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Biogenetically Patterned Transformation of Eudesmanolide to Eremophilanolide. IV.[1] Conversion of Alantolactone to Several Furanoeremophilane Derivatives

Isao Kitagawa, Hirotaka Shibuya, and Machiko Kawai

Faculty of Pharmaceutical Sciences, Osaka University[2]

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Biogenetic-type conversions of an eudesmane-type sesquiterpene alantolactone (**4**) to several furanoeremophilanes (**10a**, **10b**, **12a**, **12b**) including naturally occurring 6-acetoxy-1,10-epoxy-euryopsin (**12b**) have been accomplished. The conversions constitute the formal total syntheses of these furanoeremophilanes *via* the biogenetic-type angular methyl migration of the eudesmane-type precursor. It has been also demonstrated that the biogenetic-type transformation starting from the eudesmane-type 5α,6α-epoxide may be a useful process in the synthetic pathway of eremophilane-type sesquiterpene.

Keywords——biogenetic-type transformation; alantolactone; 5α,6α-epoxy-eudesman-8β,12-olide; eremophilane-type butenolide; synthesis of furanoeremophilane; 6-acetoxy-1,10-epoxy-euryopsin

Recently, we have reported a successful biogenetic-type transformation of an eudesmanolide to related eremophilanolides *via* a 1,2-shift of the angular methyl at C-10 of the eudesmanolide.[1,3] The transformation was accomplished by treatment of 5α,6α-epoxy-eudesman-8β,12-olide (**1**) with formic acid in acetone under reflux to furnish several eremophilanolides (*e.g.* **2**, **3**). This was the first example of biogenetic-type direct conversion of an eudesmane-type sesquiterpene leading to eremophilane-type derivatives.

Since the conversion of **1** to **2** and **3** was achieved in good yields,[3b] we have next attempted to apply this reaction step for the synthesis of eremophilane-type sesquiterpene, and the object has been attained by starting with alantolactone 5α,6α-epoxide (**5**). As described in the present paper, a transformation product (**6**), which was obtained by formic acid treatment of **5**, has been converted to several furanoeremophilane derivatives. Since alantolactone (**4**)[4] has been already synthesized by Marshall, *et al.*,[4b,c] the present derivations constitute formal total syntheses of these furanoeremophilanes through the biogenetic-type angular methyl migration.

Acid Treatment of Alantolactone 5α,6α-Epoxide (5)

An epoxide (**5**), which was prepared by *m*-chloroperbenzoic acid oxidation of alantolactone (**4**), has been assigned as the 5α,6α-epoxide of **4** on the basis of its infrared (IR) and proton magnetic resonance (PMR) spectra: an absorption band at 985 cm^{-1} for an epoxide function; a doublet of $J=3$ Hz at δ 2.89 for 6-H, and two doublets of $J=3$ Hz each at δ 5.73 and δ 6.33

1) Part III: I. Kitagawa, H. Takeno, H. Shibuya, and I. Yosioka, *Chem. Pharm. Bull.* (Tokyo), **23**, 2686 (1975).
2) Location: *133–1, Yamada-kami, Suita, Osaka, 565, Japan.*
3) *a*) I. Kitagawa, Y. Yamazoe, R. Takeda, and I. Yosioka, *Tetrahedron Lett.*, **1972**, 4843; *b*) I. Kitagawa, Y. Yamazoe, H. Shibuya, R. Takeda, H. Takeno, and I. Yosioka, *Chem. Pharm. Bull.* (Tokyo), **22**, 2662 (1974); *c*) I. Kitagawa, H. Shibuya, Y. Yamazoe, H. Takeno, and I. Yosioka, *Tetrahedron Lett.*, **1974**, 111; *d*) I. Kitagawa, H. Shibuya, H. Takeno, T. Nishino, and I. Yosioka, *Chem. Pharm. Bull.* (Tokyo), **24**, 56 (1976).
4) *a*) K. Tsuda, K. Tanabe, I. Iwai, and K. Funakoshi, *J. Am. Chem. Soc.*, **79**, 5721 (1957); *b*) J.A. Marshall and N. Cohen, *J. Org. Chem.*, **29**, 3727 (1964); *c*) J.A. Marshall, N. Cohen, and A.R. Hochstetler, *J. Am. Chem. Soc.*, **88**, 3408 (1966).

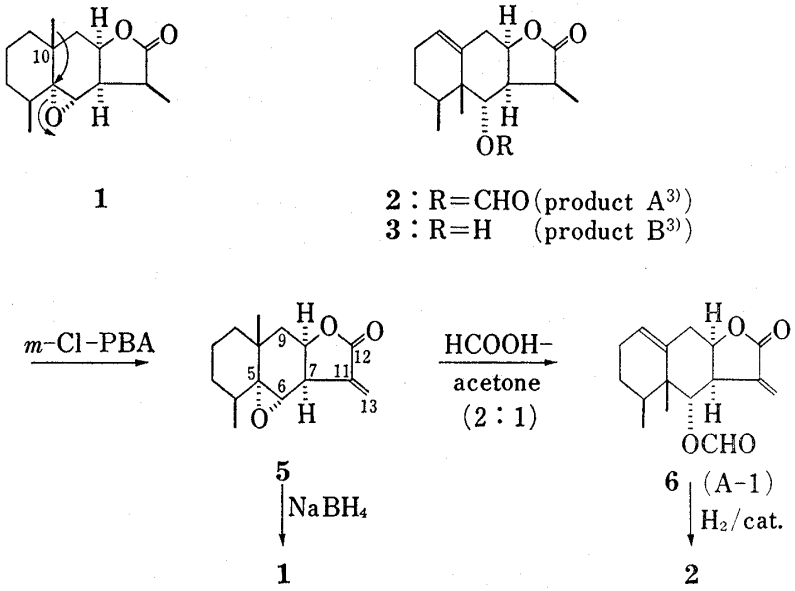

Chart 1

Table I. Spin Decoupling Experiments of **6** (90 MHz)

Decoupled proton (δ)	Irradiated at δ					
	5.46 (6-H)	3.23 (7-H)	4.67 (8-H)	2.74 (9-H_A)[a]	5.75 (13-H_A)	6.34 (13-H_B)
1-H (5.60, m)				Varied		
6-H (5.46, d)	—	Singlet				
7-H (3.23, d.d.d.d.)	Varied	—	Varied		Varied	Varied
8-H (4.67, d.t)		Triplet-like	—	Varied		
9-H_A (2.74, d.d)			Broad singlet	—		
13-H_A (5.75, d)		Singlet			—	
13-H_B (6.34, d)		Singlet				—

a) One of two protons at C-9.

for terminal methylene protons (13-H_2), and on the basis of derivation of **5** to 5α,6α-epoxy-eudesman-8β,12-olide (**1**)[3] by sodium borohydride reduction.

Treatment of the epoxide (**5**) with a formic acid–acetone (2: 1) mixture under reflux[3b] afforded a product (**6**, designated as A-1) in an 87% yield. The IR spectrum of A-1 (**6**) exhibits absorption bands due to γ-lactone (1772 cm^{-1}), ester (1728 cm^{-1}), and double bond (1668 cm^{-1}), while the PMR spectrum shows the presence of one tertiary methyl (δ 0.93, s, 5-CH_3), one secondary methyl (δ 0.83, d, J= 7 Hz, 4-CH_3), three olefinic protons (1H at δ 5.60, m, 1-H; 1H each at δ 5.75 and δ 6.34, each d, J= 3 Hz, 13-H_2), and two methine protons of which one is geminal to a lactonic carboxyl function (δ 4.67, d.t, J= 8 and 7 Hz, 8-H), and another to a formyloxyl function (δ 5.46, d, J= 3.5 Hz, 6-H). The spin-decoupling experiments of **6** (Table I) support the formulation of **6** and among these results, the change of a one-proton doublet at δ 5.46 (6-H) to a singlet upon irradiation at δ 3.23 (7-H) is a positive evidence for assuming the presence of a tertiary methyl at C-5[3a,b] and the alteration of a one-proton multiplet at δ 5.60 (1-H) upon irradiation at δ 2.74 (9-H_A) is indicative of the location of double bond in **6** being at C-1,10. The structure **6** has been finally established by quantitative conversion of **6** to **2** (product A[3]) through homogeneous catalytic hydrogenation over tris(triphenylphosphine)rhodium chloride,[5] thus alantolactone (**4**) being transformed to an eremophilane-type compound (**6**) in a high yield.

5) A.J. Birch and K.A.M. Walker, *J. Chem. Soc.* (*C*), **1966**, 1894.

Conversion of 6 to Several Furanoeremophilanes (10a, 10b, 12a, 12b)

Next, conversion of **6** to several furanoeremophilane-type compounds, which possess an oxygen function at C-6, has been carried out. Since most of hitherto known furanoeremophilanes possess a C-6 oxygen function of β configuration, in order to accomplish the desired conversion, it has become necessary to reverse the configuration of C-6α oxygen function in **6** together with modification of the α-methylene-γ-lactone moiety to a furan ring.

Alkaline treatment of **6** followed by regeneration of the lactone ring with acid gave a 6α-hydroxyl derivative (**7**), whose structure has been substantiated by the IR (3600 cm^{-1} for hydroxyl) and PMR (Table II) spectra. Chromium trioxide oxidation of **7** afforded a keto-lactone (**8**), which possesses a ketone function (IR: 1702 cm^{-1}) and a butenolide moiety (IR: 1764, 1658 cm^{-1}; ultraviolet (UV) spectrum: λ_{max} 237 nm, ε=9950). As is apparent from the PMR spectrum of **8** (Table II), signals due to a terminal methylene (13-H_2) in **7** have disappeared, and instead an olefinic methyl signal is newly observed at δ 2.00. It has become clear

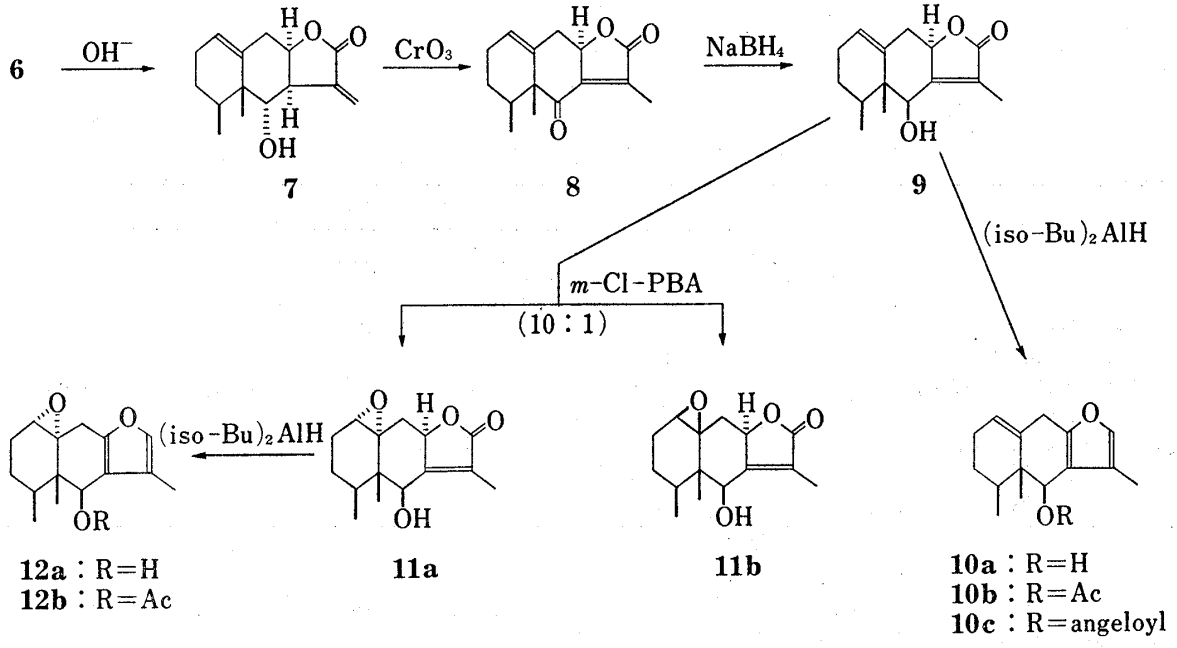

Chart 2

TABLE II. PMR Data of **7**, **8**, **9**, **11a**, and **11b**[a]
(Coupling Constants in Parentheses are given in Hz)

	7	8	9	11a	11b[b]
1-H	5.88(m)	5.91(m)	5.73(m)	3.05(t, 3)	3.23(br. d)
6-H	3.98(d, 6)	—	4.33(br. s)	[c]	[d]
7-H	3.23(m)	—	—	—	—
8-H	4.66(d.t, 6 and 7)	4.79(m)	4.45(m)	[c]	[d]
13-H_2	5.66(d, 3) 6.26(d, 3)	—	—	—	—
4-CH_3	1.00(d, 7)	1.12(d, 7)	1.09(d, 7)	1.07(d, 7)	1.05(d, 7)
5-CH_3	0.96(s)	1.08(s)	0.91(s)	0.93(s)	1.10(s)
11-CH_3	—	2.00(d, 2)	2.04(t, 2)	2.05(t, 1)	2.20(t, 1)

a) Abbreviations: br.d=broad doublet. br.s=broad singlet, d=doublet, d.t=doublet of triplet, m=multiplet, s=singlet, t=triplet.
b) Taken in pentadeuteropyridine.
c) A two-proton multiplet for 6-H and 8-H is observed between δ 4.70—4.95.
d) A two-proton multiplet for 6-H and 8-H is observed between δ 4.95—5.05.

that the double bond at C-11,13 in **7** is isomerized to C-7,11 in **8** by concomitant conjugation with the carbonyl function at C-6.

Reduction of **8** with sodium borohydride gave quantitatively a 6β-hydroxy-butenolide (**9**), whose spectral properties are consistent with the structure: IR (3618, 1749, and 1680 cm^{-1}), UV (λ_{max} 232 nm, ε=8700), and PMR (Table II). The 6β-hydroxyl configuration of **9** follows stereochemical considerations for the sodium borohydride reduction. On reduction of **9** with diisobutylaluminum hydride in toluene,[6] a furan derivative (**10a**) was obtained. The IR spectrum of **10a** shows absorption bands ascribable to hydroxyl (3440 cm^{-1}), double bond (1630 cm^{-1}), and a furan ring (1562, 1035, and 890 cm^{-1}) whereas the UV spectrum also shows the presence of a furan ring in **10a** (λ_{max} 219 nm, ε=6000). In the PMR spectrum of **10a** (Table III), a one-proton broad singlet at δ 6.89 is assigned to 12-H (α in the furan ring) and is involved in a long-range coupling with a three-proton doublet at δ 2.02 (J= 1 Hz) assignable to 11-CH_3 (β in the furan ring), thus the structure **10a** being confirmed.

On acetylation of **10a** with acetic anhydride and pyridine, was obtained a monoacetate (**10b**)(IR: 1734 cm^{-1}, no hydroxyl). The PMR data of **10b** are quite alike those reported for naturally occurring 6-angeloyloxy-euryopsin (**10c**)[7] except signals due to their acyl functions, thus supporting the structure assignment of **10c**, which was previously proposed by Bohlmann, *et al.*[7] on the basis of spectroscopic evidence.

TABLE III. PMR Data of **10a**, **10b** **12a**, and **12b**[a]

	10a	**10b**	**12a**	**12b**
1-H	5.56(m)	5.63(m)	2.97(m)	3.02(m)
6-H	4.54(m)	6.07(d.d, 2 and 3)	4.75(m)	6.17(m)
12-H	6.89(br. s)[b]	6.96(br. s)[c]	7.05(br. s)	7.04(br. s)
4-CH_3	1.02(d, 7)	0.93(d, 7)	1.05(d, 7)	1.14(d, 7)
5-CH_3	0.94(s)	1.03(s)	0.99(s)	1.24(s)
11-CH_3	2.02(d, 1)[b]	1.82(d, 1)[c]	2.01(d, 1)	1.85(br. s)
$OCOCH_3$	—	2.12(s)	—	2.08(s)

a) Abbreviations: d.d=doublet of doublet, and others are same as in Table II.
b, c) These assignments were respectively confirmed by the spin-decoupling experiments.

On the other hand, *m*-chloroperbenzoic acid oxidation of **9** furnished two epoxides (**11a**, **11b**) in a 10:1 ratio. Based on their spectral properties, the major (**11a**) and minor (**11b**) epoxides have been considered isomeric each other in regard to their epoxide ring configurations. They have been assigned as 1α,10α-epoxide (**11a**) for the major and 1β,10β-epoxide (**11b**) for the minor on the basis of more favored attack of the reagent from the α-side of **9**. Reduction of **11a** with diisobutylaluminum hydride in tetrahydrofuran yielded an epoxy-furan (**12a**). The IR spectrum of **12a** shows the presence of hydroxyl (3400 cm^{-1}), a furan ring (1564, 1040, and 889 cm^{-1}) and an epoxide function (985 cm^{-1}) while the UV spectrum shows an absorption maximum due to a furan ring (λ_{max} 218 nm, ε=5500). In the PMR spectrum of **12a** (Table III), as in the case of **10a**, signals due to α-proton (δ 7.05, br.s, 12-H) and β-methyl (δ 2.01, d, J=1 Hz, 11-CH_3) on the furan ring are observed, thus the structure **12a** being confirmed. Acetylation of **12a** gave a monoacetate (**12b**) whose physical properties are consistent with those reported for naturally occurring 6-acetoxy-1,10-epoxy-euryopsin[7] thus offering a further support for the structure **12b** proposed by Bohlmann, *et al.*[7]

As a conclusion, the successful conversion of an eudesmane-type sesquiterpene alantolactone (**4**) to several furanoeremophilanes (**10a**, **10b**, **12a**, **12b**) has been accomplished. It has been demonstrated that the present biogenetic-type transformation may be a useful pathway

6) H. Minato and T. Nagasaki, *J. Chem. Soc.* (*C*), **1966**, 377.
7) F. Bohlmann, C. Zdero, and N. Rao, *Chem. Ber.*, **105**, 3523 (1972).

for the synthesis of eremophilane-type sesquiterpene, for example, *via* a pre-synthesized 5α,-6α-epoxy-eudesmanolide.

Experimental[8]

Epoxidation of Alantolactone (4) giving 5——To a solution of **4** (1.0 g) in CH_2Cl_2 (12 ml) was added dropwise a solution of *m*-chloroperbenzoic acid (895 mg) in CH_2Cl_2 (15 ml). The total mixture was kept stirring at room temperature for one hour, treated with 10% aq. Na_2SO_3, and extracted with CH_2Cl_2. The CH_2Cl_2 extract was washed successively with 5% aq. $NaHCO_3$ and water, and dried over $MgSO_4$. Evaporation of the solvent gave **5** (1.05 g), which was recrystallized from EtOH to give colorless needles of mp 149°, $[\alpha]_D^{26}$ +94.8° (c=1.0, $CHCl_3$). *Anal.* Calcd. for $C_{15}H_{20}O_3$: C, 72.55; H, 8.12. Found: C, 72.36; H, 8.12. IR $\nu_{max}^{CHCl_3}$ cm^{-1}: 1762, 1661, 985. PMR ($CDCl_3$) δ: 1.04 (3H, d, J=7 Hz, 4-CH_3), 1.11 (3H, s, 10-CH_3), 2.89 (1H, d, J=3 Hz, 6-H), 3.65 (1H, d.d.d.d, J=9, 3, 3, and 2.5 Hz, 7-H), 4.64 (1H, d.d.d, J=9, 4.5, and 2 Hz, 8-H), 5.73 (1H, d, J=2.5 Hz, 13-H_A), 6.33 (1H, d, J=3 Hz, 13-H_B). MS *m/e* (%): 248 (M^+, 23), 109 (100).

$NaBH_4$ Reduction of 5 giving 1——To a solution of **5** (10 mg) in MeOH (2 ml) was added $NaBH_4$ (5 mg), and the total solution was kept stirring at room temperature for 75 min, treated with 3 drops of 10% aq. H_2SO_4 and water. The precipitate was collected by filtration and crystallized from EtOH to give a product (5.4 mg) which was identified with **1** by mixed melting point, thin-layer chromatography (TLC) ($CHCl_3$–ether=5: 1, *n*-hexane–ether=1: 1, *n*-hexane–acetone=10: 1), gas–liquid chromatography (GLC), and IR (KBr).

Treatment of 5 with HCOOH-Acetone (2: 1) giving 6——A solution of **5** (1.8 g) in acetone (freshly distilled, 30 ml) and 99% HCOOH (60 ml) was refluxed under nitrogen atmosphere for one hour. After cooling, the reaction mixture was neutralized with 5% aq. KOH and extracted with ether. The ether extract was washed successively with sat. aq. $NaHCO_3$ and water, and worked up in the usual manner. An oily product (1.91 g) thus obtained was purified by column chromatography (silica gel, 45 g, *n*-hexane–ether=4: 1) to give A-1 (**6**, 1.8 g). **6**, colorless oil, $[\alpha]_D^{13}$ −20° (c=1.0, $CHCl_3$). IR ν_{max}^{film} cm^{-1}: 1772, 1728, 1668. PMR ($CDCl_3$) δ: 0.87 (3H, d, J=7 Hz, 4-CH_3), 0.93 (3H, s, 5-CH_3), 3.23 (1H, d.d.d.d, J=8, 3, 3, and 3.5 Hz, 7-H), 4.67 (1H, d.t, J=8 and 7 Hz, 8-H), 5.46 (1H, d, J=3.5 Hz, 6-H), 5.60 (1H, m, 1-H), 5.75 (1H, d, J=3 Hz, 13-H_A), 6.34 (1H, d, J=3 Hz, 13-H_B), 8.03 (1H, s, OCHO). MS *m/e* (%): 276 (M^+, 10), 230 (100). High resolution MS *m/e*: Found: 276.136; Calcd. for $C_{16}H_{20}O_4$ (M^+) 276.136.

Homogeneous Catalytic Hydrogenation of 6 giving 2——To a solution of **6** (7 mg) in dry benzene (1.5 ml) was added tris(triphenylphosphine)rhodium chloride (12 mg), and the total solution was shaken under hydrogen atmosphere for 1.5 hr. After removing benzene under reduced pressure, the residue was purified by column chromatography (alumina 2 g, *n*-hexane–ether=2: 1) to give a product (4 mg) which was identified with **2** (product A[3]) by TLC ($CHCl_3$–ether=5: 1), GLC, and $[\alpha]_D$.

Deformylation of 6 giving 7——To a solution of **6** (1.05 g) in benzene (14 ml) was added 5% aq. KOH (20 ml), and the total mixture was refluxed for 30 min with stirring. After cooling, the reaction mixture was acidified with 5% aq. HCl and extracted with EtOAc. The EtOAc extract was then treated with 5% aq. HCl (to adjust pH<1), and heated at 60° for 5 min, washed successively with sat. aq. $NaHCO_3$ and water, and worked up in the usual manner to give **7** (934 mg), mp 110—110.5°, colorless needles (recrystallized from *n*-hexane–ether), $[\alpha]_D^{14}$ −57° (c=1.0, $CHCl_3$). *Anal.* Calcd. for $C_{15}H_{20}O_3$: C, 72.55; H, 8.12. Found: C, 72.33; H, 8.12. IR $\nu_{max}^{CHCl_3}$ cm^{-1}: 3600, 1762, 1662. PMR ($CDCl_3$) δ: as given in Table II. MS *m/e* (%): 248 (M^+, 6), 43 (100).

CrO_3 Oxidation of 7 giving 8——To a stirred solution of **7** (934 mg) in acetone (25 ml) was added dropwise Jones reagent[9] at 0° (the sufficient consumption of the reagent was monitored by change of the color). After keeping stirred at room temperature for 40 min, the reaction mixture was treated with ice-water and extracted with ether. The ether extract was washed successively with sat. aq. $NaHCO_3$ and water, and worked up in the usual manner. An oily product (462 mg) thus obtained was purified by column chromatography (silica gel 11 g, $CHCl_3$–ether=20: 1) to give **8** (380 mg), mp 105°, colorless needles (recryst. from acetone), $[\alpha]_D^{14}$ −91° (c=1.0, $CHCl_3$). *Anal.* Calcd. for $C_{15}H_{18}O_3$: C, 73.14; H, 7.37. Found: C, 73.08; H, 7.37. IR $\nu_{max}^{CHCl_3}$ cm^{-1}: 1764, 1702, 1658. UV λ_{max}^{EtOH} nm (ε): 237 (9950). PMR ($CDCl_3$) δ: as given in Table II. MS *m/e* (%): 246 (M^+, 100).

$NaBH_4$ Reduction of 8 giving 9——To a solution of **8** (100 mg) in MeOH (7 ml) was added $NaBH_4$ (4.2 mg). The total solution was kept stirring at 0° for 30 min, treated successively with ice-water and 10% aq. H_2SO_4, and extracted with EtOAc. The EtOAc extract was then washed successively with sat. aq. $NaHCO_3$ and water, and worked up in the usual manner to give **9** (101 mg), mp 161—162.5°, colorless plates (recryst. from *n*-hexane–acetone), $[\alpha]_D^{12}$ −78° (c=1.0, $CHCl_3$). *Anal.* Calcd. for $C_{15}H_{20}O_3$: C, 72.55; H, 8.12. Found:

8) The instruments used for obtaining the physical data and the experimental conditions for chromatography were same as in our previous reports.[1,3d] For measuring the specific rotations, JASCO DIP-181 Digital Polarimeter was also used.

9) C. Djerassi, R.R. Engle, and A. Bowers, *J. Org. Chem.*, **21**, 1547 (1956).

C, 72.37; H, 8.08. IR $\nu_{max}^{CHCl_3}$ cm^{-1}: 3618, 1749, 1680. UV λ_{max}^{EtOH} nm (ε): 232 (8700). PMR ($CDCl_3$) δ: as given in Table II. MS *m/e* (%): 248 (M^+, 12), 230 (100).

(iso-Bu)$_2$AlH Reduction of 9 giving 10a——To a solution of **9** (130 mg) in dry toluene (5 ml) was added a solution of (iso-Bu)$_2$AlH (115 mg) in dry toluene (0.6 ml) and the total solution was kept stirring at −20° under nitrogen atmosphere for 2 hr, treated with 10% aq. H_2SO_4, and extracted with ether. The ether extract was washed successively with sat. aq. $NaHCO_3$ and water, and worked up in the usual manner. An oily product (138 mg) thus obtained was purified by column chromatography (silica gel 4 g, $CHCl_3$) to give **10a** (54 mg), colorless oil, $[\alpha]_D^{14}$ +49.5° (c=1.0, $CHCl_3$). IR ν_{max}^{film} cm^{-1}: 3440, 1630, 1562, 1035, 890. UV λ_{max}^{EtOH} nm (ε): 219 (6000). PMR ($CDCl_3$) δ: as given in Table III. MS *m/e* (%): 232 (M^+, 89), 109 (100). High resolution MS *m/e*: Found: 232.146; Calcd. for $C_{15}H_{20}O_2$ (M^+) 232.146.

Acetylation of 10a giving 10b——A solution of **10a** (40 mg) in pyridine (2 ml) and Ac_2O (2 ml) was heated at 100° for one hour. After cooling, the reaction mixture was poured into ice-water and extracted with ether. The ether extract was then washed successively with 5% aq. HCl, 5% aq. $NaHCO_3$, and water, and worked up in the usual manner to give an oily product (31 mg). Purification of the product by preparative TLC (petr. ether–ether=3: 2) gave **10b** (26 mg), colorless oil, $[\alpha]_D^{20}$ +18° (c=0.25, $CHCl_3$). IR $\nu_{max}^{CHCl_3}$ cm^{-1}: 1734, 1633. UV λ_{max}^{EtOH} nm (ε): 219 (6000). PMR ($CDCl_3$) δ: 2.95 (1H, br.d, J=17 Hz, 9-H$_A$), 3.44 (1H, br.d, J=17 Hz, 9-H$_B$), and other signals as given in Table III. MS *m/e* (%): 274 (M^+, 8), 199 (100). High resolution MS *m/e*: Found: 274.157; Calcd. for $C_{17}H_{22}O_3$ (M^+) 274.157.

Epoxidation of 9 giving α-Epoxide (11a) and β-Epoxide (11b)——To a solution of **9** (280 mg) in CH_2Cl_2 (5 ml) was added dropwise a solution of *m*-chloroperbenzoic acid (260 mg) in CH_2Cl_2 (13 ml) and the total solution was heated under reflux for 2 hr. After cooling, the reaction mixture was treated with 10% aq. Na_2SO_3 and extracted with CH_2Cl_2. The CH_2Cl_2 extract was washed successively with 5% aq. $NaHCO_3$ and water, and worked up in the usual manner. The product (white powder, 262 mg) was then subjected to column chromatography (silica gel 10 g, $CHCl_3$–ether=5: 1) to afford **11a** (181 mg) and **11b** (18 mg). **11a**, mp 187°, colorless needles (recryst. from acetone), $[\alpha]_D^{24}$ −158° (c=1.13, $CHCl_3$). IR $\nu_{max}^{CHCl_3}$ cm^{-1}: 3603, 1751, 1678. UV λ_{max}^{EtOH} nm (ε): 224 (9000). PMR ($CDCl_3$) δ: as given in Table II. MS *m/e* (%): 264 (M^+, 2), 126 (100). High Resolution MS *m/e*: Found: 264.136; Calcd. for $C_{15}H_{20}O_4$ (M^+) 264.136. **11b**, amorphous, $[\alpha]_D^{24}$ −57° (c=0.1, pyridine). IR ν_{max}^{KBr} cm^{-1}: 3480, 1737, 1680. UV λ_{max}^{EtOH} nm (ε): 221 (8050). PMR (d_5-pyridine) δ: as given in Table II. MS *m/e* (%): 264 (M^+, 1), 123 (100). High resolution MS *m/e*: Found: 264.136; Calcd. for $C_{15}H_{20}O_4$ (M^+) 264.136.

(iso-Bu)$_2$AlH Reduction of 11a giving 12a——To a solution of **11a** (80 mg) in dry tetrahydrofuran (2 ml) was added a solution of (iso-Bu)$_2$AlH (140 mg) in dry tetrahydrofuran (1.7 ml). The total solution was kept stirring at −20° under nitrogen atmosphere for 7 hr, treated with 10% aq. H_2SO_4, and extracted with ether. The ether extract was then washed successively with 5% aq. $NaHCO_3$ and water, and worked up in the usual manner. An oily product (61 mg) thus obtained was purified by preparative TLC ($CHCl_3$–ether=1: 1) to give **12a** (42 mg), colorless oil, $[\alpha]_D^{21}$ −19° (c=0.54, $CHCl_3$). IR $\nu_{max}^{CHCl_3}$ cm^{-1}: 3471, 1564, 1040, 985, 881. UV λ_{max}^{EtOH} nm (ε): 219 (5500). PMR ($CDCl_3$) δ: as given in Table III. MS *m/e* (%): 248 (M^+, 49), 124 (100). High resolution MS *m/e*: Found: 248.142; Calcd. for $C_{15}H_{20}O_3$ (M^+) 248.141.

Acetylation of 12a giving 12b——A solution of **12a** (24 mg) in pyridine (1 ml) and Ac_2O (1 ml) was heated at 90° for 2 hr. After cooling, the reaction mixture was treated as for acetylation of **10a** (*vide supra*). An oily product (19 mg) thus obtained was purified by preparative TLC ($CHCl_3$–ether=5: 1) to give **12b** (9 mg), colorless oil, $[\alpha]_D^{21}$ −44° (c=0.52, $CHCl_3$). IR $\nu_{max}^{CHCl_3}$ cm^{-1}: 1764. UV λ_{max}^{EtOH} nm (ε): 220 (5500). PMR ($CDCl_3$) δ: as given in Table III. MS *m/e* (%): 290 (M^+, 1), 109 (100). High resolution MS *m/e*: Found: 290.152; Calcd. for $C_{17}H_{22}O_4$ (M^+) 290.152.

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