Studies on the Constituents of *Juglans* Species. I. Structural Determination of (4*S*)- and (4*R*)-4-Hydroxy-α-tetralone Derivatives from the Fruit of *Juglans mandshurica* MAXIM. var. *sieboldiana* MAKINO

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Received February 15, 2005; accepted April 11, 2005

Four enantiomerically pure new α-tetralones, (4*S*)- and (4*R*)-5-hydroxy-4-methoxy-α-tetralones and (4*S*)- and (4*R*)-5,8-dihydroxy-4-methoxy-α-tetralones were isolated, together with five known ones, (4*S*)- and (4*R*)-4,8-dihydroxy-α-tetralones, (4*S*)-4,8-dihydroxy-5-methoxy-α-tetralone and (4*S*)- and (4*R*)-4-hydroxy-α-tetralones, from the fruit of *Juglans mandshurica* MAXIM. var. *sieboldiana* MAKINO. Their structures were established on the basis of spectral analysis. To the best of our knowledge, this is the first isolation of the (4*R*)-4-hydroxy-α-tetralone derivative from *Juglans* species.

Key words *Juglans mandshurica*; Juglandaceae; (4*R*)-4-hydroxy-α-tetralone

Juglans mandshurica MAXIM. var. *sieboldiana* MAKINO (Juglandaceae, Japanese name: Onigurumi), a walnut tree, is widely planted in Japan. Several parts of this plant have been used in folk medicines and the fruit has been used for the treatment of chilblains and athlete's foot.[1] As far as we know, there is no report regarding the chemical constituents of the fruit of this plant distributed in Japan, though the isolation of several naphthalenyl glucosides, α-tetralonyl glucosides, and a phenolbutyric acid glucoside from *J. mandshurica* MAXIM. collected from a mountain area of Wuchang, Heilongjiang Province, China has been reported in the literature.[2,3] This paper describes the structural elucidation of four newly isolated enantiomerically pure α-tetralones [(4*S*)-**2**, (4*R*)-**2**, (4*S*)-**3** and (4*R*)-**3**] along with five known ones [(4*S*)-**1**, (4*R*)-**1**, (4*S*)-**4**, (4*S*)-**5** and (4*R*)-**5**], from the fruit of *J. mandshurica* MAXIM. var. *sieboldiana* MAKINO.

Compound **1**, $[\alpha]_D$ +14.5° ($CHCl_3$), was estimated as (4*S*)-4,8-dihydroxy-α-tetralone (isosclerone,[4—6] regiolone[7,8]) by comparing the spectral data and the optical rotation, with those reported in the literature, however, chiral HPLC analysis of **1** showed two peaks (**1a**: $[\alpha]_D$ +24.5°, **1b**: $[\alpha]_D$ −26.0°, the ratio of *ca.* 5 : 1). From their sign of the optical rotations[2,4—13] and comparison of the circular dichroism (CD) data (Fig. 1) with those of 4*S*- and 4*R*-configured isosclerone[4,13] and analogous compounds,[9,12,14] the absolute configurations at C-4 in **1a** and **1b** were determined to be *S* and *R*, respectively. This deduction was further supported by application of the exciton chirality method (see Experimental).[15] Consequently, the absolute structures of **1a** and **1b** were concluded to be (4*S*)[4—8] and (4*R*)-4,8-dihydroxy-α-tetralones,[13] respectively.

Compound **2** was obtained as an amorphous powder, $[\alpha]_D$ ±0° ($CHCl_3$). The molecular formula was determined to be $C_{11}H_{12}O_3$ by high-resolution (HR)-EI-MS. Its ^{1}H- and ^{13}C-NMR spectra were similar to those of **1**, however, they lacked signals from the C-8 chelated and C-4 hydroxyl groups of **1** and instead showed signals characteristic of a methoxyl [δ_H 3.59 (3H, s). δ_C 55.2] and non-chelated phenolic hydroxyl [δ_H 8.55 (1H, s)] groups. The ^{13}C-NMR signal at C-1 of **2** was shifted by −7.8 ppm in comparison with that of **1**. These features suggested that **2** was 5-hydroxy-4-methoxy-α-tetralone. This deduction was supported by ^{1}H-detcted heteronuclear multiple bond correlation (HMBC) experiment (Fig. 2). The optical rotation of **2** was almost zero and chiral HPLC analysis (see Experimental) indicated that **2** existed as a racemate (**2a**, **2b**; the ratio of *ca.* 1 : 1). As can be seen in Fig. 3, the CD Cotton effects of **2a** and **2b** were strongly dominated by the conformation of the cyclohexenone ring and the sign of the Cotton effect in the $\pi\rightarrow\pi^*$ region may be attributed to the axial-chirality effect of axial (and/or quasi-axial) H or a substituent at the α-position, adjacent to the carbonyl group.[16,17] Namely, the conformation of the cyclohexenone ring was determined as half-chair or sofa form on the basis of the nuclear Overhauser enhancement spectroscopy (NOESY) correlation [H-4/one of the methylene protons at C-2 (δ 2.58)] and the coupling constant of H-4 (dd, J=10.2, 4.4 Hz). The CD spectra of **2a** and **2b** showed strongly positive ($\Delta\varepsilon$ +5.8 at 221 nm) and negative ($\Delta\varepsilon$ −6.1 at 220 nm) Cotton effects, suggesting one of the methylene protons (δ 2.58) at C-2 had β- and α-quasi-axial orientations with respect to the cyclohexenone ring, respectively (Fig. 4). On the other hand, the sign of the weakly negative [**2a**: $\Delta\varepsilon$ −0.8 at 341 nm)] and positive [**2b**: $\Delta\varepsilon$ −0.8 at 340 nm)] Cotton effects (n→π^*) could be interpreted under

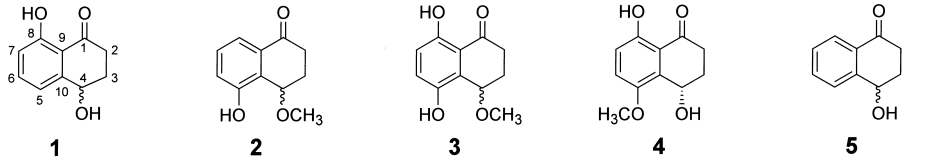

Chart 1

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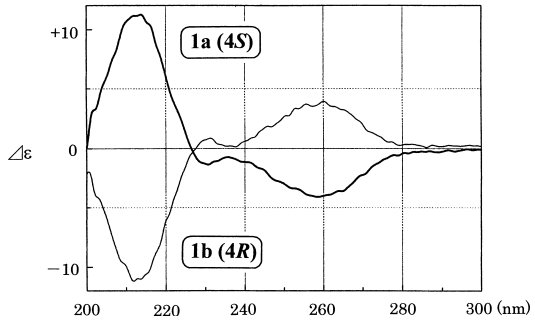

Fig. 1. The CD Spectra of **1a** (4*S*) and **1b** (4*R*) (MeOH)

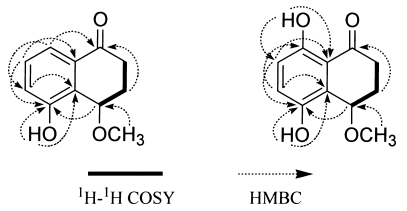

Fig. 2. ^{1}H–^{1}H COSY and HMBC Correlations of **2** and **3**

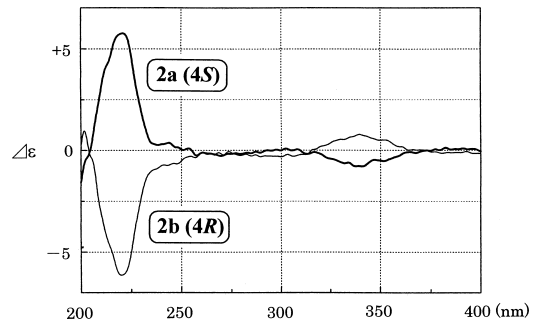

Fig. 3. The CD Spectra of **2a** (4*S*) and **2b** (4*R*) (MeOH)

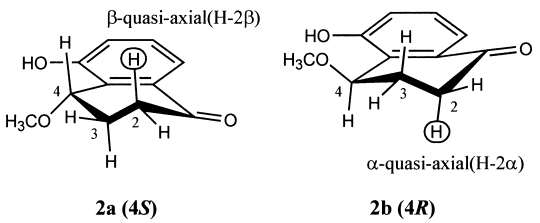

Fig. 4. Probably Conformations of Cyclohexenone Rings of **2a** and **2b**

the assumption that the half-chair form of the cyclohexenone ring is a more stable conformation than the sofa form in the molecular arrangement.[18] From the above CD effects, the absolute configuration at C-4 of **2a** and **2b** was assigned as *S* and *R*, and this conclusion is in agreement with the sign of the optical rotations[2,4—13] (**2a**: $[\alpha]_D$ +50.0°, **2b**: $[\alpha]_D$ −50.0°), respectively. On the basis of these results, the absolute structures of **2a** and **2b** were determined to be (4*S*)- and (4*R*)-5-hydroxy-4-methoxy-α-tetralones, respectively.

Compound **3** was obtained as an amorphous powder, $[\alpha]_D$ ±0° ($CHCl_3$). The molecular formula was determined to be $C_{11}H_{12}O_4$ by HR-EI-MS. The ^{1}H-NMR spectrum of **3** was similar to that of **2**, except for the presence of a C-8 chelated hydroxyl group [δ 12.1 (1H, s)]. Furthermore, there were remarkable differences in the ^{1}H-NMR spectrum, with the aromatic protons of **3** appearing as a pair of *ortho* coupled doublets (J=9.0 Hz) at δ 6.88 and 7.08. These features suggested that **3** was 5,8-dihydroxy-4-methoxy-α-tetralone. This deduction was supported by the HMBC experiment (Fig. 2). The conformation of the cyclohexenone ring of **3** was the same as that of **2** by the NOESY correlation [H-4/one of the methylene protons at C-2 (δ 2.59)] and the coupling constant of H-4 (dd, J=9.9, 4.3 Hz). The optical rotation of **3** was almost zero and chiral HPLC analysis indicated that **3** existed as a racemate (**3a**, **3b**; the ratio of *ca.* 1 : 1). Because the amounts of **3a** and **3b** were very small, the absolute configuration at C-4 of **3a** and **3b** could not be determined by their optical rotations. On the other hand, the CD Cotton effects of **3a** and **3b** were symmetrical opposites (Fig. 5). The CD spectrum of **3a** showed a strong positive Cotton effect at about 226 nm ($\Delta\varepsilon$ +5.9) and a weak negative one at 267 nm ($\Delta\varepsilon$ −1.4), which were similar to those of **1a** (4*S*) and (4*S*)-4,5,8-trihydroxy-α-tetralone,[2] whereas **3b** was the same signs of the Cotton effects on that of **1b** (4*R*), indicating that the absolute configuration at C-4 of **3a** is *S* and that of **3b** is *R*, respectively. On the basis of these results, the absolute structures of **3a** and **3b** were determined to be (4*S*)- and (4*R*)-5,8-dihydroxy-4-methoxy-α-tetralones, respectively.

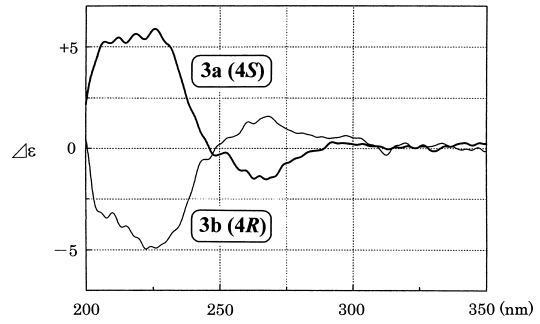

Fig. 5. The CD Spectra of **3a** (4*S*) and **3b** (4*R*) (MeOH)

The planar structure of compound **4** was identified by comparison of the spectroscopic data with published values as the known fungal metabolite 4,8-dihydroxy-5-methoxy-α-tetralone.[19] Chiral HPLC analysis of **4** showed a single peak under the same conditions and the optical rotation, $[\alpha]_D$ +13.5° ($CHCl_3$), exhibited a positive sign[2,4—13] which indicated that the absolute configuration at C-4 of **4** is, at least mainly, 4*S*-configured. The similar CD Cotton curves for **4** [$\Delta\varepsilon$ (nm): −1.18 (258), +4.56 (210)] and **3a** (4*S*) also helped to assign the absolute configuration at C-4 as *S*. Consequently, the structure of **4** was established as (4*S*)-4,8-dihydroxy-5-methoxy-α-tetralone. Buchanan *et al.*[19] reported the same plane structure with **4** from an unidentified species of the fungus, *Daldina*, but its absolute configuration at C-4 was not determined. The spectral data including the optical rotation, $[\alpha]_D$ +16.7° ($CHCl_3$), for the fungal metabolite reported in the literature were in good agreement with those of **4** having a 4*S*-configuration, indicating that the fungal metabolite seems to be identical with **4**. Therefore, this is the second isolation of **4** from a natural source.

Compound **5**, $[\alpha]_D$ +16.8° ($CHCl_3$), was estimated as (4*S*)-4-hydroxy-α-tetralone[2,8,11] by comparing the spectral data and the optical rotation with those reported in the literature, however, chiral HPLC analysis of **5** showed two peaks (**5a**, **5b**) in ratio *ca.* 10 : 1. From the above findings and the sign of the optical rotation of **5**,[2,4—13] the structure of **5** was

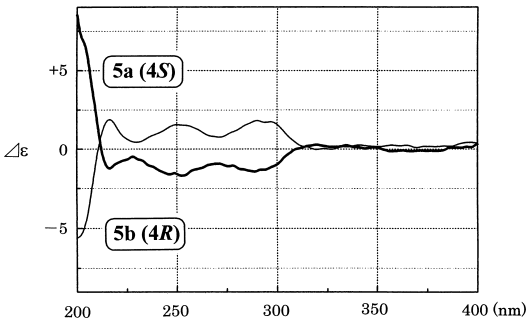

Fig. 6. The CD Spectra of **5a** (4*S*) and **5b** (4*R*) (MeOH)

identified as a mixture enriched with (4*S*)-enantiomer of 4-hydroxy-α-tetralone.[2,8,11] Because the amounts of **5a** and **5b** were very small, their absolute configurations at C-4 could not be determined by their optical rotations. On the other hand, the CD spectrum of **5a** was similar to that of (4*S*)-4-hydroxy-α-tetralone,[2] whereas **5b** exhibited CD Cotton effects of symmetrical opposites signs, indicating that the absolute configuration at C-4 of **5a** is *S* and that of **5b** is *R* (Fig. 6). On the basis of these results, the absolute structures of **5a** and **5b** were determined to be (4*S*)-[2,8,11] and (4*R*)-4-hydroxy-α-tetralones,[11] respectively. Compound **5b** (4*R*) was isolated from a natural source for the first time, however, **5b** (4*R*) has already been synthesized.[11]

The absolute configuration at C-4 of the 4-hydroxy-α-tetralone derivative isolated from *Juglans* species is all *S*, and to the best of our knowledge, this is the first isolation of the 4*R*-enantiomer from this species. However, racemic 4-hydroxy-α-tetralone derivatives are encountered in fungal metabolites,[20,21] and it is very interesting to note that **1** and **5** were comprised of a mixture enriched with the (4*S*)-enantiomers, while **2** and **3** occurred as a racemate in the same plant.

Experimental

General Experimental Procedures Optical rotations were measured on a JASCO DIP-360 digital polarimeter. UV spectra were recorded with a Beckman DU-64 spectrometer. The ^{1}H- and ^{13}C-NMR spectra were recorded with a JEOL JNM-GSX 400 (400 MHz, 100 MHz, respectively) spectrometer. Chemical shifts are given on a δ (ppm) scale with tetramethylsilane (TMS) as an internal standard. MS data were recorded on a JEOL JMS-303 mass spectrometer. The CD spectra were obtained with a JASCO J-720 spectropolarimeter. Column chromatography was carried out on Kieselgel 60 (Merck; 230—400 mesh). Preparative HPLC was carried out on a Tosoh HPLC system [pump, CCPS; detector, UV-8020]. Analytical TLC was performed on precoated silica gel plates (Merck, 0.25 mm thickness).

Plant Material The ripened fruit of *Juglans mandshurica* Maxim. var. *sieboldiana* Makino was collected near Nakano, Nagano prefecture, Japan, in September 2004 and identified by one of the authors (M. Kikuchi).

Extraction and Isolation The fruit of *J. mandshurica* Maxim. var. *sieboldiana* Makino (1.2 kg) was extracted with MeOH at room temperature for 20 d. The MeOH extract was concentrated under reduced pressure and the residue (57.0 g) was suspended in water. This suspension was successively extracted with $CHCl_3$, Et_2O, AcOEt, *n*-BuOH and H_2O. The $CHCl_3$-soluble fraction was concentrated under reduced pressure to produce a residue (3.0 g). The extract was chromatographed on a silica gel column using an *n*-hexane–AcOEt gradient, and the eluate was separated into thirteen fractions (frs. 1—13). Fraction 9 was subjected to prep. HPLC [column, Cosmosil 5C_{18}-AR (10 mm i.d.×25 cm, Nacalai Tesque); mobile phase, MeOH–H_2O (2 : 3); UV detector, 205 nm; flow rate, 1.5 ml/min; column temp., 40 °C] to give two peaks (peaks 1, 2). Peak 1 was purified by prep. HPLC [column, TSK gel OH-120 (7.8 mm i.d.×30 cm, Tosoh); mobile phase, *n*-hexane–EtOH (19 : 1); UV detector, 205 nm; flow rate, 1.5 ml/min; column temp., 27 °C] to give **1** (4.5 mg) and **2** (1.2 mg). Peak 2 was purified by prep. HPLC [column, TSK gel ODS-120A (7.8 mm i.d.×30 cm, Tosoh); mobile phase, MeOH–H_2O (1 : 3); UV detector, 205 nm; flow rate, 1.5 ml/min; column temp., 40 °C] to give **3** (0.5 mg) and **4** (1.1 mg). Fraction 10 purified by prep. HPLC [column, Cosmosil 5C_{18}-AR (10 mm i.d.×30 cm); mobile phase, MeOH–H_2O (2 : 3); UV detector, 205 nm; flow rate, 1.5 ml/min; column temp., 40 °C] to give **5** (0.9 mg).

4,8-Dihydroxy-α-tetralone (**1**) [**1a** (4*S*), **1b** (4*R*). *ca.* 5 : 1]: Amorphous powder, $[\alpha]_D^{27}$ +14.5° (*c*=0.33, $CHCl_3$). UV λ_{max} (MeOH) nm (log ε): 330 (3.48), 257 (3.85), 214 (4.12). EI-MS *m/z* (rel. int): 178 (M^+, 100), 160 (14), 150 (31), 132 (20), 121 (85). HR-EI-MS *m/z*: 178.0612 (M^+, Calcd for $C_{10}H_{10}O_3$: 178.0630). The NMR data were identified with those of reported data.[4—8,13]

Chiral HPLC Analysis of Compound 1 Compound **1** was analyzed by chiral HPLC [column, Chiralcel OD (4.6 mm i.d.×25 cm, Daicel); mobile phase, *n*-hexane–iso PrOH (19 : 1); UV detector, 250 nm; flow rate, 0.7 ml/min; column temp., 27 °C]. Compound **1** exhibited two peaks at 26.3 and 29.6 min at a ratio of *ca.* 5 : 1, and separation of **1** into its enantiomers [**1a** (4*S*, 2.8 mg), **1b** (4*R*, 0.5 mg)] was achieved.

(4*S*)-4,8-Dihydroxy-α-tetralone [**1a** (4S)]: Amorphous powder, $[\alpha]_D^{27}$ +24.5° (*c*=0.14, $CHCl_3$). CD (*c*=1.46×10^{-4} M, MeOH) $\Delta\varepsilon$ (nm): −4.1 (259), +11.3 (214).

(4*R*)-4,8-Dihydroxy-α-tetralone [**1b** (4*R*)]: Amorphous powder, $[\alpha]_D^{27}$ −26.0° (*c*=0.03, $CHCl_3$). CD (*c*=1.15×10^{-4} M, MeOH) $\Delta\varepsilon$ (nm): +3.9 (260), −11.2 (212).

Benzoylation of 1a (4*S*) and 1b (4*R*) A solution of **1a** (4*S*) (1.4 mg) or **1b** (4*R*) (0.3 mg) in benzoyl chloride (50 μl) and pyridine (50 μl) was allowed to stand at room temp. for 24 h. The reaction mixture was poured into H_2O and extracted with Et_2O. The Et_2O extract was washed with saturated aqueous $NaHCO_3$. The Et_2O was evaporated and the residue was purified by prep. HPLC [column, TSK gel ODS-120T (7.8 mm i.d.×30 cm, Tosoh); mobile phase, MeOH–H_2O (3 : 1); UV detector, 250 nm; flow rate, 1.5 ml/min; column temp., 27 °C] to give **1a-B** (1.7 mg) and **1b-B** (0.3 mg), respectively.

(4*S*)-4,8-Dibenzoyloxy-α-tetralone (**1a-B**): Amorphous powder, $[\alpha]_D^{27}$ −123.7° (*c*=0.14, $CHCl_3$). UV λ_{max} (MeOH) nm (log ε): 280 (3.50), 231 (4.51), 207 (4.39). EI-MS *m/z*: 386 (M^+). HR-EI-MS *m/z*: 386.1152 (M^+, Calcd for $C_{24}H_{18}O_5$: 386.1154). ^{1}H-NMR (400 MHz, $CDCl_3$) δ: 8.25 (2H, m), 8.23 (2H, m), 7.46—7.65 (8H, m), 7.26 (1H, m), 6.42 (1H, dd, *J*=6.2, 3.7 Hz, H-4), 2.97 (1H, ddd, *J*=17.6, 9.5, 5.1 Hz, H-2$_B$), 2.70 (1H, ddd, *J*=17.6, 7.0, 4.8 Hz, H-2$_A$), 2.52 (1H, dddd, *J*=13.5, 9.5, 4.8, 3.7 Hz, H-3$_B$), 2.45 (1H, dddd, *J*=13.5, 7.0, 6.2, 5.1 Hz, H-3$_A$). CD (*c*=3.77×10^{-5} M, MeOH) $\Delta\varepsilon$ (nm): −18.3 (240), +14.4 (222), +27.3 (202).

(4*R*)-4,8-Dibenzoyloxy-α-tetralone (**1b-B**): Amorphous powder, $[\alpha]_D^{27}$ +135.0° (*c*=0.018, $CHCl_3$). UV λ_{max} (MeOH) nm (log ε): 280 (3.51), 230 (4.48), 205 (4.42). EI-MS *m/z*: 386 (M^+). HR-EI-MS *m/z*: 386.1150 (M^+, Calcd for $C_{24}H_{18}O_5$: 386.1154). ^{1}H-NMR (400 MHz, $CDCl_3$) δ: 8.25 (2H, m), 8.23 (2H, m), 7.46—7.65 (8H, m), 7.26 (1H, m), 6.42 (1H, dd, *J*=6.2, 3.7 Hz, H-4), 2.97 (1H, ddd, *J*=17.6, 9.5, 5.1 Hz, H-2$_B$), 2.70 (1H, ddd, *J*=17.6, 7.0, 4.8 Hz, H-2$_A$), 2.52 (1H, dddd, *J*=13.5, 9.5, 4.8, 3.7 Hz, H-3$_B$), 2.45 (1H, dddd, *J*=13.5, 7.0, 6.2, 5.1 Hz, H-3$_A$). CD (*c*=3.50×10^{-5} M, MeOH) $\Delta\varepsilon$ (nm): +16.1 (240), −10.9 (222), −25.9 (203).

5-Hydroxy-4-methoxy-α-tetralone (**2**) [**2a** (4*S*), **2b** (4*R*). *ca.* 1 : 1]: Amorphous powder, $[\alpha]_D^{27}$ ±0° (*c*=0.09, $CHCl_3$). UV λ_{max} (MeOH) nm (log ε): 315 (3.15), 256 (3.52), 221 (3.95), 205 (3.80). EI-MS *m/z* (rel. int): 192 (M^+, 43), 160 (100), 149 (8), 132 (38), 131 (56). HR-EI-MS *m/z*: 192.0817 (M^+, Calcd for $C_{11}H_{12}O_3$: 192.0787). ^{1}H- and ^{13}C-NMR: Table 1.

Chiral HPLC Analysis of Compound 2 Compound **2** was analyzed by chiral HPLC under the conditions described above. Compound **2** exhibited two peaks at 28.8 and 48.8 min at a ratio of *ca.* 1 : 1, and separation of **2** into its enantiomers [**2a** (4*S*, 0.5 mg), **2b** (4*R*, 0.5 mg)] was achieved.

(4*S*)-5-Hydroxy-4-methoxy-α-tetralone [**2a** (4*S*)]: Amorphous powder, $[\alpha]_D^{27}$ +50.0° (*c*=0.03, $CHCl_3$). CD (*c*=1.36×10^{-4} M, MeOH) $\Delta\varepsilon$ (nm): −0.8 (341), +5.8 (221).

(4*R*)-5-Hydroxy-4-methoxy-α-tetralone [**2b** (4*R*)]: Amorphous powder, $[\alpha]_D^{27}$ −50.0° (*c*=0.03, $CHCl_3$). CD (*c*=1.28×10^{-4} M, MeOH) $\Delta\varepsilon$ (nm): +0.8 (340), −6.1 (220).

5,8-Dihydroxy-4-methoxy-α-tetralone (**3**) [**3a** (4*S*), **3b** (4*R*). *ca.* 1 : 1]: Amorphous powder, $[\alpha]_D^{27}$ ±0° (*c*=0.072, $CHCl_3$). UV λ_{max} (MeOH) nm (log ε): 369 (3.24), 262 (3.59), 228 (3.79), 207 (3.84). EI-MS *m/z* (rel. int.): 208 (M^+, 16), 176 (100), 148 (27), 147 (30), 121 (30). HR-EI-MS *m/z*: 208.0719 (M^+, Calcd for $C_{11}H_{12}O_4$: 208.0735). ^{1}H- and ^{13}C-NMR: Table 1.

Chiral HPLC Analysis of Compound 3 Compound **3** was analyzed by chiral HPLC under the conditions described above. Compound **3** exhibited two peaks at 21.5 and 23.5 min at a ratio of *ca.* 1 : 1, and separation of **3** into its enantiomers [**3a** (4*S*, 0.12 mg), **3b** (4*R*, 0.11 mg)] was achieved.

Table 1. ^{1}H (400 MHz)- and ^{13}C (100 MHz)-NMR Chemical Shifts of **2** and **3** ($CDCl_3$)

	2		**3**	
	δ_H	δ_C	δ_H	δ_C
1	—	196.4	—	203.0
2	2.58 m	35.9	2.59 ddd (17.3, 12.7, 4.6)	35.4
	2.85 ddd (16.6, 6.8, 4.0)		2.85 br dt (17.3, 4.6)	
3	2.17 br ddd (13.7, 10.2, 4.0)	27.0	2.17 br ddd (12.7, 9.9, 4.6)	31.4
	2.51 m		2.49 ddt (12.7, 4.6, 4.3)	
4	5.01 dd (10.2, 4.4)	77.3	4.93 dd (9.9, 4.3)	77.2
5	—	156.2	—	147.6
6	7.10 dd (7.8, 1.2)	122.3	7.08 d (9.0)	127.0
7	7.31 t (7.8)	129.6	6.88 d (9.0)	118.9
8	7.60 dd (7.8, 1.2)	119.2	—	156.9
9	—	132.7	—	115.0
10	—	126.6	—	124.1
5-OH	8.55 s	—	7.86 s	—
8-OH	—	—	12.1 s	—
OCH_3	3.59 s	55.2	3.56 s	55.4

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

(4*S*)-5,8-Dihydroxy-4-methoxy-α-tetralone [**3a** (4*S*)][22]: Amorphous powder, CD ($c=6.48\times10^{-5}$ M, MeOH) $\Delta\varepsilon$ (nm): −1.4 (267), +5.9 (226).

(4*R*)-5,8-Dihydroxy-4-methoxy-α-tetralone [**3b** (4*R*)][22]: Amorphous powder, CD ($c=6.71\times10^{-5}$ M, MeOH) $\Delta\varepsilon$ (nm): +1.6 (268), −5.0 (222).

(4*S*)-4,8-Dihydroxy-5-methoxy-α-tetralone [(4*S*)-**4**]: Amorphous powder, $[\alpha]_D^{27}$ +13.5° ($c=0.08$, $CHCl_3$). UV λ_{max} (MeOH) nm (log ε): 365 (3.44), 259 (3.70), 230 (4.04), 210 (3.97). EI-MS *m/z* (rel. int.): 208 (M^+, 100), 190 (12), 180 (11), 175 (28), 165 (10), 151 (25), 137 (27). HR-EI-MS *m/z*: 208.0711 (M^+, Calcd for $C_{11}H_{12}O_4$: 208.0735). CD ($c=7.08\times10^{-5}$ M, MeOH) $\Delta\varepsilon$ (nm): −1.18 (258), +4.56 (210). The NMR data were identified with those of reported data.[19]

Chiral HPLC Analysis of Compound 4 Compound **4** was analyzed by chiral HPLC under the conditions described above. Compound **4** exhibited a single peak at 26.3 min.

4-Hydroxy-α-tetralone (**5**) [**5a** (4*S*), **5b** (4*R*). *ca.* 10 : 1]: Amorphous powder, $[\alpha]_D^{27}$ +16.8° ($c=0.08$, $CHCl_3$). UV λ_{max} (MeOH) nm (log ε): 285 (3.13), 246 (3.85), 205 (4.08). EI-MS *m/z* (rel. int.): 162 (M^+, 50), 144 (10), 134 (72), 105 (100). HR-EI-MS *m/z*: 162.0696 (M^+, Calcd for $C_{10}H_{12}O_2$: 162.0680). The NMR data were identified with those of reported data.[2,8,11]

Chiral HPLC Analysis of Compound 5 Compound **5** was analyzed by chiral HPLC under the conditions described above. Compound **5** exhibited two peaks at 27.0 and 29.8 min at a ratio of *ca.* 10 : 1, and separation of **5** into its enantiomers [**5a** (4*S*, 0.8 mg), **3b** (4*R*, 0.09 mg)] was achieved.

(4*S*)-4-Hydroxy-α-tetralone [**5a** (4*S*)][22]: Amorphous powder, CD ($c=8.78\times10^{-5}$ M, MeOH) $\Delta\varepsilon$ (nm): −1.4 (289), −1.7 (253), −1.2 (216), +7.0 (202 sh).

(4*R*)-4-Hydroxy-α-tetralone [**5b** (4*R*)][22]: Amorphous powder, CD ($c=5.51\times10^{-5}$ M, MeOH) $\Delta\varepsilon$ (nm): +1.4 (290), +0.9 (256), +1.7 (217), −6.0 (202).

Acknowledgments The authors are grateful to Mrs. S. Sato and T. Matsuki of Tohoku Pharmaceutical University for conducting the NMR and MS measurements.

References and Notes

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