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Synthesis of Both Enantiomers of the BC-ring Part of Ciguatoxin

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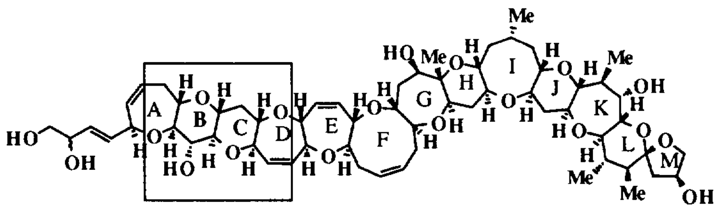
Abstract: Both enantiomers of the BC-ring part skeleton of ciguatoxin were synthesized from D-galactose. Copyright © 1996 Elsevier Science Ltd

INTRODUCTION

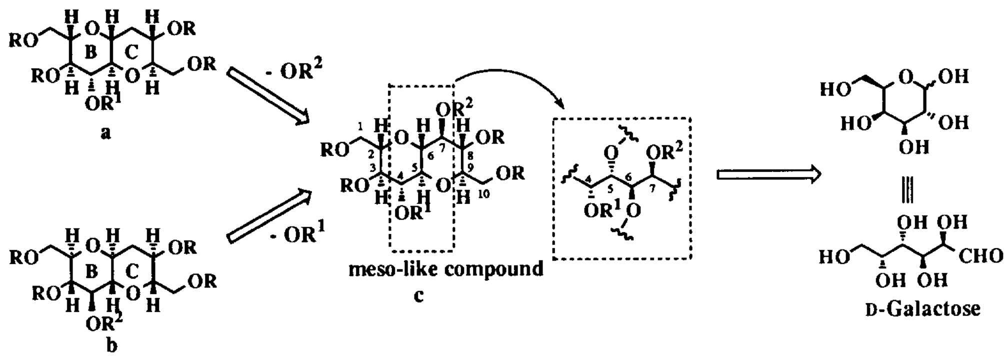
Ciguatoxin **1** has been isolated as the principal toxin causing ciguatera from the moray eel *Gymnothorax javanicus*. The structure of **1** proposed by Yasumoto and Murata has a characteristic polycyclic system including 13 medium sized cyclic ethers,[1] but the absolute configuration has not yet been determined. Its interesting biological activities and limited availability from natural sources have made **1** one of the most challenging synthetic target molecules.[2] Accordingly, we started to synthesize both enantiomers of **1** in order to determine its absolute configuration.



Ciguatoxin 1

The study in this paper is to construct the BC-ring part of **1**. We paid an attention to the symmetrical character in the part, that is, if a hydroxyl group is introduced temporally on the methylene part in the C-ring, the target molecule would be regarded as the *meso*-like compound **c** (Scheme 1). Either compound **a** or compound **b** would possibly be constituted as a part of the whole structure **1** having the right absolute configuration. Therefore, we planned to synthesize both **a** and **b** efficiently which correspond to the enantiomeric skeletons of the BC-ring part on **1** by discrimination of R^1 and R^2 of the commom intermediate **c**. The configurations of the successive asymmetric carbons at C-4, 5, 6 and 7 in compound **c** were corresponding to those of D-galactose. Accordingly, we intended to synthesize both **a** and **b** *via* **c** starting from D-galactose and the details are described in this paper.

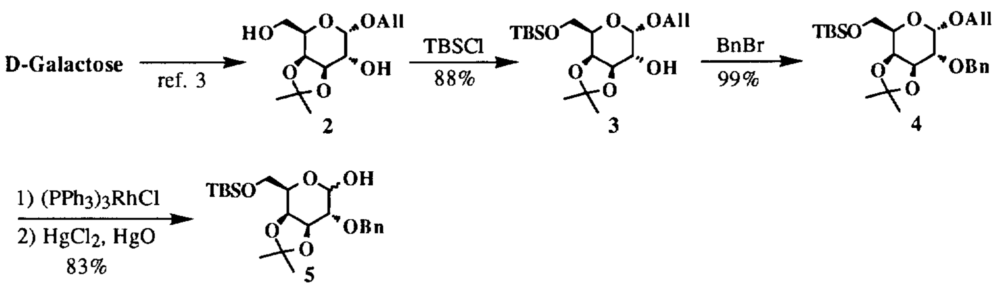
Scheme 1



RESULTS AND DISCUSSION

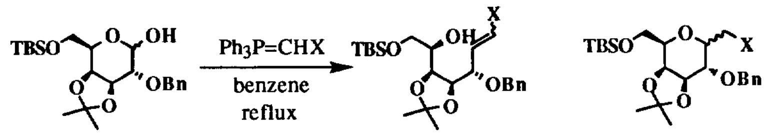
The synthesis commenced with the known compound **2** which was prepared in three steps from D-galactose.[3] The primary alcohol of **2** was transformed into the *t*-butyldimethylsilyl (TBS) ether **3**, the secondary alcohol of which was protected to the benzyl (Bn) ether **4**. Compound **4** provided a hemiacetal **5** with $(PPh_3)_3RhCl$ and then with $HgCl_2$ and HgO[4] in good yield (Scheme 2).

Scheme 2



For the purpose of *E*-olefin elongation, Wittig reaction of **5** was examined under various conditions, and the several results are shown in Table 1. Treatment of **5** with Ph_3P=CHCOOMe (entry 1) provided only *E*-olefin in low yield, along with a mixture of tetrahydropyrans in 45% yield. The tetrahydropyrans seemed to be formed by the intramolecular Michael attack of the hydroxyl group to initially formed α, β-unsaturated ester.[5] The result reveals that the olefin formed would take the conformation suitable for ring closure. Therefore, we attempted to reduce the electron-withdrawing property of the X part of the intermediate. Use of Ph_3P=CHCN endured cyclization to afford the olefins mainly, though the *E*/*Z* ratio was not selective (1/1) (entry 2). Use of Ph_3P=CHCOS^{t}Bu provided a complex mixture (entry 3). Finally, use of Ph_3P=CHCOO^{t}Bu (entry 4) was led to no cyclized compounds, and an *E*-olefin was obtained in a practical yield (67%, *E*/*Z* ratio was 2/1). The change in *E*/*Z* selectivities of olefins between entries 2 and 4 was probably due to the difference between the stabilities in the betaines from Ph_3P=CHCOO^{t}Bu and Ph_3P=CHCN. The different stabilities would result from the difference of bulkiness in the respective COO^{t}Bu and CN groups. Horner-Emmons modification of Wittig reaction to **5** resulted in no reaction.

Table 1

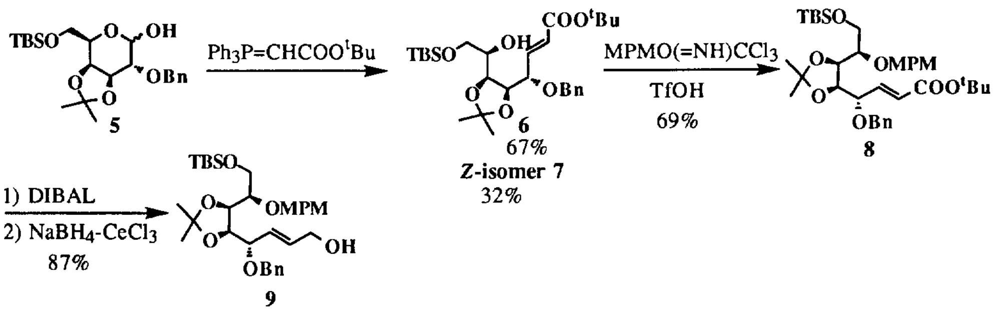


5 olefin tetrahydropyran

entry	X	time	olefin	tetrahydropyran	recovery of 5
1	COOMe	8 h	36% (*E* only)	45% ($\alpha:\beta = 5:1$)	16%
2	CN	41 h	71% ($E:Z = 1:1$)	18% ($\alpha:\beta = 4:1$)	6%
3	COS^{t}Bu	24 h		complex mixture	
4	COO^{t}Bu	6 h	99 % ($E:Z = 2:1$)	0%	0 %

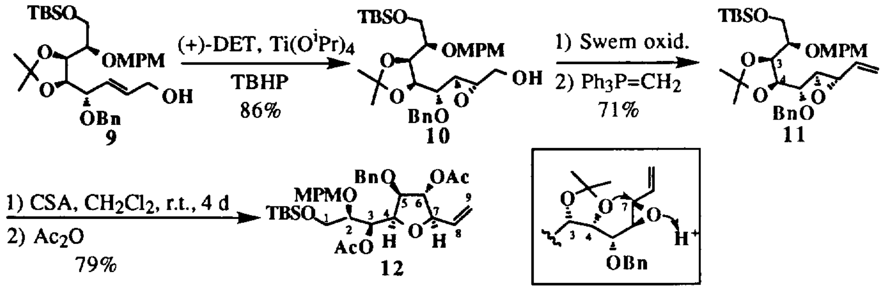
After **5** was changed into *E*-olefin **6**, the secondary hydroxyl group in **6** was protected with 4-methoxybenzyl-2,2,2-trichloroacetimidate [MPMO(=NH)CCl_3] and trifluoromethanesulfonic acid (TfOH)[6] to give the 4-methoxybenzyl (MPM) ether **8** (Scheme 3). Reduction of **8** with diisobutylaluminium hydride (DIBAL) and then with $NaBH_4$-$CeCl_3$ gave an allylic alcohol **9** in good yield.

Scheme 3



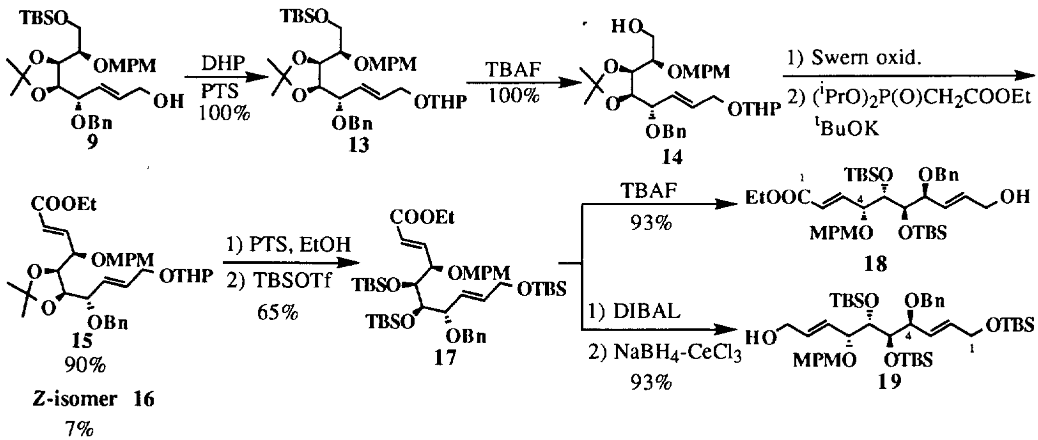
Sharpless epoxidation[7] of **9** with (+)-diethyl tartrate [(+)-DET] gave epoxy alcohol **10** in good yield,[8] which was oxidized to the aldehyde under Swern conditions[9] and subjected to Wittig reaction to afford terminal olefin **11** (Scheme 4). The intramolecular cyclization of **11** under acidic conditions by Nicolaou[10] led to a formation of tetrahydrofuran **12**[11] in a 5-endo fashion, but not a tetrahydropyran ring as a 6-endo product. This reaction proceeded exclusively by attack of the oxygen atom at C-4 because of the fixed conformation originated from the presence of acetonide group. Therefore, removal of the acetonide group of **11** was attempted resulting in decomposition. Furthermore, the cyclization under protic conditions gave a complex mixture because of the higher reactivity of the epoxide part than that of the acetonide group. Consequently, the acetonide group was obliged to be exchanged by other protective group before construction of the epoxide.

Scheme 4



The hydroxyl group in **9** was protected as the tetrahydropyranyl (THP) ether, and desilylation of **13** with tetrabutylammonium fluoride (TBAF) gave alcohol **14**, which was subjected to Swern oxidation and a Horner-Emmons reaction to afford *E*-olefin **15** in high yield (Scheme 5). The THP and acetonide groups of **15** were hydrolyzed under acidic conditions to give a triol, which was protected with TBSOTf to afford tris-TBS ether **17**. **17** afforded allylic alcohol **18** with TBAF, while **17** was reduced with DIBAL and then with $NaBH_4$-$CeCl_3$ to give another allylic alcohol **19**.

Scheme 5



Epoxidation of allylic alcohols was examined as shown in Scheme 6 and Table 2. Reaction of **18** under Sharpless conditions gave tetrahydropyran **20**[12] with recovery of **18** and no epoxy alcohol (Scheme 6). **20** seemed to be produced by epoxidation followed by 6-exo type internal cyclization by MPM ether oxygen atom *in situ*. Then, epoxidation of an alternate allylic alcohol **19** was attempted under Sharpless conditions (Table 2). The result in entry 1 was sluggish, producing α-epoxide **21** (17%), tetrahydropyran **23** (38%),[13] and recovery of **19** (18%). The reaction with *t*-butylhydroperoxide (TBHP) and vanadyloxy acetylacetonate [$VO(acac)_2$] (entry 2) gave a complex mixture. These results imply that the oxygens at C-4 in **18** and **19** might be suitably oriented for intramolecular cyclizations.[14] On the other hand, epoxidation of **19** was attempted with *m*-chloroperbenzoic acid (*m*CPBA) as a peracid (entry 3).[8] Resultingly, α-epoxide **21** (26%) and β-epoxide **22** (49%) were obtained with recovery of **19** (2%). This result might be due to effective steric hindrance. Consequently, it was found to be rather difficult to obtain selectively **21** using **19**. Further chemical conversion of **22** into **21** was also fruitless.

Scheme 6

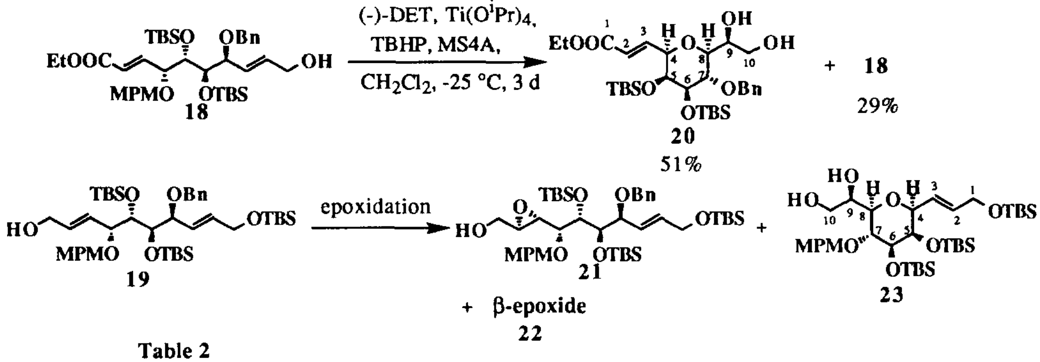
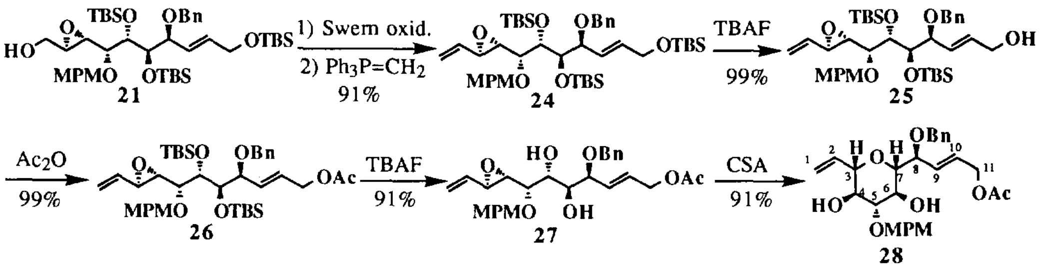


Table 2

entry	reagents and conditions	21	22	23	19
1	(+)-DET, Ti(O^{i}Pr)$_4$, TBHP, CH_2Cl_2, -25 °C, 9 d	17%	0%	38%	18%
2	$VO(acac)_2$, TBHP, benzene, r.t., 5 h	complex mixture			
3	*m*CPBA, Na_2HPO_4, CH_2Cl_2, r.t., 18 h	26%	49%	0%	2%

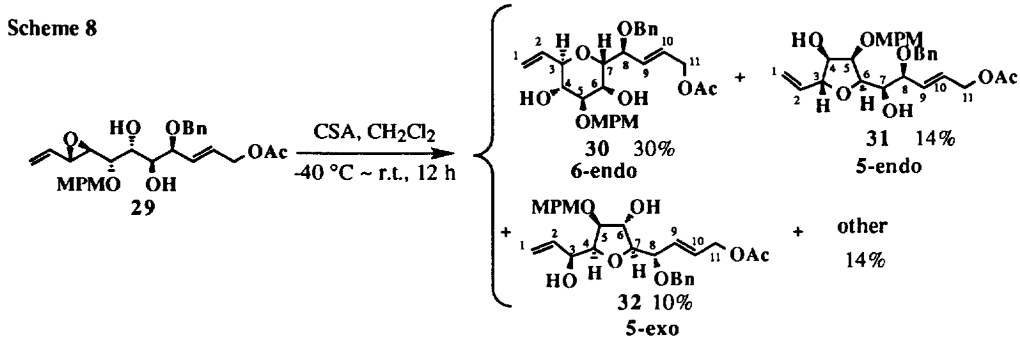
However, the synthesis was continued using the epoxy alcohol **21** (Scheme 7). **21** was oxidized to the aldehyde and subjected to Wittig reaction to afford a terminal olefin **24**, which was partially desilylated with TBAF (0 °C, 1 h) to an allylic alcohol **25**. **25** afforded the corresponding acetate **26**, which yielded diol **27** with TBAF (r.t., 2 h). The epoxide opening by the internal hydroxyl group of **27** gave exclusively rise to tetrahydropyran **28** in 91% yield as a single isomer from 6-endo type cyclization regardless of four possible reactive positions.[15]

Scheme 7



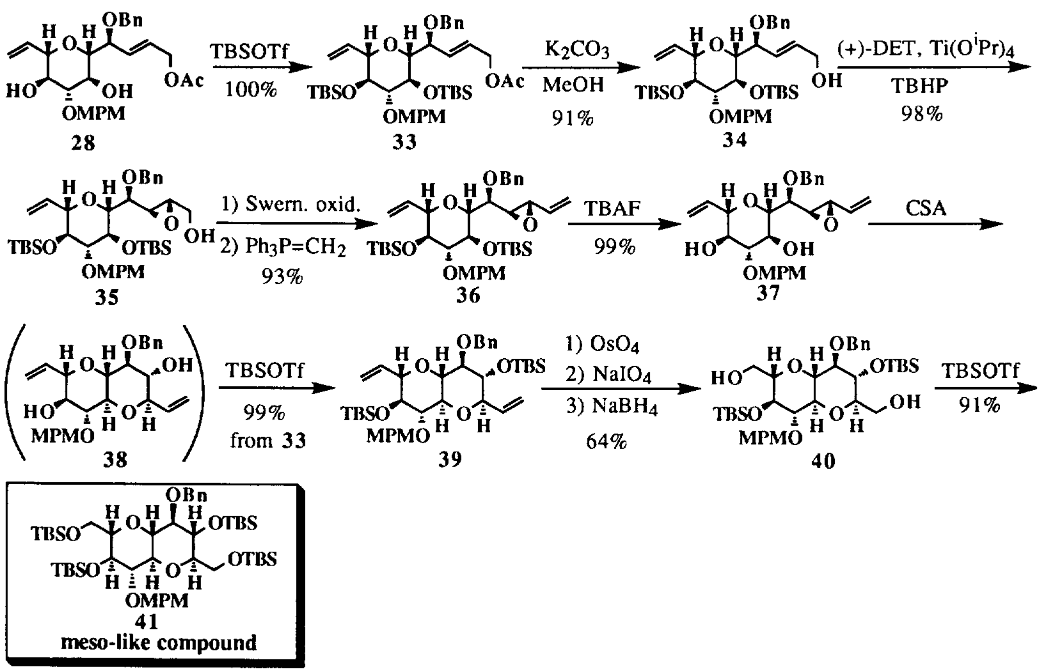
On the other hand, the corresponding β-epoxide **29** produced **30** (6-endo cyclization, 30% yield),[16a] **31** (5-endo cyclization, 14% yield),[16b] **32** (5-exo cyclization, 10% yield),[16c] and other unknown products (14% yield) (Scheme 8). The product **28** has all equatorial substituents on the tetrahydropyran ring. It would be reasonable to suppose that, if the conformation in the transition state for the ring closure would be similar to that of the product, these substituents could take more energetically favorable conformation for epoxide opening from **27** in the transition state. Likewise, **30** has two axial and three equatorial substituents on the tetrahydropyran ring, and these substituents would be also suitable for production of tetrahydrofurans **31** and **32** in the transition states for ring closure of **29**. Therefore, it should be emphasized that conversion of **27** into **28** is a specified reaction.

Scheme 8



Preparation of the *meso*-like compound **41** is shown in Scheme 9. **28** was protected with TBSOTf to afford the bis-TBS ether **33**. Saponification of **33** with K_2CO_3 and MeOH obtained allylic alcohol **34**. Sharpless asymmetric epoxidation of **34** using (+)-DET yielded an epoxy alcohol **35** in good selectivity (>99% de) and high yield (98%). **35** was oxidized to the aldehyde and subjected to Wittig reaction to produce terminal olefin **36**, which gave **37** with TBAF. Furthermore, cyclization of the epoxy alcohol **37** with 10-camphorsulfonic acid (CSA) afforded a crude two ring-fused compound **38**, the hydroxyl group of which was immediately protected to give **39** in an excellent total yield because of the unstability of **38**. Both the terminal olefins in **39** were treated with OsO_4, $NaIO_4$, and then with $NaBH_4$ to yield diol **40**, which led to the desired *meso*-like compound **41** with TBSOTf.

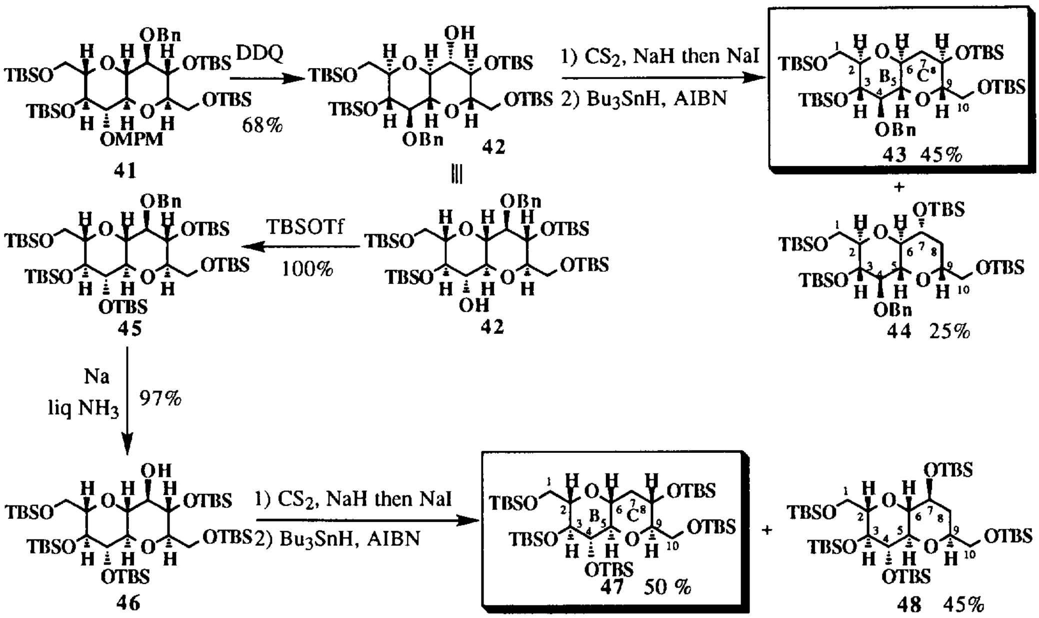
Scheme 9



Finally, transformations of the *meso*-like compound **41** to both enantiomers **43** and **47** are shown in Scheme 10. The MPM ether of **41** was detached with 2,3-dichloro-5,6-dicyano-1,4-benzoquinone (DDQ) and the product **42** was converted to the corresponding xanthate, which was reduced with Bu_3SnH[17] giving **43** one of the desired enantiomers. The by-product **44** was also obtained in 25% yield. The 1, 2-rearrangement of the TBS group in formation of **44** would be induced in the preparation stage of xanthate. Another enantiomer corresponding to **43** should be synthesized if the Bn ether of **41** could be removed. However, the reaction did not proceed under various reaction conditions [H_2, Raney-Ni (W2 or W4), EtOH, reflux or H_2, Pd/C, EtOH, reflux] because of its highly hindered position. Accordingly, after protection of the hydroxyl group of **42** as the TBS ether followed by Bn ether removal with Na/liq. NH_3, deoxygenation at the hydroxyl group *via* Barton reaction[17] proceeded smoothly to produce another enantiomer **47** along with by-product **48**.

In conclusion, both enantiomers of the BC-ring part skeleton of ciguatoxin was successfully synthesized starting from commercially available D-galactose *via* the *meso*-like compound. Further studies aiming at the total synthesis of **1** are now in progress in our laboratory.

Scheme 10



EXPERIMENTAL

General: All reactions involving air- or moisture-sensitive reagents were conducted under argon atmosphere, and solvents and reagents were dried and distilled before use. Ether, tetrahydrofuran (THF), and toluene were distilled from sodium benzophenone ketyl. Dichloromethane and benzene were distilled from calcium hydride (CaH_2). Molecular sieves 4Å (MS4A) were finely powered and activated at 220 °C for 3 h *in vacuo*. All reactions were monitored by thin-layer chromatography with precoated silica gel (SiO_2) plates (E. Merck, Silica gel 60 F_{254} Art. 5554). Flash chromatography utilized silica gel (SiO_2) (E. Merck, Silica gel 60, 70-230 mesh ASTM, Art. 7734). Preparative thin-layer chromatography (PTLC) utilized precoated silica gel (SiO_2) plates (E. Merck, Silica gel 60 F_{254} Art. 5554). Develosil 60-5 (NOMURA CHEMICAL) was used as preparative high pressure liquid chromatography (HPLC) column. Infrared (IR) spectra were obtained on a Hitachi 270-30 infrared spectrophotometer. ^{1}H NMR spectra were recorded on a JEOL FX-270 (270 MHz) and α-400 (400 MHz) in $CDCl_3$ unless otherwise stated. Splitting patterns are designated as "s, d, t, q, m, and br," indicating "singlet, doublet, triplet, quartet, multiplet, and broad," respectively. High-resolution mass spectra (HR-MS) were obtained on a JEOL JMS-HX-110, JMS-AX-500, or JMS-SX-102A mass spectrometers. Optical rotation were recorded on JASCO DIP-360 digital polarimeter using $CHCl_3$ as a solvent. Melting points were measured on YANAGIMOTO micromelting point apparatus.

Allyl 6-*O*-*tert*-butyldimethylsilyl-3,4-*O*-isopropylidene-α-D-galactopyranoside (3).
To a solution of **2** (5.10 g, 19.6 mmol), triethylamine (TEA) (6 ml, 45 mmol), and 4-(dimethylamino)pyridine (DMAP) (cat. amount) in dichloromethane (100 ml) was added TBSCl (3.25 g, 21 mmol), and the mixture was stirred at room temperature for 10 h. The reaction mixture was diluted with ether, washed with saturated aqueous $NaHCO_3$ and brine, dried over $MgSO_4$, filtered, and concentrated. The crude product was purified by column chromatography on SiO_2 (hexane:ethyl acetate, 4:1) to afford **3** (6.47 g, 88% yield) as a colorless oil: $[\alpha]_D^{23}$ +81.1° (*c* 0.72); ^{1}H NMR (270 MHz) δ 6.00-5.85 (1H, m), 5.29 (1H, dq, *J* = 17, 2 Hz), 5.21 (1H, dq, *J* = 10, 2 Hz), 4.90 (1H, d, *J* = 4 Hz), 4.33-4.17 (3H, m), 4.10-4.00 (2H, m), 3.89-3.72 (3H, m), 2.22 (1H, br d, *J* = 7 Hz), 1.50 (3H, s), 1.34 (3H, s), 0.90 (9H, s), and 0.08 (6H, s); IR (film) ν_{max} 3464, 3084, 2932, 2856, 1474, 1380, 1166, 1032, and 840 cm^{-1}; HR-FAB-MS calcd. for $C_{18}H_{35}O_6Si$ (M^++H) 375.2204, found *m/z* 375.2189.

Allyl 2-*O*-benzyl-6-*O*-*tert*-butyldimethylsilyl-3,4-*O*-isopropylidene-α-D-galactopyranoside (4).
Benzyl bromide (41.2 ml, 0.347 mmol) was added dropwise to a stirred suspension of **3** (118 mg, 0.315 mmol) and NaH [13.9 mg (60% in oil), 0.347 mmol] in THF (1.5 ml) at room temperature. After 15 h at room temperature, the reaction was completed and water was added to the mixture. The mixture was diluted with ether, washed with brine, dried over $MgSO_4$, filtered, and concentrated. The crude product was purified by column chromatography on SiO_2 (hexane:ethyl acetate, 15:1) to afford **4** (142 mg, 97% yield) as a colorless oil: $[\alpha]_D^{21}$ +73.3° (*c* 0.53); ^{1}H NMR (270 MHz) δ 7.37-7.26 (5H, m), 6.00-5.86 (1H, m), 5.32 (1H, dq, *J* = 17, 2 Hz), 5.22 (1H, dq, *J* = 10, 2 Hz), 4.82 (1H, d, *J* = 4 Hz), 4.79 (1H, d, *J* = 12 Hz), 4.70 (1H, d, *J* = 12 Hz), 4.34 (1H, dd, *J* = 5, 8 Hz), 4.21 (1H, dd, *J* = 2, 5 Hz), 4.18 (1H, ddt, *J* = 5, 14, 2 Hz), 4.03 (1H, dt, *J* = 2, 7 Hz), 3.97 (1H, ddt, *J* = 6, 14, 2 Hz), 3.83 (1H, dd, *J* = 7, 10 Hz), 3.76 (1H, dd, *J* = 7, 10 Hz), 3.51 (1H, dd, *J* = 4, 8 Hz), 1.38 (3H, s), 1.33 (3H, s), 0.89 (9H, s), and 0.07 (6H, s); IR (film) ν_{max} 3064, 3032, 2932, 2856, 1456, 1380, 1218, 1104, and 838 cm^{-1}; HR-FAB-MS calcd. for $C_{25}H_{41}O_6Si$ (M^++H) 465.2673, found *m/z* 465.2655.

2-*O*-Benzyl-6-*O*-*tert*-butyldimethylsilyl-3,4-*O*-isopropylidene-D-galactopyranose (5).
A mixture of **4** (122 mg, 0.263 mmol) and $(Ph_3P)_3RhCl$ (1.2 mg) in ethanol (2 ml) containing diisopropylethylamine (50 μl, 0.287 mmol) was heated under reflux for 3 h, cooled, and evaporated *in vacuo* to a brown residue which was dissolved in dichloromethane. The solution was washed with brine, dried over $MgSO_4$, filtered, and concentrated, and the yellow syrup was dissolved in 9:1 acetone-water (2 ml) containing HgO (156 mg). $HgCl_2$ (156 mg) in 9:1 acetone-water (1 ml) was added dropwise. The reaction mixture was stirred at room temperature for 30 min. The solvent was evaporated and the residue was dissolved in ether, and the solution was washed with saturated aqueous KI and brine, dried over $MgSO_4$, filtered, and concentrated. The crude product was purified by column chromatography on SiO_2 (benzene:ethyl acetate, 10:1) to afford **5** (99 mg, 2 steps 89% yield) as white crystals: m.p. 124-126 °C; $[\alpha]_D^{19}$ +15.5° (*c* 0.50); ^{1}H NMR (270 MHz) δ 7.36-7.26 (5H, m), 5.18 (1H, br s), 4.83-4.65 (2H, m), 4.40 (1H, t, *J* = 6 Hz), 4.29-4.18 (2H, m), 3.87-3.72 (3H, m), 3.60 (1H, dd, *J* = 4, 6 Hz), 3.43 and 3.20 (totally 1H, each br m), 1.43 and 1.41 (totally 3H, each s), 1.34 (3H, s), 0.90 and 0.89 (totally 9H, each s), and 0.07 (6H, s); IR (KBr) ν_{max} 3360, 3040, 2936, 2896, 1472, 1378, 1248, 1130, 1098, and 832 cm^{-1}; HR-FAB-MS calcd. for $C_{22}H_{37}O_6Si$ (M^++H) 425.2360, found

m/z 425.2371.

***tert*-Butyl (2*E*,4*S*,5*R*,6*S*,7*R*)-4-*O*-benzyl-8-*O*-*tert*-butyldimethylsilyl-5,6-*O*-isopropylidene-4,5,6,7,8-pentahydroxy-2-octenoate (6).**

A solution of **5** (283 mg, 0.667 mmol) and Ph_3P=CHCOO^{t}Bu (1.50 g, 4.00 mmol) in benzene (3 ml) was heated under reflux for 6 h. The solvent was evaporated *in vacuo*. The residue was purified by column chromatography on SiO_2 (hexane:ethyl acetate, 16:1) to afford **6** (218 mg, 67% yield) as a pale yellow oil, and Z-isomer **7** (107 mg, 32% yield) was also obtained.

Data for **6**: $[\alpha]_D^{21}$ +25.3° (*c* 2.72); ^{1}H NMR (270 MHz) δ 7.35-7.26 (5H, m), 6.85 (1H, dd, *J* = 7, 16 Hz), 6.03 (1H, dd, *J* = 1, 16 Hz), 4.64 (1H, d, *J* = 12 Hz), 4.45 (1H, d, *J* = 12 Hz), 4.31-4.25 (1H, m), 4.24 (1H, dd, *J* = 2,7 Hz), 4.19 (1H, dd, *J* = 4, 7 Hz), 3.75-3.62 (2H, m), 3.58 (1H, dd, *J* = 7, 9 Hz), 2.99 (1H, br d, *J* = 2 Hz), 1.52 (3H, s), 1.50 (3H, s), 1.36 (3H, s), 0.88 (3H, s), and 0.05 (6H, s); IR (film) ν_{max} 3512, 3068, 2936, 2860, 1718, 1658, 1464, 1370, 1250, 1154, and 838 cm^{-1}; HR-FAB-MS calcd. for $C_{28}H_{47}O_7Si$ (M^++H) 523.3092, found *m/z* 523.3120.

Data for **7**: ^{1}H NMR (270 MHz) δ 7.34-7.26 (5H, m), 6.35 (1H, dd, *J* = 9, 12 Hz), 5.95 (1H, dd, *J* = 1, 12 Hz), 5.25 (1H, br d, *J* = 9 Hz), 4.59 (1H, d, *J* = 11Hz), 4.43 (1H, d, *J* = 11 Hz), 4.30 (1H, *J* = 3, 7 Hz), 4.24 (1H, dd, *J* = 2, 7 Hz), 3.80-3.56 (4H, m), 1.53 (3H, s), 1.47 (9H, s), 1.34 (3H, s), 0.98 (9H, s), and 0.07 (6H, s).

***tert*-Butyl (2*E*,4*S*,5*R*,6*S*,7*R*)-4-*O*-benzyl-8-*O*-*tert*-butyldimethylsilyl-5,6-*O*-isopropylidene-7-*O*-*p*-methoxybenzyl-4,5,6,7,8-pentahydroxy-2-octenoate (8).**

To a solution of **6** (1720 mg, 3.475 mmol) and 4-methoxybenzyl-2,2,2-trichloroacetimidate (1.44 ml, 6.950 mmol) in ether (55 ml) was added dropwise a 11.3 mM solution of TfOH in ether (0.923 ml, 10.43 μmol) at room temperature for 10 min. The reaction mixture was washed with saturated aqueous $NaHCO_3$ and brine, dried over $MgSO_4$, filtered, and concentrated. The residue was diluted with a mixture of hexane-ethyl acetate (20:1), and then the remaining solid was separated by filtration. The filtrate was concentrated. The residue was purified by column chromatography on SiO_2 (hexane:ethyl acetate, 20:1) to afford **8** (1537 mg, 69% yield) as a pale yellow oil: $[\alpha]_D^{22}$ +13.9° (*c* 1.93); ^{1}H NMR (270 MHz) δ 7.36-7.18 (7H, m), 6.80 (2H, d, *J* = 9 Hz), 6.76 (1H, dd, *J* = 7, 16 Hz), 5.89 (1H, br d, *J* = 16 Hz), 4.58 (1H, d, *J* = 12 Hz), 4.57 (2H, br s), 4.31 (1H, d, *J* = 12 Hz), 4.27-4.15 (2H, m), 3.77 (3H, s), 3.82-3.55 (4H, m), 1.57 (3H, s), 1.49 (9H, s), 1.39 (3H, s), 0.87 (9H, s), and 0.03 (6H, s); IR (film) ν_{max} 3064, 3032, 2936, 2860, 1718, 1614, 1516, 1464, 1304, 1252, 1154, 1088, and 838 cm^{-1}; HR-FAB-MS calcd. for $C_{28}H_{47}O_7Si$ (M^+-H) 641.3511, found *m/z* 641.3511.

(2*E*,4*S*,5*R*,6*S*,7*R*)-4-*O*-Benzyl-8-*O*-*tert*-butyldimethylsilyl-5,6-*O*-isopropylidene-7-*O*-*p*-methoxybenzyl-oct-2-ene-1,4,5,6,7,8-hexaol (9).

8 (115.5 mg, 0.180 mmol) was dissolved in dichloromethane (6 ml) and then cooled to -78 °C. DIBAL (0.93 M solution in hexane, 0.43 ml, 0.400 mmol) was added dropwise to the solution and the mixture was stirred at -78 °C for 30 min, and mixed with water (ca. 0.05 ml). The mixture was diluted with ether, allowed to warm to room temperature, and vigorously stirred for 1 h, and then the remaining solid was separated by filtration. The filtrate was concentrated. The residue and $CeCl_3 \cdot 7H_2O$ (201 mg, 0.540 mmol) were dissolved in MeOH (10 ml), and $NaBH_4$ (excess) was added at room temperature until the reaction was completed. The reaction mixture was mixed with water and extracted with ethyl acetate. The organic layer was washed with brine, dried over $MgSO_4$, filtered, and concentrated. The crude product was purified by column chromatography on SiO_2 (hexane:ethyl acetate, 4:1) to afford **9** (87.5 mg, 2 steps 87% yield) as a pale yellow oil: $[\alpha]_D^{22}$ +5.90° (*c* 1.21); ^{1}H NMR (270 MHz) δ 7.35-7.20 (7H, m), 6.82 (2H, d, *J* = 9 Hz), 6.88 (1H, dt, *J* = 16, 5 Hz), 5.66 (1H, dd, *J* = 8, 16 Hz), 4.57 (1H, d, *J* = 12 Hz), 4.57 (2H, s), 4.43 (1H, d, *J* = 12 Hz), 4.19-4.04 (5H, m), 3.78 (3H, s), 3.77-3.59 (3H, m), 1.55 (3H, s), 1.39 (3H, s), 0.88 (9H, s), and 0.04 (6H, s); IR (film) ν_{max} 3464, 3064, 3032, 2936, 2860, 1614, 1516, 1466, 1380, 1250, 1088, 838, and 780 cm^{-1}; HR-FAB-MS calcd. for $C_{32}H_{49}O_7Si$ (M^++H) 573.3249, found *m/z* 573.3258.

(2*E*,4*S*,5*R*,6*S*,7*R*)-4-*O*-Benzyl-8-*O*-(*tert*-butyldimethylsilyl)-5,6-*O*-isopropylidene-7-*O*-(*p*-methoxybenzyl)-1-*O*-tetrahydropyranyloct-2-ene-1,4,5,6,7,8-hexaol (13).

To a solution of **9** (100 mg, 0.175 mmol) and dihydropyran (DHP) (32 µl, 0.375 mmol) in dichloromethane (2 ml) was added pyridinium *p*-toluenesulfonate (PPTS) (4.4 mg, 0.0175 mmol), and the mixture was stirred at room temperature for 4 h. The reaction mixture was washed with saturated aqueous $NaHCO_3$ and brine, dried over $MgSO_4$, filtered, and concentrated. The crude product was purified by column chromatography on SiO_2 (hexane:ethyl acetate, 7:1) to afford **13** (115 mg, 100% yield) as a pale yellow oil: $[\alpha]_D^{22}$ +1.60° (*c* 1.14); ^{1}H NMR (270 MHz) δ 7.36-7.23 (5H, m), 7.21 (1H, d, *J* = 9 Hz), 6.80 (1H, d, *J* = 9 Hz), 5.79-5.70 (2H, m), 4.65-4.55 (4H, m), 4.40 (1H, d, *J* = 12 Hz), 4.30-4.15 (3H, m), 4.13-3.94 (2H, m), 3.90-3.45 (5H, m), 3.78 (3H, s), 1.90-1.60 (6H, m), 1.55 (3H, s), 1.39 (3H, s), 0.87 (9H, s), and 0.03 (6H, s); IR (film) ν_{max} 3068, 2936, 2860, 1616, 1516, 1250, 1080, and 838 cm^{-1}; HR-FAB-MS calcd. for $C_{37}H_{55}O_8Si$ (M^+-H) 655.3668, found *m/z* 655.3680.

(2*E*,4*S*,5*R*,6*S*,7*R*)-4-*O*-Benzyl-5,6-*O*-isopropylidene-7-*O*-*p*-methoxybenzyl-1-*O*-tetrahydropyranyloct-2-ene-1,4,5,6,7,8-hexaol (14).

To a solution of **13** (113 mg, 0.172 mmol) in THF (2 ml) was added dropwise TBAF (1.0 M solution in THF, 0.344 ml, 0.344 mmol). The mixture was stirred at room temperature for 30 min, poured into water, and extracted with ether. The organic layer was washed with water and brine, dried over $MgSO_4$, filtered, and concentrated. The crude product was purified by column chromatography on SiO_2 (hexane:ethyl acetate, 2:1) to afford **14** (94 mg, 100% yield) as a pale yellow oil: $[\alpha]_D^{22}$ +13.1° (*c* 1.13); ^{1}H NMR (270 MHz) δ 7.36-7.23 (5H, m), 7.21 (1H, d, *J* = 9 Hz), 6.81 (1H, d, *J* = 9Hz), 5.71 (2H, br d, *J* = 4 Hz), 4.67-4.51 (4H, m), 4.39 (1H, d, *J* = 12 Hz), 4.30-4.14 (2H, m), 4.08-3.92 (2H, m), 3.90-3.70 (2H, m), 3.79 (3H, s), 3.63-3.43 (2H, m), 1.89-1.65 (6H, m), 1.56 (3H, s), and 1.39 (3H, s); IR (film) ν_{max} 3488, 3068, 2944, 2872, 1614, 1516, 1250, 1036, and 816 cm^{-1}; HR-FAB-MS calcd. for $C_{31}H_{43}O_8$ (M^++H) 543.2959, found *m/z* 543.2941.

Ethyl (2*E*,4*R*,5*S*,6*R*,7*S*,8*E*)-7-*O*-benzyl-5,6-*O*-isopropylidene-4-*O*-*p*-methoxybenzyl-10-*O*-tetrahydropyranyl-4,5,6,7,10-pentahydroxy-2,8-decadienoate (15).

To a solution of oxalyl chloride (61 µl, 0.698 mmol) in dichloromethane (3 ml) was added dimethyl sulfoxide (DMSO) (63 µl, 0.897 mmol) in dichloromethane (1 ml) at -78 °C and the mixture was stirred at -78 °C for 30 min. **14** (117 mg, 0.214 mmol) in dichloromethane (1.5 ml) was added and the mixture was stirred at -78 °C for 1 h. TEA (298 µl, 2.14 mmol) was added at -78 °C and the mixture was stirred at 0 °C for 10 min. The reaction mixture was partitioned between a mixture of benzene-ether (4:1) and water. The organic layer was washed with brine, dried over $MgSO_4$, filtered, and concentrated. The crude aldehyde was obtained, and immediately used for the next reaction without further purification.

To an ice-cold solution of $(^iPrO)_2P(O)CH_2CO_2Et$ (102 µl, 0.428 mmol) in THF (3 ml) was added ^{t}BuOK (40 mg, 0.428 mmol). After being stirred at 0 °C for 1.5 h, the mixture was cooled in a dry-ice acetone bath. To the stirred solution, the crude aldehyde in THF (1.5 ml) was added dropwise and the mixture was stirred at -78 °C for 30 min. The mixture was poured into ether and saturated aqueous NH_4Cl, and the water layer was thoroughly extracted with dichloromethane. The combined organic layers were washed with brine, dried over $MgSO_4$, filtered, and concentrated. The residue was purified by column chromatography on SiO_2 (hexane:ethyl acetate, 7:1) to afford **15** (118 mg, 2 steps 90% yield) as a pale yellow oil, and *Z*-isomer **16** (9 mg, 2 steps 7% yield) was also obtained.

Data for **15**: $[\alpha]_D^{22}$ -24.8° (*c* 1.09); ^{1}H NMR (270 MHz) δ 7.32-7.24 (5H, m), 7.25 (1H, d, *J* = 9 Hz), 6.85 (1H, dd, *J* = 7, 16 Hz), 6.80 (1H, d, *J* = 9 Hz), 5.88 (1H, d, *J* = 16 Hz), 5.72-5.45 (2H, m), 4.65-4.55 (2H, m), 4.48 (1H, d, *J* = 12 Hz), 4.31 (1H, d, *J* = 12 Hz), 4.29 (1H, d, *J* = 12 Hz), 4.27-4.21 (5H, m), 4.18-4.05 (2H, m), 4.00-3.75 (2H, m), 3.78 (3H, s), 3.75-3.42 (2H, m), 1.90-1.45 (6H, m), 1.58 (3H, s), 1.39 (3H, s), and 1.30 (3H, t, *J* = 7 Hz); IR (film) ν_{max} 3064, 2944, 2872, 1724, 1614, 1516, 1250, 1176, 1062, 1036, and 870 cm^{-1}; HR-FAB-MS calcd. for $C_{35}H_{47}O_8$ (M^++H) 611.3221, found *m/z* 611.3256.

Data for **16**: ^{1}H NMR (270 MHz) δ 7.39-7.24 (5H, m), 7.11 (1H, d, *J* = 9 Hz), 7.10 (1H, d, *J* = 9Hz), 6.78 (1H, d, *J* = 9 Hz), 6.34 (1H, dd, *J* = 8, 12 Hz), 5.96 (1H, d, *J* = 12 Hz), 5.65-5.43 (2H, br m), 5.15 (1H, br d, *J* = 8 Hz), 4.68-4.51 (3H, m), 4.41 (1H, d, *J* = 12 Hz), 4.32-4.21 (3H, m), 4.21-3.98 (2H, m), 4.12 (2H, q, *J* = 7

Hz), 3.90-3.75 (1H, m), 3.79 (3H, s), 3.55-3.45 (2H, m), 1.90-1.45 (6H, m), 1.58 (3H, s), 1.39 (3H, s), and 1.27 (3H, t, J = 7 Hz).

Ethyl (2*E*,4*R*,5*S*,6*R*,7*S*,8*E*)-7-benzyloxy-5,6,10-Tris(*tert*-butyldimethylsilyloxy)-4-*p*-methoxybenzyloxy-2,8-decadienoate (17).

To a solution of **15** (65 mg, 0.106 mmol) in EtOH (1 ml) was added *p*-toluenesulufonic acid monohydrate (PTS·H_2O) (2 mg, 0.011 mmol), and the solution was stirred at room temperature for 25 h. The reaction mixture was diluted with ethyl acetate, washed with saturated aqueous $NaHCO_3$ and brine, dried over $MgSO_4$, filtered, and concentrated. The crude triol was obtained, and immediately used for the next reaction without further purification.

To a solution of the crude triol and 2,6-lutidine (138 µl, 1.208 mmol) in dichloromethane (5 ml) was added dropwise TBSOTf (131 µl, 0.572 mmol) at 0 °C, and the mixture was stirred at 0 °C for 30 min. The reaction mixture was mixed with brine, and the water layer was extracted with dichloromethane, and the combined organic layers were washed with brine, dried over $MgSO_4$, filtered, and concentrated. The residue was purified by column chromatography on SiO_2 (hexane:ethyl acetate, 30:1) to afford **17** (57 mg, 2 steps 65% yield) as a pale yellow oil: $[\alpha]_D^{22}$ -4.20° (*c* 1.37); ^{1}H NMR (270 MHz) δ 7.30-7.20 (5H, m), 7.21 (1H, d, J = 9 Hz), 6.93 (1H, dd, J = 7, 16 Hz), 6.85 (1H, d, J = 9Hz), 6.03 (1H, d, J = 16 Hz), 5.72 (1H, br dt, J = 16, 4 Hz), 5.58 (1H, br dd, J = 7, 16 Hz), 4.51 (1H, d, J = 12 Hz), 4.43 (1H, d, J = 12 Hz), 4.29 (2H, d, J = 12 Hz), 4.20 (2H, q, J = 7 Hz), 4.17-4.15 (3H, br m), 4.07 (1H, br t, J = 8 Hz), 3.84 (1H, br t, J = 9 Hz), 3.80 (3H, s), 3.73 (1H, br t, J = 9 Hz), 1.30 (3H, t, J = 7 Hz), 0.91 (9H, s), 0.86 (9H, s), 0.85 (9H, s), 0.07 (6H, s), 0.06 (3H, s), 0.04 (3H, s), 0.03 (3H, s), and 0.01 (3H, s); IR (film) ν_{max} 3064, 2956, 2860, 1724, 1616, 1516, 1252, 1094, and 836 cm^{-1}; HR-FI-MS calcd. for $C_{45}H_{77}O_8Si_3$ (M^++H) 829.4928, found *m/z* 829.4905.

Ethyl (2*E*,4*R*,5*S*,6*R*,7*S*,8*E*)-7-benzyloxy-5,6-Bis(*tert*-butyldimethylsilyloxy)-10-hydroxy-4-*p*-methoxybenzyloxy-2,8-decadienoate (18).

To a solution of **17** (79.0 mg, 0.0951 mmol) in THF (3 ml) was added dropwise TBAF (1.0 M solution in THF, 95.1 µl, 0.0951 mmol), and the mixture was stirred at 0 °C for 1 h. The solution was poured into water and extracted with ether. The organic layer was washed with water and brine, dried over $MgSO_4$, filtered, and concentrated. The crude product was purified by column chromatography on SiO_2 (hexane:ethyl acetate, 5:1) to afford **18** (63.4 mg, 93% yield) as a pale yellow oil: $[\alpha]_D^{22}$ -11.9° (*c* 1.01); ^{1}H NMR (270 MHz) δ 7.30-7.20 (5H, m), 7.22 (2H, d, J = 9 Hz), 6.95 (1H, dd, J = 7, 16 Hz), 6.85 (2H, d, J = 9 Hz), 6.00 (1H, dd, J = 1, 16 Hz), 5.76 (1H, dt, J = 16, 5 Hz), 5.53 (1H, br dd, J = 7, 16 Hz), 4.50 (1H, d, J = 11 Hz), 4.46 (1H, d, J = 11 Hz), 4.34 (1H, d, J = 11 Hz), 4.31 (1H, d, J = 11 Hz), 4.22 (1H, q, J = 7 Hz), 4.15-4.00 (4H, m), 3.87-3.71 (2H, m), 3.80 (3H, s), 1.31 (3H, t, J = 7 Hz), 0.87 (9H, s), 0.85 (9H, s), 0.04 (3H, s), 0.03 (3H, s), 0.01 (3H, s), and -0.01 (3H, s); IR (film) ν_{max} 3480, 3068, 2936, 2860, 1724, 1616, 1515, 1252, 1086, and 836 cm^{-1}.

(2*E*,4*R*,5*S*,6*R*,7*S*,8*E*)-7-Benzyloxy-5,6,10-Tris(*tert*-butyldimethylsilyloxy)-4-*p*-methoxybenzyloxy-2,8-decadien-1-ol (19).

17 (66.2 mg, 0.0806 mmol) was dissolved in dichloromethane (2 ml) and then cooled to -78 °C. DIBAL (0.93 M solution in hexane, 0.182 ml, 0.169 mmol) was added dropwise to the solution and the mixture was stirred at -78 °C for 30 min. The solution was mixed with water (ca. 0.01 ml), diluted with ether, and allowed to warm to room temperature. The mixture was vigorously stirred for 1 h, and then the remaining solid was separated by filtration. The filtrate was concentrated. The residue and $CeCl_3 \cdot 7H_2O$ (90 mg, 0.242 mmol) were dissolved in MeOH (3 ml), and $NaBH_4$ (excess) was added at room temperature until the reaction was completed. The reaction mixture was poured into water and extracted with ethyl acetate. The combined organic layers were washed with brine, dried over $MgSO_4$, filtered, and concentrated. The crude product was purified by column chromatography on SiO_2 (hexane:ethyl acetate, 5:1) to afford **19** (59.0 mg, 2 steps 93% yield) as a pale yellow oil: $[\alpha]_D^{23}$ +7.80° (*c* 0.97); ^{1}H NMR (270 MHz) δ 7.31-7.24 (5H, m), 7.21 (2H, d, J = 9 Hz), 6.83 (2H, d, J = 9 Hz), 5.87-5.66 (2H, m), 5.63-5.50 (2H, m), 4.54 (1H, d, J = 12 Hz), 4.42 (1H, d, J = 12 Hz), 4.32 (1H, d, J = 12 Hz), 4.26 (1H, d, J = 12 Hz), 4.17 (2H, br d, J = 4 Hz), 4.12-4.03 (2H, br m), 3.95-3.85 (2H, m), 3.79 (3H, s), 3.74 (2H, dd, J = 4, 8 Hz), 0.92 (9H, s), 0.867 (9H, s), 0.856 (9H, s), 0.08 (6H, s), 0.05 (3H, s), 0.03 (3H, s), and 0.004 (6H, s); IR (film) ν_{max} 3456, 3068, 2936, 2856, 1616, 1516, 1250, 1076, and 836 cm^{-1}; HR-FAB-MS calcd. for $C_{43}H_{75}O_7Si_3$ (M^++H) 787.4825, found *m/z* 787.4783.

(2*R*,3*R*,4*R*,5*S*,6*R*,7*S*,8*E*)-7-Benzyloxy-5,6,10-Tris(*tert*-butyldimethylsilyloxy)-2,3-epoxy-4-*p*-methoxybenzyloxy-8-decen-1-ol (21).

To a solution of **19** (296 mg, 0.375 mmol) and Na_2HPO_4 (160 mg, 1.125 mmol) in dichloromethane (20 ml) was added *m*CPBA (71 mg, 0.413 mmol), and the mixture was stirred at room temperature for 18 h. The mixture was poured into saturated aqueous $NaHCO_3$ and saturated aqueous $Na_2S_2O_3$. The water layer was extracted with dichloromethane. The combined organic layers were washed with brine, dried over $MgSO_4$, filtered, and concentrated. The crude product was purified by column chromatography on SiO_2 (hexane:ethyl acetate, 5:1) to afford a mixture of **21** and **22**. The mixture was isolated by HPLC [column: Develosil 60-5, eluate: hexane-ethyl acetate (5:1)] to afford **21** (80 mg, 26% yield) and **22** (148 mg, 49% yield) as both pale yellow oils.

Data for **21**: $[\alpha]_D^{22}$ +32.4° (c 0.47); ^1H NMR (270 MHz) δ 7.31-7.25 (7H, m), 6.84 (2H, d, J = 9 Hz), 5.84 (1H, br dt, J = 16, 5 Hz), 5.65 (1H, br dd, J = 7, 16 Hz), 4.65-4.45 (3H, m), 4.30 (1H, d, J = 12 Hz), 4.19 (2H, br d, J = 2 Hz), 3.97-3.77 (3H, m), 3.80 (3H, s), 3.52-3.38 (2H, m), 3.19 (1H, dd, J = 2, 6 Hz), 3.10 (1H, dt, J = 2, 4 Hz), 0.91 (9H, s), 0.87 (18H, s), 0.10 (3H, s), 0.07 (3H, s), 0.04 (3H, s), 0.02 (3H, s), and -0.01 (3H, s); IR (film) ν_{max} 3464, 3064, 2936, 2856, 1616, 1516, 1252, 1096, and 836 cm^{-1}; HR-FAB-MS calcd for $C_{43}H_{74}O_8Si_3$ (M^+) 802.4693, found *m/z* 802.4735.

Data for **22**: ^1H NMR (270 MHz) δ 7.31-7.20 (7H, m), 6.84 (2H, d, J = 9 Hz), 5.75 (1H, dt, J = 16, 4 Hz), 5.12 (1H, br d, J = 16 Hz), 4.56 (1H, d, J = 12 Hz), 4.48 (2H, br s), 4.33 (1H, d, J = 12 Hz), 4.17 (2H, br d, J = 3 Hz), 3.94-3.88 (2H, m), 3.83 (1H, d, J = 7 Hz), 3.80 (3H, s), 3.75-3.65 (1H, br m), 3.61 (1H, dd, J = 4, 7 Hz), 3.53-3.40 (1H, br m), 3.21 (1H, dd, J = 2, 4 Hz), 3.02 (1H, dd, J = 2, 5 Hz), 0.91 (9H, s), 0.887 (9H, s), 0.882 (9H, s), 0.10 (3H, s), 0.07 (6H, s), 0.04 (3H, s), 0.02 (3H, s), and -0.01 (3H, s).

(3*R*,4*R*,5*R*,6*S*,7*R*,8*S*,9*E*)-8-Benzyloxy-6,7,11-Tris(*tert*-butyldimethylsilyloxy)-3,4-epoxy-5-*p*-methoxybenzyloxy-1,9-undecadiene (24).

To a solution of oxalyl chloride (36 μl, 0.414 mmol) in dichloromethane (5 ml) was added DMSO (61 μl, 0.827 mmol) in dichloromethane (1 ml) at -78 °C and the mixture was stirred at -78 °C for 30 min. **21** (66.5 mg, 0.0827 mmol) in dichloromethane (1.5 ml) was added and the mixture was stirred at -78 °C for 1 h. TEA (220 μl, 1.654 mmol) was then added at -78 °C and the mixture was stirred at 0 °C for 10 min. The mixture was partitioned between a mixture of benzene-ether (4:1) and water. The organic layer was washed with brine, dried over $MgSO_4$, filtered, and concentrated. The crude aldehyde was obtained, and immediately used for the next reaction without further purification.

To an ice-cold suspension of $Ph_3P^+CH_3Br^-$ (144 mg, 0.414 mmol) in THF (5 ml) was added dropwise a 1M solution of sodium bis(trimethylsilyl)amide (NaHMDS) in THF (331 μl, 0.331 mmol), and the mixture was stirred at 0 °C for 1.5 h. The crude aldehyde in THF (2 ml) was added dropwise and the mixture was stirred at 0 °C for 30 min. The mixture was poured into ether and saturated aqueous NH_4Cl, and the water layers were thoroughly extracted with dichloromethane. The combined organic layers were washed with brine, dried over $MgSO_4$, filtered, and concentrated. The residue was purified by column chromatography on SiO_2 (hexane:ethyl acetate, 40:1) to afford **24** (59.9 mg, 2 steps 91% yield) as a pale yellow oil: $[\alpha]_D^{20}$ +5.31° (c 0.93); ^1H NMR (270 MHz) δ 7.30-7.26 (7H, m), 6.84 (2H, d, J = 9 Hz), 5.81 (1H, br dt, J = 16, 4 Hz), 5.68 (1H, br dd, J = 7, 16 Hz), 5.52-5.46 (2H, m), 5.30 (1H, br dd, J = 3, 12 Hz), 4.66 (1H, d, J = 12 Hz), 4.55 (1H, d, J = 12 Hz), 4.52 (1H, d, J = 12 Hz), 4.26 (1H, d, J = 12 Hz), 4.17 (2H, br d, J = 3 Hz), 3.95-3.80 (3H, m), 3.80 (3H, s), 3.40 (1H, dd, J = 7, 8Hz), 3.34 (1H, dd, J = 2, 7 Hz), 3.04 (1H, dd, J = 2, 7 Hz), 0.91 (9H, s), 0.88 (9H, s), 0.86 (9H, s), 0.07 (3H, s), 0.06 (6H, s), 0.04 (3H, s), -0.004 (3H, s), and -0.01 (3H, s); IR (film) ν_{max} 3064, 3032, 2956, 2932, 2892, 2856, 1616, 1518, 1474, 1250, 1094, 836, and 776 cm^{-1}; HR-FAB-MS calcd. for $C_{44}H_{75}O_7Si_3$ (M^++H) 799.4823, found *m/z* 799.4846.

(2*E*,4*S*,5*R*,6*S*,7*R*,8*R*,9*R*)-4-Benzyloxy-5,6-Bis(*tert*-butyldimethylsilyloxy)-8,9-epoxy-7-*p*-methoxybenzyloxy-2,10-undecadien-1-ol (25).

To a solution of **24** (58.2 mg, 0.0728 mmol) in THF (3 ml) was added dropwise TBAF (1.0 M solution in THF, 74.3 μl, 0.0743 mmol), and the mixture was stirred at 0 °C for 1 h. The solution was poured into water and extracted with ether. The organic layer was washed with water and brine, dried over $MgSO_4$, filtered, and concentrated. The crude product was purified by column chromatography on SiO_2 (hexane:ethyl acetate, 5:1) to afford **25** (49.3 mg, 99% yield) as a pale yellow oil: $[\alpha]_D^{22}$ +5.26° (*c* 0.76); ^{1}H NMR (270 MHz) δ 7.34-7.22 (7H, m), 6.86 (2H, d, *J* = 9 Hz), 5.87 (1H, dt, *J* = 16, 5 Hz), 5.63 (1H, br dd, *J* = 8, 16 Hz), 5.52-5.40 (2H, m), 5.31 (1H, br dd, *J* = 3, 9 Hz), 4.64 (1H, d, *J* = 11 Hz), 4.57 (1H, d, *J* = 11 Hz), 4.51 (1H, d, *J* = 12 Hz), 4.32 (1H, d, *J* = 12 Hz), 4.17-4.09 (2H, br m), 3.96 (1H, br t, *J* = 8 Hz), 3.85 (2H, br t, *J* = 8 Hz), 3.80 (3H, s), 3.45 (1H, dd, *J* = 2, 7 Hz), 3.09 (1H, dd, *J* = 2, 6 Hz), 0.88 (9H, s), 0.86 (9H, s), 0.08 (3H, s), 0.03 (3H, s), 0.000 (3H, s), and -0.003 (3H, s); IR (film) ν_{max} 3464, 3068, 3032, 2956, 2936, 2888, 2856, 1614, 1518, 1466, 1252, 1088, 836, and 778 cm^{-1}; HR-FAB-MS calcd. for $C_{38}H_{61}O_7Si_2$ (M^++H) 685.3957, found *m/z* 685.3972.

(3*R*,4*R*,5*R*,6*S*,7*R*,8*S*,9*E*)-11-Acetoxy-8-benzyloxy-6,7-Bis(*tert*-butyldimethylsilyloxy)-3,4-epoxy-5-*p*-methoxybenzyloxy-1,9-undecadiene (26).

To a solution of **25** (48.0 mg, 0.0701 mmol), TEA (78.2 μl, 0.561 mmol), and DMAP (cat. amount) in dichloromethane (3 ml) was added acetic anhydride (Ac_2O) (26.4 μl, 0.280 mmol), and the mixture was stirred at room temperature for 10 min. The reaction mixture was diluted with ether, washed with saturated aqueous $NaHCO_3$ and brine, dried over $MgSO_4$, filtered, and concentrated. The crude product was purified by column chromatography on SiO_2 (hexane:ethyl acetate, 5:1) to afford **26** (50.6 mg, 99% yield) as a pale yellow oil: $[\alpha]_D^{22}$ +6.6° (*c* 0.79); ^{1}H NMR (270 MHz) δ 7.29-7.26 (5H, m), 6.87 (2H, d, *J* = 9 Hz), 5.83 (1H, br dt, *J* = 16, 5 Hz), 5.70 (1H, br dd, *J* = 7, 16 Hz), 5.58-5.48 (2H, m), 5.30 (1H, br dd, *J* = 3, 9 Hz), 4.65 (1H, d, *J* = 11 Hz), 4.56 (2H, br d, *J* = 5 Hz), 4.55 (1H, d, *J* = 11 Hz), 4.50 (1H, d, *J* = 12 Hz), 4.29 (1H, d, *J* = 12 Hz), 3.98 (1H, dd, *J* = 7, 8 Hz), 3.85-3.81 (2H, m), 3.80 (3H, s), 3.41 (1H, br dd, *J* = 6, 8 Hz), 3.31 (1H, br dd, *J* = 2, 6 Hz), 3.09 (1H, dd, *J* = 2, 6 Hz), 2.06 (3H, s), 0.88 (9H, s), 0.86 (9H, s), 0.07 (3H, s), 0.02 (3H, s), 0.000 (3H, s), and -0.009 (3H, s); IR (film) ν_{max} 3064, 3032, 2956, 2932, 2892, 2856, 1746, 1616, 1516, 1466, 1250, 1088, 836, and 778 cm^{-1}; HR-FI-MS calcd. for $C_{40}H_{62}O_8Si_2$ (M^+) 726.3985, found *m/z* 726.3954.

(2*E*,4*S*,5*S*,6*R*,7*S*,8*R*,9*R*)-1-Acetoxy-4-benzyloxy-8,9-epoxy-7-*p*-methoxybenzyloxy-2,10-undecadiene-5,6-diol (27).

To a solution of **26** (49.0 mg, 0.0674 mmol) in THF (3 ml) was added dropwise TBAF (1.0 M solution in THF, 202 μl, 0.202 mmol), and the mixture was stirred at room temperature for 2 h. The solution was poured into water, and extracted with ethyl acetate. The organic layer was washed with water and brine, dried over $MgSO_4$, filtered, and concentrated. The crude product was purified by column chromatography on SiO_2 (hexane:ethyl acetate, 2:1) to afford **27** (30.4 mg, 91% yield) as a pale yellow oil: $[\alpha]_D^{21}$ +0.75° (*c* 0.61); ^{1}H NMR (270 MHz) δ 7.34-7.22 (7H, m), 6.87 (2H, *J* = 9 Hz), 5.88-5.81 (2H, m), 5.69-5.44 (2H, m), 5.32 (1H, br dd, *J* = 2, 10 Hz), 4.80 (1H, d, *J* = 11 Hz), 4.61 (1H, d, *J* = 11 Hz), 4.61 (2H, br d, *J* = 5 Hz), 4.55 (1H, d, *J* = 11 Hz), 4.39 (1H, d, *J* = 11 Hz), 4.21-4.16 (1H, br m), 3.80 (3H, s), 3.68 (1H, br dt, *J* = 2, 8 Hz), 3.55 (1H, br dt, *J* = 3, 9 Hz), 3.51 (1H, br dd, *J* = 2, 9 Hz), 3.25 (1H, dd, *J* = 2, 7 Hz), 3.20 (1H, br dd, *J* = 2, 7 Hz), 2.54 (1H, d, *J* = 9 Hz), 2.36 (1H, d, *J* = 8 Hz), and 2.09 (3H, s); IR (film) ν_{max} 3492, 3064, 3032, 2936, 1740, 1614, 1518, 1250, 1090, and 1034 cm^{-1}; HR-FI-MS calcd. for $C_{28}H_{34}O_8$ (M^+) 498.2254, found *m/z* 498.2245.

(2*S*,3*S*,4*R*,5*R*,6*S*,1'*S*,2'*E*)-3,5-Dihydroxy-4-*p*-methoxybenzyloxy-6-vinyl-2-(4'-acetoxy-1'-benzyloxy-2'-butenyl)-oxane (28).

To a solution of **27** (34.2 mg, 68.6 μmol) in dichloromethane (2 ml) was added CSA (1.6 mg, 6.86 μmol) at -40 °C, and the mixture was stirred and allowed to warm to room temperature for 14 h. The reaction mixture was poured into saturated aqueous $NaHCO_3$ and diluted with ethyl acetate, and the water layer was extracted with ethyl acetate. The combined organic layers were washed with brine, dried over $MgSO_4$, filtered, and concentrated. The crude product was purified by column chromatography on SiO_2 (hexane:ethyl acetate, 3:2) to afford **28** (31.0 mg, 91% yield) as a colorless oil: $[\alpha]_D^{19}$ +38.5° (*c* 0.47); ^{1}H NMR (270 MHz) δ 7.35-7.26 (7H, m), 6.89 (2H, d, *J* = 9 Hz), 5.92-5.82 (3H, m), 5.35 (1H, br d, *J* = 18 Hz), 5.27 (1H, br d, *J* = 11 Hz), 4.86 (1H, d, *J* = 11 Hz), 4.74 (1H, d, *J* = 11 Hz), 4.69 (1H, d, *J* = 12 Hz), 4.62 (2H, br d, *J* = 4 Hz), 4.40 (1H, d, *J* = 12 Hz), 4.21-4.12 (1H, br m), 3.86-3.75 (1H, m), 3.80 (3H, s), 3.61 (1H, br dd, *J* = 7, 9 Hz), 3.41-3.22 (3H, m), 2.62 (1H, br d, *J* = 2 Hz), 2.09 (3H, s), and 2.05 (1H, br s); IR (film) ν_{max} 3504, 3064, 3032, 2880, 1740, 1616, 1516, 1250, 1092, 1060, and 1028 cm^{-1}; HR-FI-MS calcd. for $C_{28}H_{34}O_8$ (M^+) 498.2254, found *m/z* 498.2288.

(2*R*,3*S*,4*R*,5*R*,6*S*,1'*S*,2'*E*)-3,5-Bis(*tert*-butyldimethylsilyloxy)-4-*p*-methoxybenzyloxy-6-vinyl-2-(4'-acetoxy-1'-benzyloxy-2'-butenyl)-oxane (33).

To a solution of **28** (22.8 mg, 45.7 μmol) and 2,6-lutidine (80.4 μl, 694 μmol) in dichloromethane (5 ml) was added dropwise TBSOTf (75.8 μl, 330 μmol) at 0 °C, and the mixture was stirred at room temperature for 27 h. The mixture was poured into brine, and the water layer was extracted with dichloromethane, and the combined organic layers were washed with brine, dried over $MgSO_4$, filtered, and concentrated. The residue was purified by column chromatography on SiO_2 (hexane:ethyl acetate, 20:1) to afford **33** (33.4 mg, 100% yield) as a colorless oil: $[\alpha]_D^{16}$ -3.80° (*c* 0.47); ^{1}H NMR (270 MHz) δ 7.35-7.26 (5H, m), 7.20 (2H, d, *J* = 9 Hz), 6.84 (2H, d, *J* = 9 Hz), 6.02 (1H, dd, *J* = 10, 16 Hz), 5.95-5.75 (2H, m), 5.35 (1H, br d, *J* = 18 Hz), 5.20 (1H, br d, *J* = 12 Hz), 4.91 (1H, d, *J* = 12 Hz), 4.69 (1H, d, *J* = 12 Hz), 4.58 (2H, br d, *J* = 6 Hz), 4.55 (1H, d, *J* = 12 Hz), 4.34 (1H, d, *J* = 12 Hz), 4.20 (1H, dd, *J* = 2, 10 Hz), 4.03 (1H, t, *J* = 10 Hz), 3.80 (3H, s), 3.62 (1H, br dd, *J* = 7, 10 Hz), 3.50 (1H, t, *J* = 10 Hz), 3.32 (1H, t, *J* = 10 Hz), 3.24 (1H, dd, *J* = 2, 10 Hz), 2.08 (3H, s), 0.83 (9H, s), 0.81 (9H, s), 0.04 (3H, s), 0.00 (3H, s), -0.11 (3H, s), and -0.15 (3H, s); IR (film) ν_{max} 3064, 3032, 2956, 2932, 2888, 2856, 1746, 1618, 1516, 1474, 1250, 1070, 838, and 780 cm^{-1}; HR-FAB-MS calcd. for $C_{40}H_{61}O_8Si_2$ (M^+-H) 725.3906, found *m/z* 725.3915.

(2*R*,3*S*,4*R*,5*R*,6*S*,1'*S*,2'*E*)-3,5-Bis(*tert*-butyldimethylsilyloxy)-4-*p*-methoxybenzyloxy-6-vinyl-2-(1'-benzyloxy-4'-hydroxy-2'-butenyl)-oxane (34).

To a solution of **33** (32.8 mg, 45.0 μmol) in MeOH (1 ml) was added K_2CO_3 (62 mg, 450 μmol), and the mixture was stirred at room temperature for 1 h and poured into water and ether. The water layer was extracted with ether, and the combined organic layers were washed with brine, dried over $MgSO_4$, filtered, and concentrated. The crude product was purified by column chromatography on SiO_2 (hexane:ethyl acetate, 5:1) to afford **34** (29.6 mg, 96% yield) as a colorless amorphous: $[\alpha]_D^{15}$ -2.29° (*c* 0.69); ^{1}H NMR (270 MHz) δ 7.34-7.26 (5H, m), 7.19 (2H, d, *J* = 9 Hz), 6.84 (2H, d, *J* = 9 Hz), 6.02-5.80 (3H, m), 5.36 (1H, br d, *J* = 16 Hz), 5.20 (1H, br d, *J* = 10 Hz), 4.91 (1H, d, *J* = 12 Hz), 4.70 (1H, d, *J* = 12 Hz), 4.55 (1H, d, *J* = 12 Hz), 4.40 (1H, d, *J* = 12 Hz), 4.21 (1H, br dd, *J* = 2, 8 Hz), 4.15 (2H, br m), 4.04 (1H, t, *J* = 9 Hz), 3.80 (3H, s), 3.60 (1H, br dd, *J* = 7, 9 Hz), 3.50 (1H, t, *J* = 9 Hz), 3.32 (1H, t, *J* = 9 Hz), 3.22 (1H, dd, *J* = 2, 9 Hz), 0.83 (9H, s), 0.81 (9H, s), 0.05 (3H, s), 0.00 (3H, s), -0.11 (3H, s), and -0.16 (3H, s); IR (film) ν_{max} 3448, 3068, 3032, 2956, 2932, 2888, 2856, 1616, 1516, 1466, 1250, 1104, 1066, 836, and 778 cm^{-1}; HR-FAB-MS calcd. for $C_{38}H_{61}O_7Si_2$ (M^++H) 685.3957, found *m/z* 685.3968.

(2*R*,3*S*,4*R*,5*R*,6*S*,1'*S*,2'*S*,3'*S*)-3,5-Bis(*tert*-butyldimethylsilyloxy)-4-*p*-methoxybenzyloxy-6-vinyl-2-(1'-benzyloxy-2',3'-epoxy-4'-hydroxybutyl)-oxane (35).

To a cold (-30 °C) suspension of $Ti(O^iPr)_4$ (11.8 μl, 40.2 μmol) and MS4A (80 mg) in dichloromethane (1 ml) was added L(+)-DET (7.6 μl, 44.2 μmol) and the mixture was stirred at -30 °C for 30 min. To the mixture was added TBHP (5.54 M solution in toluene, 24 μl, 132.7 μmol) at -30 °C and the mixture was stirred at -30 °C for 30 min. To the mixture, a solution of **34** (28.5 mg, 41.5 μmol) in dichloromethane (1 ml) was added dropwise at -30 °C, and the mixture was stirred at -20 °C for 24 h. The solution was poured into a solution of tartaric acid (81 mg) and $FeSO_4 \cdot 7H_2O$ (33 mg) in water (2 ml) at 0 °C, and stirred at 0 °C for 10 min. The water layer was extracted with ether (5 × 20 ml). To the combined organic layers was added 30% NaOH brine solution (0.08 ml) at 0 °C, and the mixture was vigorously stirred at 0 °C for 20 min, and mixed with water. The water layer was extracted with ether. The combined organic layers were washed with brine, dried over $MgSO_4$, filtered, and concentrated. The crude product was purified by column chromatography on SiO_2 (hexane:ethyl acetate, 5:1) to afford **35** (28.7 mg, 98% yield) as a colorless oil: $[\alpha]_D^{14}$ -6.05° (*c* 0.69); ^1H NMR (270 MHz) δ 7.42-7.26 (5H, m), 7.20 (2H, d, *J* = 9 Hz), 6.84 (2H, d, *J* = 9 Hz), 5.87 (1H, ddd, *J* = 7, 10, 17 Hz), 5.32 (1H, br d, *J* = 17 Hz), 5.19 (1H, br d, *J* = 10 Hz), 4.92 (1H, d, *J* = 12 Hz), 4.99 (1H, d, *J* = 12 Hz), 4.68 (1H, d, *J* = 12 Hz), 4.57 (1H, d, *J* = 12 Hz), 4.02 (1H, br t, *J* = 8 Hz), 3.80 (3H, s), 3.78-3.70 (1H, br m), 3.70-3.57 (2H, br m), 3.50 (1H, t, *J* = 8 Hz), 3.40 (2H, t, *J* = 8 Hz), 3.35-3.31 (2H, m), 2.99-2.92 (1H, br m), 0.82 (9H, s), 0.79 (9H, s), 0.00 (6H, s), -0.12 (3H, s), and -0.14 (3H, s); IR (film) ν_{max} 3492, 3068, 3032, 2956, 2932, 2888, 2856, 1618, 1516, 1474, 1250, 1110, 1068, 836, and 780 cm^{-1}; HR-FAB-MS calcd. for $C_{38}H_{61}O_8Si_2$ $(M^+ + H)$ 701.3906, found *m/z* 701.3890.

(2*R*,3*S*,4*R*,5*R*,6*S*,1'*S*,2'*S*,3'*S*)-3,5-Bis(*tert*-butyldimethylsilyloxy)-4-*p*-methoxybenzyloxy-6-vinyl-2-(1'-benzyloxy-2',3'-epoxy-4'-pentenyl)-oxane (36).

To a solution of oxalyl chloride (17 µl, 196 µmol) in dichloromethane (2 ml) was added DMSO (29 µl, 391 µmol) in dichloromethane (0.2 ml) at -78 °C and the mixture was stirred at -78 °C for 30 min. **35** (27.5 mg, 39.1 µmol) in dichloromethane (1.5 ml) was then added and the mixture was stirred at -78 °C for 1 h. TEA (109 µl, 782 µmol) was added at -78 °C and the mixture was stirred at 0 °C for 10 min. The mixture was partitioned between a mixture of benzene-ether (4:1) and water. The organic layer was washed with brine, dried over $MgSO_4$, filtered, and concentrated. The crude aldehyde was obtained, and immediately used for the next reaction without further purification.

To an ice-cold suspension of $Ph_3P^+CH_3Br^-$ (68 mg, 196 µmol) in THF (1 ml) was added dropwise a 1M solution of NaHMDS in THF (156 µl, 156 µmol), and the mixture was stirred at 0 °C for 1 h. The crude aldehyde in THF (1.5 ml) was then added dropwise, and the mixture was stirred at 0 °C for 20 min. The mixture was poured into ether and saturated aqueous NH_4Cl, and the water layer was thoroughly extracted with dichloromethane. The combined organic layers were washed with brine, dried over $MgSO_4$, filtered, and concentrated. The residue was purified by column chromatography on SiO_2 (hexane:ethyl acetate, 40:1) to afford **36** (25.3 mg, 2 steps 93% yield) as a colorless oil: $[\alpha]_D^{16}$ +0.15° (*c* 0.63); ^1H NMR (270 MHz) δ 7.42-7.26 (5H, m), 7.20 (2H, d, *J* = 9 Hz), 6.84 (2H, d, *J* = 9 Hz), 5.87 (1H, ddd, *J* = 6, 10, 17 Hz), 5.65-5.46 (2H, m), 5.35-5.28 (2H, m), 5.18 (1H, br d, *J* = 10 Hz), 4.94 (1H, d, *J* = 12 Hz), 4.91 (1H, d, *J* = 12 Hz), 4.69 (1H, d, *J* = 12 Hz), 4.56 (1H, d, *J* = 12 Hz), 4.00 (1H, t, *J* = 9 Hz), 3.80 (3H, s), 3.63 (1H, br dd, *J* = 6, 9 Hz), 3.49 (1H, t, *J* = 9 Hz), 3.42-3.30 (4H, m), 3.12 (1H, dd, *J* = 2, 7 Hz), 0.81 (9H, s), 0.79 (9H, s), 0.00 (6H, s), -0.13 (3H, s), and -0.15 (3H, s); IR (film) ν_{max} 3064, 3032, 2956, 2932, 2892, 2856, 1618, 1516, 1474, 1250, 1136, 1110, 1086, 1066, 836, and 778 cm^{-1}; HR-FAB-MS calcd. for $C_{39}H_{61}O_7Si_2$ $(M^+ + H)$ 697.3957, found *m/z* 697.3931.

(2*S*,3*S*,4*R*,5*R*,6*S*,1'*S*,2'*S*,3'*S*)-3,5-Dihydroxy-4-*p*-methoxybenzyloxy-6-vinyl-2-(1'-benzyloxy-2',3'-epoxy-4'-pentenyl)-oxane (37).

To a solution of **36** (23.6 mg, 33.8 µmol) in THF (1 ml) was dropwise added TBAF (1.0 M solution in THF, 202 µl, 202 µmol) and the mixture was stirred at room temperature for 2 h. The mixture was poured into water, and extracted with ethyl acetate. The organic layer was washed with water and brine, dried over $MgSO_4$, filtered, and concentrated. The crude product was purified by column chromatography on SiO_2 (hexane:ethyl acetate, 2:1) to afford **37** (30.4 mg, 91% yield) as a colorless oil: $[\alpha]_D^{16}$ +25.0° (*c* 0.67); ^1H NMR (270 MHz) δ 7.38-7.26 (7H, m), 6.89 (2H, *J* = 9 Hz), 5.88 (1H, ddd, *J* = 7, 11, 17 Hz), 5.63-5.42 (2H, m), 5.39-5.23 (3H, m), 4.87 (1H, d, *J* =12 Hz), 4.85 (1H, d, *J* =12 Hz), 4.73 (1H, d, *J* =12 Hz), 4.66 (1H, d, *J* =12 Hz), 3.90-3.82 (1H, m), 3.80 (3H, s), 3.63 (1H, br dd, *J* = 8, 9 Hz), 3.47-3.36 (2H, m), 3.35-3.19 (4H, m), 2.52 (1H, d, *J* = 3 Hz), and 2.07 (1H, br s); IR (film) ν_{max} 3488, 3064, 3032, 2920, 1614, 1516, 1458, 1304, 1250, 1096, 1030, 936, 824, and 698 cm^{-1}; HR-FAB-MS calcd. for $C_{27}H_{32}O_7$ (M^+) 468.2149, found *m/z* 468.2135.

(1*S*,3*R*,4*S*,5*R*,6*R*,8*S*,9*R*,10*S*)-5-Benzyloxy-4,9-Bis(*tert*-butyldimethylsilyloxy)-10-*p*-methoxybenzyl-oxy-3,8-divinyl-2,7-dioxabicyclo[4.4.0]decane (39).

To a solution of **37** (12.5 mg, 26.7 μmol) in dichloromethane (1 ml) was added CSA (0.6 mg, 2.67 μmol) at -40 °C, and the mixture was stirred and allowed to warm to room temperature for 12 h. The mixture was poured into saturated aqueous $NaHCO_3$ and diluted with ethyl acetate, and the water layer was extracted with ethyl acetate. The combined organic layers were washed with brine, dried over $MgSO_4$, filtered, and concentrated. The crude product was not purified by column chromatography on SiO_2 because of its unstablity. The crude **38** (12.9 mg) as a white solid was obtained as a rather pure state, and immediately used for the next reaction without further purification: **38**. m.p. 173-175 °C; $[\alpha]_D^{18}$ +5.52° (*c* 0.63); ^{1}H NMR (270 MHz) δ 7.36-7.26 (7H, m), 6.88 (2H, d, *J* = 9 Hz), 5.98 (1H, ddd, *J* = 6, 11, 18 Hz), 5.97 (1H, ddd, *J* = 6, 11, 18 Hz), 5.43 (1H, dt, *J* = 18, 2 Hz), 5.42 (1H, dt, *J* = 18, 2 Hz), 5.30 (1H, dt, *J* = 11, 2 Hz), 5.28 (1H, dt, *J* = 11, 2 Hz), 5.02 (1H, d, *J* = 12 Hz), 4.94 (1H, d, *J* = 12 Hz), 4.70 (1H, d, *J* = 12 Hz), 4.64 (1H, d, *J* = 12 Hz), 3.82-3.72 (2H, m), 3.80 (3H, s), 3.66-3.43 (2H, m), 3.40-3.27 (4H, m), and 2.35-2.20 (2H, br m); IR ($CDCl_3$) ν_{max} 3598, 3094, 3034, 2896, 1614, 1518, 1251, 1176, 1134, 1104, 1041, and 1041 cm^{-1}; HR-FI-MS calcd. for $C_{27}H_{32}O_7$ (M^+) 468.2149, found *m/z* 468.2173.

To a solution of the crude **38** (11.3 mg) and 2,6-lutidine (42.4 μl, 366 μmol) in dichloromethane (3 ml) was added dropwise TBSOTf (40.0 μl, 174 μmol) at 0 °C, and the mixture was stirred at room temperature for 15 h. The mixture was poured into brine, and the water layer was extracted with dichloromethane, and the combined organic layers were washed with brine, dried over $MgSO_4$, filtered, and concentrated. The residue was purified by column chromatography on SiO_2 (hexane:ethyl acetate, 10:1) to afford **39** (16.2 mg, 99% yield from **37**) as a white solid: m.p. 103-105 °C; $[\alpha]_D^{17}$ +0.22° (*c* 0.41); ^{1}H NMR (270 MHz) δ 7.36-7.26 (7H, m), 6.83 (2H, d, *J* = 9 Hz), 5.98-5.83 (2H, m), 5.36 (1H, br d, *J* = 17 Hz), 5.31 (1H, br d, *J* = 17 Hz), 5.22 (1H, br d, *J* = 9 Hz), 5.19 (1H, br d, *J* = 9 Hz), 4.98 (1H, d, *J* = 11 Hz), 4.89 (1H, d, *J* = 11 Hz), 4.65 (1H, d, *J* = 11 Hz), 4.59 (1H, d, *J* = 11 Hz), 3.79 (3H, s), 3.77-3.66 (2H, m), 3.52-3.38 (6H, m), 0.88 (9H, s), 0.87 (9H, s), 0.04 (3H, s), 0.01 (6H, s), and 0.00 (3H, s); IR (film) ν_{max} 3084, 3036, 2956, 2932, 2888, 2856, 1616, 1518, 1474, 1364, 1250, 1124, 1098, 1074, 858, 838, and 778 cm^{-1}; HR-FI-MS calcd. for $C_{39}H_{60}O_7Si_2$ (M^++H) 696.3879, found *m/z* 696.3824.

(1*S*,3*R*,4*S*,5*R*,6*R*,8*S*,9*R*,10*S*)-5-Benzyloxy-4,9-Bis(*tert*-butyldimethylsilyloxy)-3,8-Bis(hydroxymethyl)-10-*p*-methoxybenzyloxy-2,7-dioxabicyclo[4.4.0]decane (40).

To a solution of **39** (32.1 mg, 46.1 μmol) and *N*-methylmorpholine-*N*-oxide (NMO) (32.4 mg, 277 μmol) in 8:2:1 acetone-acetonitrile-water (4 ml) was added a solution of OsO_4 in ^{t}BuOH (5mg/ml) (334 μl, 4.62 μmol) at room temperature, and the mixture was stirred at room temperature for 50 h. The mixture was poured into saturated aqueous Na_2SO_3 and extracted with ethyl acetate. The organic layer was dried over $MgSO_4$, filtered, and concentrated. The crude tetraol was obtained, and immediately used for the next reaction without further purification.

To a solution of the tetraol in 2:1 THF-water (2 ml) was added $NaIO_4$ (39.4 mg, 184 μmol) at room temperature, and the mixture was stirred at room temperature for 4 h. The mixture was extracted with ethyl acetate, and the organic layer was washed with brine, dried over $MgSO_4$, filtered, and concentrated. The crude dialdehyde was obtained, and immediately used for the next reaction without further purification.

To a solution of dialdehyde in MeOH (2 ml) was added $NaBH_4$ (excess) at room temperature until the reaction was completed. The mixture was poured into water and extracted with ethyl acetate. The organic layer was washed with brine, dried over $MgSO_4$, filtered, and concentrated. The crude product was purified by column chromatography on SiO_2 (hexane:ethyl acetate, 5:1) to afford **40** (20.9 mg, 3 steps 64% yield) as white crystals: m.p. 161-163 °C; $[\alpha]_D^{18}$ -0.03° (*c* 0.30); ^{1}H NMR (270 MHz) δ 7.36-7.26 (7H, m), 6.86 (2H, d, *J* = 9 Hz), 4.82 (1H, d, *J* = 11 Hz), 4.77 (1H, d, *J* = 11 Hz), 4.76 (1H, d, *J* = 11 Hz), 4.66 (1H, d, *J* = 11 Hz), 3.80 (3H, s), 3.80-3.70 (2H, m), 3.70-3.47 (5H, m), 3.47-3.34 (2H, m), 3.34-3.16 (3H, m), 0.88 (9H, s), 0.87 (9H, s), 0.06 (3H, s), 0.05 (6H, s), and 0.04 (3H, s); IR (film) ν_{max} 3500, 3032, 2956, 2932, 2888, 2856, 1616, 1518, 1466, 1364, 1250, 1094, 1048, 858, 838, and 780 cm^{-1}; HR-FAB-MS calcd. for $C_{37}H_{59}O_9Si_2$

(M^+-H) 703.3699, found *m/z* 703.3686.

(1*S*,3*R*,4*S*,5*R*,6*R*,8*S*,9*R*,10*S*)-5-Benzyloxy-4,9-Bis(*tert*-butyldimethylsilyloxy)-3,8-Bis(*tert*-butyldimethylsilyloxymethyl)-10-*p*-methoxybenzyloxy-2,7-dioxabicyclo[4.4.0]decane (*Meso*-like compound 41).

To a solution of **40** (26.5 mg, 37.6 μmol) and 2,6-lutidine (33.1 μl, 135 μmol) in dichloromethane (5 ml) was added dropwise TBSOTf (31.2 μl, 135 μmol) at 0 °C, and the mixture was stirred at room temperature for 30 min. The mixture was poured into brine, and the water layer was extracted with dichloromethane, and the combined organic layers were washed with brine, dried over $MgSO_4$, filtered, and concentrated. The residue was purified by column chromatography on silica gel (hexane:ethyl acetate, 40:1) to afford **41** (32.0 mg, 91% yield) as a colorless oil: $[\alpha]_D^{20}$ -1.30° (*c* 0.80); ^{1}H NMR (270 MHz) δ 7.37-7.25 (7H, m), 6.85 (2H, d, *J* = 9 Hz), 5.17 (1H, d, *J* = 11 Hz), 5.08 (1H, d, *J* = 11 Hz), 4.60 (1H, d, *J* = 11 Hz), 4.53 (1H, d, *J* = 11 Hz), 3.82-3.63 (6H, m), 3.80 (3H, s), 3.46-3.33 (2H, m), 3.30-3.17 (4H, m), 0.86 (9H, s), 0.852 (9H, s), 0.849 (9H, s), 0.83 (9H, s), 0.06 (3H, s), 0.05 (3H, s), 0.02 (3H, s), +0.00 (3H, s), -0.00 (3H, s), -0.01 (3H, s), -0.02 (3H, s), and -0.05 (3H, s); IR (film) ν_{max} 3036, 2956, 2932, 2884, 2856, 1616, 1518, 1474, 1466, 1364, 1250, 1112, 1096, 1064, 858, 836, and 778 cm^{-1}; HR-FAB-MS calcd. for $C_{49}H_{87}O_9Si_4$ (M^+-H) 931.5429, found *m/z* 931.5394.

(1*R*,3*S*,4*R*5*S*,6*S*,8*R*,9*S*,10*R*)-10-Benzyloxy-4,9-Bis(*tert*-butyldimethylsilyloxy)-3,8-Bis(*tert*-butyldimethylsilyloxymethyl)-5-hydroxy-2,7-dioxabicyclo[4.4.0]decane (42).

To a solution of **41** (7.1 mg, 7.61 μmol) in dichloromethane (1 ml) and water (0.1 ml) was added DDQ (5.2 mg, 22.8 μmol) at room temperature, and the mixture was stirred at room temperature for 2 h. The mixture was poured into saturated aqueous $NaHCO_3$ and extracted with dichloromethane. The organic layer was washed with brine, dried over $MgSO_4$, filtered, and concentrated. The residue was purified by PTLC on SiO_2 (hexane:ethyl acetate, 5:1) to afford **42** (4.2 mg, 68% yield) as a colorless oil: $[\alpha]_D^{20}$ -1.30° (*c* 0.80); ^{1}H NMR (270 MHz) δ 7.37-7.20 (5H, m), 5.12 (1H, d, *J* = 11 Hz), 4.60 (1H, d, *J* = 11 Hz), 3.90-3.70 (4H, m), 3.67 (1H, t, *J* = 9 Hz), 3.64 (1H, t, *J* = 9 Hz), 3.52 (1H, t, *J* = 9 Hz), 3.41 (1H, t, *J* = 9 Hz), 3.27-3.17 (2H, m), 3.18 (1H, t, *J* = 9 Hz), 3.00 (1H, t, *J* = 9Hz), 0.890 (9H, s), 0.885 (9H, s), 0.86 (9H, s), 0.85 (9H, s), 0.16 (3H, s), 0.12 (3H, s), 0.056 (3H, s), 0.052 (3H, s), 0.050 (3H, s), 0.01 (3H, s), -0.015 (3H, s), and -0.022 (3H, s); IR (film) ν_{max} 3612, 3480, 3064, 3032, 2956, 2932, 2884, 2860, 1474, 1466, 1362, 1254, 1098, 836, and 778 cm^{-1}; HR-FAB-MS calcd. for $C_{41}H_{81}O_8Si_4$ (M^++H) 813.5010, found *m/z* 813.4988.

(1*R*,3*S*,4*R*,6*S*,8*R*,9*S*,10*R*)-10-Benzyloxy-4,9-Bis(*tert*-butyldimethylsilyloxy)-3,8-Bis(*tert*-butyldimethylsilyloxymethyl)-2,7-dioxabicyclo[4.4.0]decane (One of the enantiomers of the BC-ring part, 43).

A mixture of **42** (4.5 mg, 5.53 μmol), NaH (13.2 mg, 553 μmol. washed with hexane), and imidazole (trace) in THF (1 ml) was stirred at room temperature for 30 min. To the mixture was added CS_2 (25 μl, 416 μmol) and the mixture was stirred at room temperature for 2 h. To the solution was added MeI (25 μl, 402 μmol) and the mixture was stirred at room temperature for 10 min. The mixture was poured into water and ether. The water layer was extracted with ether. The combined organic layers were washed with brine, dried over $MgSO_4$, filtered, and concentrated. The crude xanthate was obtained, and immediately used for the next reaction without further purification.

To a solution of the crude xanthate and 2,2'-azobisisobutyronitrile (AIBN) (1.4 mg, 8.84 μmol) in toluene (1 ml) was added Bu_3SnH (4.4 μl, 16.6 μmol) at reflux temperature and the mixture was stirred and heated under reflux for 1 h, and concentrated. The residue was purified by PTLC on SiO_2 (hexane:ethyl acetate, 5:1, and hexane:dichloromethane:ether, 50:49:1) to afford **43** (2.0 mg, 2 steps 45% yield) and **44** (1.1 mg, 2 steps 25% yield) as both colorless oils.

Data for **43**: $[\alpha]_D^{20}$ +1.50° (*c* 0.10); ^{1}H NMR (400 MHz) δ 7.38-7.21 (5H, m), 5.15 (1H, d, *J* = 11 Hz), 4.46 (1H, d, *J* = 11 Hz), 3.82 (1H, dd, *J* = 2, 11 Hz, H-1), 3.77 (1H, dd, *J* = 4, 11 Hz, H-1), 3.75 (2H, br s, H-10), 3.71 (1H, ddd, *J* = 5, 9, 11 Hz, H-6), 3.65 (1H, t, *J* = 9 Hz, H-3) 3.37 (1H, t, *J* = 9 Hz, H-4), 3.20 (1H, ddd, *J* = 2, 4, 9 Hz, H-2), 3.14-3.10 (1H, m, H-9), 3.10 (1H, t, *J* = 9 Hz, H-5), 3.08 (1H, br dt, *J* = 4, 10 Hz, H-8), 2.33-2.27 (1H, br m, H-7-eq), 1.48 (1H, br q, J = 11 Hz, H-7-ax), 0.882 (9H, s), 0.878 (9H, s), 0.86 (9H, s), 0.84 (9H, s), 0.08 (3H, s), 0.07 (3H, s), 0.06 (3H, s), 0.05 (3H, s), 0.04 (3H, s), 0.005 (3H, s), -0.01 (3H, s), and -0.03 (3H, s); IR (film) ν_{max} 3064, 3036, 2956, 2932, 2856, 1474, 1466, 1362, 1254, 1156, 1098, 860, and 836 cm^{-1}; HR-FAB-MS calcd. for $C_{41}H_{81}O_7Si_4$ (M^++H) 797.5061, found m/z 795.5107.

Data for **44**: ^{1}H NMR (400 MHz) δ 7.37-7.21 (5H, m), 5.08 (1H, d, J = 11 Hz), 4.59 (1H, d, J = 11 Hz), 3.83 (1H, dd, J = 2, 11 Hz, H-1), 3.79 (1H, dd, J = 3, 11 Hz, H-1), 3.70 (1H, t, J = 9 Hz, H-3), 3.72-3.64 (1H, m, H-7), 3.64-3.57 (1H, m, H-10), 3.50-3.41 (1H, m, H-9), 3.49-3.45 (1H, m, H-10), 3.42 (1H, t, J = 9 Hz, H-4), 3.20 (1H, ddd, J = 2, 3, 9 Hz, H-2), 3.11 (1H, t, J = 9 Hz, H-5), 2.95 (1H, dd, J = 8, 9, H-6), 1.96 (1H, br ddd, J = 1, 6, 12 Hz, H-8-eq), 1.38 (1H, br q, J = 11 Hz, H-8-ax), 0.881 (9H, s), 0.876 (9H, s), 0.85 (9H, s), 0.84 (9H, s), 0.090 (3H, s), 0.085 (3H, s), 0.050 (3H, s), 0.046 (3H, s), 0.035 (3H, s), 0.02 (3H, s), -0.009 (3H, s), and -0.013 (3H, s).

(1*R*,3*R*,4*S*,6*R*,8*S*,9*S*,10*S*)-4,9,10-Tris(*tert*-butyldimethylsilyloxy)-3,8-Bis(*tert*-butyldimethylsilyloxy-methyl)-2,7-dioxabicyclo[4.4.0]decane (Another enantiomer of the BC-ring part, 47).

To a solution of **42** (3.0 mg, 3.69 μmol) and 2,6-lutidine (10.0 μl, 92.3 μmol) in dichloromethane (0.7 ml) was added dropwise TBSOTf (9.0 μl, 36.9 μmol) at room temperature, and the mixture was stirred at room temperature for 3 days. The solution was poured into brine, and the water layers were extracted with dichloromethane, and the combined organic layer was washed with brine, dried over $MgSO_4$, filtered, and concentrated. The residue was purified by PTLC on SiO_2 (hexane:ethyl acetate, 15:1) to afford **45** (4.0 mg, 100% yield) as a colorless oil: ^{1}H NMR (270 MHz) δ 7.35-7.20 (5H, m), 5.22 (1H, d, J = 11 Hz), 4.56 (1H, d, J = 11 Hz), 3.89-3.54 (7H, m), 3.38 (1H, t, J = 9 Hz), 3.35-3.14 (3H, m), 3.00 (1H, dd, J = 8, 9 Hz), 0.90 (9H, s), 0.89 (18H, s), 0.83 (9H, s), 0.81 (9H, s), 0.14 (3H, s), 0.14 (3H, s), 0.12 (3H, s), 0.108 (3H, s), 0.100 (3H, s), 0.06 (3H, s), 0.04 (3H, s), 0.03 (3H, s), -0.01 (3H, s), -0.05 (3H, s), and -0.06 (3H, s); IR (film) ν_{max} 3064, 3032, 2956, 2932, 2888, 2856, 1474, 1466, 1362, 1254, 1154, 1098, 838, and 778 cm^{-1}.

To a solution of **45** (4.0 mg, 3.69 μmol) in THF (1.0 ml) and liq. NH_3 (2 ml) was added Na metal (ca. 1mm^3) at -78 °C, and the mixture was stirred at -78 °C for 25 min. To the mixture was added solid NH_4Cl (excess), and then liq. NH_3 was evaporated at room temperature. The residue was diluted with water and ethyl acetate, and the water layer was extracted with ethyl acetate. The combined organic layers were washed with brine, dried over $MgSO_4$, filtered, and concentrated. The crude product was purified by PTLC on SiO_2 (hexane:ethyl acetate, 20:1) to afford **46** (3.5 mg, 97% yield) as a colorless oil: ^{1}H NMR (270 MHz) δ 3.88-3.77 (3H, br m), 3.74-3.60 (3H, m), 3.56-3.43 (2H, m), 3.35-3.11 (2H, m), 3.06-2.88 (2H, m), 0.89 (36H, br s), 0.88 (9H, s), 0.15 (3H, s), 0.14 (3H, s), 0.12 (3H, s), 0.11 (3H, s), 0.10 (3H, s), 0.074 (3H, s), 0.070 (3H, s), 0.052 (3H, s), 0.050 (3H, s), and 0.04 (3H, s); IR (film) ν_{max} 3612, 3516, 2956, 2932, 2888, 2860, 1474, 1466, 1362, 1256, 1098, 838, and 778 cm^{-1}.

A mixture of **46** (3.5 mg, 4.18 μmol), NaH (13.2 mg, 553 μmol. washed with hexane), and imidazole (trace) in THF (1 ml) was stirred at room temperature for 30 min. To the mixture was added CS_2 (25 μl, 416 μmol) and the mixture was stirred at room temperature for 2.5 h. To the solution was added MeI (25 μl, 402 μmol) and the mixture was stirred at room temperature for 10 min. The reaction mixture was poured into water and ether. The water layer was extracted with ether. The combined organic layers were washed with brine, dried over $MgSO_4$, filtered, and concentrated. The crude xanthate was obtained, and immediately used for the next reaction without further purification.

To a solution of crude xanthate and AIBN (1.0 mg, 6.31 μmol) in toluene (1 ml) was added Bu_3SnH (4.0 μl, 15.1 μmol) at reflux temperature and the mixture was heated under reflux for 1 h, and concentrated. The residue was purified by PTLC on SiO_2 (hexane:ethyl acetate, 10:1, and hexane:dichloromethane:ether, 100:49:1) to afford **47** (1.7 mg, 2 steps 50% yield) and **48** (1.5 mg, 2 steps 45% yield) as both colorless oils.

Data for **47**: $[\alpha]_D^{20}$ -0.71° (c 0.07); ^{1}H NMR (400 MHz) δ 3.83 (1H, dd, J = 2, 11 Hz, H-10), 3.82 (1H, dd J = 3, 11 Hz, H-1), 3.76 (1H, dd, J = 4, 11 Hz, H-10), 3.76-3.68 (1H, m, H-8), 3.65 (1H, dd, J = 6, 11 Hz, H-1), 3.61 (1H, t, J = 8 Hz, H-4), 3.54 (1H, t, J = 8 Hz, H-3), 3.27 (1H, ddd, J = 3, 6, 8 Hz, H-2), 3.09 (1H, ddd, J = 4, 9, 11 Hz, H-6), 3.06 (1H, ddd, J = 2, 4, 9 Hz, H-9), 2.85 (1H, dd, J = 8, 9 Hz, H-5), 2.31 (1H, ddd, J = 4, 5, 11 Hz, H-7-eq), 1.44 (1H, q, J = 11 Hz, H-7-ax), 0.898 (9H, s), 0.890 (9H, s), 0.887 (9H, s), 0.883 (9H, s), 0.87 (9H, s), 0.14 (3H, s), 0.12 (3H, s), 0.10 (3H, s), 0.07 (3H, s), 0.06 (6H, s), 0.05 (9H, s), and 0.04 (3H, s); IR (film) ν_{max} 2956, 2932, 2892, 2856, 1474, 1466, 1254, 1096, 858, 836, and 776 cm^{-1}; HR-FAB-MS calcd. for $C_{40}H_{89}O_7Si_5$ (M^++H) 821.5457, found *m/z* 821.5499.

Data for **48**: ^{1}H NMR (400 MHz) δ 3.83 (1H, dd J = 2, 11 Hz, H-1), 3.77 (1H, dd, J = 4, 10 Hz, H-10), 3.68 (1H, dd, J = 5, 11 Hz, H-1), 3.67 (1H, t, J = 9 Hz, H-4), 3.68-3.62 (1H, m, H-7), 3.56 (1H, t, J = 9 Hz, H-3), 3.45 (1H, dd, J = 7, 10 Hz, H-10), 3.43-3.37 (1H, m, H-9), 3.22 (1H, ddd, J = 2, 5, 9 Hz, H-2), 2.92 (1H, t, J = 9 Hz), 2.84 (1H, t, J = 9 Hz, H-5), 2.06 (1H, ddd, J = 2, 5, 13 Hz, H-8-eq), 1.37 (1H, br q, J = 12 Hz, H-8-ax), 0.892 (9H, s), 0.887 (9H, s), 0.883 (9H, s), 0.881 (9H, s), 0.87 (9H, s), 0.11 (3H, s), 0.10 (3H, s), 0.085 (6H, s), 0.083 (6H, s), 0.05 (6H, s), and 0.04 (6H, s).

REFERENCES AND NOTES

1. a) Murata, M.; Legrand, A.-M.; Ishibashi, Y.; Fukui, M.; Yasumoto, T. *J. Am. Chem. Soc.* **1990**, *112*, 4380. b) Lewis, R. J.; Sellin, M.; Poli, M. A.; Norton, R. S.; MacLeod, J. K.; Sheil, M. M. *Toxicon* **1991**, *29*, 1115. c) Murata, M.; Legrand, A.-M.; Scheuer, P. J.; Yasumoto, T. *Tetrahedron Lett.* **1992**, *33*, 525. d) Satake, M.; Murata, M.; Yasumoto, T. *Tetrahedron Lett.* **1993**, *34*, 1975. e) Lewis, R. J.; Norton, R. S.; Berereton, I. M.; Eccles, C. D. *Toxicon* **1993**, *31*, 637.
2. For other synthetic studies, see: a) Alvarez, E.; Díaz, M. T.; Pérez, R.; Martín, J. D. *Tetrahedron Lett.* **1991**, *32*, 2241. b) Alvarez, E.; Zurita, D.; Martín, J. D. *Tetrahedron Lett.* **1991**, *32*, 2245. c) Zárraga, M.; Martín, J. D. *Tetrahedron Lett.* **1991**, *32*, 2249. d) Alvarez, E.; Rodríguez, M. L.; Zurita, D.; Martín, J. D. *Tetrahedron Lett.* **1991**, *32*, 2253. e) Sato, O.; Hirama, M. *Synlett.* **1992**, 705. f) Alvarez, E.; Rico, M.; Rodríguez, M. L.; Zurita, D.; Martín, J. D. *Tetrahedron Lett.* **1992**, *33*, 3385. g) Ravelo, J. L.; Regueiro, A.; Martín, J. D. *Tetrahedron Lett.* **1992**, *33*, 3389. h) Soler, M. A.; Palazón, J. M.; Martín, V. S. *Tetrahedron Lett.* **1993**, *34*, 5471. i) Sasaki, M.; Hasegawa, A.; Tachibana, K. *Tetrahedron Lett.* **1993**, *34*, 8489. j) Sasaki, M.; Inoue, M.; Tachibana, K. *J. Org. Chem.* **1994**, *59*, 715. k) Alvarez, E.; Díaz, M. T.; Pérez, R.; Ravelo, J. L.; Regueiro, A.; Vera, J. A.; Zurita, D.; Martín, J. D. *J. Org. Chem.* **1994**, *59*, 2848. l) Oka, T.; Murai, A. *Chem. Lett.* **1994**, 1611. m) Alvarez, E.; Díaz, M. T.; Hanxing, L.; Martín, J. D. *J. Am. Chem. Soc.* **1995**, *117*, 1437. n) Hosokawa, S.; Isobe, M. *Synlett.* **1996**, 351. o) Oguri, H.; Hishiyama, S.; Oishi, T.; Hirama, M. *Synlett.* **1996**, 1252.
3. a) Collins, P. M.; Eder, H. *J. Chem. Soc. Perkin Trans. 1* **1984**, 1525. b) Barili, P. L.; Berti, G.; Catelani, G.; Colonna, F.; Marra, A. *Tetrahedron Lett.* **1986**, *27*, 2707.
4. El-Shenawa, H. A.; Schuerch, C. *Carbohydr. Res.* **1984**, *131*, 239.
5. Acton, E. M.; Ryan, K. J.; Smith, T. H. *Carbohydr. Res.* **1981**, *97*, 235.
6. Nakajima, N.; Horita, K.; Abe, R.; Yonemitsu, O. *Tetrahedron Lett.* **1988**, *29*, 4139.
7. a) Katsuki, T.; Sharpless, K. B. *J. Am. Chem. Soc.* **1980**, *102*, 5974. b) Gao, Y.; Hanson, R. M.; Klunder, J. M.; Ko, S. Y.; Masamune, H.; Sharpless, K. B. *J. Am. Chem. Soc.* **1987**, *109*, 5765.
8. Epoxidation of **9** with *m*CPBA gave **10** in 86% yield, along with β-epoxide in 10% yield.
9. Mancuso, A. J.; Huang, S.-L.; Swern, D. *J. Org. Chem.* **1978**, *43*, 2480.
10. Nicolaou, K. C.; Prasad, C. V. C.; Somers, P. K.; Hwang, C.-K. *J. Am. Chem. Soc.* **1989**, *111*, 5330.
11. ^{1}H NMR (270 MHz) of **12**: δ 7.35-7.21 (7H, m), 6.85 (2H, d, J = 9 Hz), 5.91 (1H, ddd, J = 7, 10, 17 Hz, H-8), 5.38 (1H, dd, J = 2, 9 Hz, H-3), 5.29 (1H, br d, J = 17 Hz, H-9-trans), 5.14 (1H, br d, J = 10 Hz, H-9-cis), 5.04 (1H, d, J = 2 Hz, H-6), 4.79 (1H, d, J = 11 Hz), 4.65 (1H, d, J = 11 Hz), 4.61 (1H, d, J = 11 Hz), 4.42 (1H, d, J = 11 Hz), 4.22 (1H, br d, J = 7 Hz, H-7), 4.19 (1H, dd, J = 3, 9 Hz,

H-4), 3.93-3.89 (1H, m, H-2), 3.80 (3H, s), 3.78 (1H, d, *J* = 3 Hz, H-5), 3.72 (1H, dd, *J* = 4, 10 Hz, H-1), 3.57 (1H, dd, *J* = 8, 10 Hz, H-1), 2.12 (3H, s), 1.85 (3H, s), 0.88 (9H, s), 0.034 (3H, s), and 0.029 (3H, s).

12. ^{1}H NMR (270 MHz) of peracetylated compound of **20**: δ 7.40-7.26 (5H, m), 6.78 (2H, d, *J* = 4, 16 Hz, H-3), 6.04 (1H, br d, *J* = 16 Hz, H-2), 5.44 (1H, br d, *J* = 7 Hz, H-9), 4.86 (1H, d, *J* = 12 Hz), 4.72 (1H, d, *J* = 12 Hz), 4.29 (1H, dd, *J* = 3, 10 Hz, H-10), 4.20 (2H, q, *J* = 7 Hz), 4.11 (1H, dd, *J* = 8, 10 Hz, H-10), 4.02 (1H, br d, *J* = 3 Hz, H-4), 3.88 (1H, br s, H-5), 3.76 (1H, t, *J* = 9 Hz, H-7), 3.70 (1H, dd, *J* = 2, 9 Hz, H-6), 3.52 (1H, br d, *J* = 9 Hz, H-8), 2.07 (3H, s), 2.00 (3H, s), 1.28 (3H, t, *J* = 7 Hz), 0.95 (9H, s), 0.89 (3H, s), 0.19 (3H, s), 0.112 (3H, s), 0.107 (3H, s), and 0.01 (3H, s).

13. ^{1}H NMR (400 MHz) of peracetylated compound of **23**: δ 7.33 (2H, d, *J* = 9 Hz), 6.86 (2H, d, *J* = 9 Hz), 5.76 (1H, br dt, *J* = 16, 4 Hz, H-2), 5.66 (1H, br dd, *J* = 5, 16 Hz, H-3), 5.41 (1H, ddd, *J* = 1, 3, 8 Hz, H-9), 4.78 (1H, d, *J* = 11 Hz), 4.64 (1H, d, *J* = 11 Hz), 4.21-4.08 (4H, m, H-1 and 10), 3.82 (1H, br d, *J* = 5 Hz, H-4), 3.78 (3H, s), 3.75 (1H, d, *J* = 2 Hz, H-5), 3.70 (1H, t, *J* = 9 Hz, H-7), 3.66 (1H, dd, *J* = 2, 9 Hz, H-6), 3.44 (1H, dd, *J* = 1, 9 Hz, H-8), 2.06 (3H, s), 1.98 (3H, s), 0.96 (9H, s), 0.92 (9H, s), 0.90 (9H, s), 0.18 (3H, s), 0.13 (3H, s), 0.11 (3H, s), 0.06 (6H, s), and 0.03 (3H, s).

14. a) Johnston, B. D.; Oehlschlarer, A. C. *J. Org. Chem.* **1982**, *47*, 5384. b) Pridgen, L. N.; Schilcrat, S. C.; Lantos, I. *Tetrahedron Lett.* **1984**, *25*, 2835.

15. ^{1}H NMR (400 MHz) of peracetylated compound of **28**: δ 7.32-7.24 (5H, m), 7.16 (2H, d, *J* = 9 Hz), 6.84 (2H, d, *J* = 9 Hz), 5.90 (1H, dd, *J* = 8, 16 Hz, H-9), 5.79 (1H, dt, *J* = 16, 5 Hz, H-10), 5.77 (1H, ddd, *J* = 7, 10, 16 Hz, H-2), 5.32 (1H, t, *J* = 10 Hz, H-6), 5.27 (1H, br d, *J* = 16 Hz, H-1-trans), 5.21 (1H, br d, *J* = 10 Hz, H-1-cis), 4.97 (1H, t, *J* = 10 Hz, H-4), 4.62 (2H, br d, *J* = 5 Hz, H-11), 4.55 (1H, d, *J* = 11 Hz), 4.54 (1H, d, *J* = 11 Hz), 4.49 (1H, d, *J* = 11 Hz), 4.28 (1H, d, *J* = 11 Hz), 3.84 (1H, dd, *J* = 3, 8 Hz, H-8), 3.79 (3H, s), 3.68 (1H, dd, *J* = 7, 10 Hz, H-3), 3.67 (1H, t, *J* = 10 Hz, H-5), 3.48 (1H, dd, *J* = 3, 10 Hz, H-7), 2.10 (3H, s), 1.96 (3H, s), and 1.80 (3H, s).

16. a) ^{1}H NMR (400 MHz) of peracetylated compound of **30**: δ 7.40-7.25 (5H, m), 7.17 (2H, d, *J* = 9 Hz), 6.85 (2H, d, *J* = 9 Hz), 5.90 (1H, br dd, *J* = 9, 18 Hz, H-9), 5.75 (1H, dt, *J* = 18, 6 Hz, H-10), 5.80-5.69 (1H, m, H-2), 5.41 (1H, t, *J* = 8 Hz, H-6), 5.37-5.22 (2H, m, H-1), 5.30 (1H, t, *J* = 4 Hz, H-4), 4.61 (2H, br d, *J* = 5 Hz, H-11), 4.58 (1H, d, *J* = 12 Hz), 4.54 (1H, d, *J* = 12 Hz), 4.55-4.48 (1H, m, H-3), 4.37 (1H, d, *J* = 12 Hz), 4.32 (1H, d, *J* = 12 Hz), 3.94 (1H, dd, *J* = 5, 9 Hz, H-8), 3.80 (3H, s), 3.69 (1H, dd, *J* = 5, 8 Hz, H-7), 3.63 (1H, dd, *J* = 4, 8 Hz, H-5), 2.11 (3H, s), 2.09 (3H, s), and 1.91 (3H, s).

b) ^{1}H NMR (400 MHz) of peracetylated compound of **31**: δ 7.38-7.22 (5H, m), 7.15 (2H, d, *J* = 9 Hz), 6.83 (2H, d, *J* = 9 Hz), 6.01 (1H, br dt, *J* = 18, 11 Hz, H-2), 5.83 (1H, br dt, *J* = 16, 6 Hz, H-10), 5.56 (1H, br dd, *J* = 8, 16 Hz, H-9), 5.30 (1H, t, *J* = 6 Hz, H-4), 5.15 (1H, br d, *J* = 11 Hz, H-1-cis), 5.14 (1H, br d, *J* = 18 Hz, H-1-trans), 4.95 (2H, br d, *J* = 4 Hz, H-11), 4.93 (1H, dd, *J* = 4, 8 Hz, H-7), 4.57 (1H, d, *J* = 12 Hz), 4.55 (1H, d, *J* = 12 Hz), 4.53 (1H, d, *J* = 12 Hz), 4.38 (1H, d, *J* = 12 Hz), 4.18 (1H, dd, *J* = 5, 8 Hz, H-6), 4.12 (1H, br dd, *J* = 4, 8 Hz, H-8), 3.96 (1H, dd, *J* = 5, 6 Hz, H-5), 3.76 (3H, s), 3.67 (1H, dd, *J* = 6, 11 Hz, H-3), 2.07 (3H, s), 2.05 (3H, s), and 2.00 (3H, s).

c) ^{1}H NMR (400 MHz) of peracetylated compound of **32**: δ 7.38-7.18 (7H, m), 6.86 (2H, d, *J* = 9 Hz), 5.92-5.72 (2H, m, H-2, and 10), 5.62 (1H, br dd, *J* = 6, 18 Hz, H-9), 5.40 (1H, dd, *J* = 2, 11 Hz, H-3), 5.31 (1H, br d, *J* = 18 Hz, H-1-trans), 5.18 (1H, br d, *J* = 11 Hz, H-1-cis), 5.04 (1H, dd, *J* = 5, 8 Hz, H-6), 4.62 (1H, d, *J* = 12 Hz), 4.58-4.48 (4H, m, H-4, 7, and 11), 4.45 (1H, d, *J* = 12 Hz), 4.38 (1H, d, *J* = 12 Hz), 4.33 (1H, d, *J* = 12 Hz), 4.31 (1H, br d, *J* = 6 Hz, H-8), 4.19 (1H, t, *J* = 5 Hz, H-5), 2.09 (3H, s), 2.06 (3H, s), and 1.90 (3H, s).

17. Barton, D. H. R.; McCombie, S. W.; *J. Chem. Soc., Perkin Trans. 1* **1975**, *61*, 313.

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