# Synthesis of (−)-Conduritol F, (+)-Conduritol B, Cyclophellitol from L-Quebrachitol

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The methyl ether of cyclitols with vicinal hydroxyl group was cleaved chemoselectively in preference to both *cis*-and *trans*-cyclohexylidene moieties by $AlCl_3$–*n*-$Bu_4NI$ to afford parent alcohols in good yields. (−)-Conduritol F was prepared from L-quebrachitol, an optically active cyclitol from the serum of rubber trees, in five steps by use of the demethylation reaction. The first chiral synthesis of (+)-conduritol B and the total synthesis of cyclophellitol, a novel β-glucosidase inhibitor, are described.

L-Quebrachitol (1L-(−)-2-*O*-methyl-*chiro*-inositol) is a naturally occurring optically active inositol, obtained from the serum of rubber trees,[1] and is of interest as a chiral source for the synthesis of natural products.[2] In particular, Paulsen and his co-workers reported the syntheses of branched-chain cyclitols,[3] and Chida and Ogawa extensively studied the synthesis of natural products such as (−)-isoavenaciolide, bengamide A, and simmondsin.[4]

In our laboratory, as part of an exploration of the utility of L-quebrachitol, we have reported diastereoselective reduction[5] and addition of organometallics to α-keto esters[6] and 1,3-dipolar cycloaddition of nitrile oxide to acrylic esters with chiral cyclitols from L-quebrachitol as chiral auxiliaries.[7] We found that the methyl ether of cyclitol with a vicinal OH group is cleaved chemoselectively in preference to the *trans*-cyclohexylidene moiety by $AlCl_3$–NaI in $CH_3CN$,[8] affording parent alcohols in good yields. Thus D-*myo*-inositol 1-phosphate was synthesized by the demethylation reaction.[9]

Here, we describe the chemoselective demethylation of methyl ether mediated by $AlCl_3$–*n*-$Bu_4NI$ and efficient syntheses of (−)-condutriol F, (+)-conduritol B, and cyclophellitol (Fig. 1).[10]

**Synthesis of (−)-Conduritol F and (+)-Conduritol B.** There is interest in the synthesis of conduritols (5-cyclohexene-1,2,3,4-tetrols)[11] because these compounds are useful precursors for the preparation of cyclitols and pseudosugars, and because their derivatives have interesting biological activities.[12] Six stereoisomers of conduritol, designated A to F, are possible; conduritols A and D are meso, and conduritols B, C, E, and F are pairs of enantiomers. The synthesis of conduritols in optically active forms has been the focus of much effort. Scalemic conduritols have been prepared from carbohydrates[13] via Ferrier rearrangement,[14] form microbial oxidation of benzene,[15] and via the Diels–Alder reaction.[16]

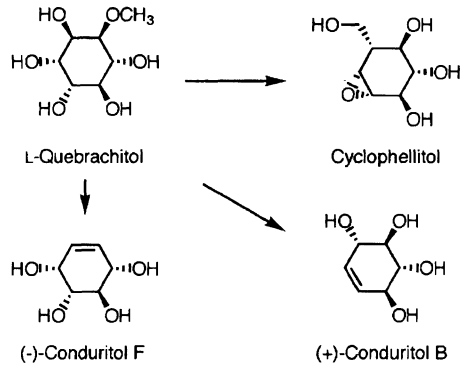



Fig. 1.

We present here a straightforward synthesis of (−)-conduritol F starting from L-quebrachitol by $AlCl_3$–*n*-$Bu_4NI$-mediated demethylation.[3b,17] Chemoselective demethylation of the methyl ether was necessary. The results of the cleavage reactions are shown in Table 1. Treatment of **1**, prepared form L-quebrachitol in one step, with $AlCl_3$ (4 equiv) and NaI (4 equiv) in $CH_3CN$ at room temperature for 30 min gave 1L-1,2:5,6-di-*O*-cyclohexylidene-*chiro*-inositol (**3**) in 40% yield (Entry 1). Its structure was confirmed by comparison with a sample prepared separately by another route.[18] Probably the formation of 1L-1,2:3,4-di-*O*-cyclohexylidene-*chiro*-inositol (**2**) was followed by migration of the *trans*-cyclohexylidene moiety under acidic conditions to give **3** (Scheme 1). The cleavage reaction in the presence of pyridine (10 equiv) in $CH_3CN$ at room temperature suppressed the migration and afforded **2** in 57% yield (Entry 3). Concurrent cleavage of the cyclohexylidene moiety took place. Thus we examined the iodide source. The counter-cation affected the chemoselective cleavage of methyl ether. Tetrabutylammonium iodide instead of NaI suppressed the cleavage of the cyclohexylidene moiety[19] to afford **2** in 78% yield (Entry 7).

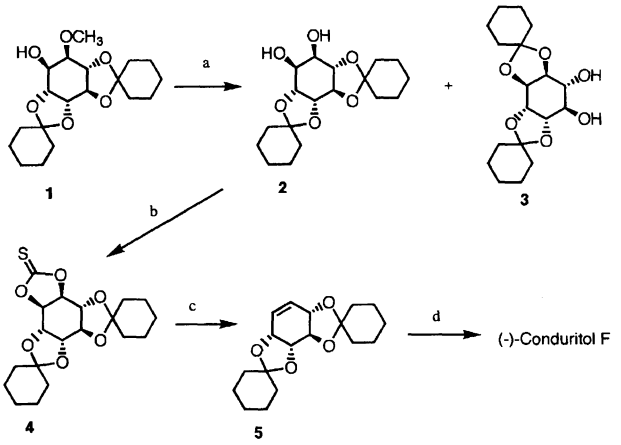
Treatment of **2** with *N*,*N*′-thiocarbonyldiimidazole in acetone gave a cyclic thiocarbonate **4**, which upon reaction with trimethyl phosphite afforded **5** in a high yield. Deprotection of the cyclohexylidene groups with trifluoroacetic acid-methanol afforded (−)-conduritol F as a crystalline solid, and its spectroscopic ($^1H$ NMR)[16b] and physical data ($[\alpha]_D$ and mp) were identical to those reported elsewhere.[3c,15b] Thus, (−)-conduritol F was synthesized in five steps from L-quebrachitol in a high yield.

Next, we report the synthesis of (+)-conduritol B, starting from D-3,4,5,6-tetra-*O*-benzoyl-*myo*-inositol (**6**),[9] which is readily available from L-quebrachitol (Scheme 2). Racemic and (−)-conduritol B have al-

Table 1. Results of Demethylation of Methyl Ether of **1** in $CH_3CN$

| Entry | $AlCl_3$ (equiv) | Metal Iodide (equiv) | Base (equiv) | Time h | Yield/% **2** | **3** | **1** |
|---|---|---|---|---|---|---|---|
| 1 | 5 | NaI(5) | — | 2 | 0 | 40 | 0 |
| 2 | 10 | NaI(10) | $NEt_3$(10) | 42 | 38 | 0 | 17 |
| 3 | 10 | NaI(10) | Pyridine(10) | 20 | 57 | 0 | 13 |
| 4 | 10 | NaI(10)[a] | Pyridine(10) | 17 | 49 | 0 | 0 |
| 5 | 10 | KI(10) | Pyridine(10) | 34 | 41 | 0 | 37 |
| 6 | 10 | LiI(10) | Pyridine(10) | 22 | 59 | 0 | 25 |
| 7 | 10 | *n*-$Bu_4NI$(10) | Pyridine(10) | 26 | 78 | 0 | 12 |
| 8 | 10 | LiBr(10) | Pyridine(10) | 35 | 19 | 0 | 76 |
| 9 | 10 | *n*-$Bu_4NBr$(10) | Pyridine(10) | 32 | 60 | 0 | 36 |

a) 18-Crown-6 (1 equiv) was added.




Scheme 1. a) See text, b) *N,N'*-thiocarbonyldiimidazole, acetone reflux, 9 h, 90%, c) $P(OCH_3)_3$, reflux, 6 h, d) 80% trifluoroacetic acid in methanol, 90% from **2**.

ready been synthesized,[20] but (+)-isomer has not been prepared so far. Treatment of **6** with *N,N'*-thiocarbonyldiimidazole followed by trimethyl phosphite gave **8** in a high yield. Methanolysis of the benzoyl groups afforded (+)-conduritol B, and the spectroscopic and physical properties were in good accord with those of (−)-conduritol.[3c,16b]

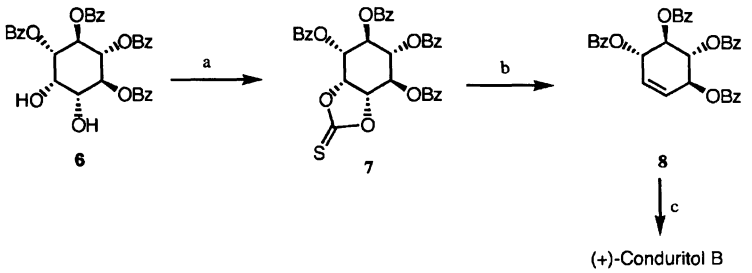
**Synthesis of Cyclophellitol.** Cyclophellitol is a novel β-glucosidase inhibitor isolated from the culture filtrate of a mushroom.[21] Tatsuta et al. reported the first synthesis of cyclophellitol starting from L-glucose, involving the intramolecular cycloaddition of nitrile oxide with olefin.[22,23] The addition of carbanion derived from Meldrum's acid to Pd–π-allyl complex led to an intermediate.[24] We synthesized cyclophellitol from L-quebrachitol taking advantage of the chemoselective cleavage of methyl ether catalyzed by $AlCl_3$–*n*-$Bu_4NI$.

Total synthesis of cyclophellitol starts from olefination of 2L-(2,3,5/4,6)2,3:4,5-di-*O*-cyclohexylidene-6-*O*-methyl-2,3,4,5,6-pentahydroxycyclohexanone (**9**), readily available in two steps from L-quebrachitol.[9b] Introduction of a methylene moiety by the Witting reaction gave unsatisfactory results probably because of steric hindrance of the vicinal oxygen functionality; treatment of **9** with methylenetriphenylphosphorane gave **10** in 20% yield (Scheme 3). Both Horner–Emmons and Nozaki reagents[25] ($CH_2I_2$–Zn–$TiCl_4$) gave unsatisfactory results. Of the various methods examined, Peterson olefination[26] gave the best results. Addition of $Me_3SiCH_2MgCl$ to **9** in THF followed by addition of KH gave **10** in 58% yield.

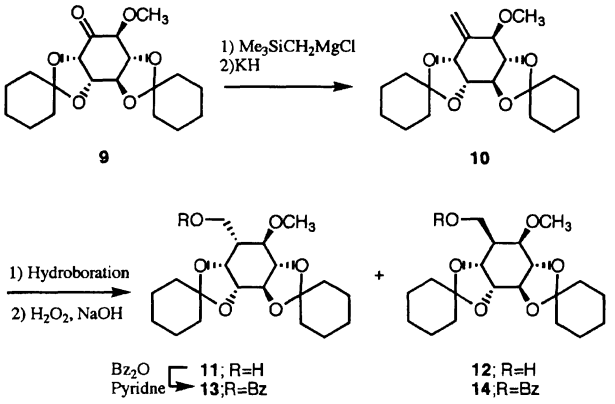
Next we studied hydroboration of the methylene moiety (Table 2). Treatment of **4** with $BH_3$·THF followed by $H_2O_2$ afforded an epimeric mixture of **11** and **12**, which were readily separated as benzoates **13** and **14**. Less sterically demanding borane reagents such as $BH_3$·THF and $BH_3$·$SMe_2$ had no selectivity (Entries 1 and 2). A combination of *o*-phenylenedioxyborane and $[RhCl(PPh_3)_3]$[27] afforded mostly an equatorial isomer (Entry 3).

The stereochemistry of **13** and **14** was readily identified after cleavage of the *trans*-cyclohexylidene (Fig. 2). The coupling constant of diaxial proton $J_{5,6}$=10.4 Hz of **15** was larger than the $J_{5,6}$=5.8 Hz of **16**, so more polar isomer **15** probably had the benzoyloxymethyl group in the equatorial orientation. We confirmed the structure further at the final stage of total synthesis by comparison with cyclophellitol.

Demethylation of both methyl ether and *trans*-cyclohexylidene moieties of **13** by $AlCl_3$–*n*-$Bu_4NI$ in $CH_3CN$ proceeded chemoselectively in preference to that of the *cis*-cyclohexylidene moiety to afford a triol **17** in 63% yield; the reaction with $AlCl_3$–NaI, although it afforded **17** in 35—60% yield, gave less reproducible yields (Scheme 4). Cleavage of the bonzoyl group followed by perbenzylation in a one-pot reaction involved treatment of **17** with NaH and benzyl bromide followed by the addition of $NaOCH_3$ and NaH–benzyl bromide, giving **18** in 83% yield. Acidic hydrolysis of the *cis*-cyclohexylidene moiety afforded a diol **19**. Regioselective triflation of the equatorially oriented 2-hydroxyl group with trifluoromethanesulfonic anhydride ($Tf_2O$)[28] followed by acetylation of the axial OH group gave **21**. $S_N2$ reaction of **21** with *n*-$Bu_4NI$[29] in benzene with reflux for 6 h led quantitatively to an axial iodide **22**. Sodium iodide did not react under these reaction condi-




Scheme 2. a) *N,N'*-thiocarbonyldiimidazole, acetone reflux, 5 h, 91%, b) $P(OCH_3)_3$, reflux, 5 h, 97%, c) $NaOCH_3$, $CH_3OH$, r.t.




Scheme 3.

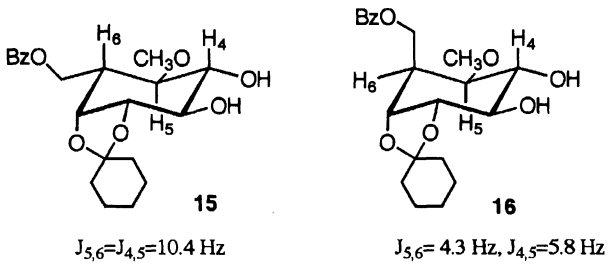
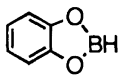



Fig. 2.

Table 2. Results of the Hydroboration of **10**[a)]

| Entry | Reagent | Conditions[b)] | Yield/% **13** | **14** |
|---|---|---|---|---|
| 1 | $BH_3$·THF | r. t. 1 h | 31 | 30 |
| 2 | $BH_3$·$SMe_2$ | r. t. 22 h | 20 | 20 |
| 3 |  | r. t. 17 h | 33 | 6 |
| 4 | $[RhCl(Ph_3P)_3]$ 9-BBN | r. t.—50 °C, 23 h | 4 | 12 |

a) Products were isolated as benzoates. b) Reaction conditions for the hydroboration.

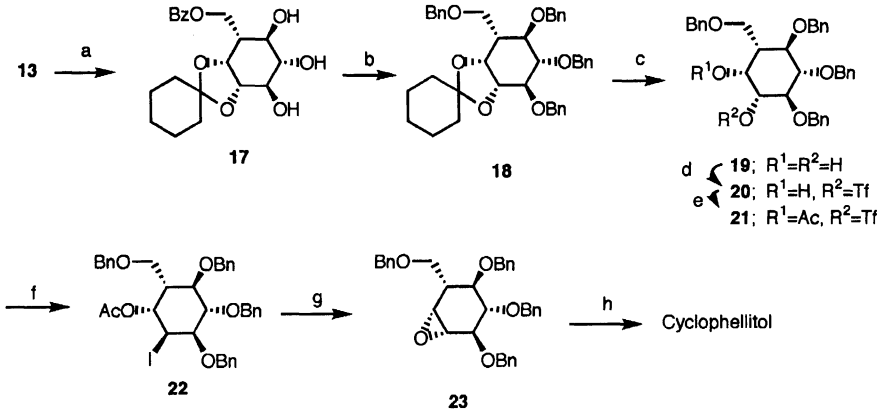
tions. The acetyl group was necessary for a smooth $S_N2$ reaction to take place; the reaction of **20** with NaI or *n*-$Bu_4NI$ followed by *O*-acetylation gave **22** in low yields. The iodide **22** was treated with NaOMe at room temperature for 1 h to afford an epoxide **23**. Deprotection of the benzyl protecting groups completed the synthesis, giving cyclophellitol quantitatively. The spectroscopic ($^1H$ and $^{13}C$ NMR) and physical properties ($[\alpha]_D$ and mp) were in good accord with the reported values.[21)]

## Experimental

The melting points were recorded on a Yamato melting point apparatus and are uncorrected. NMR spectra were observed with a JEOL GSX-270 spectrometer with tetramethylsilane as the internal standard. IR spectra were recorded on a Hitachi EPI G-3 spectrometer. Specific rotations were recorded with a Union PM-101 digital polarimeter. $AlCl_3$ was ground into fine powder and stored under an $N_2$ atmosphere. Products were purified by column chromatography on silica gel (Wako gel C-300) or preparative TLC on silica gel (Wako gel B-5F).

**1L-1,2:3,4-Di-*O*-cyclohexylidene-*chiro*-inositol (2).** To a solution of **1**[9b)] (106 mg, 0.298 mmol) in $CH_3CN$ (2.5 ml) were added successively pyridine (242 μl, 2.98 mmol), $AlCl_3$ (398 mg, 2.98 mmol), and *n*-$Bu_4NI$ (1.10 g, 2.98 mmol) at 0 °C, and the resulting mixture was stirred at room temperature for 11 h. The reaction was quenched by the addition of ice water and the product was extracted with $CH_2Cl_2$. The combined organic layer was washed with 10% $Na_2CO_3$ and dried over anhydrous $Na_2SO_4$, to dryness. The resulting residue was purified with $SiO_2$ column chromatography to afford **2** as an amorphous solid (79 mg, 78%). IR (Nujol) 3450, 1270, 1160, 1090, 940, and 800 $cm^{-1}$; $^1H$ NMR ($CDCl_3$) $\delta$=1.25—1.73 (20H, m, $(CH_2)_{10}$), 2.94 (1H, brd, $J$=2.4 Hz, OH), 3.08 (1H, d, brd, $J$=2.8 Hz, OH), 3.63 (1H, dd, $J_{3,4}$=10.4 Hz, $J_{2,3}$=6.7 Hz, H-3), 3.71 (1H, dd, $J_{3,4}$=10.4 Hz, $J_{4,5}$=7.7 Hz, H-4), 4.08—4.21 (2H, m, H-5, 6), 4.33—7.40 (2H, m, H-1,2); $[\alpha]_D^{28}$ −27° (*c* 1.1, $CHCl_3$). Found; C, 63.59; H, 8.53%. Calcd for $C_{18}H_{28}O_6$: C, 63.51; H, 8.29%.

**1L-1,2:5,6-Di-*O*-cyclohexylidene-*chiro*-inositol (3).** To a solution of **1** (100 mg, 0.283 mmol) in $CH_3CN$ (1.0 ml) were added powdered $AlCl_3$ (189 mg, 1.41 mmol) and NaI (212 mg, 1.41 mmol) at 0 °C. After stirring of the mixture at room temperature for 2 h, the reaction was quenched by the addition of ice water and the aqueous layer was extracted with ethyl acetate. The combined organic layer was washed with 10% $Na_2CO_3$ solution and dried over anhydrous $Na_2SO_4$ to dryness. The resulting residue was purified by $SiO_2$ column chromatography (hexane : ethyl acetate=2 : 1) to afford **3** as crystals (38.8 mg) in 40% yield. Mp 207—209 °C (lit, 209—210 °C);[18)] IR (Nujol) 3470, 3300, and 1080 $cm^{-1}$; $^1H$ NMR (270 MHz, $CDCl_3$–$CD_3OD$, v/v=10/1) $\delta$=1.30—1.75 (10H, m, $(CH_2)_{10}$), 2.50 (2H, brs, OH), 3.43—




Scheme 4. a) $AlCl_3$–*n*-$Bu_4NI$, $CH_3CN$, 63%; b) $PhCH_2Br$, NaH, $NaOCH_3$, DMF, 83%' c) $CF_3COOH$–$CH_3OH$, 90%; d) $(CF_3SO_2)_2O$–Pyridine, 98%; e) $Ac_2O$, r. t. overnight; f) *n*-$Bu_4NI$, benzene reflux, 11 h, 96% from **20**; g) $NaOCH_3$, $CH_3OH$–THF, 100%; h) Pd/C, $H_2$, 100%.

3.53 (2H, m, H-3,4), 4.07—4.22 (2H, m, H-2,5), 4.31—4.38 (2H, m, H-1,6); $[\alpha]_D^{24}$ −24° (*c* 1.1, $CHCl_3$) (lit, $[\alpha]_D$ −16° (*c* 1.4, $CHCl_3$).[18] Found: C, 63.33; H, 8.59%. Calcd for $C_{18}H_{28}O_6$: C, 63.51; H, 8.29%.

**1L-3,4:5,6-Di-*O*-cyclohexylidene-1,2-*O*-thiocarbonyl-*chiro*-inositol (4).** A solution of **2** (71.0 mg, 0.209 mmol) and *N*,*N*′-thiocarbonyldiimidazole (42.8 mg, 0.240 mmol) in dry acetone (4.0 ml) was refluxed for 6 h. After addition of *N*,*N*′-thiocarbonyldiimidazole (55.8 mg, 0.313 mmol), the mixture was refluxed for 3 h more. The mixture was allowed to cool to room temperature and the reaction was quenched by the addition of water (5 ml). The mixture was extracted with $CH_2Cl_2$. The combined organic layer was washed successively with 1 mol dm$^{-3}$ HCl, sat. $NaHCO_3$ solution, and brine and concentrated to leave an oil, which was purified by column chromatography ($SiO_2$, $CH_2Cl_2$ : hexane=2 : 3) to give **4** as an amorphous solid (73 mg) in 90% yield. $[\alpha]_D^{22}$ −4.8° (*c* 1.1, $CHCl_3$); IR (Nujol) 1340, 1280, 1240, 980, and 710 cm$^{-1}$; $^1$H NMR ($CDCl_3$) $\delta$=1.41—1.70 (20H, m, $(CH_2)_{10}$), 3.62 (1H, dd, $J_{3,4}$=11.0 Hz, $J_{3,4}$=7.5 Hz, H-4), 3.84 (1H, dd, $J_{2,3}$=7.3 Hz, H-3), 4.48 (1H, t, $J_{5,6}$=7.4 Hz, H-5), 4.54 (1H, dd, $J_{1,6}$=4.6 Hz, $J_{5,6}$=7.4 Hz, H-6), 5.01—5.30 (2H, m, H-1,2). Found: C, 59.72; H, 6.90%. Calcd for $C_{16}H_{26}O_6S$: C, 59.67; H, 6.85%.

**1L-(1,2,4/3)-5-Cyclohexane-1,2,3,4-tetrol [(−)-conduritol-F].** A solution of **4** (189 mg, 0.493 mmol) in trimethyl phosphite (10 ml) was refluxed for 6 h. The solvent was evacuated under reduced pressure to afford crude **5** as an oil, which was treated with 80% trifluoroacetic acid in methanol (10 ml) at room temperature overnight. The solvent was removed under reduced pressure to leave an oil, to which water was added. The aqueous layer was washed with $CH_2Cl_2$ and the water was removed under reduced pressure. The remaining oil was treated with an ion-exchange resin (Diaion SK1B, $H^+$ form) followed by Amberlite (IRA-904, $Cl^-$ form) to give (−)-conduritol-F as crystals (57 mg) in 79% yield from **3**. The crystals were further purified by recrystallization from a mixture of $Et_2O$ and MeOH (v/v=2 : 1). Mp 131—132 °C (lit, 131—132 °C);[15b] $^1$H NMR ($CD_3OD$) $\delta$=3.41 (1H, dd, $J_{3,4}$=4.3 Hz, $J_{2,3}$=10.4 Hz, H-3), 3.61 (1H, dd, $J_{1,2}$=7.6 Hz, H-2), 3.86—3.98 (1H, m, H-1), 4.16 (1H, t, $J_{4,5}$=4.3 Hz, H-4), 5.71 (1H, dd, $J_{1,6}$=10.1 Hz, $J_{5,6}$=1.8 Hz, H-6), 5.79 (1H, ddd, $J_{1,5}$=10.1 Hz, H-5); $[\alpha]_D^{22.5}$ −71° (*c* 0.75, $CH_3OH$), (lit, $[\alpha]_D^{20}$ −70.5° (*c* 0.75, $CH_3OH$)).[3c]

**D-3,4,5,6-Tetra-*O*-benzoyl-1,2-*O*-thiocarbonyl-*myo*-inositol (7).** A solution of **6**[9b] (43 mg, 0.071 mmol) and *N*,*N*′-thiocarbonyldiimidazole (15 mg, 0.082 mmol) in dry acetone (1.0 ml) was refluxed for 5 h. The reaction mixture was allowed to cool to room temperature and the reaction was quenched by addition of water (5 ml). The mixture was extracted with $CH_2Cl_2$. The combined organic layer was washed successively with 1 mol dm$^{-3}$ HCl, sat. $NaHCO_3$ solution, and brine and concentrated to leave an oil, which was purified by column chromatography ($SiO_2$, $CH_2Cl_2$ : hexane=9 : 1) to give **7** as crystals (42 mg) in 91% yield. Mp 270—271 °C; $^1$H NMR ($CDCl_3$ : DMSO−$d_6$=3 : 1, v/v), $\delta$=5.72 (1H, dd, $J$=5.8 Hz, 7.9 Hz), 5.80 (1H, dd, $J$=3.4 Hz, 7.9 Hz), 5.88—5.92 (2H, m), 6.00—6.10 (2H, m), 7.32—7.67 (12H, m, aromatic), 7.87—8.08 (8H, m, aromatic); $[\alpha]_D^{18.0}$ +62° (*c* 0.37, $CH_3OH$). Found: C, 65.75; H, 4.24%. Calcd for $C_{35}H_{26}O_{10}S$: C, 65.82; H, 4.10%.

**1D-(1,3/2,4)-1,2,3,4-Tetra-*O*-benzoyl-5-cyclohexene-1,2,3,4-tetrol (8).** A solution of **7** (42 mg, 0.075 mmol) in trimethyl phosphite (2 ml) was refluxed for 5 h. The solvent was evacuated under pressure to afford crude **8** as an oil, which was purified by thin-layer chromatography ($SiO_2$, $CH_2Cl_2$ : hexane=4 : 1) to give **8** as crystalline solids (40 mg) in 97% yield. Mp 186—187 °C; $^1$H NMR ($CDCl_3$) $\delta$=6.04—6.08 (6H, m), 7.26—7.57 (12H, m, aromatic), 7.75—8.02 (8H, m, aromatic). Found: C, 72.19; H, 4.83%. Calcd for $C_{34}H_{26}O_8$: C, 72.59; H, 4.66%.

**1D-(1,3/2,4)-5-Cyclohexnene-1,2,3,4-tetrol [(+)-Conduritol B].** To a solution of **8** (33.4 mg, 0.0594 mmol) in a mixture of methanol (1.5 ml) and tetrahydrofuran (0.8 ml) was added NaH (60%, 10.7 mg, 0.268 mmol) at 0 °C. After being stirred at room temperature overnight, the reaction was quenched by the addition of 1 mol dm$^{-3}$ HCl. The aqueous layer was washed with ether and concentrated to dryness. The remaining residue was treated with an ion-exchange resin (Diaion SK1B, $H^+$ form) followed by Amberlite IRA-904 ($Cl^-$ form)) to give (+)-conduritol B as a crystalline solid (8.7 mg, quantitatively). Mp 177—178 °C (MeOH), (lit, (−)-isomer mp 179 °C);[3c] $^1$H NMR ($CD_3OD$)

$\delta$=3.32—3.43 (2H, m, H-2,3), 4.01—4.13 (2H, m, H-1,4), 5.57 (2H, d, H-5,6); $[\alpha]_D^{22}$ +191° (*c* 1.26, $CH_3OH$), (lit, (−)-isomer $[\alpha]_D^{20}$ −179° (*c* 1.2, $CH_3OH$)).[16b] Found: C, 49.02; H, 7.03%. Calcd for $C_6H_{10}O_4$: C, 49.32; H, 6.90%.

**1L-(1,2,4/3,5)-1,2:3,4-Di-*O*-cyclohexylidene-5-*O*-methylene-1,2,3,4,5-cyclohexanepentol(10).** To a solution of **9**[9b] (5.24 g, 14.9 mmol) in THF (120 ml) was added a solution of $(CH_3)_3SiCH_2MgCl$ (17.8 ml, 4.6 mmol, 2.52 mmol/ml) in $Et_2O$ at 0 °C. Stirring was continued at room temperature for 9 h, followed by heating to reflux for 2 h. The reaction was quenched by the addition of ice water (40 ml) and the aqueous layer was extracted with ethyl acetate (40 ml×3). The combined organic layer was successively washed with 5% $KHSO_4$ (10 ml), 2.5% $NaHCO_3$ solution (10 ml), and brine (10 ml), dried over anhydrous $Na_2SO_4$, and concentrated to leave an oil, which was purified by column chromatography ($SiO_2$, ethyl acetate : hexane=1 :20), to afford a diastereomeric mixture of alcohol (4.96 g, 76%). A solution of the mixture (4.96 g, 11.3 mmol) in THF (50 ml) was added dropwise to a flask containing KH (30%, 4.55 g, 34.0 mmol) at 0 °C for 30 min. After the mixture was stirred at room temperature for 3 h, the reaction was quenched by the addition of ice water (40 ml). The aqueous layer was extracted with ethyl acetate (40 ml×3). The combined organic layer was successively washed with 5% $KHSO_4$ solution, 2.5% $NaHCO_3$ solution, and brine (10 ml), dried over anhydrous $Na_2SO_4$, and concentrated to afford an oil, which was purified by column chromatography ($SiO_2$, ethyl acetate : hexane=1 : 20) to give **10** as an oil (3.0 g) in 76% yield. IR ($CHCl_3$) 3000, 2930, 2850, 1600, 1430, 1340, 1260, 1200, 1150, 910, 700, and 650 $cm^{-1}$; $^1H$ NMR ($CDCl_3$) $\delta$=1.25—1.78 (20H, m, $(CH_2)_{10}$), 3.44 (3H, s, $OCH_3$), 3.50—3.65 (2H, m, H-3,4), 3.99 (1H, d, $J_{4,5}$=6.4 Hz, H-5), 4.32 (1H, t, $J_{2,3}=J_{1,2}$=7.1 Hz, H-2), 4.76 (1H, d, $J_{1,2}$=7.1 Hz, H-1), 5.36—5.41 (1H, m, $CH_2$=), 5.54—5.60 (1H, m, $CH_2$=); $[\alpha]_D^{24}$ +33.6° (*c* 1.92, $CHCl_3$). Found: C, 68.09; H, 8.55%. Calcd for $C_{20}H_{30}O_5$: C, 68.54; H, 8.63%.

**L-(1,2,4,6/3,5)-1,2:3,4-Di-*O*-cyclohexylidene-6-hydroxymethyl-5-*O*-methyl-1,2,3,4,5-chclohexanepentol (11).** A 1.0-mol $dm^{-3}$ solution of $BH_3$·THF (7.02 ml, 7.02 mmol) in THF was added dropwise to a solution of **10** (2.46 g, 7.02 mmol) in THF (12 ml) for 5 min. After the mixture was stirred at room temperature for 4 h, another portion of $BH_3$·THF (2.8 ml, 2.8 mmol) in THF was added dropwise at room temperature to the reaction mixture. After being stirred at room temperature for 1 h more, the reaction was quenched by the addition of water (2 ml), 3 mol $dm^{-3}$ NaOH solution (5 ml), and 30% $H_2O_2$ solution (5 ml) and was stirred 1 h more at 50 °C. The reaction was quenched by the addition of ice water (10 ml) and the mixture was extracted with ether (100 ml×3). The combined organic layer was washed with brine (10 ml), dried over anhydrous $Na_2SO_4$, and concentrated to leave an oil, which was purified by column chromatography ($SiO_2$, ethyl acetate : hexane=1 : 6) to afford a mixture of **11** and **12** as an amorphous solid (1.9 g) in 74% yield. IR ($CHCl_3$) 3550, 2930, 2850, 1430, 1390, 1350, 1320, 1260, 1200, 1150, 1130, 1080, 1020, 900, and 840 $cm^{-1}$; $^1H$ NMR ($CDCl_3$) $\delta$=1.10—1.90 (20H, m, $(CH_2)_{10}$), 1.82—1.94 (1H, m, H-6), 2.81 (1H, t, OH), 3.36 (1H, t, $J_{5,4}=J_{3,4}$=10.1 Hz, H-4), 3.51 (1H, t, $J_{2,3}$=10.1 Hz, H-3), 3.61 (3H, s, $OCH_3$), 3.74 (1H, t, $J_{5,6}$=10.1 Hz, H-5), 3.92—4.05 (2H, m, Ha, Hb), 4.20 (1H, dd, $J_{1,2}$=4.9 Hz, H-2), 4.43 (1H, t, $J_{1,6}=J_{1,2}$=4.9 Hz, H-1).

**1L-(1,2,4,6/3,5)-6-Benzoyloxymethyl-1,2:3,4-di-*O*-cyclohexylidene-5-*O*-methyl-1,2,3,4,5-cyclohexanepentol (13) and Its (1,2,4/3,5,6) Isomer (14).** To the solution of **11** and **12** (1.89 g, 5.12 mmol) obtained as described above in pyridine (15 ml) were added a catalytic amount of 4-dimethylaminopyridine and benzoic anhydride (1.74 g, 7.68 mmol) at 0 °C. After the mixture was stirred at room temperature overnight, the reaction was quenched by the addition of ice water. The aqueous layer was extracted with ethyl acetate (15 ml×3). The combined organic layer was successively washed with 5% $KHSO_4$ solution (5 ml), 2.5% $NaHCO_3$ solution, and brine (5 ml), dried over anhydrous $Na_2SO_4$, and concentrated to leave an oil, which was purified by column chromatography ($SiO_2$, ethyl acetate : hexane=1 : 50—1 : 5) to afford **13** as an amorphous solid (1.1 g) in 31% yield from **10**. IR (Nujol) 1720, 1590, 1440, 1360, 1270, 1160, 1100, 970, 920, 900, 840, and 750 $cm^{-1}$; $^1H$ NMR ($CDCl_3$) $\delta$=1.25—1.70 (20H, m, $(CH_2)_{10}$), 2.25—2.36 (1H, m, H-6), 3.37 (1H, t, $J_{5,6}=J_{3,4}$=9.8 Hz, H-4), 3.50 (1H, t, $J_{5,6}=J_{4,5}$=9.8 Hz, H-5), 3.57 (3H, s, $OCH_3$), 3.58 (1H, t, $J_{2,3}$=9.8 Hz, H-3), 4.20 (1H, dd, $J_{1,2}$=5.2 Hz, H-2), 4.50 (1H, t, $J_{1,6}$=5.2 Hz, H-1), 4.59 (1H, dd, $J_{7b,6}$=9.5 Hz, $J_{7a,7b}$=10.7 Hz, H-7b), 4.78 (1H, dd, $J_{7a,6}$=4.6 Hz, H-7a), 7.39—7.60 (3H, m, aromatic), 7.99—8.02 (2H, m, aromatic); $[\alpha]_D^{27}$ +40.3° (*c* 1.44, $CHCl_3$). Found: C, 68.53; H, 7.72%. Calcd for $C_{27}H_{36}O_7$: C, 68.62; H, 7.68%.

Further elution gave **14** as an amorphous solid (1.1 g) in 30% yield from **10**. IR (Nujol) 3400, 1720, 1360, 1270, 1160, 1100, 1070, 1040, 930, 900, and 840 $cm^{-1}$; $^1H$ NMR ($CDCl_3$) $\delta$=1.22—1.78 (20H, m, $(CH_2)_{10}$), 2.46—2.58 (1H, m, H-6), 3.42 (3H, s, $OCH_3$), 3.63 (1H, dd, $J_{2,3}$=6.7 Hz, $J_{3,4}$=10.7 Hz, H-3), 3.79 (1H, dd, $J_{3,4}$=10.7 Hz, $J_{4,5}$=6.7 Hz, H-4), 3.81 (1H, t, $J_{5,6}$=6.7 Hz, H-5), 4.29 (1H, t, $J_{1,6}=J_{1,2}$=6.7 Hz, H-1), 4.34 (1H, t, $J_{1,2}$=6.7 Hz, H-2), 4.53 (1H, d, $J_{7b,6}$=7.9 Hz, H-7b), 4.54 (1H, d, $J_{7a,6}$=6.1 Hz, H-7a), 7.40—7.60 (3H, m, aromatic), 8.02—8.07 (2H, m, aromatic); $[\alpha]_D^{27}$ +39° (*c* 1.3, $CHCl_3$). Found: C, 68.57; H, 7.68%. Calcd for $C_{27}H_{36}O_7$: C, 68.62; H, 7.68%.

**1L-(1,2,4,6/3,5)-6-Benzoyloxymethyl-1,2-*O*-cyclohexylidene-5-*O*-methyl-1,2,3,4,5-cyclohexanepentol (15).** To a solution of **13** (35 mg, 0.074 mmol) in a mixture of $CH_2Cl_2$ (0.5 ml) and methanol (0.3 ml) was added acetyl chloride (5 μl) at 0 °C. After the reaction mixture was stirred at that temperature for 2 h, the reaction was quenched by the addition of 2.5% $NaHCO_3$. The aqueous layer was extracted with $CH_2Cl_2$, and the combined organic layer was washed with brine, dried over anhydrous $Na_2SO_4$, and concentrated to dryness to leave an oil. The crude material was purified by column chromatography ($SiO_2$, ethyl acetate : hexane=2 : 1) to afford **15** as a syrup (16 mg) in 56% yield. IR (Nujol) 3370, 1710, 1260, 1100, 1060, 1020, 1000, and 920 $cm^{-1}$; $^1H$ NMR ($CDCl_3$) $\delta$=1.10—1.90 (10H, m, $(CH_2)_{10}$), 2.22—2.35 (1H, m, H-6), 3.06 (1H, s, OH), 3.36 (1H, t, $J_{4,5}=J_{5,6}$=10.4 Hz, H-5), 3.44 (1H, t, $J_{3,4}$=10.4 Hz, H-4), 3.62 (3H, s, $OCH_3$), 3.64 (1H, t, $J_{2,3}$=10.4 Hz, H-3), 3.97 (1H, dd, $J_{1,2}$=4.9 Hz, H-2), 4.40 (1H, t, $J_{1,6}$=4.9 Hz, H-1), 4.54 (1H, dd, $J_{7b,6}$=8.5 Hz, $J_{7a,7b}$=10.7 Hz, H-7b), 4.80 (1H, dd, $J_{7a,6}$=4.3 Hz, H-7a), 7.20—7.60 (3H, m, aromatic), 8.02—8.05 (2H, m, aromatic); $[\alpha]_D^{25}$ +36° (*c* 2.1, $CHCl_3$). Found: C, 64.03; H, 7.23%. Calcd for $C_{21}H_{28}O_7$: C, 64.27; H, 7.19%.

**1L-(1,2,4/3,5,6)-6-Benzoyloxymethyl-1,2-*O*-cyclohexylidene-5-*O*-methyl-1,2,3,4,5-cyclohexanepentol (16).** This compound was prepared from **14** resembling to that of **15** as a syrup. IR (Nujol) 3400, 1710, 1260, 1090, 1060, 1010, and 920 $cm^{-1}$; $^1H$ NMR ($CDCl_3$) $\delta$=1.20—1.78 (10H, m, $(CH_2)_{10}$), 2.65—2.75 (1H, m, H-6), 2.88 (1H, brs, OH), 3.09 (1H, brs, OH), 3.45 (3H, s, $OCH_3$), 3.62 (1H, dd, $J_{4,5}$=4.3 Hz, $J_{5,6}$=5.8 Hz, H-5), 3.73—3.86 (2H, m, H-3, 4), 4.18 (1H, dd, $J_{2,3}$=7.0 Hz, $J_{1,2}$=6.0 Hz, H-2), 4.29 (1H, t, $J_{1,6}$=6.0 Hz, H-1), 4.46—4.58 (2H, m, H-7a,7b), 7.20—7.60 (3H, m, aromatic), 8.02—8.05 (2H, m, aromatic); $[\alpha]_D^{24}$ −15° (*c* 3.3, $CHCl_3$). Found: C, 64.06; H, 7.18%. Calcd for $C_{21}H_{28}O_7$: C, 64.27; H, 7.19%.

**1L-(1,2,4,6/3,5)-6-Benzoyloxymethyl-1,2-*O*-cyclohexylidene-1,2,3,4,5-cyclohexanepentol (17).** To a solution of **13** (41 mg, 0.087 mmol) in $CH_3CN$ (0.6 ml) were added NaI (165 mg, 1.10 mmol) and $AlCl_3$ (147 mg, 1.10 mmol) at 0 °C. After the reaction mixture was stirred at room temperature for 3 h, the reaction was quenched by the addition of ice water. The aqueous layer was extracted with $CH_2Cl_2$ (5 ml×3). The combined organic layer was successively washed with brine (2 ml), 10% $Na_2SO_3$ solution, and brine (3 ml), dried over anhydrous $Na_2SO_4$, and concentrated to leave an oil, which was purified by column chromatography ($SiO_2$, ethyl acetate : hexane=1 : 6) to afford **17** as a syrup (20 mg) in 61% yield. IR ($CHCl_3$) 3600—3300 (br), 2400, 1700, 1500, 1410, 1200, 1040, 920, 720 (br), and 650 $cm^{-1}$; $^1H$ NMR ($CDCl_3$) $\delta$=1.25—1.70 (10H, m, $(CH_2)_5$), 2.20—2.35 (1H, m, H-6), 3.38 (1H, t, $J_{5,4}=J_{3,4}$=10.1 Hz, H-4), 3.59 (1H, t, $J_{2,3}$=10.1 Hz, H-3), 3.68 (1H, t, $J_{5,6}$=10.1 Hz, H-5), 3.99 (1H, dd, $J_{1,2}$=4.6 Hz, H-2), 4.08 (2H, brs, OH), 4.37 (1H, t, $J_{1,6}$=4.6 Hz, H-1), 4.39 (1H, brs, OH), 4.56 (1H, dd, $J_{7b,6}$=9.2 Hz, $J_{7a,7b}$=11.0 Hz, H-7b), 4.84 (1H, dd, $J_{7a,6}$=4.3 Hz, H-7a), 7.37—7.57 (3H, m, aromatic), 7.99—8.02 (2H, m, aromatic).

**1L-(1,2,4,6/3,5)-3,4,5-Tri-*O*-benzyl-6-benzyloxymethyl-1,2-*O*-cyclohexylidene-1,2,3,4,5-cyclohexanepentol (18).** To a solution of **17** (226 mg, 0.597 mmol) in DMF (8 ml) was added NaH (60%, 119 mg, 2.98 mmol) at 0 °C. After the reaction mixture was stirred at that temperature for 10 min, benzyl bromide (355 μl, 2.98 mmol) was added. The mixture was stirred at room temperature for 3 h more. After the addition of NaH (72 mg, 1.8 mmol) and methanol (10 μl) to the reaction mixture at 0 °C, stirring was continued at room temperature for 1 h more. To the solution were added successively NaH (120 mg, 3.00 mmol) and benzyl bromide (355 μl, 2.98 mmol) and the mixture was stirred at room temperature for 1 h. The reaction was quenched by the addition of ice water. The aqueous layer was extracted with ethyl acetate (10 ml×3). The combined organic layer was successively washed with brine (5 ml), sat. $NaHCO_3$ solution (5 ml)), and brine (5 ml), dried over anhydrous $Na_2SO_4$, and concentrated to leave an oil, which was purified by column chromatography ($SiO_2$, ethyl acetate : hexane=1 : 15) to afford **18** (322 mg) in 84.5% yield. IR ($CHCl_3$) 3000, 2920, 2850, 1480, 1430, 1340, 1180, 1010, 900, 680, and 640 $cm^{-1}$; $^1H$ NMR $\delta$=1.30—1.75 (10H, m, $(CH_2)_5$), 2.15—2.30 (1H, m, H-6), 3.47 (1H, t, $J_{5,4}=J_{3,4}$=9.2 Hz, H-4), 3.58 (1H, dd, $J_{5,6}$=11.0 Hz, H-5), 3.66 (1H, dd, $J_{7b,6}$=8.2 Hz, $J_{7a,7b}$=8.4 Hz, H-b), 3.69 (1H, dd, $J_{2,3}$=7.0 Hz, H-3), 3.85 (1H, dd, $J_{7a,6}$=4.3 Hz, H-7a), 4.12 (1H, dd, $J_{1,2}$=5.2 Hz, H-2), 4.46 (1H, dd, $J_{1,6}$=1.0 Hz, $J_{1,2}$=5.2 Hz, H-1), 4.47 (1H, d, $J$=10.7 Hz, PhCH), 4.53 (2H, s, $PhCH_2$), 4.74 (1H, d, $J$=10.7 Hz, PhCH), 4.75 (1H, d, $J$=10.7 Hz, PhCH), 4.86 (1H, d, $J$=10.7 Hz, PhCH), 4.89 (1H, d, $J$=10.7 Hz, PhCH), 4.93 (1H, d, $J$=10.7 Hz, PhCH), 7.15—7.20 (20H, m, aromatic). $[\alpha]_D^{24}$ +17° (*c* 2.0, $CHCl_3$). Found: C, 77.69; H, 7.50%. Calcd for $C_{41}H_{46}O_6$: C, 77.57; H, 7.30%.

**1L-(1,2,4,6/3,5)-Tri-*O*-benzyl-6-benzyloxymethyl-1,2,3,4,5-cyclohexanepentol (19).** A solution of **18** (16.9 mg, 0.027 mmol) in a mixture of trifluoroacetic acid and methanol (2.5 ml, 8/1, v/v) was stirred at room temperature for 2 h. The solvent was removed under reduced pressure and the remaining oil was purified by thin-layer chromatography ($SiO_2$, ethyl acetate : hexane=1 : 2) to afford **19** as a crystalline solid (13 mg) in 90% yield. Mp 118—119 °C (ethyl acetate–hexane); IR ($CHCl_3$) 3450 (br), 3000, 2870, 1480, 1440, 1340, 1200, 1060, 910, 740 (br), 660, and 560 $cm^{-1}$; $^1H$ NMR ($CDCl_3$) $\delta$=1.68—1.80 (1H, m, H-6), 2.38 (1H, brs, OH), 3.30 (1H, brs, OH), 3.85 (1H, dd, $J_{7a,6}$=3.1 Hz, $J_{7a,7b}$=9.0 Hz, H-7a), 3.55 (1H, t, $J_{5,4}=J_{3,4}$=9.0 Hz, H-4), 3.72 (1H, dd, $J_{7b,6}$=3.1 Hz, H-7b), 3.83 (1H, t, $J_{5,6}$=9.3 Hz, H-5), 3.89 (1H, dd, $J_{2,3}$=9.3 Hz, $J_{1,2}$=3.7 Hz, H-2), 3.91 (1H, t, $J_{2,3}$=9.3 Hz, H-3), 4.25 (1H, brs, H-1), 4.47 (2H, s, $PhCH_2$), 4.51 (1H, d, $J$=11.3 Hz, PhCH), 4.78 (1H, d, $J$=11.3 Hz, PhCH), 4.86—4.96 (4H, m, $PhCH_2$), 7.16—7.33 (20H, m, aromatic); $[\alpha]_D^{24}$ +7.7° (*c* 1.30, $CHCl_3$). Found: C, 75.72; H, 7.13%. Calcd for $C_{35}H_{38}O_6$: C, 75.79; H, 6.91%.

**1L-(1,2,4,6/3,5)-3,4,5-Tri-*O*-benzyl-6-benzyloxymethyl-2-*O*-trifluoromethylsulfonyl-1,2,3,4,5-cyclohexanepentol (20).** To a solution of **19** (52 mg, 0.093 mmol) in $CH_2Cl_2$ (0.3 ml) were added pyridine (15 μl, 0.18 mmol) and trifluoromethanesulfonic anhydride (24 μl, 0.141 mmol) at 0 °C. After the mixture was stirred at that temperature for 2 h, ice water (3 ml) was added. The aqueous layer was extracted with ethyl acetate (5 ml×3) and the combined organic layer was successively washed with brine (3 ml), sat. $NaHCO_3$ solution (3 ml), and brine (3 ml), dried over anhydrous $Na_2SO_4$, and concentrated to dryness to afford an oil, which was purified by column chromatography ($SiO_2$, ethyl acetate : hexane=1 : 4) to afford **20** as a syrup (63.8 mg) in 98% yield. This compound was unstable, and so was used in the next step without further purification. $^1H$ NMR ($CDCl_3$) $\delta$=1.60—1.72 (1H, m, H-6), 3.58 (1H, t, $J_{4,5}=J_{3,4}$=9.5 Hz, H-4), 3.73 (1H, dd, $J_{7a,6}$=2.7 Hz, $J_{7a,7b}$=9.2 Hz, H-7a), 3.78 (1H, brs, OH), 3.96 (1H, dd, $J_{7b,6}$=4.0 Hz, H-7b), 4.02 (1H, dd, $J_{5,6}$=11.3 Hz, H5), 4.21 (1H, t, $J_{2,3}$=9.5 Hz, H-3), 4.42 (1H, d, $J$=11.6 Hz, PhCH), 4.47 (1H, brs, H-6), 4.50 (1H, d, $J$=11.6 Hz, PhCH), 4.51 (1H, d, $J$=11.6 Hz, PhCH), 4.70 (1H, dd, $J_{1,2}$=2.8 Hz, H-2), 4.78—4.93 (5H, m, PhCH), 7.13—7.43 (20H, m, aromatic).

**1L-(1,2,4,6/3,5)-1-*O*-Acetyl-3,4,5-tri-*O*-benzyl-6-benzyloxymethyl-2-*O*-trifluoromethylsulfonyl-1,2,3,4,5-cyclohexanepentol (21).** To a solution of **20** (63.5 mg, 0.0925 mmol) in pyridine (2.0 ml) were added a catalytic amount of 4-dimethylaminopyridine and acetic anhydride (175 μl, 0.185 mmol) and the reaction mixture was stirred at room temperature overnight. The reaction was quenched by the addition of ice water. The aqueous layer was extracted with $CH_2Cl_2$ (5 ml×3). The combined organic layer was successively washed with 5% $KHSO_4$ solution (5 ml), brine (5 ml), dried over anhydrous $Na_2SO_4$, and concentrated to leave an oil, which was purified by column chromatography

($SiO_2$, ethyl acetate : benzene = 1 : 150) to afford **21** as an amorphous solid (67.0 mg, quantitatively). This compound was unstable, and so was used in the next step without further purification. $^1$H NMR ($CDCl_3$) $\delta$=1.82—1.95 (1H, m, H-6), 1.93 (3H, s, $COCH_3$), 3.46 (1H, dd, $J_{7a,7b}$=9.2 Hz, $J_{7a,6}$=7.3 Hz, H-7a), 3.64 (1H, t, $J_{4,5}=J_{3,4}$=9.4 Hz, H-4), 3.65 (1H, dd, $J_{7b,6}$=3.4 Hz, H-7b), 3.80 (1H, dd, $J_{5,6}$=11.4 Hz, H-S), 4.00 (1H, t, $J_{2,3}$=9.4 Hz, H-3), 4.34, 4.39 (2H, ABq, $J$=11.6 Hz, $PhCH_2$), 4.56(1H, d, $J$=11.6 Hz, PhCH), 4.78 (1H, dd, $J_{1,2}$=3.1 Hz, H-2), 4.84—4.90 (5H, m, $PhCH_2$), 5.82 (1H, t, $J_{1,6}$=3.1 Hz, H-1), 7.15—7.38 (20H, m, aromatic); $[\alpha]_D^{24.5}$ +36° ($c$ 1.6, $CHCl_3$).

**1L-(1,4,6/2,3,5)-1-*O*-Acetyl-3,4,5-tri-*O*-benzyl-6-benzyloxymethyl-2-iodo-1,3,4,5-cyclohexanetetrol (22).** A solution of **21** (67 mg, 0.092 mmol) and $n$-$Bu_4NI$ (112 mg, 0.303 mmol) in benzene (5 ml) was refluxed for 11 h. The reaction was quenched by the addition of ice water. The aqueous layer was extracted with ethyl acetate (5 ml×3). The combined organic layer was successively washed with 10% $Na_2SO_3$ (2 ml), brine (2 ml), sat. $NaHCO_3$ solution (2 ml), and brine (2 ml), dried over anhydrous $Na_2SO_4$, and concentrated to leave an oil, which was purified by column chromatography ($SiO_2$, ethyl acetate : benzene = 1 : 150) to afford **22** as an amorphous solid (63 mg) in amorphous solid (63 mg) in 96% yield from **20**. $^1$H NMR ($CDCl_3$) $\delta$=1.77 (3H, s, $COCH_3$), 2.88—3.00 (1H, m, H-6), 2.97 (1H, dd, $J_{3,4}$=9.0 Hz, $J_{2,3}$=4.0 Hz, H-3), 3.42 (1H, t, $J_{4,5}$=9.0 Hz, H-4), 3.62—3.36 (2H, m, H-7a, H-7b), 3.91 (1H, t, $J_{5,6}$=9.0 Hz, H-5), 4.31 (1H, d, $J$=11.6 Hz, PhCH), 4.46 (1H, dd, $J_{1,2}$=11.6 Hz, H-2), 4.47 (1H, d, $J$=11.6 Hz, PhCH), 4.49 (1H, d, $J$=11.6 Hz, PhCH), 4.57 (1H, d, $J$=11.6 Hz, PhCH), 4.69 (1H, d, $J$=11.6 Hz, PhCH), 4.78 (1H, d, $J$=11.6 Hz, PhCH), 4.89 (1H, d, $J$=11.6 Hz, PhCH), 4.96 (1H, d, $J$=11.6 Hz, PhCH), 5.46 (1H, t, $J_{1,6}$=2.5 Hz, H-1), 7.18—7.40 (20H, m, aromatic); $[\alpha]_D^{24}$ +40° ($c$ 1.5, $CHCl_3$).

**(1*S*,2*R*,3*S*,4*R*,5*R*,6*R*)-2,3,4-Tris(benzyloxy)-5-benzyloxymethyl-7-oxabicyclo[4.1.0]heptane (23).** To a solution of **22** (20 mg, 0.028 mmol) in a mixture of methanol (0.6 ml) and THF (0.6 ml) was added NaH (60%, 6.8 mg, 0.17 mmol) at 0 °C and the mixture was stirred at that temperature for 20 min. The reaction was quenched by the addition of ice water. The aqueous layer was extracted with ethyl acetate (5 ml×3). The combined organic layer was successively washed with 5% $KHSO_4$ solution (2 ml), brine (2 ml), sat. $NaHCO_3$ solution (2 ml), and brine (2 ml), dried over anhydrous $Na_2SO_4$, and concentrated to leave an oil, which was purified by column chromatography ($SiO_2$, ethyl acetate : benzene = 1 : 100) to afford **23** as a crystalline solid (17 mg, quantitatively). Mp 58.5—60.0 °C; $^1$H NMR ($CDCl_3$) $\delta$=2.30 (1H, m, H-5), 3.20 (1H, d, $J_{1,6}$=3.7 Hz, H-1), 3.26 (1H, t, $J_{3,4}=J_{4,5}$=10.1 Hz, H-4), 3.48 (1H, brdd, $J_{5,6}$<1 Hz, H-6), 3.55 (1H, dd, $J_{2,3}$=8.2 Hz, H-3), 3.57 (1H, t, $J_{8a,8b}=J_{8b,5}$=8.9 Hz, H-8b), 3.75 (1H, dd, $J_{8a,5}$=3.2 Hz, H-8a), 3.86 (1H, d, H-2), 4.39 (1H, d, $J$=10.7 Hz, PhCH), 4.50, 4.55 (2H, ABq, $J$=12.2 Hz, $PhCH_2$), 4.70—4.85 (5H, m, PhCH), 7.10—7.40 (20H, m, aromatic); $[\alpha]_D^{26}$ +76.1° ($c$ 0.67, $CHCl_3$). Found: C, 78.28; H, 6.67%. Calcd for $C_{35}H_{36}O_5$: C, 78.33; H, 6.76%.

**(+)-Cyclophellitol.** A solution of **23** (23.1 mg, 0.043 mmol) in a mixture of methanol (5 ml) and ethyl acetate (2 ml) was treated with 5% Pd–C (25 mg) at room temperature overnight. The catalyst was filtered off and the solvent was removed under pressure to give (+)-cyclophellitol as a crystalline solid quantitatively. $^1$H NMR ($D_2O$, internal standard of HOD as 4.80) $\delta$=2.03—2.13 (1H, m, H-5), 3.21 (1H, t, $J_{3,4}=J_{4,5}$=9.5 Hz, H-4), 3.22 (1H, d, $J_{1,2}$=0 Hz, $J_{1,6}$=4.3 Hz, H-1), 3.33 (1H, dd, $J_{2,3}$=8.4 Hz, H-3), 3.51 (1H, brd, H-6), 3.74 (1H, d, H-2), 3.78 (1H, dd, $J_{8a,8b}$=11.3 Hz, $J_{8b,5}$=7.3 Hz, H-8b), and 3.96 (1H, dd, $J_{8a,5}$=3.8 Hz, H-8a); $^{13}$C NMR ($D_2O$, internal standard of dioxane as 67.40) $\delta$=44.21 (C-5), 56.73 (C-1), 56.99 (C-6), 61.20 (C-8), 67.47 (C-4), 71.61 (C-2), and 77.03 (C-3); Mp 148.5—150.5 °C ($Et_2O$ : MeOH = 1 : 1); $[\alpha]_D^{24}$ +103° ($c$ 0.380, $H_2O$) (lit, Mp 149—151 °C; $[\alpha]_D^{27}$ +103° ($c$ 0.5, $H_2O$).[21]

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