Stereoselective Synthesis of the C'D'E'F'-Ring System of Maitotoxin and the FG-Ring system of Gambierol

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Supporting Information

Nitrile 7.

To a mixture of diol **6** (887 mg, 3.17 mmol) and 2,6-lutidine (3.69 mL, 31.7 mmol) in CH_2Cl_2 (32 mL) was added Tf_2O (0.61 mL, 3.64 mmol) dropwise at –78 °C over 10 min. After stirring at –78 °C for 1 h, TBSOTf (1.45 mL, 6.33 mmol) was added dropwise to the reaction mixture at the same temperature. After stirring at –78 °C for 1 h and at 0 °C for 2 h, the reaction mixture was quenched with saturated $NaHCO_3$ solution at 0 °C. The aqueous layer was extracted with Et_2O and the combined organic layer was washed with brine, dried over $MgSO_4$, and filtrated. The filtrate was concentrated *in vacuo* to give a crude triflate (5.42 g) which was immediately used for the next reaction without purification.

To a solution of the crude triflate (5.42 g) in DMSO (32 mL) were added powdered molecular sieves 4A (633 mg) and NaCN (1.55 g, 31.7 mmol) at room temperature. After stirring at 80 °C for 40 min, H_2O was added to the reaction mixture at room temperature. After stirring at the same temperature for 20 min, the reaction mixture was extracted with Et_2O. The combined organic layer was washed with brine, dried over $MgSO_4$, and filtrated. After removal of the solvent *in vacuo*, the residue (4.18 g) was purified by flash column chromatography on silica gel (hexane : Et_2O = 10 : 1) to give nitrile **7** (1.33 g, 100% in 2 steps).

7: $[\alpha]^{25}_{D}$ +26.3 (*c* 1.06, $CHCl_3$); IR (ATR) 2929, 2857, 2359, 1458, 1364, 1253, 1089, 836, 776, 697 cm^{-1}; ^1H NMR (500 MHz, $CDCl_3$) δ 7.45-7.50 (m, 2H), 7.33-7.40 (m, 3H), 5.53 (s, 1H), 4.26 (dd, *J* = 10.3, 4.5 Hz, 1H), 3.83 (dd, *J* = 11.5, 4.5 Hz, 1H), 3.70 (dd, *J* = 10.3, 9.5 Hz, 1H), 3.60 (ddd, *J* = 9.5, 9.5, 4.5 Hz, 1H), 3.56 (ddd, *J* = 11.3, 9.5, 4.1 Hz, 1H), 2.60 (d, *J* = 16.5 Hz, 1H), 2.58 (d, *J* = 16.5 Hz, 1H), 2.24 (ddd, *J* = 12.0, 4.5, 4.1 Hz, 1H), 1.83 (ddd, *J* = 12.0, 11.5, 11.3 Hz, 1H), 1.34 (s, 3H), 0.89 (s, 9H), 0.14 (s, 3H), 0.12 (s, 3H); ^{13}C NMR (125 MHz, $CDCl_3$) δ 137.2, 129.1, 128.3, 126.1, 116.8, 101.8, 76.7, 76.5, 70.9, 69.6, 66.8, 34.3, 29.2, 25.6, 17.7, 15.9, -4.0, -5.1; HRMS (FAB) calcd for $C_{22}H_{34}NO_4Si$ $(M+H^+)$ 404.2257, found 404.2255.

Ketone 8.

To a solution of nitrile **7** (27.3 mg, 67.6 μmol) in CH_2Cl_2 (1 mL) was added DIBAH (0.90 M in *n*-hexane, 0.11 mL, 0.101 mmol) dropwise at –78 °C. After stirring at –78 °C for 1 h, the reaction mixture was quenched with *i*-PrOH (0.1 mL) and H_2O (0.1 mL) at –78 °C, warmed to room temperature, and stirred at the same temperature for 1 h. After addition of SiO_2 (0.5 g) and $MgSO_4$ (0.5 g) at room temperature, the mixture was diluted with EtOAc and stirred for 1 h. The resulting mixture was filtrated through a Celite pad and evaporated. The residue (26.0 mg) was purified by flash column chromatography on silica gel (hexane : Et_2O = 10 : 1) to give an aldehyde (23.8 mg, 87%).

To a solution of the aldehyde (23.8 mg, 58.5 μmol) in THF (1 mL) was added MeMgBr (0.93 M in THF, 95 μL, 87.8 μmol) dropwise at 0 °C. After stirring at 0 °C for 20 min and at room temperature for 40 min, the reaction mixture was diluted with Et_2O, washed with saturated NH_4Cl solution and then brine. The organic layer was dried over $MgSO_4$, and filtrated. After removal of the solvent *in vacuo*, the residue (25.5 mg) was purified by flash column chromatography on silica gel (hexane : Et_2O = 5 : 1) to give an alcohol (21.9 mg, 89%).

To a solution of the alcohol (21.9 mg, 51.8 μmol) in CH_2Cl_2 (1 mL) were added powdered molecular sieves 4A (26 mg) and *N*-methylmorpholine *N*-oxide (NMO) (9.1 mg, 77.7 μmol) at room temperature. After stirring at the same temperature for 45 min, tetrapropylammonium perruthenate (TPAP) (1.0 mg, 2.85 μmol) at room temperature. After stirring at the same temperature for 1.5 h, the reaction mixture was transferred to silica gel column and purified by flash column chromatography (hexane : Et_2O = 10 : 1) to give ketone **8** (20.2 mg, 93%).

8: $[\alpha]^{23}_{D}$ +30.9 (*c* 1.01, $CHCl_3$); IR (ATR) 2929, 2856, 1706, 1458, 1362, 1251, 1089, 1028, 836, 775, 697 cm^{-1}; ^1H NMR (500 MHz, $CDCl_3$) δ 7.46-7.50 (m, 2H), 7.32-7.39(m, 3H), 5.50 (s, 1H), 4.21 (dd, *J* = 9.4, 3.9 Hz, 1H), 3.90 (dd, *J* = 11.3, 4.7 Hz, 1H), 3.61 (dd, *J* = 9.7, 9.4 Hz, 1H), 3.57 (ddd, *J* = 9.7, 8.7, 3.9 Hz, 1H), 3.47 (ddd, *J* = 11.8, 8.7, 4.2 Hz, 1H), 2.65 (d, *J* = 12.6 Hz, 1H), 2.54 (d, *J* = 12.6 Hz, 1H), 2.18 (s, 3H), 2.17 (ddd, *J* = 11.8, 4.7, 4.2 Hz, 1H), 1.82 (ddd, *J* = 11.8, 11.8, 11.3 Hz, 1H), 1.29 (s, 3H), 0.87 (s, 9H), 0.10 (s, 3H), 0.09 (s, 3H); ^{13}C NMR (125 MHz, $CDCl_3$) δ 208.0, 137.4, 129.1, 128.3, 126.1, 101.8, 78.5, 77.1, 70.8, 69.9, 66.3, 51.8, 34.4, 33.3, 25.7, 17.8, 16.3, -4.1, -4.9; HRMS (FAB) calcd for $C_{23}H_{37}O_5Si$ ($M+H^+$) 421.2410, found 421.2388.

Enol Ether 9.

To a solution of ketone **8** (570 mg, 1.36 mmol) in THF was added *n*-$Bu_4NF{\bullet}xH_2O$ (535 mg) at 0 °C. After stirring at room temperature for 2.5 h, the reaction mixture was quenched with saturated $NaHCO_3$ solution and diluted with EtOAc. The aqueous layer was extracted with EtOAc and the combined organic layer was washed with brine, dried over $MgSO_4$ and filtrated. After removal of the solvent *in vacuo*, the residue (924 mg) was purified by flash column chromatography on silica gel (hexane : EtOAc = 2 : 1) to give an alcohol (487 mg).

To a solution of the alcohol (487 mg) in CH_2Cl_2 (14 mL) were added *N*-methylmorpholine (0.60 mL, 5.42 mmol) and ethyl propiolate (0.28 mL, 2.71 mmol) at room temperature. After stirring at the same temperature for 6 h, the reaction mixture was diluted with Et_2O and washed with H_2O. The aqueous layer was extracted with Et_2O and the combined organic layer was washed with brine, dried over $MgSO_4$, and filtrated. After removal of the solvent *in vacuo*, the residue (893 mg) was purified by flash column chromatography on silica gel (hexane : EtOAc = 3 : 1) to give enol ether **9** (544 mg, 99% in 2 steps).

9: $[\alpha]^{22}_{D}$ +46.7 (*c* 1.03, $CHCl_3$); IR (ATR) 2977, 1702, 1641, 1369, 1187, 1093, 1013, 954, 698 cm^{-1}; ^1H NMR (500 MHz, $CDCl_3$) δ 7.53 (d, *J* = 12.4 Hz, 1H), 7.45-7.48 (m, 2H), 7.32-7.39 (m, 3H), 5.51 (s, 1H), 5.35 (d, *J* = 12.4 Hz, 1H), 4.39 (dd, *J* = 11.7, 4.8 Hz, 1H), 4.23 (m, 1H), 4.12-4.21 (m, 2H), 3.58-3.65 (m, 2H), 3.50 (ddd, *J* = 12.0, 8.6, 4.2 Hz, 1H), 2.72 (d, *J* = 13.4 Hz, 1H), 2.50 (d, *J* = 13.4 Hz, 1H), 2.40 (ddd, *J* = 11.9, 4.8, 4.2 Hz, 1H), 2.18 (s, 3H), 1.90 (ddd, *J* = 12.0, 11.9, 11.7 Hz, 1H), 1.37 (s, 3H), 1.27 (t, *J* = 7.1 Hz, 3H); ^{13}C NMR (125 MHz, $CDCl_3$) δ 207.1, 167.5, 160.9, 137.1, 129.2, 128.3, 126.1, 101.7, 99.0, 79.0, 76.7, 76.5, 69.6, 66.5, 59.9, 50.7, 33.4, 30.6, 17.3, 14.3; HRMS (FAB) calcd for $C_{22}H_{29}O_7$ ($M+H^+$) 405.1913, found 405.1914.

Tertiary Alcohol 10.

To a solution of enol ether **9** (112 mg, 0.277 mmol) in MeOH (25 μL, 0.610 mmol) and THF (2.8 mL) was added SmI_2 (0.1 M in THF, 6.5 mL, 0.65 mmol) dropwise at 0 °C over 10 min. After stirring at the same temperature for 5 min, the reaction mixture was quenched with a mixture of 50% $Na_2S_2O_3$ solution and saturated $NaHCO_3$ solution. The aqueous layer was extracted with EtOAc and the combined organic layer was washed with brine, dried over $MgSO_4$, and filtrated. After removal of the solvent *in vacuo*, the residue (177 mg) was purified by flash column chromatography on silica gel (hexane : EtOAc = 2 : 1) to give tertiary alcohol

10 (111 mg, 99%).

10: mp 151-3 °C; $[\alpha]^{20}_{D}$ +21.5 (*c* 1.01, $CHCl_3$); IR (ATR) 3477, 2980, 2870, 1732, 1377, 1289, 1186, 1094, 1028, 750, 699 cm^{-1}; ^{1}H NMR (600 MHz, $CDCl_3$) δ 7.49 (dd, *J* = 7.8, 1.5 Hz, 2H), 7.35-7.40 (m, 3H), 5.52 (s, 1H), 4.23 (dd, *J* = 9.8, 4.4 Hz, 1H), 4.12-4.22 (m, 2H), 3.79 (dd, *J* = 9.3, 4.4 Hz, 1H), 3.74 (ddd, *J* = 9.8, 9.3, 4.4 Hz, 1H), 3.69 (dd, *J* = 9.8, 9.8 Hz, 1H), 3.57 (ddd, *J* = 11.7, 9.3, 4.4 Hz, 1H), 3.28 (dd, *J* = 12.2, 3.4 Hz, 1H), 2.68 (dd, *J* = 15.6, 4.4 Hz, 1H), 2.47 (dd, *J* = 15.6, 9.3 Hz, 1H), 2.21 (ddd, *J* = 11.7, 4.4, 3.4 Hz, 1H), 2.09 (d, *J* = 12.7 Hz, 1H), 1.80 (ddd, *J* = 12.2, 11.7, 11.7 Hz, 1H), 1.75 (br d, *J* = 12.7 Hz, 1H), 1.34 (s, 3H), 1.32 (s, 3H), 1.27 (t, *J* = 7.1 Hz, 3H); ^{13}C NMR (150 MHz, $CDCl_3$) δ 171.9, 137.3, 129.1, 128.3, 126.1, 102.0, 84.1, 80.9, 79.0, 73.7, 70.4, 70.1, 66.2, 60.8, 54.0, 35.1, 30.2, 24.2, 15.9, 14.2; HRMS (FAB) calcd for $C_{22}H_{31}O_7$ ($M+H^+$) 407.2070, found 407.2068.

Allyl Alcohol 12.

To a solution of tertiary alcohol **10** (466 mg, 1.15 mmol) in CH_2Cl_2 (12 mL) were added 2,6-lutidine (0.40 mL, 3.44 mmol) and TMSOTf (0.33 mL, 1.72 mmol) at 0 °C. After stirring at the same temperature for 15 min, the reaction mixture was quenched with saturated $NaHCO_3$ solution and diluted with Et_2O. The aqueous layer was extracted with Et_2O and the combined organic layer was washed with brine, dried over $MgSO_4$ and filtrated. After removal of the solvent *in vacuo*, the residue (944 mg) was purified by flash column chromatography on silica gel (hexane : Et_2O = 8 : 1) to give a silyl ether (532 mg, 97%).

To a solution of the silyl ether (532 mg, 1.11 mmol) in toluene (11 mL) was added DIBAH (0.90 M in *n*-hexane, 1.36 mL, 1.22 mmol) dropwise at –78 °C over 5 min. After stirring at –78 °C for 15 min, the reaction mixture was quenched with *i*-PrOH (0.3 mL) and H_2O (0.3 mL) at –78 °C, warmed to room temperature, and stirred at the same temperature for 2 h. After addition of SiO_2 (1.8 g) and $MgSO_4$ (3.6 g) at room temperature, the mixture was diluted with EtOAc and stirred for 40 min. The resulting mixture was filtrated through a Celite pad and evaporated to give a crude aldehyde (513 mg) which was used for the next reaction without purification.

To a solution of the crude aldehyde (513 mg) in toluene was added (carbethoxyethylidene)triphenylphosphorane (604 mg, 1.67 mmol) at room temperature. After stirring at 100 °C for 1.5, the reaction mixture was transferred to silica gel column and purified by flash column chromatography (hexane : Et_2O = 8 : 1) to give an ester (565 mg, 98% in 2 steps).

To a solution of the ester (565 mg) in toluene (11 mL) was added DIBAH (0.90 M in *n*-hexane, 2.66 mL, 2.40 mmol) dropwise at –78 °C. After stirring at –78 °C for 10 min, the reaction mixture was quenched with *i*-PrOH (0.6 mL) and H_2O (0.6 mL) at –78 °C, warmed to room temperature, and stirred at the same temperature for 1 h. After addition of SiO_2 (3.6 g) and $MgSO_4$ (7.2 g) at room temperature, the mixture was diluted with EtOAc and stirred for 30 min. The resulting mixture was filtrated through a Celite pad and evaporated. The residue (700 mg) was purified by flash column chromatography on silica gel (hexane : EtOAc = 10 : 1) to give allyl alcohol **12** (480 mg, 92%).

12: mp 52-4 °C; $[\alpha]^{24}_D$ +59.5 (*c* 1.05, $CHCl_3$); IR (ATR) 3448, 2954, 2866, 1375, 1251, 1078, 838, 750, 697 cm^{-1}; ^1H NMR (500 MHz, $CDCl_3$) δ 7.47-7.50 (m, 2H), 7.32-7.39(m, 3H), 5.58 (ddq, *J* = 7.4, 6.1, 1.3(q) Hz, 1H), 5.52 (s, 1H), 4.29 (dd, *J* = 9.5, 3.8 Hz, 1H), 4.02 (d, *J* = 5.4 (coupled with OH) Hz, 2H), 3.74 (ddd, *J* = 9.9, 8.8, 3.8 Hz, 1H), 3.69 (dd, *J* = 9.9, 9.5 Hz, 1H), 3.56 (ddd, *J* = 11.4, 8.8, 4.5 Hz, 1H), 3.25 (dd, *J* = 10.0, 2.3 Hz, 1H), 3.22 (dd, *J* = 12.4, 3.6 Hz, 1H), 2.42 (br dd, *J* = 14.8, 7.4 Hz, 1H), 2.23 (ddd, *J* = 11.2, 4.5, 3.6 Hz, 1H), 2.07 (d, *J* = 12.1 Hz, 1H), 2.02 (ddd, *J* = 14.8, 10.0, 6.1 Hz, 1H), 1.82 (br d, *J* = 12.1 Hz, 1H), 1.81 (ddd, *J* = 12.4, 11.4, 11.2 Hz, 1H), 1.68 (br s, 3H), 1.35 (s, 3H), 1.33 (s, 3H), 0.13 (s, 9H); ^{13}C NMR (125 MHz, $CDCl_3$) δ 137.4, 136.0, 129.0, 128.3, 126.1, 123.5, 101.9, 88.7, 80.8, 79.1, 73.8, 73.8, 70.2, 68.9, 66.1, 54.2, 30.3, 27.0, 24.9, 16.1, 13.8, 2.6; HRMS (FAB) calcd for $C_{26}H_{41}O_6Si$ ($M+H^+$) 477.2672, found 477.2672.

Epoxy Alcohol 13.

To a mixture of allyl alcohol **12** (191 mg, 0.400 mmol), (+)-diethyl L-tartrate (24.8 mg, 0.120 mmol), and powdered molecular sieves 4A (95 mg) in CH_2Cl_2 (2.4 mL) was added $Ti(O\textit{i}\text{-}Pr)_4$ (24 μL, 80.1 μmol) at –20 °C. After stirring at the same temperature for 20 min, *t*-BuOOH (3.22 M in CH_2Cl_2, 0.19 mL, 0.600 mmol) was added dropwise to the reaction mixture at –20 °C. After stirring at the same temperature for 22 h, the reaction mixture was quenched with 10% NaF solution (0.15 mL) at –20 °C, warmed to room temperature, diluted with EtOAc, and stirred at the same temperature for 1 h. After addition of SiO_2 (0.6 g) and $MgSO_4$ (1.2 g) at room temperature, the mixture was furthermore diluted with EtOAc and stirred for 30 min. The resulting mixture was filtrated through a Celite pad and evaporated. The residue (229 mg) was purified by flash column chromatography on silica gel (hexane : EtOAc = 5 : 1) to give epoxy alcohol **13** (197 mg, 100%).

13: mp 62-4 °C; $[\alpha]^{25}_D$ +42.1 (*c* 1.03, $CHCl_3$); IR (ATR) 3462, 2954, 2867, 1375, 1251, 1149, 1095, 1040, 838, 750, 698 cm^{-1}; ^1H NMR (500 MHz, $CDCl_3$) δ 7.47-7.50 (m, 2H), 7.32-7.39 (m, 3H), 5.52 (s, 1H), 4.24 (dd, *J* = 9.7, 4.1 Hz, 1H), 3.74 (ddd, *J* = 10.0, 9.1, 4.1 Hz, 1H), 3.70 (dd, *J* = 12.3, 4.7 (coupled with OH) Hz, 1H), 3.69 (dd, *J* = 10.0, 9.7 Hz, 1H), 3.61 (dd, *J*

= 12.3, 8.6 (coupled with OH) Hz, 1H), 3.57 (ddd, *J* = 11.2, 9.1, 4.4 Hz, 1H), 3.33 (dd, *J* = 9.4, 2.6 Hz, 1H), 3.27 (dd, *J* = 6.9, 5.6 Hz, 1H), 3.26 (dd, *J* = 12.3, 3.5 Hz, 1H), 2.25 (ddd, *J* = 11.3, 4.4, 3.5 Hz, 1H), 2.09 (d, *J* = 12.2 Hz, 1H), 1.83 (d, *J* = 12.2 Hz, 1H), 1.83 (ddd, *J* = 12.3, 11.3, 11.2 Hz, 1H), 1.72-1.85 (m, 2H), 1.34 (s, 3H), 1.34 (s, 3H), 1.30 (s, 3H), 0.11 (s, 9H); ^{13}C NMR (125 MHz, $CDCl_3$) δ 137.3, 129.1, 128.3, 126.1, 101.9, 86.7, 80.8, 79.1, 73.7, 73.6, 70.2, 66.2, 65.3, 60.4, 58.4, 54.1, 30.3, 28.1, 24.8, 16.2, 14.0, 2.6; HRMS (FAB) calcd for $C_{26}H_{41}O_7Si$ ($M+H^+$) 493.2622, found 493.2626.

Vinylepoxide 14.

To a solution of epoxy alcohol **13** (62.5 mg, 0.127 mmol) in CH_2Cl_2 (1 mL) were added powdered molecular sieves 4A (63 mg) and *N*-methylmorpholine *N*-oxide (NMO) (22.3 mg, 0.190 mmol) at room temperature. After stirring at the same temperature for 15 min, tetrapropylammonium perruthenate (TPAP) (2.2 mg, 6.34 μmol) at room temperature. After stirring at the same temperature for 30 min, the reaction mixture was transferred to silica gel column and roughly purified by flash column chromatography (hexane : Et_2O = 4 : 1) to give an aldehyde (56.2 mg).

To a solution of methyltriphenylphosphonium bromide (81.6 mg, 0.288 mmol) in THF (1 mL) was added $NaN(TMS)_2$ (1.0 M in THF, 0.19 mL, 0.190 mmol) at 0 °C. After stirring at the same temperature for 20 min, a solution of the aldehyde (56.2 mg) in THF (2 mL) was added to the reaction mixture at 0 °C. After stirring at the same temperature for 15 min, the reaction mixture was quenched with saturated NH_4Cl solution and diluted with EtOAc. The aqueous layer was extracted with EtOAc and the combined organic layer was washed with brine, dried over $MgSO_4$ and filtrated. After removal of the solvent *in vacuo*, the residue (103 mg) was purified by flash column chromatography on silica gel (hexane : Et_2O = 10 : 1) to give vinylepoxide **14** (42.8 mg, 69% in 2 steps).

14: mp 171-2 °C; $[\alpha]^{23}_D$ +60.8 (*c* 1.01, $CHCl_3$); IR (ATR) 2955, 2866, 1374, 1251, 1148, 1095, 838, 749, 697 cm^{-1}; ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.47-7.50 (m, 2H), 7.32-7.39 (m, 3H), 5.68 (dd, *J* = 17.4, 10.8 Hz, 1H), 5.52 (s, 1H), 5.34 (dd, *J* = 17.4, 1.0 Hz, 1H), 5.20 (dd, *J* = 10.8, 1.0 Hz, 1H), 4.24 (dd, *J* = 9.7, 4.0 Hz, 1H), 3.74 (ddd, *J* = 9.9, 9.1, 4.0 Hz, 1H), 3.68 (dd, *J* = 9.9, 9.7 Hz, 1H), 3.57 (ddd, *J* = 11.2, 9.1, 4.4 Hz, 1H), 3.34 (dd, *J* = 8.8, 3.4 Hz, 1H), 3.26 (dd, *J* = 12.3, 3.6 Hz, 1H), 3.06 (dd, *J* = 7.0, 5.5 Hz, 1H), 2.23 (ddd, *J* = 11.3, 4.4, 3.6 Hz, 1H), 2.09 (d, *J* = 12.1 Hz, 1H), 1.83 (d, *J* = 12.1 Hz, 1H), 1.83 (ddd, *J* = 12.3, 11.3, 11.2 Hz, 1H), 1.75-1.85 (m, 2H), 1.41 (s, 3H), 1.34 (s, 3H), 1.34 (s, 3H), 0.12 (s, 9H); ^{13}C NMR (125 MHz, $CDCl_3$) δ 141.0, 137.3, 129.1, 128.3, 126.1, 115.9, 102.0, 86.7, 80.8, 79.1, 73.7, 73.6, 70.2, 66.2, 63.3, 59.0, 54.1, 30.3, 28.6, 24.8, 16.2, 14.7, 2.6; HRMS (FAB) calcd for

$C_{27}H_{41}O_6Si$ (M+H$^+$) 489.2672, found 489.2672.

Vinyl Alcohol 15.

To a solution of vinylepoxide **14** (22.4 mg, 45.8 μmol) in THF (2 mL) was added *n*-Bu_4NF (1.0 M in THF, 69 μL, 69.0 μmol) at room temperature. After stirring at the same temperature for 30 min, the reaction mixture was evaporated. The residue was purified by flash column chromatography on silica gel (hexane : EtOAc = 1 : 1) to give an alcohol (18.9 mg, 99%).

To a solution of the alcohol (10.2 mg, 24.5 μmol) in toluene (2 mL) was added 10-camphorsulfonic acid (CSA) (1.2 mg, 4.9 μmol) at 0 °C. After stirring at the same temperature for 3.5 h, the reaction mixture was quenched with Et_3N and evaporated. The residue was purified by flash column chromatography on silica gel (hexane : EtOAc = 2 : 1) to give vinyl alcohol **15** (7.5 mg, 74%).

15: mp 108-110 °C; $[\alpha]^{26}_{D}$ +16.8 (*c* 1.09, $CHCl_3$); IR (neat) 3468, 3008, 2950, 2873, 1457, 1378, 1098, 1021, 916, 755, 699 cm^{-1}; ^{1}H NMR (600 MHz, $CDCl_3$) δ 7.47-7.51 (m, 2H), 7.33-7.39 (m, 3H), 5.91 (dd, *J* = 17.1, 10.7 Hz, 1H), 5.52 (s, 1H), 5.29 (dd, *J* = 17.1, 1.0 Hz, 1H), 5.08 (dd, *J* = 10.7, 1.0 Hz, 1H), 4.24 (dd, *J* = 10.3, 4.4 Hz, 1H), 3.80 (ddd, *J* = 10.3, 9.8, 4.4 Hz, 1H), 3.78 (dd, *J* = 9.8, 5.9 Hz, 1H), 3.69 (dd, *J* = 10.3, 10.3 Hz, 1H), 3.58 (ddd, *J* = 11.5, 9.8, 4.9 Hz, 1H), 3.39 (dd, *J* = 12.7, 3.4 Hz, 1H), 3.33 (dd, *J* = 12.7, 3.4 Hz, 1H), 2.25 (ddd, *J* = 11.2, 4.9, 3.4 Hz, 1H), 2.18 (ddd, *J* = 11.7, 5.9, 3.4 Hz, 1H), 2.10 (d, *J* = 12.2 Hz, 1H), 1.88 (ddd, *J* = 12.7, 11.5, 11.2 Hz, 1H), 1.87 (ddd, *J* = 12.7, 11.7, 9.8 Hz, 1H), 1.71 (br d, *J* = 12.2 Hz, 1H), 1.49 (s, 3H), 1.42 (s, 3H), 1.39 (s, 3H); ^{13}C NMR (150 MHz, $CDCl_3$) δ 145.3, 137.3, 129.1, 128.3, 126.1, 112.7, 102.1, 83.44, 83.36, 79.4, 77.8, 74.6, 74.2, 73.3, 70.2, 66.1, 52.6, 30.6, 30.2, 22.6, 21.6, 17.6; HRMS (FAB) calcd for $C_{24}H_{32}O_6Na$ (M+Na$^+$) 439.2097, found 439.2095.

Ester 16.

A solution of vinylepoxide **15** (14.1 mg, 33.9 μmol) in CH_2Cl_2 (3 mL) was treated with ozone at –78 °C for 1 min. The reaction mixture was quenched with Me_2S at –78 °C, stirred at room temperature for 30 min, and then evaporated to give a crude aldehyde which was used for the next reaction without purification.

To a solution of the crude aldehyde in toluene (2 mL) was added methyl (triphenylphosphoranylidene)acetate (23 mg, 67.7 mmol) at room temperature. After stirring at 100 °C for 1 h, the reaction mixture was transferred to silica gel column and purified by flash column chromatography (hexane : EtOAc = 2 : 1) to give ester **16** (11.5 mg, 72% in 2 steps).

16: $[\alpha]^{27}_{D}$ +20 (*c* 0.68, $CHCl_3$); IR (neat) 3450, 2951, 1719, 1378, 1288, 1099, 1051, 1033, 755, 700 cm^{-1}; ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.47-7.51 (m, 2H), 7.33-7.39 (m, 3H), 7.03 (d, *J* = 15.6 Hz, 1H), 6.07 (d, *J* = 15.6 Hz, 1H), 5.53 (s, 1H), 4.24 (dd, *J* = 10.1, 4.1 Hz, 1H), 3.77-3.82 (m, 2H), 3.75 (s, 3H), 3.69 (dd, *J* = 10.1, 10.1 Hz, 1H), 3.58 (ddd, *J* = 11.0, 9.6, 4.4 Hz, 1H), 3.30 (dd, *J* = 12.4, 3.2 Hz, 1H), 3.28 (dd, *J* = 12.4, 3.2 Hz, 1H), 2.24 (ddd, *J* = 11.2, 4.4, 3.2 Hz, 1H), 2.17 (ddd, *J* = 11.9, 5.5, 3.2 Hz, 1H), 2.10 (d, *J* = 12.2 Hz, 1H), 1.91 (m, 1H), 1.88 (m, 1H), 1.71 (br d, *J* = 12.2 Hz, 1H), 1.48 (s, 3H), 1.43 (s, 3H), 1.42 (s, 3H); ^{13}C NMR (125 MHz, $CDCl_3$) δ 167.5, 154.0, 137.3, 129.1, 128.4, 126.2, 118.2, 102.1, 83.5, 83.2, 79.4, 77.3, 74.5, 73.6, 73.5, 70.2, 66.2, 52.4, 51.6, 31.0, 30.2, 23.0, 21.4, 17.6; HRMS (FAB) calcd for $C_{26}H_{34}O_8Na$ ($M+Na^+$) 497.2151, found 497.2148.

Lactone 17.

To a solution of ester **16** (8.7 mg, 18.3 μmol) in EtOAc (2 mL) was added 10% Pd on carbon at room temperature. After stirring at the same temperature under H_2 for 2 h, the reaction mixture was filtrated through a Celite pad and evaporated to give a crude saturated ester (7.6 mg) which was used for the next reaction without purification.

To a solution of the crude saturated ester (7.6 mg) in MeOH (0.5 mL) and H_2O (0.15 mL) was added LiOH (3 mg, 80 μmol) at room temperature. After stirring at the same temperature for 3.5 h, the reaction mixture was evaporated, diluted with EtOAc, and neutralized with 1N HCl at 0 °C. The aqueous layer was extracted with EtOAc and the combined organic layer was washed with brine, dried over $MgSO_4$, filtrated, and evaporated to give a crude carboxylic acid (8.5 mg) which was used for the next reaction without purification.

To a solution of the crude carboxylic acid (8.5 mg) in pyridine (0.5 mL) was added acetic anhydride (0.5 mL) at room temperature. After stirring at the same temperature for 1.5 h, the reaction mixture was evaporated with toluene azeotropically. The residue was purified by flash column chromatography on silica gel (hexane : EtOAc = 1 : 1) to give lactone **17** (5.3 mg, 65% in 3 steps).

17: mp 282-4 °C; $[\alpha]^{27}_{D}$ -54 (*c* 0.32, $CHCl_3$); IR (ATR) 2926, 1741, 1457, 1376, 1211, 1095, 1064, 1040, 1014, 751, 699 cm^{-1}; ^{1}H NMR (600 MHz, $CDCl_3$) δ 7.47-7.51 (m, 2H), 7.33-7.39 (m, 3H), 5.53 (s, 1H), 4.24 (dd, *J* = 10.3, 4.4 Hz, 1H), 4.16 (dd, *J* = 11.7, 4.4 Hz, 1H), 3.80

(ddd, *J* = 10.3, 9.3, 4.4 Hz, 1H), 3.69 (dd, *J* = 10.3, 10.3 Hz, 1H), 3.58 (ddd, *J* = 11.2, 9.3, 4.4 Hz, 1H), 3.33 (dd, *J* = 12.7, 3.4 Hz, 1H), 3.30 (dd, *J* = 12.2, 2.5 Hz, 1H), 2.83 (ddd, *J* = 18.6, 11.7, 3.9 Hz, 1H), 2.68 (ddd, *J* = 18.6, 9.8, 4.9 Hz, 1H), 2.28 (ddd, *J* = 11.7, 4.4, 2.5 Hz, 1H), 2.27 (ddd, *J* = 12.2, 4.4, 3.4 Hz, 1H), 2.07 (d, *J* = 12.2 Hz, 1H), 2.03 (ddd, *J* = 12.2, 11.7, 11.7 Hz, 1H), 1.93 (ddd, *J* = 11.7, 9.8, 3.9 Hz, 1H), 1.89 (ddd, *J* = 12.7, 12.2, 11.2 Hz, 1H), 1.82 (ddd, *J* = 11.7, 11.7, 4.9 Hz, 1H), 1.63 (br d, *J* = 12.2 Hz, 1H), 1.48 (s, 3H), 1.44 (s, 3H), 1.39 (s, 3H); ^{13}C NMR (150 MHz, $CDCl_3$) δ 171.4, 137.2, 129.2, 128.4, 126.1, 102.2, 84.6, 84.3, 79.7, 79.4, 74.7, 74.5, 72.7, 70.2, 66.2, 52.2, 35.3, 30.2, 27.5, 27.0, 22.5, 20.9, 18.0; HRMS (FAB) calcd for $C_{25}H_{32}O_7Na$ (M+Na$^+$) 467.2046, found 467.2044.