

Supporting Information

Base-Catalyzed Diels-Alder Reactions of 2*H*-Pyran-2,5-diones: A Mild Approach to Basiliolide B

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General Information

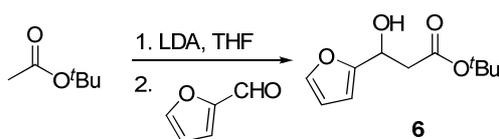
All air and water sensitive reactions were carried out under a nitrogen atmosphere with dry solvents under anhydrous conditions, unless otherwise noted. All the chemicals were purchased commercially and used without further purification. Anhydrous THF were distilled from sodium-benzophenone, and dichloromethane was distilled from calcium hydride. Yields refer to chromatographically, unless otherwise stated.

Reactions were monitored by thin-layer chromatography (TLC) carried out on 0.25 mm Tsingdao silica gel plates (60F-254) that were analyzed by staining with KMnO₄ (200 mL H₂O of 1.5 g KMnO₄, 10 g K₂CO₃ and 1.25 mL of 10% aqueous NaOH). Tsingdao silica gel (60, particle size 0.040–0.063 mm) was used for flash chromatography.

Melting points were uncorrected and determined on X-6 micro-melting point meter (Beijing Tech Instrument Co. LTD). IR spectra were obtained using Nicolet Avatar 360 FT-IR Spectrometer. NMR spectra were recorded on either a Bruker Advance 300 (¹H: 300 MHz, ¹³C: 75.5 MHz), or Bruker Advance 500 (¹H: 500 MHz, ¹³C: 125 MHz). The following abbreviations were used to explain the multiplicities: s = singlet, d = doublet, t = triplet, q = quartet, m = multiplet, b = broad. High resolution mass spectra were obtained from Finnigan MAT95 Mass Spectrometer. Crystallographic data were obtained from Oxford diffraction single crystal X-ray diffractometer (Gemini S Ultra).

Experimental Details

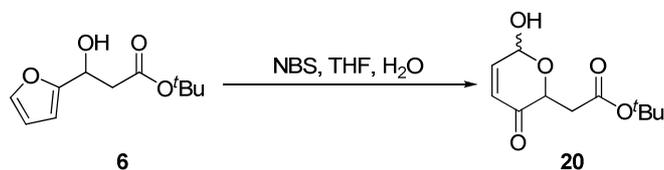
Synthesis of compound 6



To a stirred solution of LDA (generated from *n*-BuLi (9 mL, 22.5 mmol) and *i*-PrNH₂ (3.15 mL, 22.5 mmol) in THF (40 mL)) at -78 °C was added *t*-butyl acetate (2.0 mL, 15 mmol) in THF (10 mL) dropwise. The resulting solution was kept at the same temperature for 2 h. Then freshly distilled 2-furaldehyde (1.37 mL, 16.5 mmol) in THF (10 mL) was added. After stirred at -78 °C for another 1.5 h, the reaction was quenched by saturated aqueous NH₄Cl solution. The aqueous phase was extracted by diethylether (x3) and the combined organic extracts were washed with saturated aqueous NH₄Cl solution and brine, dried over Na₂SO₄, filtered and concentrated under reduced pressure. Silica gel flash column chromatography of the residue gave a yellow oil (2.69 g, 85%) as the product, *R*_f = 0.52 (silica gel, hexanes: ethyl acetate = 3: 1); ¹H NMR (300 MHz, CDCl₃) δ 7.38 (dd, 1H, *J* = 1.8 Hz, 0.9 Hz), 6.33 (dd, 1H, *J* = 3 Hz, 1.8 Hz), 6.27 (d, 1H, *J* = 3 Hz), 5.09 (dd, 1H, *J* =

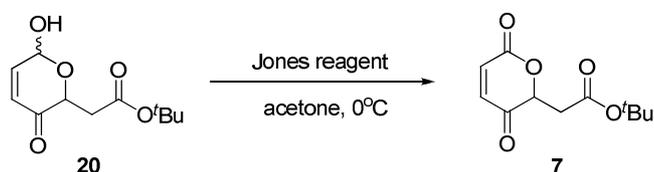
8.1 Hz, 4.5 Hz), 2.79 (m, 2H), 1.46 (s, 9H); ^{13}C NMR (500 MHz, CDCl_3) δ 171.42, 155.26, 142.22, 110.35, 106.28, 81.74, 64.60, 41.03, 28.23; IR (KBr) 3436, 2979, 2933, 1727, 1393, 1368, 1153, 1011, 740 cm^{-1} ; HRMS (ESI/[M+Na] $^+$) calcd. for $\text{C}_{11}\text{H}_{16}\text{O}_4\text{Na}$: 235.0946, found 235.0949.

Synthesis of compound 20



To a stirred solution of **6** (4.47 g, 21.1 mmol) in THF/H₂O (68 mL/17 mL) was added NaHCO₃ (3.54 g, 42.2 mmol), NaOAc (1.73 g, 21.1 mmol) and then NBS (4.13 g, 23.2 mmol) in one portion at 0 °C.¹ After stirring at 0 °C for 10 min, TLC showed the consumption of the starting material. The reaction was then quenched with saturated aqueous Na₂S₂O₃ solution. The aqueous phase was extracted by diethylether (x3) and the combined extracts were washed with saturated aqueous NH₄Cl solution and brine, dried over Na₂SO₄, filtered and concentrated under reduced pressure. Silica gel flash column chromatography of the residue gave a yellow oil (4.67 g, 97%) as the product, R_f = 0.53 (silica gel, hexanes: ethyl acetate = 1: 1); ^1H NMR (500 MHz, CDCl_3 , a mixture of diastereomers) δ 6.96 (dd, 0.25H, J = 10.5 Hz, 1.5 Hz), 6.91 (dd, 0.75H, J = 10 Hz, 3.5 Hz), 6.18 (dd, 0.25H, J = 10.5 Hz, 1.5 Hz), 6.14 (d, 0.75H, J = 10.5 Hz), 5.70 (s, 0.25H), 5.64 (d, 0.75H, J = 3 Hz), 4.96 (dd, 0.75H, J = 7.5 Hz, 4 Hz), 4.53 (ddd, 0.25H, J = 7.5 Hz, 4 Hz, 1 Hz), 2.92 (dd, 0.25H, J = 16.5 Hz, 4 Hz), 2.90 (dd, 0.75H, J = 16.5 Hz, 4 Hz), 2.74 (dd, 0.25H, J = 16.5 Hz, 7.5 Hz), 2.68 (dd, 0.75H, J = 16.5 Hz, 7.5 Hz), 1.45 (s, 9H); ^{13}C NMR (500 MHz, CDCl_3) δ 195.06, 194.65, 170.28, 170.07, 148.06, 144.42, 128.47, 127.44, 90.92, 87.93, 81.74, 81.46, 75.71, 71.17, 37.59, 36.61, 28.25; IR (KBr) 3433, 2979, 2935, 1728, 1697, 1394, 1369, 1296, 1249, 1156, 1092, 1034 cm^{-1} ; HRMS (ESI/[M+Na] $^+$) calcd. for $\text{C}_{11}\text{H}_{16}\text{O}_5\text{Na}$: 251.0895, found 251.0893.

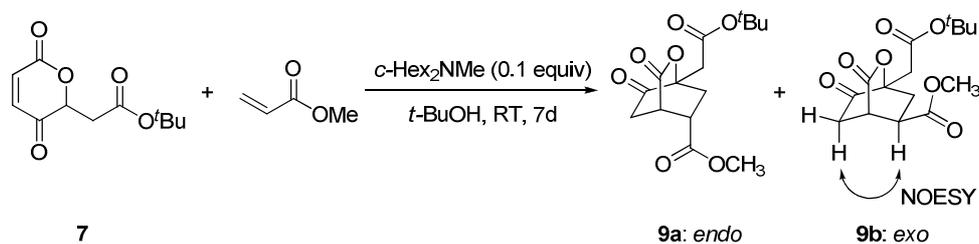
Synthesis of compound 7



To a stirred solution of **20** (0.5 g, 2.19 mmol) in acetone (15 mL) at 0 °C was added Jones reagent² (2.3 mL, 2.9 M) dropwise. After stirring at 0 °C for 30 min, TLC showed the consumption of the starting material and the reaction was quenched by adding *i*-PrOH (1 mL) slowly at 0 °C. The mixture was filtered through a pad of celite and washed with diethylether. The filtrate was washed with brine (x2). The organic layer was dried over MgSO₄ and

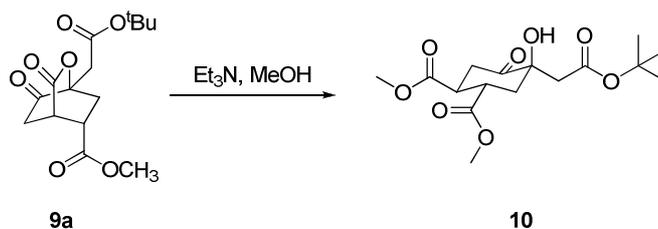
filtered. Concentration of the solution gave a pale yellow solid (0.49 g, 99%) as the product, which was used directly in the next steps without further purification; R_f = 0.41 (silica gel, hexanes: ethyl acetate = 1: 1); $^1\text{H NMR}$ (500 MHz, CDCl_3) δ 6.93 (d, 1H, J = 10 Hz), 6.86 (d, 1H, J = 10 Hz), 5.09 (t, 1H, J = 4.2 Hz), 3.20 (dd, 1H, J = 17.3 Hz, 4 Hz), 2.99 (dd, 1H, J = 17.3 Hz, 4.4 Hz), 1.43 (s, 9H); $^{13}\text{C NMR}$ (500 MHz, CDCl_3) δ 192.02, 168.21, 160.18, 138.51, 135.49, 82.71, 79.94, 39.02, 28.19; IR (KBr) 3072, 3005, 2983, 2924, 1725, 1698, 1619, 1367, 1271, 1241, 1159, 1120, 1083, 865, 837 cm^{-1} ; HRMS (ESI/[$\text{M}+\text{Na}$] $^+$) calcd. for $\text{C}_{11}\text{H}_{14}\text{O}_5\text{Na}$: 249.0739, found 249.0733.

A representative procedure for base-catalyzed Diels-Alder Reaction



To a stirred solution of **7** (23 mg, 0.1 mmol) and methyl acrylate (45 μL , 0.5 mmol) in $t\text{-BuOH}$ (1.5 mL) was added $c\text{-Hex}_2\text{NMe}$ (2.1 μL , 0.01 mmol). The reaction was stirred at room temperature and monitored by TLC until the starting material was consumed. Silica gel (ca. 0.3 g) was added to the reaction mixture. After removal of the volatiles, the residue was purified by flash chromatography to give the DA products (18 mg, 58%, $\text{endo}:\text{exo}$ = 8.5: 1). The ratio of **9a** and **9b** was determined by comparison of the $^1\text{HNMR}$ signals (δ_{endo} = 3.21 ppm, δ_{exo} = 3.01 ppm). **9a** (white solid): mp = 91-92 $^\circ\text{C}$, R_f = 0.66 (silica gel, hexanes: ethyl acetate = 1: 1); $^1\text{H NMR}$ (500 MHz, CDCl_3) δ 3.76 (s, 3H), 3.38(q, 1H, J = 3 Hz), 3.21 (m, 1H), 2.83 (d, 1H, J = 16.5 Hz), 2.67 (m, 5H), 1.44 (s, 9H); $^{13}\text{C NMR}$ (500 MHz, CDCl_3) δ 201.28, 171.31, 170.87, 167.40, 84.69, 81.87, 53.02, 39.47, 37.62, 37.56, 35.06, 30.96, 28.15; IR (KBr) 2984, 2959, 2918, 2849, 1765, 1736, 1442, 1381, 1369, 1282, 1222, 1149, 1109, 1045, 958 cm^{-1} ; HRMS (ESI/[$\text{M}+\text{Na}$] $^+$) calcd. for $\text{C}_{15}\text{H}_{20}\text{O}_7\text{Na}$: 335.1107, found 335.1104; **9b** (yellow oil): R_f = 0.51 (silica gel, hexanes: ethyl acetate = 1: 1); $^1\text{H NMR}$ (500 MHz, CDCl_3) δ 3.77 (s, 3H), 3.36 (dd, 1H, J = 5 Hz, 3 Hz), 3.01 (ddd, 1H, J = 11 Hz, 6.5 Hz, 1.2 Hz), 2.78 (m, 4H), 2.62 (dd, 1H, J = 19 Hz, 2.5 Hz), 2.51 (dd, 1H, J = 15 Hz, 10.5 Hz), 1.46 (s, 9H); $^{13}\text{C NMR}$ (500 MHz, CDCl_3) δ 202.10, 171.74, 169.85, 167.45, 84.10, 81.98, 53.08, 40.57, 40.21, 38.39, 37.86, 31.47, 28.19; IR (KBr) 2977, 2951, 2916, 2848, 1774, 1734, 1393, 1368, 1218, 1156, 1103, 1033 cm^{-1} ; HRMS (ESI/[$\text{M}+\text{Na}$] $^+$) calcd. for $\text{C}_{15}\text{H}_{20}\text{O}_7\text{Na}$: 335.1107, found 335.1105.

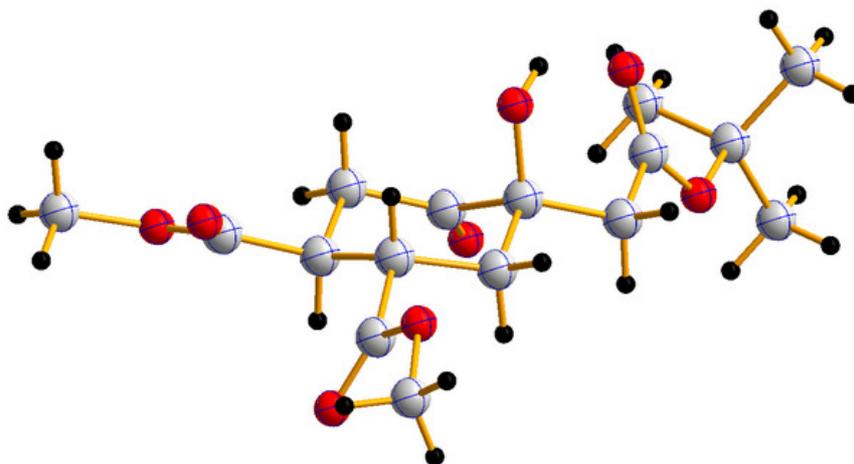
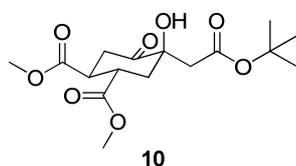
Synthesis of compound 10



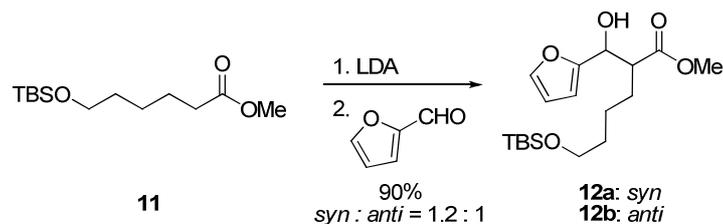
To a stirred solution of **9a** (53 mg, 0.17 mmol) in MeOH (2 mL) was added Et₃N (56 μL, 0.51 mmol). After stirring at room temperature for 2 h, TLC showed consumption of the starting material. The solution was treated with 5% aqueous HCl solution and extracted with diethylether (x3). The combined extracts were washed with brine, dried over Na₂SO₄, filtered and concentrated under reduced pressure. Silica gel column chromatography of the residue gave a white solid (47 mg, 81%) as the product: mp (CH₂Cl₂/hexane) = 98-99 °C, *R_f* = 0.31 (silica gel, hexanes: ethyl acetate = 3: 1); ¹H NMR (500 MHz, CDCl₃) δ 5.37 (d, 1H, *J* = 1.8 Hz), 3.72 (s, 3H), 3.71 (s, 3H), 3.57 (dt, 1H, *J* = 12.5 Hz, 3.5 Hz), 3.23 (t, 1H, *J* = 13.5 Hz), 2.99 (ddd, 1H, *J* = 13.5 Hz, 12.5 Hz, 4.5 Hz), 2.61 (d, 1H, *J* = 16.5 Hz), 2.53 (dd, 1H, *J* = 13 Hz, 4.5 Hz), 2.34 (dd, 1H, *J* = 14 Hz, 4 Hz), 2.27 (d, 1H, *J* = 16.5 Hz), 1.61 (dt, 1H, *J* = 14 Hz, 1.8 Hz), 1.48 (s, 9H); ¹³C NMR (500 MHz, CDCl₃) δ 207.49, 174.08, 173.04, 172.61, 82.60, 75.38, 52.42, 52.31, 45.90, 40.82, 39.97, 39.44, 38.16, 28.19. IR (KBr) 3429, 2982, 2954, 2917, 2848, 1736, 1368, 1271, 1238, 1159, 736 cm⁻¹.

X-ray crystallography of compound 10

The cif file is available in the supporting information.

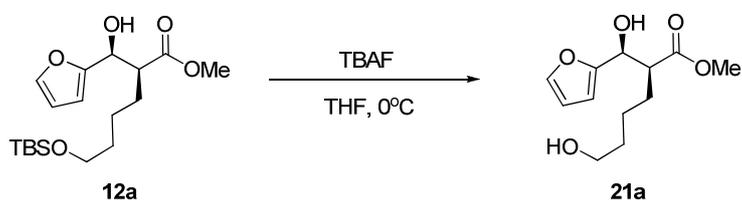


Synthesis of compound 12a and 12b



To a stirred solution of LDA (generated from *n*-BuLi (6.72 mL, 16.8 mmol) and *i*-PrNH₂ (2.69 mL, 19.2 mmol) in THF (40 mL)) at -78 °C was added **11**³ (3.12 g, 12 mmol) in THF (5 mL) dropwise. The resulting solution was stirred at the same temperature for 2 h before a solution of freshly distilled 2-furaldehyde (1.1 mL, 13.2 mmol) in THF (3 mL) was added. After another 3 h stirring at -78 °C, the reaction was quenched by saturated aqueous NH₄Cl solution. The aqueous phase was extracted by diethylether (x3) and the combined organic extracts were washed with saturated aqueous NH₄Cl solution and brine, dried over Na₂SO₄, filtered and concentrated under reduced pressure. Silica gel flash column chromatography of the residue gave a yellow oil as the product. **12a** (2.07 g, 49%): *R*_f = 0.29 (silica gel, hexanes: ethyl acetate = 5: 1); ¹H NMR (500 MHz, CDCl₃) δ 7.36 (d, 1H, *J* = 1 Hz), 6.32 (dd, 1H, *J* = 3.2 Hz, 1.8 Hz), 6.28 (d, 1H, *J* = 3.2 Hz), 4.93 (d, 1H, *J* = 6.1 Hz), 3.66 (s, 3H), 3.58 (t, 2H, *J* = 6.4 Hz), 2.89 (m, 1H), 1.73 (m, 2H), 1.51 (m, 2H), 1.34 (m, 2H), 0.89 (s, 9H), 0.03 (s, 6H); ¹³C NMR (500 MHz, CDCl₃) δ 174.89, 154.46, 142.17, 110.39, 106.92, 68.82, 62.96, 51.85, 50.53, 32.81, 27.54, 26.12, 23.98, 18.49, -5.14; IR (KBr) 3439, 2953, 2920, 2857, 1714, 1632, 1461, 1434, 1254, 1096, 832, 774, 735 cm⁻¹; HRMS (ESI/[M+Na]⁺) calcd. for C₁₈H₃₂O₅SiNa: 379.1917, found 379.1921; **12b** (1.76 g, 41%): *R*_f = 0.2 (silica gel, hexanes: ethyl acetate = 5: 1); ¹H NMR (300 MHz, CDCl₃) δ 7.38 (dd, 1H, *J* = 1.8 Hz, 0.9 Hz), 6.34 (dd, 1H, *J* = 3.3 Hz, 1.8 Hz), 6.28 (d, 1H, *J* = 3.3 Hz), 4.81 (d, 1H, *J* = 7.2 Hz), 3.72 (s, 3H), 3.56 (t, 2H, *J* = 6.3 Hz), 2.95 (m, 1H), 1.62 (m, 2H), 1.46 (m, 2H), 1.32 (m, 2H), 0.88 (s, 9H), 0.03 (s, 6H); ¹³C NMR (300 MHz, CDCl₃) δ 175.65, 154.55, 142.47, 110.38, 107.44, 68.97, 62.85, 51.98, 50.38, 32.61, 29.34, 26.09, 23.61, 18.48, -5.17; IR (KBr) 3438, 2952, 2929, 2857, 1737, 1461, 1435, 1254, 1166, 1098, 1008, 836, 775, 737 cm⁻¹; HRMS (ESI/[M+Na]⁺) calcd. for C₁₈H₃₂O₅SiNa: 379.1917, found 379.1918.

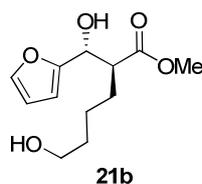
Synthesis of compound 21a



To a stirred solution of **12a** (0.2 g, 0.56 mmol) in THF (10 mL) was added a 1 M TBAF solution (1.12 mL, 1.12 mmol) slowly at 0 °C. The mixture was allowed to warm up to room temperature and stirred for 2 h. The reaction then was quenched by adding saturated aqueous NH₄Cl solution. The aqueous phase was extracted by diethylether (x3) and the combined organic extracts were washed with brine, dried over Na₂SO₄, filtered and concentrated under

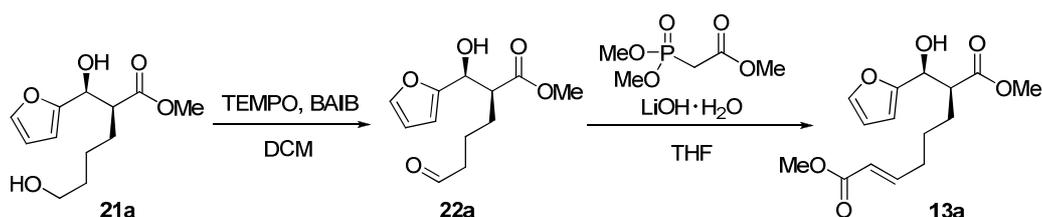
reduced pressure. Silica gel flash column chromatography of the residue gave a yellow oil (0.11g, 81%) as the product: R_f = 0.25 (silica gel, hexanes: ethyl acetate = 1: 1); ^1H NMR (300 MHz, CDCl_3) δ 7.33 (dd, 1H, J = 1.8 Hz, 0.9 Hz), 6.29 (dd, 1H, J = 3.3 Hz, 1.8 Hz), 6.24 (d, 1H, J = 3.3 Hz), 4.87 (d, 1H, J = 6.9 Hz), 3.61 (s, 3H), 3.57 (t, 2H, J = 6.6 Hz), 2.84 (m, 3H), 1.70 (m, 2H), 1.52 (m, 2H), 1.35 (m, 2H); ^{13}C NMR (300 MHz, CDCl_3) δ 174.74, 154.47, 142.14, 110.30, 106.80, 68.46, 62.40, 51.92, 50.59, 32.38, 27.60, 23.60; IR (KBr) 3412, 2951, 2866, 1727, 1436, 1374, 1257, 1045, 737 cm^{-1} ; HRMS (ESI/[$\text{M}+\text{Na}$] $^+$) calcd. for $\text{C}_{12}\text{H}_{18}\text{O}_5\text{Na}$: 265.1052. Found 265.1051.

Synthesis of compound 21b



The above procedures were followed with **12b** as the starting material and a yellow oil (76%) was obtained as the product: R_f = 0.23 (silica gel, hexanes: ethyl acetate = 1: 1); ^1H NMR (300 MHz, CDCl_3) δ 7.38 (m, 1H), 6.34 (dd, 1H, J = 3.3 Hz, 1.5 Hz), 6.29 (d, 1H, J = 3 Hz), 4.81 (d, 1H, J = 7.5 Hz), 3.73 (s, 3H), 3.60 (t, 2H, J = 6.6 Hz), 2.86 (m, 1H), 1.63 (m, 2H), 1.52 (m, 2H), 1.35 (m, 2H); ^{13}C NMR (300 MHz, CDCl_3) δ 175.55, 154.44, 142.51, 110.41, 107.52, 68.92, 62.64, 52.08, 50.39, 32.49, 29.21, 23.49; IR (KBr) 3407, 2948, 2865, 1721, 1437, 1209, 1170, 1056, 1011, 741 cm^{-1} ; HRMS (ESI/[$\text{M}+\text{Na}$] $^+$) calcd. for $\text{C}_{12}\text{H}_{18}\text{O}_5\text{Na}$: 265.1052, found 265.1053.

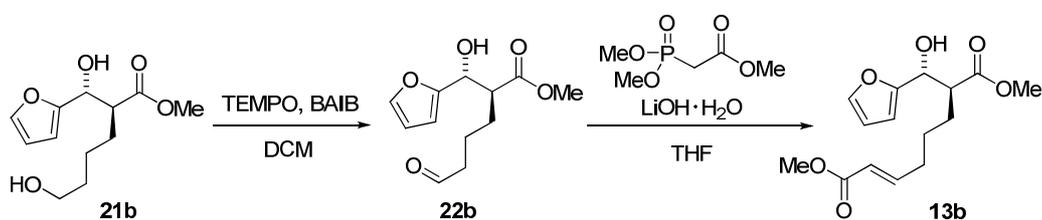
Synthesis of compound 13a



To a stirred solution of **21a** (0.20 g, 0.83 mmol) and TEMPO (12 mg, 0.083 mmol) in CH_2Cl_2 (10 ml) was added [bis(acetoxy)iodo]benzene (BAIB) (0.32 g, 1.2 mmol) at room temperature.⁴ The mixture was stirred at room temperature for 4 h and TLC showed consumption of the starting material. The reaction was then quenched by adding saturated aqueous $\text{Na}_2\text{S}_2\text{O}_3$ solution. The aqueous phase was extracted by diethylether (x3) and the combined organic extracts were washed with brine, dried over Na_2SO_4 , filtered and concentrated under reduced pressure. The crude product was used directly in the next step without further purification. To a stirred solution of the crude aldehyde **22a** and methyl 2-(dimethoxyphosphoryl)acetate (0.12 mL, 0.85 mmol) in THF (10 mL) was added

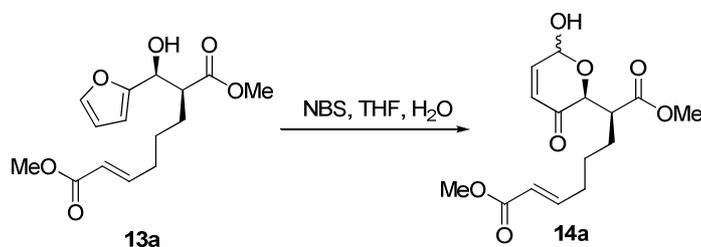
LiOH·H₂O (36 mg, 0.85 mmol).⁵ The reaction was stirred at room temperature for 20 h and then quenched by adding saturated aqueous NH₄Cl solution. The aqueous phase was extracted by diethylether (x3) and the combined organic extracts washed with brine, dried over Na₂SO₄, filtered and concentrated under reduced pressure. Silica gel flash column chromatography of the residue gave as a yellow oil (195 mg, 80% for two steps) as the product: *R*_f = 0.57 (silica gel, hexanes: ethyl acetate = 1: 1); ¹H NMR (300 MHz, CDCl₃) δ 7.36 (dd, 1H, *J* = 1.8 Hz, 0.9 Hz), 6.91 (dt, 1H, *J* = 15.6 Hz, 6.9 Hz), 6.32 (dd, 1H, *J* = 3.3 Hz, 1.5 Hz), 6.27 (d, 1H, *J* = 3.3 Hz), 5.80 (d, 1H, *J* = 15.6 Hz), 4.93 (d, 1H, *J* = 6.3 Hz), 3.71 (s, 3H), 3.66 (s, 3H), 2.88 (m, 2H), 2.19 (m, 2H), 1.73 (m, 2H), 1.46 (m, 2H); ¹³C NMR (300 MHz, CDCl₃) δ 174.60, 167.18, 154.15, 148.84, 142.24, 121.37, 110.40, 106.98, 68.64, 52.04, 51.56, 50.21, 32.08, 27.21, 26.01; IR (KBr) 3444, 2952, 1724, 1657, 1437, 1268, 1201, 1043, 1010, 736, 703 cm⁻¹; HRMS (ESI/[M+Na]⁺) calcd. for C₁₅H₂₀O₆Na: 319.1158, found 319.1164.

Synthesis of compound 13b



The above procedures were followed with **21b** as the starting materials and a yellow oil (86% for two steps) was obtained: *R*_f = 0.53 (silica gel, hexanes: ethyl acetate = 1: 1); ¹H NMR (300 MHz, CDCl₃) δ 7.37 (dd, 1H, *J* = 1.8 Hz, 0.9 Hz), 6.86 (dt, 1H, *J* = 15.6 Hz, 6.9 Hz), 6.32 (dd, 1H, *J* = 3.3 Hz, 1.8 Hz), 6.27 (d, 1H, *J* = 3.3 Hz), 5.77 (d, 1H, *J* = 15.6 Hz), 4.79 (d, 1H, *J* = 7.8 Hz), 3.72 (s, 3H), 3.70 (s, 3H), 2.94 (m, 1H), 2.59 (bs, 1H), 2.15 (m, 2H), 1.62 (m, 1H), 1.40 (m, 3H); ¹³C NMR (300 MHz, CDCl₃) δ 175.25, 167.09, 154.26, 148.54, 142.50, 121.46, 110.37, 107.59, 68.85, 52.06, 51.55, 50.21, 31.84, 28.81, 25.60; IR (KBr) 3465, 2951, 1723, 1656, 1437, 1276, 1200, 1170, 1049, 1011, 743 cm⁻¹; HRMS (ESI/[M+Na]⁺) calcd. for C₁₅H₂₀O₆Na: 319.1158, found 319.1167.

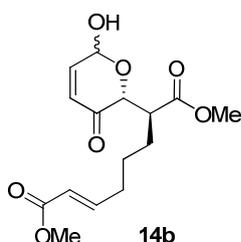
Synthesis of compound 14a



To a stirred solution of **13a** (195 mg, 0.66 mmol) in THF/H₂O (4 mL/1 mL) was added NaHCO₃ (119 mg, 1.42 mmol), NaOAc (58 mg, 0.71 mmol) and then NBS (139 mg, 0.78 mmol) in one portion at 0 °C.¹ After stirring at 0 °C for 10 min, TLC showed the

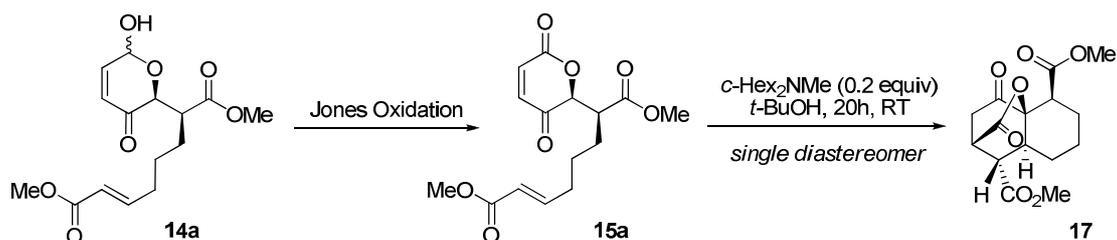
consumption of the starting material. The reaction was then quenched with saturated aqueous $\text{Na}_2\text{S}_2\text{O}_3$ solution. The aqueous phase was extracted by diethylether (x3) and the combined extracts were washed with saturated aqueous NH_4Cl solution and brine, dried over Na_2SO_4 , filtered and concentrated under reduced pressure. Silica gel flash column chromatography of the residue gave a yellow oil (0.16 g, 78%) as the product: $R_f = 0.37$ (silica gel, hexanes: ethyl acetate = 1: 1); ^1H NMR (500 MHz, CDCl_3) δ 6.93 (m, 2H), 6.16 (dd, 0.28H, $J = 10.2$ Hz, 1.6 Hz), 6.10 (d, 0.72H, $J = 10.2$), 5.86 (m, 1H), 5.71 (s, 0.28H), 5.65 (d, 0.78H, $J = 3.4$ Hz), 4.96 (d, 0.72H, $J = 5.7$ Hz), 4.47 (dd, 0.28H, $J = 6.8$ Hz, 1.2 Hz), 3.73 (m, 6H), 3.00 (m, 1H), 2.20 (m, 2H), 1.78 (m, 1H), 1.55 (m, 2H), 1.46 (m, 1H); ^{13}C NMR (500 MHz, CDCl_3) δ 194.86, 194.45, 173.84, 173.66, 167.70, 167.52, 149.20, 149.12, 148.44, 144.50, 129.05, 127.52, 121.37, 121.34, 91.82, 88.08, 78.47, 73.97, 52.14, 52.10, 51.68, 51.59, 45.52, 45.23, 31.95, 31.71, 26.80, 26.69, 25.71, 25.26; IR (KBr) 3434, 2954, 1720, 1655, 1438, 1277, 1204, 1033 cm^{-1} ; HRMS (ESI/[M+Na] $^+$) calcd. for $\text{C}_{15}\text{H}_{20}\text{O}_7\text{Na}$: 335.1107, found 335.1108.

Synthesis of compound 14b



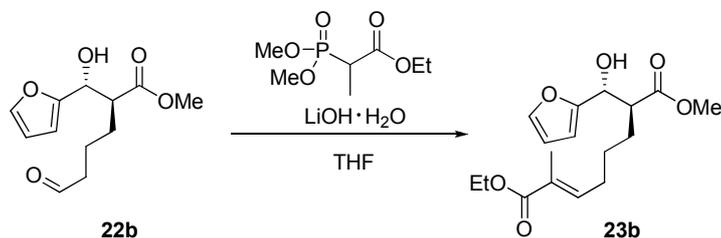
The above procedures were followed with **13b** as the starting material and a yellow oil (77%) was obtained: $R_f = 0.38$ (silica gel, hexanes: ethyl acetate = 1: 1); ^1H NMR (500 MHz, CDCl_3) δ 6.93 (m, 2H), 6.16 (m, 1H), 5.86 (m, 1H), 5.65 (d, 0.60H, $J = 3.5$ Hz), 5.62 (s, 0.40H), 4.70 (d, 0.60H, $J = 3.5$ Hz), 4.30 (d, 0.40H, $J = 4.6$ Hz), 3.72 (m, 3H), 3.67 (s, 1.2H), 3.63 (s, 1.8H), 3.19 (m, 0.6H), 3.15 (m, 0.4H), 2.23 (m, 2H), 1.88 (m, 1H), 1.72 (m, 1H), 1.63 (m, 1H), 1.54 (m, 1H); ^{13}C NMR (500 MHz, CDCl_3) δ 195.14, 194.59, 173.40, 172.61, 167.68, 167.34, 149.11, 148.77, 147.56, 144.15, 128.38, 127.69, 121.53, 121.40, 90.44, 87.78, 78.10, 73.53, 52.16, 51.93, 51.67, 51.58, 47.10, 45.69, 31.89, 31.79, 27.31, 26.70, 25.91, 25.48; IR (KBr) 3436, 2954, 1724, 1655, 1438, 1279, 1209, 1032 cm^{-1} ; HRMS (ESI/[M+Na] $^+$) calcd. for $\text{C}_{15}\text{H}_{20}\text{O}_7\text{Na}$: 335.1107, found 335.1111.

Synthesis of compound 17



To a stirred solution of **14a** (23 mg, 0.074 mmol) in acetone (5 mL) at 0 °C was added Jones reagent (77 μ L, 2.9 M) dropwise. After stirring at 0 °C for 30 min, TLC showed the consumption of the starting material and the reaction was quenched by adding *i*-PrOH (0.2 mL) slowly at 0 °C. The mixture was filtered through a pad of celite and washed with diethylether. The filtrate was washed with brine (x2). The organic layer was dried over MgSO₄ and filtered. Concentration of the solution gave a pale yellow solid as the crude product, which was used directly in the next steps without further purification. To a stirred solution of the crude **15a** in *t*-BuOH (2 mL) was added *c*-Hex₂NMe (3 μ L, 0.015 mmol) at room temperature. After 20 h stirring at room temperature, TLC showed consumption of the starting material. Silica gel (ca. 0.3 g) was added to the reaction mixture and then concentrated. Silica gel flash column chromatography of the residue gave a colorless oil (16 mg, 70 % for two steps) as the product: R_f = 0.5 (silica gel, hexanes: ethyl acetate = 1: 1); ¹H NMR (500 MHz, CDCl₃) δ 3.75 (s, 3H), 3.66 (s, 3H), 3.38 (q, 1H, J = 3 Hz), 3.04 (dd, 1H, J = 13.5 Hz, 4.5 Hz), 2.75 (m, 2H), 2.61 (t, 1H, J = 3 Hz), 2.36 (dt, 1H, J = 12 Hz, 4.5 Hz), 2.21 (m, 1H), 1.87 (m, 2H), 1.79 (dq, 1H, J = 13.5 Hz, 3.5 Hz), 1.47 (m, 1H), 1.38 (m, 1H); ¹³C NMR (500 MHz, CDCl₃) δ 203.56, 170.93, 170.77, 170.52, 85.82, 53.03, 52.17, 45.44, 42.90, 41.33, 39.32, 35.39, 28.98, 24.13, 23.62; IR (KBr) 2960, 2934, 2864, 1765, 1725, 1437, 1376, 1276, 1217, 1147, 1002, 980, 957, 757 cm⁻¹; HRMS (ESI/[M+Na]⁺) calcd. for C₁₅H₁₈O₇Na: 333.0950, found 333.0958.

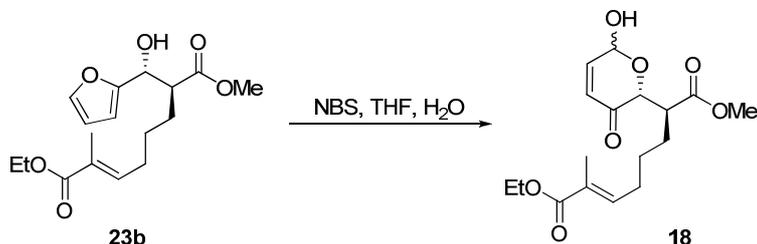
Synthesis of compound 23b



To a stirred solution crude aldehyde **22b** (87 mg, 0.36 mmol) and ethyl 2-(dimethoxyphosphoryl)propanoate (93 μ L, 0.43 mmol) in THF (4 mL) was added LiOH·H₂O (18 mg, 0.43 mmol) at room temperature.⁵ The reaction was stirred at room temperature for 48 h and then quenched by adding saturated aqueous NH₄Cl solution. The aqueous phase was extracted by diethylether (x3) and the combined organic extracts were washed with brine, dried over Na₂SO₄, filtered and concentrated under reduced pressure. Silica gel flash column chromatography of the residue gave a yellow oil (95 mg, 81%, *E*: *Z* = 8.8: 1) as the product: R_f = 0.57 (silica gel, hexanes: ethyl acetate = 1: 1); ¹H NMR (500 MHz, CDCl₃) δ 7.37 (dd, 1H, J = 1.8 Hz, 0.9 Hz), 6.65 (dt, 1H, J = 7.4 Hz, 1.4 Hz), 6.32 (dd, 1H, J = 3.2 Hz, 1.8 Hz), 6.27 (d, 1H, J = 3.2 Hz), 4.80 (d, 1H, J = 7.6 Hz), 4.17 (q, 2H, J = 7.2 Hz), 3.72 (s, 3H), 2.94 (m, 1H), 2.54 (bs, 1H), 2.12 (m, 2H), 1.79 (d, 3H, J = 0.75 Hz), 1.63 (m, 1H), 1.41 (m, 3H), 1.28 (t, 3H, J = 7.2 Hz); ¹³C NMR (500 MHz, CDCl₃) δ 175.25, 168.21, 154.52, 142.46, 141.09, 128.53, 110.39, 107.47, 68.98, 60.53, 51.96, 50.36, 29.13, 28.42, 26.25, 14.41, 12.45; IR (KBr) 3465, 2951, 2864, 1728, 1708, 1438, 1369, 1278, 1169,

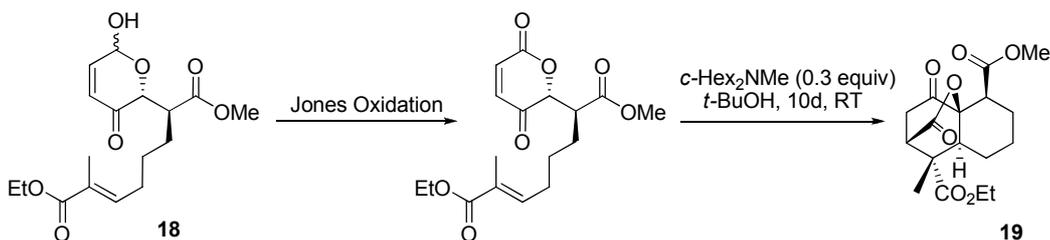
1093, 1011, 744 cm^{-1} ; HRMS (ESI/[M+Na]⁺) calcd. for $\text{C}_{17}\text{H}_{24}\text{O}_6\text{Na}$: 347.1471, found 347.1472.

Synthesis of compound 18



To a stirred solution of **23b** (87 mg, 0.27 mmol) in THF/H₂O (2 mL/0.5 mL) at 0 °C was added NaHCO₃ (45 mg, 0.54 mmol), NaOAc (22 mg, 0.27 mmol), and then NBS (53 mg, 0.3 mmol) in one portion.¹ After 15 min stirring at room temperature, the reaction was quenched by adding saturated aqueous Na₂S₂O₃ solution. The aqueous phase was extracted with diethylether and combined organic extracts were washed with saturated aqueous NH₄Cl solution and brine, dried over Na₂SO₄, filtered and concentrated under reduced pressure. Silica gel flash column chromatography of the residue afforded a yellow oil (75 mg, 82%) as the product: *R_f* = 0.41 (silica gel, hexanes: ethyl acetate = 1: 1); Major product: ¹H NMR (500 MHz, CDCl₃) δ 6.89 (dd, 1H, *J* = 10.3 Hz, 3.6 Hz), 6.73 (dt, 1H, *J* = 7.4 Hz, 1.4 Hz), 6.16 (d, 1H, *J* = 3.5 Hz), 5.66 (d, 1H, *J* = 3.5 Hz), 4.71 (d, 1H, *J* = 3.5 Hz), 4.30 (q, 2H, *J* = 7.2 Hz), 3.63 (s, 3H), 3.20 (m, 1H), 2.21 (m, 2H), 1.92 (m, 1H), 1.83 (s, 3H), 1.67 (m, 2H), 1.51 (m, 1H), 1.30 (t, 3H, *J* = 7.2 Hz); ¹³C NMR (500 MHz, CDCl₃) δ 195.16, 172.68, 168.83, 144.10, 142.09, 128.50, 127.74, 87.81, 73.54, 60.78, 51.90, 45.67, 28.44, 27.00, 26.29, 14.39, 12.53; IR (KBr) 3434, 2953, 2869, 1732, 1697, 1438, 1370, 1276, 1092, 1033, 736 cm^{-1} ; HRMS (ESI/[M+Na]⁺) calcd. for $\text{C}_{17}\text{H}_{24}\text{O}_7\text{Na}$: 363.1420, found 363.1425.

Synthesis of Compound 19

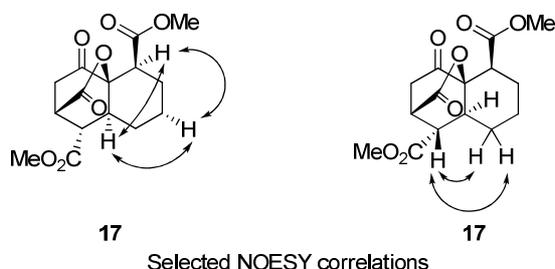


To a stirred solution of **18** (30 mg, 0.088 mmol) in acetone (1 mL) at 0 °C was added Jones reagent² (91 μL , 2.9 M) dropwise. After 40 min stirring at 0 °C, TLC showed consumption of starting and the reaction was quenched by adding *i*-PrOH (0.2 mL) slowly at 0 °C. The mixture was then filtered through a pad of celite and washed with diethylether. The filtrate was washed with brine twice and the organic layer was dried over MgSO₄, filtered and concentrated to give a yellow oil as the crude product, which was used directly in the next step without further purification. To a stirred solution of the crude product in *t*-BuOH (4.5

mL) was added *c*-Hex₂NMe (5.6 μ L, 0.026 mmol) at room temperature. After 10 d stirring at room temperature, TLC showed consumption of the starting material. Silica gel (ca. 0.3 g) was added to the reaction mixture. After removal of the volatiles, silica gel flash column chromatography of the residue afforded a pale yellow oil (15 mg, 50 % for two steps) as the product: R_f = 0.45 (silica gel, hexanes: ethyl acetate = 2: 1); ¹H NMR (500 MHz, CDCl₃) δ 4.21 (q, 2H, J = 7.1 Hz), 3.65 (s, 3H), 3.15 (t, 1H, J = 3 Hz), 3.12 (dd, 1H, J = 13.5 Hz, 4.5 Hz), 2.77 (dd, 1H, J = 19 Hz, 2Hz), 2.68 (m, 2H), 2.20 (m, 1H), 1.93 (m, 1H), 1.72 (m, 2H), 1.48 (dq, 1H, J = 13 Hz, 3.5 Hz), 1.36 (m, 1H), 1.32 (s, 3H), 1.28 (t, 3H, J = 7.1 Hz); ¹³C NMR (500 MHz, CDCl₃) δ 204.49, 173.80, 171.05, 170.67, 86.31, 62.31, 52.16, 46.93, 46.83, 43.54, 43.30, 36.52, 24.28, 23.52, 23.36, 21.49, 14.24; IR (KBr) 2951, 2924, 2849, 1771, 1736, 1460, 1442, 1227, 1203, 1166, 1001, 735 cm⁻¹; HRMS (ESI/[M+Na]⁺) calcd. for C₁₇H₂₂O₇Na: 361.1263, found 361.1270.

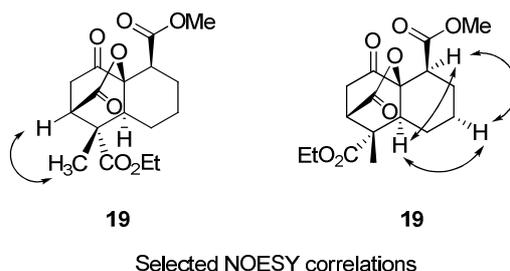
Determination of Relative Stereochemistry of Compound 17

The relative stereochemistry of compound **17** was determined by NOESY experiments.



Determination of Relative Stereochemistry of Compound 19

The relative Stereochemistry of compound **19** was determined by NOESY experiments.



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- Ref for compound 11
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