $\Delta^{20(29)}$	[223]
Kokoona zeylanica (Celastraceae)	Zeylanol, 274–276°, +17°	4	3-Oxo, 6β-OH	[224]
	Zeylanonol, 272–274°, +112.5°	4	3,21-Dioxo, 6β-OH	—
	Zeylandiol, 276–278°, +41.5°	4	3-Oxo, 6β,21β-$(OH)_2$	—
	Kokzeylanol	4	3-Oxo, 6β,27-$(OH)_2$	[225]
	Kokzeylanonol	4	6β,27-$(OH)_2$, 3, 21-dioxo	—
	Zeylasterone, 240–242°, −73.4°	4	2,3-$(OH)_2$, 6-oxo, $\Delta^{1,3,5(10),7}$, 23-nor, 24-COOH, 29-COOMe	[226]
	Kokoononol, 298–300°, +18°	4	3-Oxo, 27-OH	[227]
Lagenaria leucantha (Cucurbitaceae)	Anhydrolitsomentol, 103–105°	14	3β-OH, $\Delta^{5\ 24}$	[228]
Liquidambar formosana (Altingiaceae)	Liquidambronoric acid	2	3-Oxo, $\Delta^{20(30)}$, 28-COOH	[229]
	Ambronic acid, 192–194°, +49.4°	1	—	[230]
	Anbrolic acid, 282–284°, +52.87°	1	—	—

Table 1. (*Contd.*)

Plant	Substance mp, $[\alpha]_D$	Structure: Basic skeleton*	Structure: Groups	Ref
Lychnophora passerina (Compositae)	Substance I§	7	3β-OH; $\Delta^{20(29)}$; 30-CHO	[231]
Lysimachia maurittiana (Primulaceae)	Camelliagenin A	1	3β,16α,22α,28-$(OH)_4$, Δ^{12}	[232]
	Camelliagenin C	1	3β,16α,22α,23,28-$(OH)_5$, Δ^{12}	—
Malinkara hexandra (Sapotaceae)	Hexandrin, 177–178°, +8.18°	7	1β,28-$(OH)_2$, 3-oxo; $\Delta^{20(29)}$	[233]
Marah macrocarpus (Cucurbitaceae)	Maragenin I, 218–220°	1	3β-OH, 16-oxo, Δ^{12}, 28-nor	[234]
	Maragenin II (Ac. 215–217°)	1	3β-OH, 16-oxo, $\Delta^{12,17}$, 28-nor	—
	Maragenin III (Ac 216–218°)	1	3β-OH, 16-oxo, Δ^{17}, 28-nor	—
Marsdenia formosana (Asclepiadaceae)	Marsformol I	2	3β-OAc; 11β-OH	[235]
	Marsformol II,	7	3β-*O*-Cinnamoyl	—
	Marsformol III	2	3β-Formyl; Δ^{12}	—
	Marsformoxide A, 212–214°, −25°	R	D Friedo-urs, 11α,12α-epoxy; Δ^{14}; 3β-OAc	[236]
	Marsformoxide B, 305–308°, −31°	R	D Friedo-olean, 11α,12α-epoxy, Δ^{14}, 3β-OAc	—
	Marsformosanone, 146–147°, +351.5°	2	3-Oxo; $\Delta^{9(11),12}$	[237]
M tinctoria (Asclepiadaceae)	Lupenyl palmitate	7	3β-*O*-Palmitoyl	[238]
Maytenus rigida (Celastraceae)	Rigidenol	7	3-Oxo, 6α-OH, $\Delta^{20(29)}$	[239]
Melia azedarachta (Meliaceae)	Sendalactone, 208.5°–209°, −30°	13	3,6-Dioxo, $\Delta^{7,24}$; 21 → 16β-lactone	[240]
	Ochinal, 265–270°, +107°	16	1α-$OCOC_6H_5$, 3β-OAc, 12-CHO; 12,13-seco, Δ^{13}, 6α,23-, 7α,15β-diepoxy	[241]
	Ochinin acetate, 223–226°, +227°	16	1α-*O*-Cinnamoyl, 3β-OAc, 12-COOMe, 12,13-seco, Δ^{13}; 6α,23-, 7α,15β-diepoxy	—
	Sendanin A (benzoate, 238–239°, +72°)	16	1α-OH, 3α,12α-$(OAc)_2$, 11-oxo, 14β,15β-, 29,19-diepoxy, 29-OAc	[242]
	Sendanal, 276–277°, −14°	16	1α,6α,7α-$(OH)_3$; 3α-OAc, Δ^{14}, 28-CHO	[243]
	Triterpene B, 173–175°, −26.5°	11	Δ^{7}, 21-OH, 21,23-, 24,25-diepoxy	[244]
	Nimbolidine A, 178°, −32°	16	1α,3α-$(OAc)_2$; 7α-$OCOC_6H_5$; 12,13-seco, 12-COOMe, Δ^{13}, 28,6α-epoxy; 15β-OAc	[245]
	Nimbolidin B, 180°, −9.2°	16	1α,3α,15β-$(OAc)_3$, 7α-*O*-tigloyl, 12,13-seco, 12-COOMe, Δ^{13}, 28,6α-epoxy	—
	Nimbolinin B, −55.5°	16	1α,3α-$(OAc)_2$, 7α-*O*-tigloyl, 12,13-seco, 12ξ-OH, Δ^{13}, 28,6α-, 12β,15β-diepoxy	—
	1-Deacetylnimbolinin, −42.8°	16	1α-OH, 3α-OAc, 7α-*O*-tigloyl, 12,13-seco, 12α-OH, Δ^{13}, 28,6α-, 12β,15β-diepoxy	—
M azadirachta	3-Acetyl salannin, 214–215°, +13.4°	21	3α-OH, 1α-OCOCMe=CHMe, 28,6α-epoxy; Δ^{13}	[246]
	Salannol, 208°, +108.7°	21	3α-OH, 1α-$OCOCH_2CHMe_2$; 28,6β-epoxy, Δ^{13}	—
	1,3-Diacetyl vilasinin, 157–158°	16	1α,3α-$(OAc)_2$, 7α-OH, Δ^{14}, 28,6β-epoxy	—
M composita	Compound A, 246–247°	12	1α,7α-$(OAc)_2$, 3α-$OCOC_6H_5$, 23α,25-$(OH)_2$, Δ^{14}; 21,24-epoxy, 30-nor, 8-Me, (20*R*)	[247]
Mimusops littoralis (Sapotaceae)	Protobassic acid	1	2β,3β,6β,23-$(OH)_4$, Δ^{12}, 28-COOH	[248]
Mollugo hirta (Molluginaceae)	Mollugogenol F 211–212°, +41.26°	6	3β,16β,22-$(OH)_3$, 21α-H	[249]

Table 1 (*Contd*)

Plant	Substance mp, $[\alpha]_D$	Structure: Basic skeleton*	Structure: Groups	Ref
M spergula	Spergulatriol, 224 226 , +60 9	**6**	3β,12β,16β-$(OH)_3$, Δ^{21}, 29,30-bisnor	[250]
	Spergulagenin (tetraketone, 242-246)	**6**	3β,12β,16β-$(OH)_3$, 22-oxo, 21α-Me, 30-nor	[251]
Momordica foetida (Cucurbitaceae)	Triterpene A, 178-180	**4**	1β-OH, 3-oxo, Δ^6	[252]
Myrianthus arboreus (Urticaceae)	Methyl-2-acetyl tormentate, 134 135	**1**	2α-OAc, 3β 19α-$(OH)_2$, Δ^{12}, 28-COOMe	[253]
	Methyl-3-acetyl tormentate, 123 125	**1**	2α,19α-$(OH)_2$, 3β-OAc, Δ^{12}, 28-COOMe	—
Napoleonaea imperialis (Napoleonaeaceae)	Sapogenol I (Ac 203-205 , +63)	**1**	3β,16α,22β,24,28-$(OH)_5$, Δ^{12}	[254]
	Napoleogenol, 127 130°, +30	**1**	3β,16α,22α,24,28-$(OH)_5$, Δ^{12}, 21β-(6-deoxy-3,4-diangeloylate-β-glucopyranosyl)-oxy	—
Nepeta hindostanna (Labiatae)	Nepeticin, 215°, +22 5°	**7**	3β,11α-$(OH)_2$ $\Delta^{20(29)}$	[255]
Neottia purpurea (Orchidaceae)	Cyclonervilol, 166 169 , +37 9	**13**	3β-OH, 9,19-cyclo Δ^{22} 24-Et 29-nor	[256]
	Cyclohomonervilol, 166-167 , +40 5°	**13**	3β-OH, 9,19-cyclo, 24-CMe=CH_2, 29-nor	—
Pachysandra terminalis (Buxaceae)	Pachysandienol B, 211-213 , +153 1	**4**	3β-OH, $\Delta^{16\ 21}$, 28-nor, 16-Me	[257]
	Pachysandienol A, 238 241 , +89 5	**4**	3β-OH, $\Delta^{15\ 17(22)}$, 28-nor 16-Me	—
Periandra dulcis (Leguminosae)	Periandric acid II, 247-249°	**1**	3β-OH, Δ^{12}, 25-CHO, 30-COOH	[258]
	Periandric acid IV, 286-287°	**1**	3β-OH, Δ^{12}, 25-CH_2OH 30-COOH	—
	Aglycone I	**1**	3β-OH, Δ^{18}, 25-CHO, 29- or 30-COOH	[259]
	Aglycone III	**1**	3β-OH, Δ^{12}, 25,30-$(CH_2OH)_2$	—
Pertya robusta (Compositae)	Triterpene methyl ether	**13**	3β-OMe, $\Delta^{9(11)\ 25}$ 24-Me	[260]
Pieris japonica (Ericaceae)	Compound A, 262-263	**2**	16α-OH, 3β-OAc, 28 → 29-lactone	[261]
Pistacia palestina (Anacardiaceae)	Substance I, +3	**12**	3β-OH, $\Delta^{7\ 24}$, 20α-H	[262]
Phytolacca americana (Phytolaccaceae)	Pokeberrygenin, 208-209 , +79 2	**1**	2β,3β-$(OH)_2$, Δ^{12}, 28-COOH, 30-COOMe	[263]
P rugosa	Serjanic acid	**1**	3β-OH, Δ^{12}, 28-COOH, 30-COOMe	[264]
Pleurostylia opposita (Celastraceae)	Compound I, 214-216°, +64 4°	**7**	3-Oxo, $\Delta^{5\ 20(29)}$	[265]
	Compound II, 249-252°, −37 5	**7**	3-Oxo, 6β,20-$(OH)_2$	—
	Compound III, 196-198°, +4 0°	**7**	3-Oxo, 6β,27-$(OH)_2$, $\Delta^{20(29)}$	—
	Compound IV, 218-219 , −21 3°	**7**	3β,6β-$(OH)_2$ $\Delta^{20(29)}$	—
Polemonium coeruleum (Polemoniaceae)	Polemoniogenin 185	**2**	3β,22α 28-$(OH)_3$ $\Delta^{12\ 18}$, 24-CHO	[266]
P reptans (Polemoniaceae)	Polemoniogenin B	**1**	3β,16α,18β,28-$(OH)_4$, Δ^{12}, 23-CHO, 21β,22α-OR (R = angeloyl tigloyl or valeroyl)	[267]
Primula denticulata (Primulaceae)	Pridentigenin B	**1**	3β,16α-$(OH)_2$, Δ^{12} 28,30-epoxy, 30-OMe	[268]
	Pridentigenin E, 268-270°	**1**	3β,16α,28,30-$(OH)_4$, Δ^{12}	[269]
Prionostemma aspera (Celastraceae)	Prionostemmadione, 282-284°, −105°	**4**	3,11-Dioxo	[270]

Table 1 (*Contd*)

Plant	Substance mp, $[\alpha]_D$	Structure: Basic skeleton*	Structure: Groups	Ref
	Triterpene I, 238–241°	4	2-Oxo, 3,21β-$(OH)_2$, $\Delta^{1(10),3,5,7}$, 24-nor, 29-COOMe	[271]
	Pristimerinene	4	2-Oxo, 3-OH, $\Delta^{1(10)\,5\,7\,9(11)}$, 24,25-bisnor 29-COOMe, 11-Me	—
Pseudocedrela kotschyi (Meliaceae)	Pseudrelone B, 255–257°, −70°	23	2β,30α-$(OAc)_2$, 3β-*O*-isobutyroyl, 16,17-seco, 16-COOMe, 17oxo, 18,11α-epoxy	[272]
Pygeum acuminatum (Rosaceae)	Acuminatic acid, 264°	2	2α,3α,19α-$(OH)_3$, Δ^{12}, 28-COOH	[273]
Quercus gilva (Fagaceae)	Gilvanol, 212–215°	6	3β-OH, $\Delta^{17(21)}$-ozonide	[86]
Q suber	Triterpene I, 254°, −7 4°	4	2-Oxo, 3α-OH	[274]
	Triterpene II, 222°, −54 4°	4	2β-OAc, 3-oxo	—
Rhus javanica (Anacardiaceae)	Rhuslactone, 199–200°, +54 1°	10	3α-OH, 19,3β-epoxy, 17β-H, $\Delta^{20,23}$, 26→22-lactone	[275]
Rubia cordifolia (Rubiaceae)	Ribocoumaric acid, 215°, +24 5°	2	3β-*O*-*p*-Coumaroyl, Δ^{12}, 30-OH, 28-COOH	[276]
	Rubifolic acid, 286–287°	2	3β,30-$(OH)_2$, Δ^{12}, 28-COOH	—
Rubus fructiosus (Rosaceae)	Rubitic acid, 252–254°, +65°	2	3β,17α-$(OH)_2$; Δ^{12}; 28-COOH	[277]
Roylea elegans (Labiatae)	Moronic acid, 222°, +29°	1	3-Oxo, Δ^{18}, 28-COOH	[35]
Salacia macrosperma (Elastraceae)	Salaspermic acid, 335°	4	3α-OH, 24,3β-epoxy, 29-COOH	[278]
	Salaciaquinone methides, 203–205°	4	1,21-Dioxo; 3-OH, $\Delta^{1(10)\,3\,5,7\,9(11)}$, 12,13-Seco, 11,13-cyclo, 29-COOMe, 24-nor	[279]
S prinoides	Triterpene Q	4	1,3-Dioxo, 26-CHO	[280]
	Triterpene T	4	1,3-Dioxo, 26-OH	—
	Triterpene U	4	1,3-Dioxo, 26-COOH	—
Salvia coccinea (Labiatae)	Dehydrouvaol, 210–212°	2	3β,28-$(OH)_2$, $\Delta^{12\,20(30)}$	[281]
S leucantha	3-Epierythrodiol, 208–210°	1	3α,28-$(OH)_2$, Δ^{12}	[282]
S mexicana	Salviolide	1	3β-OH; 28→12β-lactone	[283]
S phlomoides	Triterpenoid I, 245–247°, −3.4°	7	3β,11α,20-$(OH)_3$	[284]
	Triterpenoid II, 175–176°, +9 2°	7	3β-OAc, 11α,20-$(OH)_2$	—
	Triterpenoid III, 225–227°, +46 1°	7	3-Oxo, 11α,20-$(OH)_2$	—
Sapindus mukorossi (Sapindaceae)	Triterpene	1	3β,17β-$(OH)_2$, Δ^{12}, 28-nor	[285]
Sapium baccatum (Euphorbiaceae)	Baccatin, 228–229°, −9 09°	R	D Friedo-olean, 2α,3β-$(OH)_2$, Δ^{15}, 14,17-peroxide, 28-nor	[286]
Satureja calamintha (Labiatae)	Calaminthadiol,‖ 197–199°, +87°	2	3,4-Seco, 3,28-$(OH)_2$, $\Delta^{12,4(23)}$	[287]
	Isocalaminthadiol, 195–197°, +56 7°	2	3,4-Seco, 1β,28-$(OH)_2$, $\Delta^{12,4(23)}$	[288]
Schima argentea (Theaceae)	Sapogenin I	1	3β,15α,16α,28-$(OH)_4$, 22α-OCOCMe=CHMe	[289]
Schinus molle (Ancardiaceae)	Epi-isomasticadienolactic acid (methyl ester, 151–152°, +9 1°)	11	3α-OH, $\Delta^{8,24}$, 21-CHO, 26-COOH	[290]
Scoparia dulcis (Scrophulariaceae)	Dulcioic acid, 275–277°	2	3β-OH, Δ^{12}, 30-COOH	[291]
Simarouba amara (Simaroubaceae)	20,21-Anhydromelianone, 165–166°, +34 2°	11	1β,24,25-$(OAc)_3$; $\Delta^{7,20}$, 21→23-epoxy	[292]

Table 1 (*Contd*)

Plant	Substance mp, $[\alpha]_D$	Structure: Basic skeleton*	Structure: Groups	Ref
Skimmia wallichii (Rutaceae)	Skimmiwallichin 152–154°, +67.3	**13**	3β-OMe, 9,19-cyclo, Δ^{25}, 23-CH(Me)$_2$ 24-Me	[293]
Solidago virgaurea (Compositae)	Virgaureagenin F	**1**	2β,3β,23-(OH)$_3$, Δ^{12} 28-COOH	[294]
	Virgaureagenin G	**1**	2β,3β,16α,23-(OH)$_4$ Δ^{12} 28-COOH	—
Soymida febrifuga (Meliaceae)	Compound A 186° +48°	**16**	3,21-Dioxo, 7,8-seco 7-COOMe, 16,17-seco, $\Delta^{1,14,8(30)}$, 16→17-lactone 21,23-dihydro, 23ζ-OMe	[295]
	Compound B, 248–252°	**16**	3,4-Seco, 3→4-, 16→17-dilactone 7,8-seco, 7-COOMe 16,17-seco 1α,14β-epoxy 21,23-dihydro 21-oxo, 23ζ-OMe	—
	Febrinin A, 248–250°	**23**	2β-OAc 3β-*O*-tigloyl, 30α-*O*-propionyl 16,17-seco 16→17-lactone, Δ^{14}	[296]
	Febrifugin, 195–197°	**22**	1-Oxo, 3β-*O*-angeloyl, $\Delta^{8(30)}$	[297]
Strychnos dolichothyrsa (Loganiaceae)	Filiacan-3-one, 248–249° −25.4°	R	D:A-Friedo-fernan, 3-oxo	[298]
S. potatorum (Loganiaceae)	Isomotiol, 197–199°, +17°	**9**	3β-OH Δ^{8}	[299]
Styrax officinalis (Styraceae)	21-Benzoyl barringtogenol C, 254–257°, +29.4°	**1**	3β,16α,22β,28-(OH)$_4$, 14-nor, 14α-OMe, 21β-OCOC$_6$H$_5$	[300]
Swietenia mahagoni (Meliaceae)	31-Norcycloswietenol, 131–133°, +89.5°	**13**	31-Nor, 3β-OH 9,19-cyclo, Δ^{20} 22-Me	[301]
Taraxacum japonicum (Compositae)	Neolupeol 208–209°, +115.5°	**7**	3β-OH Δ^{12} (19*R*)	[302]
	Tarolupeol, 163.5–164.5° +64.5°	**7**	3β-OH, Δ^{14}, (19*R*)	
	Neolupenyl acetate, 195.5–197° +71.4°	**7**	3β-OAc Δ^{12} (19*R*)	
	Tarolupenyl acetate, 221–223°, +70.6°	**7**	3β-OAc, Δ^{14}, (19*R*)	—
Teclea grandifolia (Rutaceae)	Tecleanin −143°	**16**	6-Oxo 3,4-seco 3→19-lactone, 1,4-epoxy Δ^{14}	[303]
	7-Deacetyl proceranone, 168–170° +31°	**16**	7α-OH $\Delta^{1,14}$ 3,4-seco 3→4-lactone	—
	7-Deacetyl azadiranone	**16**	3-Oxo, 7α-OH, $\Delta^{1,14}$	—
Tetrapanax papyriferum (Araliaceae)	Papyriogenin G, 188–189°	**1**	3α,21α-(OH)$_2$ $\Delta^{11,13(18)}$ 28→22β-lactone	[87]
	Papyriogenin D, 285–287° −183°	**1**	3-Oxo $\Delta^{11,13(18)}$, 21α-OH 28-COOH	[304]
	Papyriogenin E, 286–288°, −207°	**1**	3α,21α-(OH)$_2$, $\Delta^{13,13(18)}$, 28-COOH	
	Papyriogenin F, 275–277°, +73°	**1**	3α-OH, 21-oxo, Δ^{12}, 28-COOH	—
Thysanospermum diffusum (Rubiaceae)	Thysanolactone, 280–282°, −15°	**6**	2,3-Seco, 2→3-lactone 1β,3β-epoxy, $\Delta^{22(30)}$	[305]
Toona ciliata (Meliaceae)	Toonacilin	**16**	3-Oxo, 7,8-seco, 11α,12α-(OAc)$_2$, Δ^{1}, 14β,15β-epoxy, 7-COOMe	[306]
	6-Acetoxy toonacilin	**16**	3-Oxo, 7,8-seco 6α,11α,12α-(OAc)$_3$, Δ^{1}, 14β,15β-epoxy 7-COOMe	—
	23(*R*)-Hydroxy toonalide	**16**	3-Oxo, 11α,12α-(OAc)$_2$, $\Delta^{1,8(30)}$, 21,23-dihydro, 23(*R*)-OH, 21-oxo, 14β,15β-epoxy 8,7-seco, 7-COOMe	[307, 308]
	23(*S*)-Hydroxy toonalide, 188–189°, +37°	**16**	3-Oxo 11α,12α-(OAc)$_2$, $\Delta^{1,8(30)}$ 21,23-dihydro, 8,7-seco, 23(*S*)-OH, 21-oxo, 14β,15β-epoxy, 7-COOMe	—

Table 1. (*Contd.*)

Plant	Substance mp, $[\alpha]_D$	Structure: Basic skeleton*	Structure: Groups	Ref
	21-(*R,S*)-Hydroxy toonalide	**16**	3-Oxo, 11α,12α-$(OAc)_2$, $\Delta^{1,8(30)}$, 21,23-dihydro, 21(*R,S*)-OH, 23-oxo, 14β,15β-epoxy, 8,7-seco; 7-COOMe	—
T. surveni	Surenone, 195°, −11.1°	**16**	3,4-Seco, 6α-OH, 7-oxo, 14β,15β-epoxy, 3→4-lactone, Δ^1	[309]
	Surenin, 240°, +74.5°	**16**	3,4-Seco, 6α,7α-$(OAc)_2$, 14β,15β-epoxy, 3→4-lactone, Δ^1	
Trema orientalis (Ulmaceae)	Trematol, 215–216°, −27.8°	**R**	D C-Friedo-hopan, 3β-OH, $\Delta^{9(11)}$	[310]
Trichilia dregeana (Meliaceae)	Dregeana I	**20**	15-Oxo; 1β,14β-epoxy, 11β-OCHO, 12α-OCOCHOHCH–MeC_2H_5, $\Delta^{8(30)}$	[311]
	Dregeana II, 150°	**16**	1α,11β,12α-$(OAc)_3$, 3,4-seco, 3→4-lactone; 7,8-seco; 15-oxo, 7-COOMe, $\Delta^{8(30)}$, 16β-OH	—
	Dregeana III, 100°	**16**	1α,7α-$(OAc)_2$, 3,4-seco, 3→4-lactone, 12β-OCOCHOAcCHMeC_2H_5, Δ^{14}	—
	Dregeana IV	**16**	1α-OAc, 7α-OCOCHOHCHMe_2, 12β-OCOCHOAcCHMeC_2H_5; 3,4-seco; 3→4-lactone, Δ^{14}, 29-OH	—
T. hispida	Hispidone, +35°	**11**	3-Oxo, 23α,24β-$(OH)_2$, Δ^7, 21,24-epoxy	[312]
	Hispidol A, 118°, −80°	**11**	3α,23α,24,25-$(OH)_4$, Δ^7	[313]
	Hispidol B, 253–254°, −57°	**11**	3β,23α,24,25-$(OH)_4$, Δ^7	—
	Hispidin A	**25**	1ξ-OAc, 11β-OCHO, 12α-OCOCHOHCHMeEt, 14β-OH, 15α-*O*-angeloyl, $\Delta^{8(30)}$	[314]
	Hispidin B	**20**	11β-OCHO, 14β-OH, 12α-OCOCHOHMeEt, 15α-*O*-angeloyl; $\Delta^{1,8(30)}$	—
	Hispidin C, 245–246°, −32°	**20**	11β-OCHO, 12α-OCOCHOHMeEt; 14β-OH, 15α-OAc, $\Delta^{1,8(30)}$	—
T. prieuriana	D-4	**16**	3,4-Seco, 7,8-seco, $\Delta^{1,8(30)}$; 14β,15β-epoxy, 11β-OCHO, 12α-OCOCHOHCHMeEt, 3→4-, 7→24-dilactone	[315]
	D-5	**16**	3,4-Seco, 7,8-seco, $\Delta^{8(30)}$, 14β,15β-epoxy, 11β-OCHO, 12α-OCOCHOHCHMeEt; 1α,24-$(OH)_2$, 3→4-lactone, 7-COOMe	—
	Compound C	**16**	3,4-Seco, 7,8-seco, $\Delta^{8(30)}$, 14β,15β-epoxy, 11β-OCHO; 12α-OCOCHOHCHMeEt, 1β-OAc, 3→4-, 7→24-dilactone	—
T. roka	Trichilin A, 191–192°	**16**	1α,7α,12β-$(OH)_3$, 2α,3α-$(OAc)_2$, 11-oxo; 14β,15β-, 29,19-diepoxy; 29-OCOCHMeC_2H_5	[57]
	Trichilin B	**16**	1α,7α,12α-$(OH)_3$, 2α,3α-$(OAc)_2$, 11-oxo, 14β,15β-, 29,19-diepoxy, 29-OCOCHMeC_2H_5	—
	Trichilin C	**16**	1α,3α-$(OAc)_2$, 2β,7α,11α-$(OH)_3$; 12-oxo, 14β,15β-29,19-diepoxy, 29-OCOCHMeEt	—
	Trichilin D	**16**	1α,3α-$(OAc)_2$, 2α,7α-$(OH)_2$, 12-oxo; 14β,15β-, 29,19-diepoxy, 29-OCOCHMeEt	—
Uncaria gamblea (Rubiaceae)	7α-Acetoxy-dihydronomilin	**16**	1α,7α-$(OAc)_2$, 3,4-seco, 16,17-seco, 14β,15β-epoxy, 3→4-, 16→17-dilactone	[316]
U. thwaitesii	Uncaric acid, 270°, +65°	**2**	3β,6β,18β-$(OH)_3$, Δ^{12}, 30-COOH	[317]
	Diketouncaric acid, 265°, +82°	**2**	3,6-Dioxo, 18β-OH; Δ^{12}, 30-COOH	—
	Diacetyluncaric acid, 220°, +73°	**2**	3β,6β-$(OAc)_2$, 18β-OH, Δ^{12}; 30-COOH	—
Vernonia fasciculata (Compositae)	Fasciculatol	**11**	3β-OH; $\Delta^{8,12}$, 27,18-bisnor, 20,24-epoxy; 24-Me	[318]
Zizyphus fructus (Rhamnaceae)	Triterpene I, 208–210°, −33°	**7**	2α-OH, 3β-(*O-cis-p*-coumaroyl), $\Delta^{20(29)}$, 28-COOH	[319]

Table 1 (*Contd*)

Plant	Substance mp, $[\alpha]_D$	Structure: Basic skeleton*	Structure: Groups	Ref
	Triterpene II, 279–282°, +40	7	2α-OH, 3β-(*O-trans-p*-coumaroyl), $\Delta^{20(29)}$, 28-COOH	-
	Triterpene III, 279–280°, −17	7	3β-OH, 2α-(*O-trans-p*-coumaroyl), $\Delta^{20(29)}$, 28-COOH	
Zygophyllum fabago (Zygophyllaceae)	Dihydromachaerinic acid lactone	1	3β-OH, 28→21β-lactone	[320]

*'R' denotes rearranged structure and 'U' denotes unknown structure
†Also isolated from *B platyphylla* and *B ermani* (Betulaceae) [148]
‡Complete structure not known [220]
§Also present in *L uniflora* and *L salicifolia* (Compositae) [231]
‖Also isolated from *S graeca* (Labiatae) [287]

Table 2 Triterpenoids from miscellaneous sources

Sources	Substance, mp, $[\alpha]_D$	Structure: Basic skeleton	Structure: Groups	Ref
Bohadschia vitiensis	Sapogenin I, 209–210°, −5	13	3β,12β-$(OH)_2$, $\Delta^{9(11)}$, 20(*S*), 18→20(*S*)-lactone	[321]
Fusidium coccineum	7,8-Dehydropseudofusidic acid, +33°	15	3α,11α-$(OH)_2$, $\Delta^{7\ 17(20)\ 24}$, 21-COOH	[322]
	Fusilactidic acid, 192–193	15	3α-OH, 16β-OAc, $\Delta^{17(20)\ 24}$, 11,12-seco, 11→12-lactone, 21-COOH	
Holothuria altra	22,25-Oxidoholothurinogenin	13	3β,17-$(OH)_2$, $\Delta^{9(11)}$ 22,25-epoxy, 18→20(*S*)-lactone	[323]
	17-Deoxy-22,25-oxidoholothurinogenin	13	3β-OH, $\Delta^{9(11)}$, 22,25-epoxy, 18→20(*S*)-lactone	
Japis stellifera	Triterpene I	17	3,12-Dioxo, $\Delta^{13\ 15\ 17\ 22\ 24}$, 26-COOH	[324]
	Triterpene II, 266–268°, +45.7	17	3,12-Dioxo, $\Delta^{13\ 15\ 17\ 22\ 24}$ 22→26-lactone	
	Triterpene III	17	3β-OAc, 12-oxo, $\Delta^{13\ 15\ 17\ 22\ 24}$, 26-COOH	
Rhodomicrobium vannielii	3β-Hydroxy-17-methyl hopane	6	3β-OH, 17ξ-Me, 21ξ-H	[325]
	29-hydroxy-dimethyl hopane	6	3ξ,17ξ-$(Me)_2$, 21ξ-H, 29-CH_2OH	-
Stichopus chloronotus	Stichlorogenol, 225–226°, −42°	13	3(*S*),23(*S*)-$(OH)_2$, Δ^{7}, 18→20(*S*)-lactone	[326]
	Dehydrostichlorogenol, 239–240°, −35°	13	3(*S*),23-$(OH)_2$, $\Delta^{7\ 25}$, 18→20(*S*)-lactone	--
S japonicus	Stichopogenin A	13	3β-OH, 16-oxo $\Delta^{9(11)\ 25}$, 18→20(*S*)-lactone	[327]
	Aglycone I*	13	3β,25-$(OH)_2$, 16-oxo, $\Delta^{9(11)}$, 18→20(*S*)-lactone	[39]
	Aglycone II*	13	3β-OAc, 25-OH, 16-oxo, $\Delta^{9(11)}$, 18→20(*S*)-lactone	—
	Aglycone III*	13	3β,25-$(OAc)_2$, 16-oxo, $\Delta^{9(11)}$, 18→20(*S*)-lactone	-
Siphonochalina siphonella	Sipholenol, 169–171°	18	4α,10β,19β-$(OH)_3$, Δ^{15}	[95]
	Sipholenone, 187–188°	18	4-Oxo, 10β,19β-$(OH)_2$, Δ^{15}	--

Table 2 (*Contd.*)

Sources	Substance mp, $[\alpha]_D$	Structure: Basic skeleton	Structure: Groups	Ref
Geological				
Eocene messel shale oil (50×10^6 years)	Compound I	**6**	$\Delta^{8,11\ 13,15,17}$, 26,27,28,30-tetranor	[328]
	Compound II	**6**	$\Delta^{13,15\ 17}$, 26,27,28,30-tetranor	—
Fossil plant	Nortriterpene I	**13**	23-Oxo, 29-nor	[31]
	Nortriterpene II	**13**	23-Oxo, $\Delta^{9(11)}$, 29-nor	—
Jurassic shale oil	Substance A	**6**	25,28,30-Trisnor	[329]
Monterey shale oil	Compound I, 150–152°	**6**	17α-H, 18α-H, 21β-H, 20,30-bisnor	[89]
Sediment	Substance 3a (methyl ester, 169–176°)	**6**	17α-H, 21β-H; 22(*R*), 29-CH_2CH_2COOH	[330]
Sediment (hole 402 A)	Triterpene I	**6**	$\Delta^{13(18)}$, 22,29,30-trisnor	[331]
	Triterpene II	**6**	$\Delta^{13(18)}$, 30-nor	—
	Triterpene III	**6**	$\Delta^{17(21)}$, 30-nor	—

*Also isolated from *Thelonata ananas* [39]

Antimicrobial activity

The antifungal activity of 49 pentacyclic triterpenoids was tested *in vitro* using *Saccharomyces carlsbergenesis* as a test organism and it was found that the pentacyclic triterpene glycosides of oleanolic acid and hederagenin, with a free carboxylic group at C-28 or C-27, possess the highest fungicidal activity [338] A number of tetranortriterpenoids isolated from plants of the Meliaceae family have been found to possess antimicrobial properties. Toonacilin and 6-acetoxytoonacilin, isolated from *Toona ciliata*, showed antifeeding activity against *Epilachna verivestis* [306]. The root bark of the East African tree *Trichilia roka* yielded a series of new limonoids, the trichilins A–D, which exhibited a broad spectrum of insect antifeedant and pesticidal activity against the southern army worm, Mexican bean beetle, tobacco horn worm and other pest insects [57]. Moreover, a review dealing with methods for the determination of fusidic acid, which is used as an antimicrobial agent, in blood, bone and sputum has been published [339]

Herbicidal activity

Two compounds with the cucurbitane skeleton, cucurbitacins D and I isolated from the seed of *Purshia tridenta*, showed the seed germination inhibitory property [340] and a large number of naturally occurring compounds with the lanostane skeleton from *Neamatoloma fasciculare* and *N. membranacea* also showed the growth inhibitory properties on young plants [97, 98].

Anti-inflammatory activity

Various modified forms of glycyrrhetinic acid, such as the sodium, potassium and ammonium salts, have been synthesized because of their therapeutic importance [341, 342] Reduced forms of glycyrrhetinic acid also showed marked antiallergic and antiulcer activities in mice without undesirable aldosterone like properties [343]. Moreover, carbenoxolone, the succinic acid derivative of glycyrrhetinic acid, also possesses the antiulcer activity [344]

Effect on metabolism

The inhibitory activity of carbenoxolone on the prostaglandin (PG) metabolizing enzymes, 15-hydroxy-PG dehydrogenase and Δ^{13}-PG reductase has been studied *in vivo*. This drug in the same dose range does not influence gastric mucosal PG synthesis by a microsomal cell fraction The decrease in activation of cytoprotective PG synthesis within the gastric mucosa might contribute to the ulcer healing effect of carbenoxolone [344]. In another study the counteraction of carbenoxolone with the stimulation of lypolysis induced by glucagon (5 ng/ml) in chicken adipose tissue *in vitro* was observed [345]

The effect of ursolic acid and its derivatives on lipid metabolism in experimental atherosclerosis was studied and this revealed that their derivatives decreased the blood cholesterol, β-lipoprotein and phospholipid concentrations in rabits [346,347]. A triterpene mixture containing 59.2% acids, 32.3% neutral terpenoids, 3.5% water and 5% chlorophyll, isolated from thyme extract by-products, was found effective in experimentally induced hypercholesteremia and atherosclerosis in rats, mice, rabits and dogs [348].

The effect of three triterpenic acids and sporidesmin on enzyme activities of rat liver plasma has been studied Icterogenin and 22β-angeloyloxy oleanolic acid, which rapidly produce cholestasis *in vivo*, partially inhibited both Mg^{2+}-ATPase and Na^+-ATPase at the low concentration of 10–100 μM in an isolated rat liver plasma membrane The third triterpene, asiatic acid which does not adversely affect the bile secretion *in vitro*, was found to be an effective inhibitor of Na^+,K^+-ATPase at low concentration but did not inhibit Mg^{2+}-ATPase [349]

Effect on biosynthesis

Fusidic acid possesses not only antimicrobial activity but also exhibits a unique *in vivo* stimulation of labeled

amino acid incorporation into proteins of liver, kidney, brain and muscle of both male and female rats [350] The effects of certain pentacyclic triterpenoids on protein biosynthesis were studied and it was found that hederagenin had a marked inhibitory effect on the rate of protein biosynthesis in rat marrow [351]

The inhibitory effects of 24 triterpenoids from *Cimicifuga* species on lymphocyte blastogenesis with phytohemagglutinin were observed and a structure–activity relationship for potent suppressive activities was reported It was found that a hemiacetal group in the side chain, an oxygenated group in the C-12 position, a cyclopropane ring on ring B and a double bond at the 7,8-position were required for the activity [352]

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