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FLAVONOIDS, INOSITOL ESTERS AND PANTOLACTONE HOMOLOGUES FROM *MARSHALLIA TENUIFOLIA*

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Key Word Index—*Marshallia tenuifolia*; Compositae; prenylated phloroglucinol derivatives; prenylated flavonol; prenylated flavans; inositol esters; pantolactone homologues.

Abstract—The chloroform extract of the aerial parts of *Marshallia tenuifolia* afforded *p*-hydroxybenzaldehyde, three new prenylated derivatives of 2,4-dihydroxy-6-methoxybenzaldehyde, one new 7,6-pyranoflavonol, a new 7,8-pyranoflavan-3-ol and a new prenylated flavan-3-ol, four new polyacylated derivatives of *d*- (or *l*-) inositol, a homologue of pantolactone and a diangelyl glucoside of the latter. The structures were elucidated by spectroscopic methods.

INTRODUCTION

The isolated position of the North American genus *Marshallia* [1] relative to other members of the tribe Heliantheae has led to questions concerning its tribal status [2, 3]. Most recently it has been assigned [4] to a new monogeneric subtribe Marshalliinae of Heliantheae with a possible relationship to the Inuleae, an assignment seemingly supported by a chemical study of *Marshallia obovata* [5] and an earlier examination of *M. grandiflora* [6]. We have now studied the aerial parts of *M. tenuifolia* Raf. Isolated were *p*-hydroxybenzaldehyde, the phloroglucinol derivatives **1–3**, the new flavonoids **4a**, **5a** and **6a**, four polyacylated derivatives (**7–10**) of *d*- or *l*-inositol and the optically active γ-lactones **11** and **12**.

RESULTS AND DISCUSSION

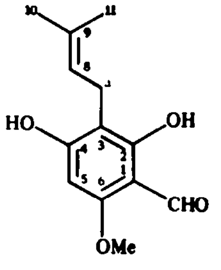
The structure of **1**, mentioned earlier only as a degradation product of flavanones **6b** and **6c** found in *M. obovata* [5], was confirmed by its previously unreported ^{1}H NMR spectrum (Table 1) and the NOE data detailed in the Experimental which established the distribution of groups on the aromatic ring. The structures of **2** and **3**, each of which contained an additional oxygen atom, followed from the ^{1}H NMR spectra (Table 1). The absolute configuration (*R*) of **2** shown in the formula was deduced using the method of Horeau and Nouaille [7] which furnished (+)-*S*-α-phenylbutyric acid in 28% optical yield. The absolute configuration of **3** remains unknown. As a significant quantity of *p*-hydroxybenzaldehyde was also found, it is possible that **1–3** are formed by enzymatic degradation of **6b** (found in *M. obovata* and *grandiflora* [5, 6]) and side-chain oxidized analogues of **6b** corresponding to **2** and **3**, although **6b** and its analogues were not detected in our extract, which was worked up only after prolonged storage.

Compound **4a** was obviously a 3,5,4′-trihydroxypyranoflavone from the mass spectrum and ^{1}H NMR spectrum (see Experimental), which showed that the

Table 1. ^{1}H NMR spectral data of compounds **1–3** ($CDCl_3$, 270 MHz)

H	**1**	**2**	**3**	**3***
5	5.88 *s*	5.97 *s*	5.89 *s*	5.73 *s*
7a	3.34 *d*(*br*) (7)	3.06 *dd* (16, 2)	2.88 *dd* (17, 5)	2.70 *dd*
7b		2.78 *dd* (16, 8)	2.63 *dd* (17, 6)	2.46 *dd*
8	5.26 *tqq* (7, 1.5, 1.5)	4.36 *dd* (*br*) (8, 2)	3.83 *dd* (6, 5)	3.29 *dd*
10†	1.82 *d* (1.5)	1.84 *br*	1.38 *s*	1.22 *s*
11	1.77 *d* (1.5)†	4.97 *br*	1.34 *s*†	1.18 *s*†
		4.87 *br*		
–CHO	10.09 *s*	10.05 *s*	10.08 *s*	10.19 *s*
OMe†	3.82 *s*	3.83 *s*	3.83 *s*	3.05 *s*
2-OH	11.95 *s*	12.06 *s*	12.10 *s*	13.52 *s*
4-OH	6.30 *s*	9.40 *s*	2.00 *s*	6.22 *s*
8-OH	—	2.80 *s*	—	—

*Run in C_6D_6.
†Intensity three protons.
Coupling constants (*J* in Hz) are given in parentheses.



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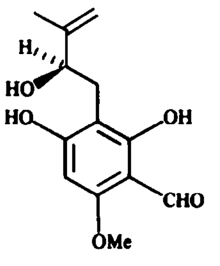

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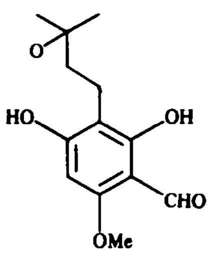

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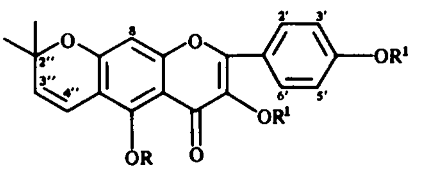
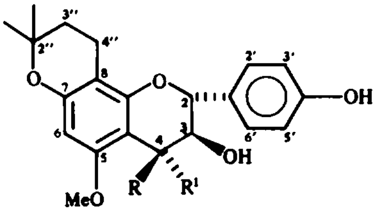
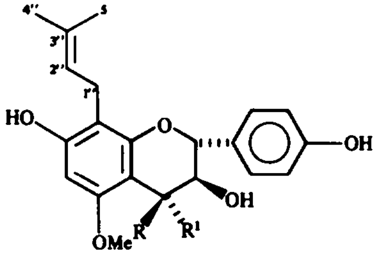


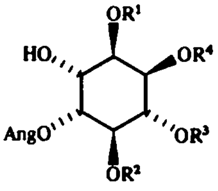
4a R = R^1 = H
4b R = R^1 = Ac
4c R = H, R^1 = Me



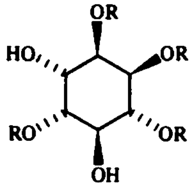
5a R = R^1 = H
5b R = R^1 = =O
5c R = OH, R^1 = H



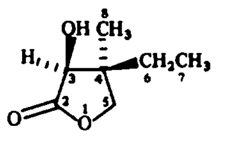
6a R = R^1 = H
6b R = OH, R^1 = H
6c R = OMe, R^1 = H



7 R^1 = R^3 = Ang, R^2 = R^4 = H
8 R^1 = Ac, R^2 = R^3 = Ang, R^4 = H
9 R^1 = H, R^2 = R^3 = Ang, R^4 = Ac
10 R^1 = R^4 = Ac, R^2 = Ang, R^3 = H



13 R = Ac, Ang, Ang



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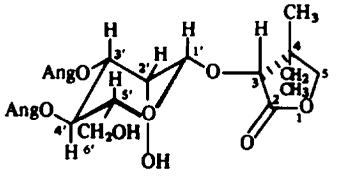

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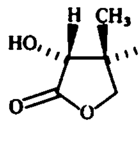

14

2′,3′,5′,6′ positions of ring B and C-6 or C-8 of ring A were unsubstituted. The linear orientation of the pyran ring was deduced from the upfield shift (Δδ0.24) of the H-4″ signal on conversion to the triacetate **4a** and by comparison with the ^{1}H NMR spectrum reported for a synthetic dimethoxy derivative (**4b**) [8].

Compound **5a** was clearly a 3,4′-dihydroxy-5-methoxypyranoflavan from the ^{1}H NMR spectrum (see Experimental). The location and orientation of the pyran ring were deduced from NOE experiments; irradiation at the frequency of the 5-OMe signal produced a 26% increase in the signal at δ6.05, which therefore had to be that of H-6. Irradiation at the frequency of H-6 did not affect the strength of the doublet at δ6.57 (H-4″), hence the pyran ring was angularly orientated. That H-2 and H-3 were *trans*-diaxial was evident from the value of $J_{2,3}$ (8 Hz); the absolute stereochemistry (2*R*,3*S*) was deduced by comparison of the CD curve with that of (+)-(2*R*,3*S*)-

catechin [9]. The structure and stereochemistry of the (+)(2*R*,3*S*)-open chain analogue **6a** were deduced in a similar manner. Four related flavan-3-ols (**5b, c** and **6b, c**) of undetermined absolute stereochemistry have been isolated from *M. obovata* [5], one (**6b**) of which was also present in *M. grandiflora* [6].

Derivatives **7–10** of *d*- (or *l*-) inositol constituted a fairly high fraction of the *M. tenuifolia* extract. The stereochemistry of the inositol portion of each molecule was established by spin decoupling and analysis of the coupling constants (Table 2); consideration of the chemical shifts showed that the three angelate residues of **7** esterified the hydroxyl groups at C-1, C-3 and C-5; that the one acetate and the three angelates of **8** and **9** esterified the hydroxyl groups at C-1, C-3, C-4 and C-5 and C-2, C-3, C-4 and C-5, respectively; and that the two acetates and the two angelates of **10** were distributed over C-1, C-2, C-4 and C-5.

The ^{13}C NMR spectral data of **7–10** are listed in Table 3; the signals of the inositol moieties were assigned by selective decoupling. The locations of the acetate functions on the inositol portion of **8–10** were established by selective decoupling of the fully coupled ^{13}C NMR spectrum, as suggested recently by Holub and co-workers [10]. Thus, in the case of **8**, the signal at δ170.2 arising from the carbonyl carbon of the acetate was in the fully coupled spectrum a complex multiplet due to long-range coupling ($^3J_{\text{C-H}}$) with the adjacent ring protons and coupling ($^2J_{\text{C-H}}$) with the methyl protons of the acetate. Irradiation at the frequency of the signal at δ5.34 previously identified as arising from H-1 collapsed the carbonyl signal to a quartet with $^2J_{\text{C-H}} = 7$ Hz. Hence the acetate was on C-1. Similarly, in the case of **9**, irradiation at the frequency of H-2 (δ5.52) collapsed the carbonyl multiplet at δ170.00 to a quartet ($J = 7$ Hz), showing that the acetate was located on C-2, whereas in the case of **10** irradiation at the frequency of H-1 (δ5.44) collapsed the carbonyl signal at δ169.7 and irradiation at the frequency of H-2 (δ5.37) collapsed the carbonyl signal at δ170.8, thus showing that the two acetates of **10** were located on C-1 and C-2. While compounds **7–10** all exhibited negative rotations, it was not established whether they belonged to the *d*- or *l*-inositol series. A similar compound (**13**) of unspecified optical activity has been found in very small quantity in *M. obovata* [5] but the relative position of the four ester residues was not determined.

Table 2. ^{1}H NMR spectral data of compounds **7–10** (CDCl$_3$, 270 MHz)

H	7	8	9	10
1	5.41 *t* (3.5)	5.34 *t*	4.34 *t*	5.44 *t*
2	4.26 *dd* (10, 3.5)	4.30 *dd*	5.52 *dd*	5.37 *dd*
3	5.23 *t* (10)	5.40 *t*	5.78 *t*	3.97 *t*
4	4.18 *t* (10)	5.76 *t*	5.69 *t*	5.61 *t*
5	5.17 *dd* (10, 3.5)	5.27 *dd*	5.48 *dd*	5.26 *dd*
6	4.27 *t* (3.5)	4.26 *t*	4.29 *t*	4.20 *t*
3′	6.19 *qq* (7, 1)	6.11 *qq*	6.11 *qq*	6.10 *qq*
3″	6.14 *qq* (7, 1)	6.09 *qq*	6.02 *qq*	6.04 *qq*
3‴	6.14 *qq* (7, 1)	6.00 *qq*	6.01 *qq*	—
4′*	2.05 *dq* (7, 1)	1.94 *dq*	1.96 *dq*	1.93 *dq*
4″*	2.01 *dq* (7, 1)	1.94 *dq*	1.90 *d*	1.90 *dq*
4‴*	2.00 *dq* (7, 1)	1.85 *dq*	1.87 *dq*	–
5′*	1.99 *dq* (1, 1)	1.83 *dq*	1.85 *dq*	1.82 *dq*
5″*	1.93 *dq* (1, 1)	1.82 *dq*	1.80 *dq*	1.81 *dq*
5‴*	1.92 *dq* (1, 1)	1.77 *dq*	1.78 *dq*	
OH	2.45 *s* 2.45 *s* 2.45 *s*	2.77 *s* 2.57 *s*	2.40 *s* 2.30 *s*	3.48 *s* 2.90 *s*
Ac*	—	2.20 *s*	2.06 *s*	2.14 *s* 2.05 *s*

*Intensity three protons.

Couplings constants (*J* in Hz) are given in parentheses.

Table 3. ^{13}C NMR spectral data of compounds **7–10** (CDCl$_3$, 67.89 MHz)

C	7	8	9	10
1*	72.6 *d*	72.6 *d*	69.9 *d*	70.0 *d*
2*	68.5 *d*	67.8 *d*	71.4 *d*	71.5 *d*
3*	75.7 *d*	72.7 *d*	69.3 *d*	70.6 *d*
4*	69.6 *d*	68.6 *d*	69.7 *d*	71.9 *d*
5*	73.7 *d*	71.3 *d*	71.8 *d*	70.9 *d*
6*	67.8 *d*	68.5 *d*	70.1 *d*	68.2 *d*
1′	169.0 *s*	168.1 *s*	166.8 *s*	168.0 *s*
1″	167.4 *s*	166.6 *s*	166.6 *s*	166.7 *s*
1‴	166.9 *s*	166.3 *s*	166.6 *s*	—
2′	127.3 *s*	127.3 *s*	127.3 *s*	127.3 *s*
2″	127.2 *s*	127.1 *s*	127.3 *s*	127.0 *s*
2‴	126.9 *s*	126.8 *s*	127.1 *s*	—
3′	140.6 *d*	140.3 *d*	139.7 *d*	140.1 *d*
3″	139.6 *d*	139.7 *d*	138.4 *d*	138.8 *d*
3‴	139.6 *d*	138.4 *d*	138.3 *d*	—
4′	16.1 *q*	15.8 *q*	15.7 *q*	15.8 *q*
4″	15.9 *q*	15.8 *q*	15.4 *q*	15.8 *q*
4‴	15.9 *q*	15.5 *q*	15.4 *q*	—
5′	20.7 *q*	21.0 *q*	207 *q*	20.8 *q*
5″	20.5 *q*	20.3 *q*	20.2 *q*	20.8 *q*
5‴	20.5 *q*	20.3 *q*	20.2 *q*	—
Ac	—	170.2 *s* 20.3 *q*	170.0 *s* 20.2 *q*	170.8 *s*, 169.7 *s* 20.3 *q*, 20.3 *q*

*Assignments by selective decoupling.

The two remaining new compounds from *M. tenuifolia*, the α-hydroxy-γ-lactone **11** and the diangelyl glucoside **12**, are of considerable interest because of their structural relationship to the lower homologue pantolactone (**14**), a degradation product of pantothenic acid in the liver and an important intermediate in its synthesis. The gross structure of **11** was apparent from the ^{1}H NMR spectrum (see Experimental) which paralleled that of the alicyclic portion of **12** (Table 4). Spin decoupling of the ^{1}H NMR spectrum of **12**, the coupling constants and the chemical shifts of H-1′, H-3′ and H-4′ showed that the carbohydrate portion of **12** was β-D-glucose esterified with angelic acid at C-3′ and C-4′, and linked to the β-carbon of the β-hydroxy-γ-lactone through C-1′. The ^{13}C NMR spectrum of **12** (Table 5) corroborated these conclusions. The relative stereochemistry of the lactone ring portion was determined by NOE experiments. Irradiation at the frequency of the methyl singlet at δ1.21 (H-8) produced 10% enhancements in the signals of H-3 at δ4.10 and of H-5b at δ3.89.* Hence H-3 and the C-4 methyl group were *cis*. Moreover, irradiation at the frequency of H-1′ (δ4.77)

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*Lactones **11** and **12** are numbered as derivatives of dihydro-2(3H)-furanone.

Table 4. ^1H NMR spectral data of compound 12 ($CHCl_3$, 270 MHz)

H		H	
3	4.20 *s*	3″	6.13 *qq* (7, 1)
5a	4.20 *d* (9.5)	3‴	6.06 *qq* (7, 1)
5b	3.89 *d* (9.5)	4″†	1.95 *dq* (7, 1)
6*	1.54 *m*	4″†	1.93 *dq* (7, 1)
7†	0.91 *t* (8)	5″†	1.85 *dq* (1, 1)
8†	1.21 *s*	5‴†	1.82 *dq* (1, 1)
1′	4.77 *d* (8)	2′-OH	3.36 *br*
2′	3.69 *dd* (10, 8)	6′-OH	2.58 *br*
3′	5.41 *t* (10)		
4′	5.13 *t* (10)		
5′	3.55 *ddd* (10, 4, 2)		
6′a	3.76 *dd* (12.5, 2)		
6′b	3.67 *dd* (12.5, 4)		

*Intensity two protons.

†Intensity three protons.

Coupling constants (*J* in Hz) are given in parentheses.

Table 5. ^{13}C NMR spectral data of compound 12 ($CDCl_3$, 67.89 MHz)*

C		C	
2	175.5 *s*	5′	74.7 *d*
3	81.9 *d*	6′	61.2 *t*
4	43.2 *s*	1″,1‴	167.4 *s*, 167.2 *s*
5	73.9 *t*	2″,2‴	127.3 *s*, 126.6 *s*
6	25.0 *t*	3″,3‴	140.5 *d*, 138.4 *d*
7	8.2 *q*	4″,4‴	15.8 *q*, 15.6 *q*
8	20.8 *q*	5″,5‴	20.3 *q*, 20.2 *q*
1′	103.5 *d*		
2′	72.6 *d*		
3′	73.6 *d*		
4′	68.2 *d*		

*Assignments by selective decoupling.

produced a very significant enhancement (18%) in the strength of the H-3 signal, showing that the conformation was such that H-3 of the lactone portion and H-1′ of the glucose portion were in close proximity. Models show that this is possible regardless of the absolute configuration (3*R*,4*R* or 3*S*,4*S*) of the γ-lactone moiety.

As regards the absolute configurations of **11** and the lactone moiety of **12**, a comparison of the CD curve of **11**, $\Delta\varepsilon_{217}^{MeOH} + 4.60$ (max), with the CD curve reported for the natural isomer *R*-(−)-pantolactone (**14**), $\Delta\varepsilon_{220}^{H_2O}$ -4.90 [12] indicates that the C-3 configurations of **11** and **14** are opposite, i.e. that **11** is 3*S*,4*S*, since the effect of substituting an ethyl for a methyl *cis* to the α-hydroxyl group of **14** on the conformation and on the magnitude of the CD is estimated to be small.* However, this conclusion raises an interesting problem. The biosynthesis of pantoic acid [(−)-(*R*)-2,4-dihydroxy-3,3-dimethylbutanoic acid] from L-valine [(−)-(*S*)-2-amino-3-methylbutanoic acid] via α-ketoisovalerate and α-ketopantoate [13–23] involves overall *inversion* at C-2. If one makes the plausible assumption that the biosynthesis of **11** in *M. tenuifolia* follows an analogous course with L-isoleucine [(+)-(2*S*,3*S*)-2-amino-3-methylpentanoic acid] (**15**) as the precursor, conversion of **15** to 3*S*,4*S*-**11** would entail overall *retention* at C-2 (as well as at C-3) of **15**. It is not easy to understand why a change from achirality to *S*-chirality at C-3 of a 4-hydroxy-3-methyl-2-oxoalkanoic acid would impose a change on the stereochemistry of the enzymatic reduction step.

Although a number of new compounds have been isolated in the course of this work, our results on *M. tenuifolia* are qualitatively similar to those reported previously for *M. obovata* [5] and reinforce the conclusion that the genus bears no close relationship to other genera in the tribe Heliantheae.

EXPERIMENTAL

Extraction of M. tenuifolia. Above-ground parts of *M. tenuifolia* Raf. (5.46 kg), collected by Dr. R. B. Channell in the flowering stage in the summer of 1960 in the vicinity of Tallahassee, were extracted with $CHCl_3$. Usual work-up [24] afforded 50 g of crude gum which was adsorbed on 80 g of silicic acid (Mallinckrodt, 100 mesh) and chromatographed over 600 g of the same adsorbent packed in hexane, 500 ml fractions being collected as follows. Fractions 1–4 (hexane), 5–8 (hexane–EtOAc, 9:1), 9–12 (hexane–EtOAc, 4:1), 13–16 (hexane–EtOAc, 2:1), 17–20 (hexane–EtOAc, 1:1), 21–24 (hexane–EtOAc, 2:3), 25–28 (hexane–EtOAc, 1:4), 29–32 (EtOAc), 33–36 (EtOAc–MeOH, 9:1).

Fraction 12 (1 g) dissolved in hexane–EtOAc (7:3) on refrigeration (−20°) deposited 0.15 g of **1** [5], mp 179° ($CHCl_3$); ^1H NMR spectrum in Table 1. The structure was confirmed by the following NOE data: (a) irradiation at the frequency of the three-proton singlet at δ3.82 (OMe) enhanced the signal at δ5.88 (H-5) by 32% and the –CHO signal at δ10.09 by 5%; (b) irradiation at the frequency of the –CHO signal at δ10.09 enhanced the OMe signal by 7.5% and the OH signal at δ11.95 by 17.5%; (c) irradiation at the frequency of H-5 affected only the intensity of the OMe signal (5%).

The mother liquor from **1** on CC (C_6H_6–EtOAc, 13:3) furnished three fractions containing impure **2**, **3** and **4a**. Further chromatography of fraction 1 ($CHCl_3$–Et_2O, 9:1) and crystallization from hexane–EtOAc (4:1, −20°) furnished 16 mg **2**. An additional 50 mg **2** was obtained by rechromatography (hexane–EtOAc, 3:1) of fraction 13 (1 g) of the original chromatogram. Fraction 2 from the mother liquor of **1** on rechromatography ($CHCl_3$–Et_2O, 9:1) gave 3 mg **3** as a gum; fraction 3 from the mother liquor of **1** on rechromatography ($CHCl_3$–Et_2O, 17:3) and crystallization (hexane–EtOAc, 1:1) gave 4 mg **4a**.

Rechromatography ($CHCl_3$–Et_2O, 9:1) of fraction 14 (1.5 g) of the original chromatogram gave 0.1 g *p*-hydroxybenzaldehyde. Column rechromatography ($CHCl_3$–Et_2O, 4:1) of fraction 16 (7 g) gave in the first fractions a mixture of **5a** and **7** which were separated by radial chromatography (hexane–Et_2O, 1:1) to give 3 mg of more polar **5a** and 0.3 g of less polar **7**. Radial chromatography (hexane–Et_2O) of several subsequent fractions

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*That the CD curves of **11** and **14** are enantiomeric has been confirmed in the laboratory of Prof. G. Snatzke, Ruhr University Bochum, who reports for **11**, $\Delta\varepsilon_{224}^{MeCN} + 2.53$, and for **14**, $\Delta\varepsilon_{223}^{MeCN}$ -2.58. According to Prof. Snatzke, the differences in the absolute values of Δε obtained in the various solvents are not particularly significant. We thank Prof. Snatzke for carrying out these measurements.

gave 80 mg **8**. The last fractions of the chromatography of fraction 16 contained 0.4 g **9**.

Rechromatography (hexane–EtOAc, 1:1) of fraction 17 (7 g) gave fractions containing **11** (less polar) and fractions containing **10** (more polar). CC (hexane–Et_2O, 2:3) gave 13 mg of pure **10**; radial chromatography (hexane–Et_2O, 2:3) furnished 80 mg of pure **11**. Rechromatography (hexane–Et_2O, 1:1) of fraction 18 (4 g) gave two fractions containing impure **6a** and crude homogeneous **12**. The latter was recrystallized from Et_2O, yield 130 mg. Repeated TLC and radial chromatography eventually furnished 2 mg of pure **6a**.

[(+)-*2,4-Dihydroxy-3(2-*(R)*-hydroxy-3-methyl-3-butenyl*]*-6-methoxybenzaldehyde* (**2**). Mp 140°, $[\alpha]^{20}_{546}$ +20.7° ($CHCl_3$; *c* 0.046), ^1H NMR: see Table 1; MS *m/z* (rel. int.): 252 $[M]^+$ (0.9), 234 (223), 219 (1.5), 181 (100), 179 (31.4), 164 (6.0), 136 (3.6), 85 (4.7), 69 (9.2), 55 (105). [Calc. for $C_{13}H_{16}O_5$: M_r, 252.0998. Found: M_r (MS), 252.0997.] For determination of the absolute stereochemistry a soln of 0.06 mmol of **2** and 0.2 mmol of α-phenylbutyric anhydride in 2 ml dry C_5H_5N was allowed to stand at room temp. for 10 hr. Usual work-up [7] gave the following readings: α_1, +0.77°; α_2, +0.60°; α_1, −1.1; $\alpha_2 = 0.11$ or an optical yield of (+)*S*-α-phenylbutyric acid of 28 %. Hence C-2′ was *R*.

2,4-Dihydroxy-3(2,3-epoxy-3-methylbutyl)-6-methoxybenzaldehyde (**3**). Gum, $[\alpha]^{20}_{546}$ −23.3° ($CHCl_3$; *c* 0.06; ^1H NMR: see Table 1; MS *m/z* (rel. int.): 252 $[M]^+$ (60), 234 (2.4), 219 (9), 194 (6.6), 181 (100), 179 (39.2), 164 (5.7), 123 (5.2), 85 (5.5), 72 (12.6), 69 (12.3), 57 (13.6). [Calc. for $C_{13}H_{16}O_5$: M_r, 252.0998. Found: M_r (MS), 252.0995].

7,6-(2″,2″-Dimethylpyrano)-3,5,4′-trihydroxyflavone (**4a**). Mp 210°; UV $\lambda^{\text{MeOH}}_{\text{max}}$ nm: 287, 303 (sh), 362; ^1H NMR ($CDCl_3$, 270 MHz): δ11.97 (*s*, 5-OH), 8.11 (2H, *d*, *J* = 9 Hz, H-2′, 6′), 6.96 (2H, *d*, *J* = 9 Hz, H-3′, 5′), 6.73 (*d*, *J* = 10 Hz, H-4″), 6.57 (*br*, 3-OH), 6.41 (H-8), 5.63 (*d*, *J* = 10 Hz, H-3″), 5.20 (*br*, 4′-OH), 1.47 (6H, *s*, 2″-Me's); MS *m/z* (rel. int.): 352 $[M]^+$ (29.3), 337 (100), 299 (82), 206 (9.3), 203 (16.7), 168 (39.4), 163 (12.1), 140 (10.1), 135 (12.5), 121 (33.7), 58 (12.5). [Calc. for $C_{20}H_{16}O_6$: M_r, 352.0947. Found: M_r (MS), 352.0947.] Acetylation of 2 mg **4a** (Ac_2O–C_5H_5N) followed by the usual work-up gave 1.6 mg of **4b** as a gum; ^1H NMR spectrum ($CDCl_3$, 270 MHz): δ7.81 (2H, *d*, *J* = 10 Hz, H-2′, 6′), 7.24 (2H, *d*, *J* = 10 Hz, H-3′, 5′), 6.76 (*s*, H-8), 6.49 (*d*, *J* = 10 Hz, H-4″), 5.77 (*d*, *J* = 10 Hz, H-3″), 2.46, 2.33 and 2.30 (3H, each, *s*, Ac), 148 (6H, *s*, 2″-Me's).

(−)-(2R,3S)-*7,8-(2″,2″-Dimethylpyrano)-3,4′-dihydroxy-5-methoxyflavan* (**5a**). Gum, $[\alpha]^{20}_{546}$ −42.1° ($CHCl_3$; *c* 0.04); CD curve (MeOH) $[\theta]_{294}$ −2210 (min), $[\theta]_{275}$ −2650 (min), $[\theta]_{237}$ −28 900 (min), $[\theta]_{229}$ 0, $[\theta]_{221}$ +9430 (max); ^1H NMR: δ7.30 (2H, *d*, *J* = 9 Hz, H-2′, 6′), 6.86 (2H, *d*, *J* = 9 Hz, H-3′, 5′), 6.57 (*d*, *J* = 10 Hz, H-4″), 6.05 (*s*, H-6), 5.38 (*d*, *J* = 10 Hz, H-3″), 4.82 (*br*, 4′-OH), 4.72 (*d*, *J* = 8 Hz, H-2), 4.03 (*dddd*, *J* = 9, 8, 6, 4 Hz, H-3), 3.78 (3H, OMe), 2.99 (*dd*, *J* = 16, 6 Hz) and 2.59 (*dd*, *J* = 16, 9 Hz, H-4a,b), 1.67 (*d*, *J* = 4, 3-OH), 1.42 (3H) and 1.41 (3H, 2″-Me's); MS *m/z* (rel. int.): 354 $[M]^+$ (17.1), 339 (4.3), 231 (15), 219 (17.5), 204 (13.3), 203 (100), 189 (4.3), 188 (3.1), 177 (5.6), 173 (4.7)., 136 (7.2), 107 (27.5). [Calc. for $C_{21}H_{22}O_5$: M_r, 354.1467. Found: M_r (MS), 354.1467.]

(−)-(2R,3S)-8-(*3,3-Dimethylallyl*)*-5-methoxy-3,7,4′-trihydroxyflavan* (**6a**). Gum, $[\alpha]^{20}_{546}$ −14.0° ($CHCl_3$; *c* 0.036); CD curve (MeOH) $[\theta]_{275}$ −1030 (min), $[\theta]_{225}$ −13 400 (sh), $[\theta]_{220}$ −18 600 (min); ^1H NMR ($CDCl_3$, 270 MHz): δ7.30 (2H, *d*, *J* = 9 Hz, H-2′, 6′), 6.84 (2H, *d*, *J* = 9 Hz, H-3′, 5′), 6.07 (*s*, H-6), 5.23 (*t* (*br*), *J* = 7 Hz, H-2′), 4.68 (*d*, *J* = 8 Hz, H-2), 4.20 (*br*, 4′-OH), 4.02 (*dddd*, *J* = 9,8,6,4 Hz, H-3), 3.75 (3H, OMe), 3.32 (2H, *d* (*br*), *J* = 7 Hz, H-1′ a,b), 2.99 (*dd*, *J* = 16, 6 Hz) and 2.59 (*dd*, *J* = 16, 9 Hz, H-4a,b), 2.70 (*d*, *J* = 4 Hz, 3-OH), 1.70 (6H, *br*, H-4″ and H-5″); MS *m/z* (rel. int.): 356 $[M]^+$ (21), 339 (1), 301 (3.6), 221 (50), 205 (30), 193 (11), 177 (15), 165 (100), 136 (26), 107 (30). [Calc. for $C_{21}H_{24}O_5$: M_r, 356.1624. Found: M_r (MS), 356.1624.]

(−)-*1,2,5-Triangelyl*-d- (*or* l)*-inositol* (**7**). IR $\nu^{\text{nujol}}_{\text{max}}$ cm^{-1}: 3460, 1730, 1645; gum; $[\alpha]^{20}_{546}$ −30.9° ($CHCl_3$; *c* 0.51); ^1H NMR and ^{13}C NMR: see Tables 2 and 3; MS *m/z* (rel. int.): 426 $[M]^+$ (1.5), 408 (17.6), 327 (25.9), 326 (35.7), 277 (1.9), 226 (3.8), 127 (4.7), 126 (37.3), 101 (6.2), 83 (100), 82 (57), 55 (71). [Calc. for $C_{21}H_{30}O_9$: M_r, 426.1890. Found: M_r (MS) 426.1892.]

(−)-*1-Acetyl-3,4,5-triangelyl*-d- (*or* l)*-inositol* (**8**). Gum; IR $\nu^{\text{nujol}}_{\text{max}}$ cm^{-1}. 3480, 1755, 1730, 1650, 1240; $[\alpha]^{20}_{546}$ −37.6° ($CHCl_3$; *c* 0.52); ^1H NMR and ^{13}C NMR: see Tables 2 and 3; MS *m/z* (rel. int.): 468 $[M]^+$ (0.6), 450 (14.3), 408 (1.6), 369 (10.6), 368 (12.6), 269 (0.5); 208 (11.2), 169 (1), 127 (2), 109 (2.8), 83 (100), 55 (46). [Calc. for $C_{23}H_{32}O_{10}$: M_r, 468.1995. Found: M_r (MS), 468.1996.]

(−)-*2-Acetyl-3,4,5-triangelyl*-d- (*or* l)*-inositol* (**9**). Gum; IR $\nu^{\text{nujol}}_{\text{max}}$ cm^{-1}: 3490, 1745, 1730, 1645, 1230; $[\alpha]^{20}_{546}$ −16.04° ($CHCl_3$; *c* 0.64); ^1H NMR and ^{13}C NMR: see Tables 2 and 3; MS *m/z* (rel. int.): 468 $[M]^+$ (0.6), 450 (11.9), 408 (2.4), 369 (13), 368 (14.2), 269 (0.4), 208 (1), 169 (0.7), 127 (1.4), 109 (2.8), 83 (100), 55 (4.6). [Calc. for $C_{23}H_{32}O_{10}$: M_r, 468.1995. Found: M_r (MS), 468.1996.]

(−)-*1,2-Diacetyl-4,5-diangelyl*-d- (*or* l)*-inositol* (**10**). Gum; IR $\nu^{\text{nujol}}_{\text{max}}$ cm^{-1}: 3450, 1750, 1725, 1645, 1240; $[\alpha]^{20}_{546}$ −10.23° ($CHCl_3$; *c* 0.80); ^1H NMR and ^{13}C NMR: see Tables 2 and 3; MS *m/z* (rel. int.): 428 $[M]^+$ (0.3), 410 (2.4), 368 (1.5), 329 (5.0), 328 (3.6), 169 (0.7), 127 (19), 109 (2.3), 83 (100), 82 (39.7), 55 (49.4). [Calc. for $C_{20}H_{28}O_{10}$: M_r, 428.1682. Found: M_r (MS), 428.1677.]

(3S,4S)-*Dihydro-3-hydroxy-4-methyl-4-ethyl-*2(3H)*-furanone* (**11**). Gum; $[\alpha]^{20}_{546}$ 4.7° ($CHCl_3$; *c* 0.26); CD curve (MeOH) $[\theta]_{217}$ +15 180 (max); IR $\nu^{CHCl_3}_{\text{max}}$ cm^{-1}: 3550, 3390, 1788; ^1H NMR: δ4.16 (*s*, H-3), 4.18 (*d*, *J* = 9.5 Hz, H-4a), 3.85 (*d*, *J* = 9.5 Hz, H-4b), 3.47 (*br*, OH), 1.47 (2H, *m*, H-5), 0.90 (3H, *t*, *J* = 8 Hz, H-7), 1.16 (3H, *s*, H-8); MS *m/z* (rel. int.): significant peaks were $[M]^+$ (absent), 126 (5), 97 (1.7), 83 (100), 82 (15), 71 (4.3), 55 (40); positive CIMS *m/z* (rel. int.): 289 $[M+H]^+$ (1), 145 $[M+H]^+$ (100), 127 (2).

(3S,4S)-3-0-(*3,4-Diangelyl-β-*D*-glucopyranosyl*)*-dihydro-3-hydroxy-4-methyl-4-ethyl-*2(3H)*-furanone* (**12**). Mp 151° (Et_2O); $[\alpha]^{20}_{546}$ −34.5° ($CHCl_3$; *c* 0.018); IR $\nu^{\text{nujol}}_{\text{max}}$ cm^{-1}: 3460, 3380, 1772, 1730, 1718, 1664, 1652; ^1H NMR and ^{13}C NMR: see Tables 4 and 5; MS *m/z* (rel. int.): $[M]^+$ (absent), 452 (0.1), 437 (0.1), 371 (0.1), 326 (5.3), 308 (0.1), 243 (1.3), 226 (5.3), 127 (9.2), 126 (5.2), 109 (1.5), 83 (100), 82 (17), 55 (56); positive CIMS *m/z* (rel. int.): 471 $[M+H]^+$ (3.0), 327 (100), 227 (4), 145 (62), 129 (26), 101 (34), 83 (32).

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