**Sml₂-Promoted Oxidation of Aldehydes
In the Presence of Electron Rich Heteroatoms**

SUPPORTING INFORMATION

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I. Materials and Methods

Except as otherwise indicated, reactions were carried out under an argon atmosphere in flame- or oven-dried glassware, and solvents were freshly distilled. Diethyl ether and THF were distilled from sodium/benzophenone. Dichloromethane was distilled from calcium hydride. Triethylamine was distilled from calcium hydride and stored over potassium hydroxide. SmI_2 was freshly prepared as a 0.1 M stock solution in THF as described by Evans, D. A.; Hoveyda, A. H. *J. Am. Chem. Soc.* **1990**, *112*, 6447-6449. Reactions were monitored by thin layer chromatography (TLC) with 0.25-mm E. Merck precoated silica gel plates. Silica gel for flash chromatography (particle size 0.040-0.063 mm) was supplied by Silicycle and Sorbent technologies. Yields refer to chromatographically and spectroscopically pure compounds unless otherwise noted. Melting points were determined on a Bristoline heated-stage microscope or a Thomas-Hoover apparatus and are corrected. ^1H and ^{13}C spectra were recorded on a Bruker AM-500 spectrometer. Chemical shifts are reported as δ values relative to internal chloroform (δ 7.24 for ^1H and δ 77.0 for ^{13}C) or benzene (δ 7.15 for ^1H and δ 128.0 for ^{13}C). Infrared spectra were recorded on a Perkin-Elmer Model 283B, a Perkin-Elmer Model 1600 FTIR, , or a Jasco FTIR-480plus spectrometer with polystyrene as external standard. Optical rotations were measured on a Perkin-Elmer model 241 polarimeter. High resolution mass spectra were measured at the University of Pennsylvania Mass Spectrometry Center.

II. Procedures

A representative procedure for constructing β -hydroxy ketones **1a-1f** is as follows: To a solution of diisopropylamine (2.80 mL, 19.7 mmol, 1.20 equiv) in 40.0 mL of anhydrous THF at $-78\text{ }^\circ\text{C}$ was added *n*-butyllithium (7.2 mL, 2.5 M in hexanes, 18.04 mmol, 1.10 equiv). The mixture was stirred for 30 min at $0\text{ }^\circ\text{C}$ and re-cooled to $-78\text{ }^\circ\text{C}$. A solution of 3-methyl-2-butanone (1.76 mL, 16.4 mmol) in 10 mL of anhydrous THF was added dropwise over 5 min and the mixture was

stirred for 1 h at -78°C . Propionaldehyde (1.43 mL, 19.7 mmol, 1.2 equiv) was added and the reaction mixture was stirred for 10 min and poured into saturated aqueous NH_4Cl . The mixture was extracted with ethyl ether (3 X 100 mL) and the combined organic layers were washed with brine (10 mL), dried over MgSO_4 , filtered, and concentrated *in vacuo*. Flash chromatography on silica gel, using ethyl acetate-hexane (1:4) as elutant, provided **1b** (1.83 g, 78% yield) as a colorless oil.

β -Hydroxy ketone 1b: IR (film) 3447 (m, br), 2969 (s), 1700 (s), 1465 (m), 1384 (m), 1044 (w) cm^{-1} ; ^1H NMR (500 MHz, CDCl_3) δ 3.92-3.87 (m, 1H), 3.12 (d, $J = 3.5$ Hz, 1H), 2.60 (dd, $J = 17.6$, 2.8 Hz, 1H), 2.55 (m, 1H), 2.48 (dd, $J = 17.5$, 9.1 Hz, 1H) 1.50-1.38 (m, 2H), 1.06 (d, $J = 7.7$ Hz, 6H), 0.90 (t, $J = 7.5$ Hz, 3H); ^{13}C NMR (125 MHz, CDCl_3) δ 216.03, 68.96, 46.10, 41.41, 29.27, 17.93, 17.90, 9.76; high resolution mass spectrum m/z 144.1226 $[(M)^+]$; calcd for $\text{C}_8\text{H}_{16}\text{O}_2$: 144.1229]

β -Hydroxy ketone 1d: IR (film) 3452 (m, br), 3083 (w), 2972 (s), 2935 (m), 1708 (vs), 1646 (w), 1468 (s), 1422 (m), 1385 (m), 1367 (m), 1208 (w), 1129 (m), 1069 (m), 1031 (m), 993 (s), 924 (m), 865 (w), 796 (w), 677 (w) cm^{-1} ; ^1H NMR (500 MHz, CDCl_3) δ 5.85 (ddd, $J = 17.0$, 10.4, 5.6 Hz, 1H), 5.29 (dd, $J = 17.2$, 1.4 Hz, 1H), 5.13 (dd, $J = 10.4$, 1.4 Hz, 1H), 4.58-4.55 (m, 1H), 3.13 (bs, 1H), 2.71 (dd, $J = 17.5$, 4.0 Hz, 1 H), 2.65 (d, $J = 7.5$ Hz, 1H), 1.11 (d, $J = 7.0$ Hz, 3H), 1.11 (d, $J = 7.2$ Hz, 3H); ^{13}C NMR (125 MHz, CDCl_3) δ 214.94, 139.10, 114.76, 68.54, 46.29, 41.40, 17.95, 17.80; high resolution mass spectrum m/z 142.0998 $[(M)^+]$; calcd for $\text{C}_8\text{H}_{14}\text{O}_2$: 142.0994]

β -Hydroxy ketone 1f : IR (film) 3480 (m, br), 2970 (s), 2935 (m), 2837 (m), 1708 (s), 1612 (s), 1586 (m), 1515 (s), 1465 (s), 1385 (m), 1303 (m), 1249 (s), 1175 (s), 1111 (m), 1075 (s), 1035 (s), 996 (m), 833 (m) cm^{-1} ; ^1H NMR (500 MHz, CDCl_3) δ 7.29 (d, $J = 8.7$ Hz, 2H), 6.89 (d, $J = 8.7$ Hz, 2H), 5.10 (ddd, $J = 8.8$, 6.4, 3.3 Hz, 1H), 3.80 (s, 3H), 3.35 (d, $J = 3.05$ Hz, 1H), 2.88 (dd, $J = 17.5$, 8.9 Hz, 1H), 2.81 (dd, $J = 17.5$, 3.4 Hz, 1H), 2.60-2.57 (m, 1H), 1.10 (d, $J = 7.0$ Hz, 3H), 1.10 (d, $J = 6.9$ Hz, 3H); ^{13}C NMR (125 MHz, CDCl_3) δ 214.86, 158.87, 135.18, 126.76, 113.68,

69.45, 55.08, 48.66, 41.34, 17.69; high resolution mass spectrum m/z 222.1255 $[(M)^+]$; calcd for $C_{13}H_{18}O_3$: 222.1256]

Ester 3a : β -Hydroxy ketone **1a** (160.0 mg, 1.01 mmol) and dithiane aldehyde **2** (155.8 mg, 1.01 mmol) were dissolved in anhydrous THF (18.2 ml) under argon atmosphere. The stirred solution was cooled to $-10\text{ }^{\circ}\text{C}$, shielded from light, and 2.02 mL (0.202 mmol) of a 0.1 M stock solution of freshly prepared Sml_2 in THF was added dropwise. After 60 min, the reaction mixture was quenched by the addition of Et_2O and saturated aqueous NaHCO_3 . The aqueous layer was extracted with Et_2O (2 X 20 mL) and the combined organics layer were washed with brine (5 mL), dried over MgSO_4 , filtered, and concentrated *in vacuo*. Flash chromatography, using ethyl acetate-hexane (1:9 to 1:6) as elutant, provided **3a** (281 mg, 89% yield) as a colorless oil : IR (film) 3510 (m, br), 2961 (vs), 1726 (vs), 1466 (m), 1422 (m), 1369 (m), 1273 (s), 1002 (m) cm^{-1} ; ^1H NMR (500 MHz, CDCl_3) δ 4.93 (ddd, $J = 10.7, 5.3, 2.3$ Hz, 1H), 4.03 (t, $J = 6.7$ Hz, 1H), 3.16–3.13 (m, 1H), 2.13–2.08 (m, 2H), 1.90–1.78 (m, 6H), 1.68–1.48 (m, 3H), 0.92 (d, $J = 6.8$ Hz, 6H), 0.91 (d, $J = 6.8$ Hz, 6H); ^{13}C NMR (125 MHz, CDCl_3) δ 174.25, 77.25, 77.00, 76.07, 71.78, 46.89, 36.21, 34.70, 33.85, 33.53, 32.15, 30.26 (2C), 25.84, 22.19, 18.76, 18.74, 17.86, 17.70; high resolution mass spectrum m/z 371.1678 $[(M+\text{Na})^+]$; calcd for $C_{17}H_{32}O_3\text{S}_2\text{Na}$: 371.1691]

Ester 3b : β -Hydroxy ketone **1b** (122.0 mg, 0.846 mmol) and dithiane aldehyde **2** (130.5 mg, 0.846 mmol) were dissolved in anhydrous THF (15.2 ml) under argon atmosphere. The stirred solution was cooled to $-10\text{ }^{\circ}\text{C}$, shielded from light, and 1.69 mL (0.17 mmol) of a 0.1 M stock solution of freshly prepared Sml_2 in THF was added dropwise. After 45 min, the reaction mixture was quenched by the addition of Et_2O and saturated aqueous NaHCO_3 . The aqueous layer was extracted with Et_2O (2 X 20 mL) and the combined organic layers were washed with brine (5 mL), dried over MgSO_4 , filtered, and concentrated *in vacuo*. Flash chromatography on silica gel, using ethyl acetate-hexane (1:4) as elutant, provided **3b** (218 mg, 78% yield) as a colorless oil : IR (film) 3510 (m, br), 2961 (vs), 1726 (vs), 1462 (m), 1423 (m), 1384 (m), 1274 (s), 1191 (s), 1146

(m), 1113 (m), 1049 (m), 1000 (m), 909 (w), 801 (w) cm^{-1} ; ^1H NMR (500 MHz, CDCl_3) δ 5.06-5.01 (m, 1H), 4.04 (t, J = 6.7 Hz, 1H), 3.22-3.20 (m, 4H), 2.74 (d, J = 3.9 Hz, 1H), 2.38 (t, J = 7.2 Hz, 2H), 2.14-2.09 (m, 4H), 1.67-1.52 (m, 6H), 0.93 (d, J = 6.8 Hz, 3H), 0.91 (t, J = 7.4 Hz, 3H), 0.90 (d, J = 6.7 Hz, 3H); ^{13}C NMR (125 MHz, CDCl_3) δ 174.07, 73.22, 71.74, 46.85, 38.84, 34.63, 33.84, 33.44, 30.21 (2C), 27.88, 25.80, 22.15, 18.62, 17.73, 9.80; high resolution mass spectrum m/z 357.1537 $[(\text{M}+\text{Na})^+]$; calcd for $\text{C}_{16}\text{H}_{30}\text{O}_3\text{S}_2\text{Na}$: 357.1534]

Ester 3c : β -Hydroxy ketone **1c** (123.0 mg, 0.945 mmol) and dithiane aldehyde **2** (145.8 mg, 0.945 mmol) were dissolved in anhydrous THF (17 ml) under argon atmosphere. The stirred solution was cooled to $-10\text{ }^\circ\text{C}$, shielded from light, and 1.89 mL (0.19 mmol) of a 0.1 M stock solution of freshly prepared Sml_2 in THF was added dropwise. After 60 min, the reaction mixture was quenched by the addition of Et_2O and saturated aqueous NaHCO_3 . The aqueous layer was extracted with Et_2O (2 X 20 mL) and the combined organic layers were washed with brine (5 mL), dried over MgSO_4 , filtered, and concentrated *in vacuo*. Flash chromatography on silica gel, using ethyl acetate-benzene-hexane (1:1:4 to 1:1:2) as elutant, provided **3c** (180 mg, 67% yield) as a colorless oil : IR (film) 3511 (m, br), 2958 (vs), 1735 (s), 1700 (vs), 1421 (m), 1377 (m), 1192 (m), 1062 (m), 988 (m), 934 (w), 908 (w), 865 (w), 803 (w), 767 (w) cm^{-1} ; ^1H NMR (500 MHz, CDCl_3) δ 5.22-5.17 (m, 1H), 4.04 (t, J = 6.64 Hz, 1H), 3.29-3.26 (m, 1H), 2.87-2.83 (m, 4H), 2.51 (d, J = 4.2 Hz, 1H), 2.35 (t, J = 7.2 Hz, 2H), 2.14-2.09 (m, 1H), 1.91-1.77 (m, 4H), 1.67-1.51 (m, 4H), 1.28 (d, J = 6.3 Hz, 3H), 0.92 (d, J = 6.4 Hz, 3H), 0.91 (d, J = 6.6 Hz, 3H); ^{13}C NMR (125 MHz, CDCl_3) δ 173.56, 71.96, 68.48, 46.89, 40.88, 34.61, 33.95, 33.51, 30.24 (2C), 25.83, 22.12, 20.83, 18.58, 17.60; high resolution mass spectrum m/z 343.1393 $[(\text{M}+\text{Na})^+]$; calcd for $\text{C}_{15}\text{H}_{28}\text{O}_3\text{S}_2\text{Na}$: 343.1378]

Ester 3d : β -Hydroxy ketone **1d** (199 mg, 1.40 mmol) and dithiane aldehyde **2** (217 mg, 1.40 mmol) were dissolved in anhydrous THF (25.2 ml) under argon atmosphere. The stirred solution was cooled to $-10\text{ }^\circ\text{C}$, shielded from light, and 2.80 mL (0.220 mmol) of a 0.1 M stock solution of freshly prepared Sml_2 in THF was added dropwise. After 45 min, the reaction mixture was

quenched by the addition of Et_2O and saturated aqueous NaHCO_3 . The aqueous layer was extracted with Et_2O (2 X 20 mL) and the combined organic layers were washed with brine (5 mL), dried over MgSO_4 , filtered, and concentrated *in vacuo*. Flash chromatography on silica gel, using ethyl acetate-hexane (1:4) as elutant, provided **3d** (312 mg, 75% yield) as a colorless oil : IR (film) 3501 (m, br), 3086 (w), 2956 (s), 1732 (vs), 1646 (w), 1452 (w), 1422 (m), 1187 (s) cm^{-1} ; ^1H NMR (500 MHz, CDCl_3) δ 5.85 (ddd, J = 16.9, 10.6, 6.0 Hz, 1H), 5.54-5.52 (m, 1H), 5.16 (d, J = 10.6 Hz, 1H), 4.04 (t, J = 6.7 Hz, 1H), 3.32 (ddd, J = 10.4, 5.4, 2.3 Hz, 1H), 2.90-2.80 (m, 4H), 2.14-2.09 (m, 1H), 1.91-1.58 (m, 8H), 0.93 (d, J = 6.7 Hz, 3H), 0.92 (d, J = 6.7 Hz, 3H); ^{13}C NMR (125 MHz, CDCl_3) δ 172.83, 136.54, 115.81, 71.92, 71.56, 46.65, 38.96, 34.41, 33.65, 33.38, 30.02 (2C), 25.64, 21.90, 18.41, 17.37; high resolution mass spectrum m/z 355.1380 $[(\text{M}+\text{Na})^+]$; calcd for $\text{C}_{16}\text{H}_{26}\text{O}_3\text{S}_2\text{Na}$: 355.1378]

Ester 3e : β -Hydroxy ketone **3e** (198 mg, 1.10 mmol) and dithiane aldehyde **2** (169 mg, 1.10 mmol) were dissolved in anhydrous THF (19.8 ml) under argon atmosphere. The stirred solution was cooled to $-10\text{ }^\circ\text{C}$, shielded from light, and 2.20 mL (0.220 mmol) of a 0.1 M stock solution of freshly prepared SmI_2 in THF was added dropwise. After 60 min, the reaction mixture was quenched by the addition of Et_2O and saturated aqueous NaHCO_3 . The aqueous layer was extracted with Et_2O (2 X 20 mL) and the combined organic layers were washed with brine (5 mL), dried over MgSO_4 , filtered, and concentrated *in vacuo*. Flash chromatography on silica gel, using ethyl acetate-hexane (1:4) as elutant, provided **3e** (320 mg, 85% yield) as a colorless oil : IR (film) 3501 (m, br), 3088 (w), 3063 (w), 3032 (w), 2957 (s), 2901 (s), 2828 (w), 1952 (w), 1881 (w), 1738 (s), 1496 (m), 1455 (s), 1422 (s), 1275 (s), 1188 (s), 1029 (s), 966 (m), 908 (m), 760 (s), 700 (s) cm^{-1} ; ^1H NMR (500 MHz, CDCl_3) δ 7.37-7.26 (m, 5H), 6.04 (dd, J = 10.8, 2.8 Hz, 1H), 4.02 (t, J = 6.7 Hz, 1H), 3.42-3.38 (m, 1H), 2.89-2.80 (m, 4H), 2.46-2.36 (m, 3H), 2.13-1.65 (m, 9H), 0.94-0.92 (m, 6H); ^{13}C NMR (125 MHz, CDCl_3) δ 172.97, 140.83, 128.39 (2C), 127.70, 126.05 (2C), 73.26, 71.93, 46.75, 41.70, 34.51, 33.79, 33.52, 30.10 (2C), 25.74, 21.98, 18.54, 17.45; high resolution mass spectrum m/z 405.1547 $[(\text{M}+\text{Na})^+]$; calcd for $\text{C}_{20}\text{H}_{30}\text{O}_3\text{S}_2\text{Na}$: 405.1534]

Ester 3f : β -Hydroxy ketone **1f** (208 mg, 0.936 mmol) and dithiane aldehyde **2** (140.6 mg, 0.936 mmol) were dissolved in anhydrous THF (16.8 ml) under argon atmosphere. The stirred solution was cooled to $-10\text{ }^{\circ}\text{C}$, shielded from light, and 16.84 mL (0.187 mmol) of a 0.1 M stock solution of freshly prepared Sml_2 in THF was added dropwise. After 15 min, the reaction mixture was quenched by the addition of Et_2O and saturated aqueous NaHCO_3 . The aqueous layer was extracted with Et_2O (2 X 20 mL) and the combined organic layers were washed with brine (5 mL), dried over MgSO_4 , filtered, and concentrated *in vacuo*. Flash chromatography on silica gel, using ethyl acetate-hexane (1:4) as elutant, provided **3f** (288 mg, 80% yield) as a colorless oil : IR (film) 3501 (m, br), 2957 (vs), 2906 (s), 2834 (m), 1729 (vs), 1612 (m), 1585 (w), 1514 (s) cm^{-1} ; ^1H NMR (500 MHz, CDCl_3) δ 7.27 (d, $J = 6.7$, 2H), 6.86 (d, $J = 6.7$, 2H), 5.98 (dd, $J = 10.6$, 2.9 Hz, 1H), 3.99 (t, $J = 6.8$ Hz, 1H), 3.39-3.36 (m, 1H), 2.86-2.76 (m, 4H), 2.43-2.32 (m, 3H), 2.10-1.96 (m, 2H), 1.86-1.63 (m, 7H), 0.91 (d, $J = 6.7$ Hz, 3H), 0.90 (d, $J = 6.8$ Hz, 3H); ^{13}C NMR (125 MHz, CDCl_3) δ 173.28, 159.37, 133.10, 127.81 (2C), 114.04 (2C), 73.28, 72.26, 55.38, 47.02, 41.67, 34.77, 34.08, 33.76, 30.36 (2C), 26.01, 22.25, 18.82, 17.68; high resolution mass spectrum m/z 435.1621 [(M+Na) $^+$; calcd for $\text{C}_{21}\text{H}_{32}\text{O}_4\text{S}_2\text{Na}$: 435.1640]

Carboxylic acid 4 :

1. A typical saponification procedure is as follows (**Entries 1, 3, 4, 7, 9, and 11, Table 2**) : To a stirred solution of isopropyl ester **3a** (45.3 mg, 0.130 mmol) in aqueous MeOH (1.6 ml, MeOH : $\text{H}_2\text{O} = 6 : 1$) at room temperature was added lithium hydroxide (27.36 mg, 0.65 mmol). The reaction mixture was stirred for 5 h at room temperature, at which time Et_3N (0.5 mL) was added, followed by H_2O (20 mL). The reaction mixture was poured directly into CH_2Cl_2 (30 mL), the layers were separated and the organic layer was discarded. The aqueous layer was acidified (1N HCl, 5 mL), extracted with CH_2Cl_2 (2 X 20 mL), and the combined organic layers were washed with brine (5 mL), dried over MgSO_4 , filtered, and concentrated *in vacuo*. Flash chromatography on silica gel, using ethyl acetate-hexane (1:4 to 1:2) as elutant, provided **4** (25.4 mg, 95% yield)

as a white solid : IR (film) 2953 (s), 2909 (vs), 2880 (s), 2843 (s), 2810 (s), 1703 (s), 1428 (s), 1347 (m), 1295 (s), 1235 (s), 1211 (s), 1178 (s), 904 (s), 869 (w), 771 (m), 681 (w) (s) cm^{-1} ; ^1H NMR (500 MHz, CDCl_3) δ 4.03 (t, J = 6.7 Hz, 1H), 2.90-2.80 (m, 4H), 2.39 (t, J = 6.8 Hz, 2H), 2.13-2.08 (m, 1H), 1.89-1.79 (m, 4H); ^{13}C NMR (125 MHz, CDCl_3) δ 179.34, 46.90, 34.50, 33.36, 30.26 (2C), 25.87, 21.74; high resolution mass spectrum m/z 206.0432 [$(\text{M})^+$; calcd for $\text{C}_8\text{H}_{14}\text{O}_2\text{S}_2$: 206.0435]

2. From oxidation and β -elimination of 3a (Entry 2, Table 2): To a stirred solution of isopropyl ester **3a** (109 mg, 0.313 mmol) in DMSO (2 ml) at room temperature was added triethylamine (0.2 mL, 1.57 mmol) and sulfur trioxide pyridine complex (203 mg, 1.25 mmol). The reaction mixture was stirred for 5 h at room temperature, at which time DBU (0.47 mL, 3.13 mmol) was added. The reaction mixture was stirred for 30 min, and diluted with CH_2Cl_2 , at which time Et_3N (0.5 mL) was added, followed by H_2O (20 mL). The reaction mixture was poured directly into CH_2Cl_2 (30 mL), the layers were separated and the organic layer was discarded. The aqueous layer was acidified (1N HCl, 5 mL), extracted with CH_2Cl_2 (2 X 20 mL), and the combined organic layers were washed with brine (5 mL), dried over MgSO_4 , filtered, and concentrated *in vacuo*. Flash chromatography on silica gel, using ethyl acetate-hexane (1:4 to 1:2) as elutant, provided **4** (55.5 mg, 86% yield) as a white solid.

3. From allyl ester 3d (Entry 6, Table 2) : To a stirred solution of allyl ester **3d** (83 mg, 0.250 mmol) in aqueous EtOH (2.5 ml, EtOH : H_2O = 9 : 1) at 70 °C was added, (triphenylphosphine)rhodium(I) chloride (46.2 mg, 0.05 mmol). The reaction mixture was stirred for 3 - 5 h at 70 °C and cooled to room temperature, at which time Et_3N (0.5 mL) was added, followed by H_2O (20 mL). The reaction mixture was poured directly into CH_2Cl_2 (30 mL), the layers were separated and the organic layer was discarded. The aqueous layer was acidified (1N HCl, 5 mL), extracted with CH_2Cl_2 (2 X 20 mL), and the combined organic layers were washed with brine (5 mL), dried over MgSO_4 , filtered, and concentrated *in vacuo*. Flash chromatography

on silica gel, using ethyl acetate-hexane (1:4 to 1:2) as elutant, provided **4** (36.0 mg, 70% yield) as a white solid.

Alternatively (Entry 5, Table 2), to a stirred solution of allyl ester **3d** (92 mg, 0.277 mmol) in THF (3 ml) at room temperature were added tetrakis(triphenylphosphine)palladium(0) (48.0 mg, 0.042 mmol) and morpholine (0.21 mL, 2.77 mmol). The reaction mixture was stirred for 1 h at room temperature, at which time Et_3N (0.5 mL) was added, followed by H_2O (20 mL). The reaction mixture was poured directly into CH_2Cl_2 (30 mL), the layers were separated and the organic layer was discarded. The aqueous layer was acidified (1N HCl, 5 mL), extracted with CH_2Cl_2 (2 X 20 mL), and the combined organic layers were washed with brine (5 mL), dried over MgSO_4 , filtered, and concentrated *in vacuo*. Flash chromatography on silica gel, using ethyl acetate-hexane (1:4 to 1:2) as elutant, provided **4** (51.5 mg, 90% yield) as a white solid.

4. From benzyl ester 3e (Entry 8, Table 2): To a stirred solution of benzyl ester **3e** (74 mg, 0.193 mmol,) in anhydrous THF (1.4 mL) at 0 °C were added 1,3-propanedithiol (0.42 mL, 0.019 mmol) and boron trifluoride-etherate (0.56 mL, 0.025 mmol). The reaction mixture was stirred for 30 min at room temperature, at which time Et_3N (0.5 mL) was added, followed by H_2O (20 mL). The reaction mixture was poured directly into CH_2Cl_2 (30 mL), the layers were separated and the organic layer was discarded. The aqueous layer was acidified (1N HCl, 5 mL), extracted with CH_2Cl_2 (2 X 20 mL), and the combined organic layers were washed with brine (5 mL), dried over MgSO_4 , filtered, and concentrated *in vacuo*. Flash chromatography on silica gel, using ethyl acetate-hexane (1:4 to 1:2) as elutant, provided **4** (36.7 mg, 92% yield) as a white solid.

5. From *p*-MeO benzyl ester 3f (Entry 10, Table 2): To a stirred solution of *p*-MeO benzyl ester **3f** (47.6 mg, 0.115 mmol) in aqueous DMSO (1 ml, DMSO : H_2O = 10 : 1) at room temperature was added DDQ (32.0 mg, 0.138 mmol). The reaction mixture was stirred for 1 h at 80 °C and cooled to room temperature, at which time Et_3N (0.5 mL) was added, followed by H_2O (20 mL).

The reaction mixture was poured directly into CH_2Cl_2 (30 mL), the layers were separated and the organic layer was discarded. The aqueous layer was acidified (1N HCl, 5 mL), extracted with CH_2Cl_2 (2 X 20 mL), and the combined organic layers were washed with brine (5 mL), dried over MgSO_4 , filtered, and concentrated *in vacuo*. Flash chromatography on silica gel, using ethyl acetate-hexane (1:4 to 1:2) as elutant, provided **4** (17.7 mg, 75% yield) as a white solid.

Aldehyde 5b : To a stirred solution of (4-methylphenyl)diphenylphosphine (1.84 g, 6.67 mmol) in Et_2O (25 mL) was added TMEDA (0.93 mL, 6.15 mmol), followed by *n*-BuLi (2.5 mL, 2.5 M in hexanes, 6.15 mmol). After 1 h, the orange reaction mixture was cooled to -78°C and a solution of the bromo dioxolane (1 g, 5.13 mmol) in Et_2O (5 mL) was quickly added. After 10 min, the cooling bath was replaced with an ice bath and the reaction was allowed to gradually warm to room temperature. After 5 h at room temperature, the reaction mixture was quenched with H_2O . The mixture was extracted with Et_2O (2 X 100 mL) and the organic layers were washed with brine (5 mL), dried over MgSO_4 , filtered, and concentrated *in vacuo*. Flash chromatography on silica gel, using ethyl acetate-hexane (1: 9 to 1 : 6) as elutant, provided the triphenylphosphino dioxolane. (1.11 g, 56% yield) as a colorless oil : IR (film) 3052 (m), 2943 (s), 2860 (s), 1584 (w), 1478 (m), 1434 (s), 1401 (m), 1134 (s), 1090 (m), 1027 (m), 944 (m), 809 (m), 744 (s), 697 (s) cm^{-1} ; ^1H NMR (500 MHz, CDCl_3) δ 7.34-7.15 (m, 14H), 4.85 (t, $J = 4.8$ Hz, 1H), 3.97-3.94 (m, 2H), 3.85-3.83 (m, 2H), 2.62 (t, $J = 7.7$ Hz, 2H), 1.71-1.66 (m, 2H), 1.50-1.47 (m, 2H); ^{13}C NMR (125 MHz, CDCl_3) δ 143.34 (s, 2C), 137.53 (d, $^1J_{\text{pc}} = 10.8$ Hz, 2C), 133.84 (d, $^2J_{\text{pc}} = 19.8$ Hz, 2C), 133.60 (d, $^2J_{\text{pc}} = 19.3$ Hz, 4C), 133.70 (m, 1C), 128.60 (d, $^3J_{\text{pc}} = 7.2$ Hz, 2C), 128.51 (m, 1C), 128.37 (d, $^3J_{\text{pc}} = 6.8$ Hz, 4C), 104.49, 64.79, 35.64, 33.70, 31.12, 23.76; ^{31}P NMR (145.73 MHz, CDCl_3) δ -5.81; high resolution mass spectrum m/z 413.1664 $[(\text{M}+\text{Na})^+]$; calcd for $\text{C}_{25}\text{H}_{27}\text{O}_2\text{PNa}$: 413.1646]

To a stirred solution of triphenylphosphino dioxolane prepared above (61 mg, 0.156 mmol) in acetone (3.12 mL) was added 3N HCl (50 μL) at room temperature. The reaction mixture was stirred, quenched with the saturated aqueous NaHCO_3 . The aqueous layer was extracted with

Et_2O (2 X 20 mL) and the combined organic layers were washed with brine (3 mL), dried over MgSO_4 , filtered, and concentrated *in vacuo*. Flash chromatography, using ethyl acetate-hexane (1:9 to 1:6) as elutant, provided **5b** (38mg, 79% yield) as a colorless oil : IR (film) 3069 (m), 2935 (s), 2858 (m), 2720 (w), 1724 (vs), 1585 (w), 1478 (s), 1434 (vs), 1401 (m), 1186 (w), 1091 (m), 1026 (w), 808 (w), 744 (vs), 697 (vs) cm^{-1} ; ^1H NMR (500 MHz, CDCl_3) δ 9.76 (s, 1H), 7.34-7.14 (m, 14H), 2.64 (m, 2H), 2.45 (m, 2H), 1.68-1.67 (m, 4H); ^{13}C NMR (125 MHz, CDCl_3) δ 202.05, 142.63 (s, 2C), 137.39 (d, $^1J_{\text{pc}} = 10.8$ Hz, 2C), 134.04 (d, $^1J_{\text{pc}} = 10.1$ Hz, 1C), 133.79 (d, $^2J_{\text{pc}} = 19.9$ Hz, 2C), 133.49 (d, $^2J_{\text{pc}} = 19.4$ Hz, 4C), 128.45 (m, 3C), 128.30 (d, $^3J_{\text{pc}} = 6.7$ Hz, 4C), 43.52, 35.28, 30.46, 21.54; ^{31}P NMR (145.73 MHz, CDCl_3) δ -5.82; high resolution mass spectrum m/z 347.1563 [(M+H) $^+$]; calcd for $\text{C}_{23}\text{H}_{23}\text{OP}$: 347.1565]

Aldehyde 5d : To a stirred solution of stannyl alcohol (2g, 5.33 mmol) in DMSO (30 ml) at room temperature was added triethylamine (2.97 mL, 21.32 mmol) and sulfur trioxide pyridine complex (2.20 g, 13.33 mmol). The reaction mixture was stirred for 1 h, then poured into Et_2O (50 mL) and H_2O (50mL). The aqueous layer was extracted with Et_2O (2 X 50 mL) and the combined organic layers were washed with brine (5 mL), dried over MgSO_4 , filtered, and concentrated *in vacuo*. Flash chromatography on silica gel, using ethyl ether-hexane (1:30 to 1: 20) as elutant, provided **5d** (1.60 g, 80% yield) as 3-4 : 1 E/Z mixture , both as colorless oils:

(E)-MAJOR : IR (film) 2956 (vs), 2925 (vs), 2714 (w), 1728 (s), 1599 (m), 1464 (m), 1376 (m), 1071 (m), 989 (m), 865 (w) cm^{-1} ; ^1H NMR (500 MHz, CDCl_3) δ 9.77 (t, $J = 1.7$ Hz, 1H), 5.97 (m, 2H), 2.55-2.47 (m, 4H), 1.50-1.45 (m, 6H), 1.32-1.28 (m, 6H), 0.94-0.85 (m, 15H); ^{13}C NMR (125 MHz, CDCl_3) δ 202.98, 146.26, 129.21, 42.69, 29.88, 29.02, 27.17, 13.60, 9.38; high resolution mass spectrum m/z 373.1539 [(M-H) $^+$]; calcd for $\text{C}_{17}\text{H}_{34}\text{OSn}$: 373.1553]

(Z)-MINOR : IR (film) 2956 (vs), 2925 (vs), 2714 (w), 1728 (s), 1599 (m), 1464 (m), 1376 (m), 1071 (m), 989 (m), 865 (w) cm^{-1} ; ^1H NMR (500 MHz, CDCl_3) δ 9.79 (m, 1H), 6.5-6.4 (m, 1H), 5.97 (m, 1H), 2.55-2.47 (m, 4H), 1.50-1.45 (m, 6H), 1.32-1.28 (m, 6H), 0.94-0.85 (m, 15H); ^{13}C NMR

(125 MHz, CDCl_3) δ 201.31, 146.14, 130.26, 43.87, 29.88, 29.14, 27.17, 13.60, 10.18; high resolution mass spectrum m/z 373.1539 $[(M-H)^+]$; calcd for $\text{C}_{17}\text{H}_{34}\text{OSn}$: 373.1553]

Aldehyde 5e : To a stirred solution of alcohol (119 mg, 0.271 mmol) in DMSO (4 mL) at room temperature under argon atmosphere were added diisopropylethylamine (0.50 mL, 2.85 mmol) and sulfur trioxide pyridine complex (86 mg, 0.542 mmol). The reaction mixture was stirred for 1 h, then poured into EtOAc (20 mL) and H_2O (20 mL). The aqueous layer was extracted with EtOAc (40 mL), the combined organic layers were washed with brine (5 mL), dried over MgSO_4 , filtered, and concentrated *in vacuo*. Flash chromatography on silica gel, using ethyl acetate-hexane (1:9) as elutant, provided **5e** (91 mg, 78% yield) as a colorless oil.

$[\alpha]_D = +36.8^\circ$ ($c = 1.0$, C_6H_6) IR (film) 2953.9 (s), 1732.5 (s), 1381.0 (m), 1026.7 (s), 835.7 (s) cm^{-1} ; ^1H NMR (500 MHz, C_6D_6) δ 9.94 (s, 1H), 4.73 (d, $J = 6.8$ Hz, 1H), 4.69 (d, $J = 6.8$ Hz, 1H), 4.20 (d, $J = 3.5$ Hz, 1H), 3.82 (d, $J = 3.5$ Hz, 1H), 3.71 (m, 1H), 3.65 (m, 1H), 3.47 (s, 3H), 2.60 (m, 1H), 2.48-2.46 (m, 5H), 2.32 (m, 1H), 1.84 (m, 1H), 1.55 (m, 2H), 1.30 (d, $J = 6.8$ Hz, 3H), 1.27 (d, $J = 7.0$ Hz, 3H), 1.23 (d, $J = 6.8$ Hz, 3H), 0.97 (m, 2H), 0.05 (s, 9H); ^{13}C NMR (125 MHz, C_6D_6) δ 201.54, 95.57, 85.36, 84.56, 66.03, 59.95, 38.55, 33.69, 31.57, 25.77, 25.70, 25.19, 18.29, 18.09, 18.06, 17.79, -1.41; high resolution mass spectrum m/z 436.2142 $[(M)^+]$; calcd for $\text{C}_{20}\text{H}_{40}\text{O}_4\text{S}_2\text{Si}$: 436.2137]

Ester 6a : β -Hydroxy ketone **1a** (51 mg, 0.32 mmol) and phenylseleno aldehyde **5a** (73 mg, 0.32 mmol) were dissolved in anhydrous THF (5.80 mL) under argon atmosphere. The stirred solution was cooled to -15°C , shielded from light, and 0.650 mL (0.064 mmol) of a 0.1 M stock solution of freshly prepared Sml_2 in THF was added dropwise. After 1 h, the reaction mixture was quenched by the addition of Et_2O and saturated aqueous NaHCO_3 . The aqueous layer was extracted with Et_2O (2 X 20 mL) and the combined organic layers were washed with brine (5 mL), dried over MgSO_4 , filtered, and concentrated *in vacuo*. Flash chromatography on silica gel, using ethyl acetate-hexane (1:6 to 1:4) as elutant, provided **6a** (105.8 mg, 85% yield) as a colorless oil : IR

(film) 3510 (m, br), 2962 (vs), 1719 (vs), 1574 (m), 1477 (m), 1438 (m), 1368 (s), 1127 (m), 736 (s) cm^{-1} ; ^1H NMR (500 MHz, CDCl_3) δ 7.51-7.49 (m, 2H), 7.28-7.24 (m, 3H) 4.93 (ddd, J = 10.6, 5.4, 2.4 Hz, 1H), 3.15-3.11 (m, 1H), 2.94 (t, J = 7.3 Hz, 2H), 2.74 (d, J = 4.0 Hz, 1H), 2.51 (t, J = 7.27 Hz, 2H), 2.02 (q, J = 7.24 Hz, 2H), 1.90-1.80 (m, 1H), 1.66-1.49 (m, 3H), 0.92 (d, J = 6.7 Hz, 3H), 0.90 (d, J = 6.8 Hz, 3H); ^{13}C NMR (125 MHz, CDCl_3) δ 173.97, 132.72 (2C), 129.57, 128.95 (2C), 126.87, 76.04, 71.76, 36.15, 33.95, 33.46, 32.08, 26.87, 25.24, 18.69, 18.66, 17.77, 17.59; high resolution mass spectrum m/z 409.1277 [(M+Na) $^+$; calcd for $\text{C}_{19}\text{H}_{30}\text{O}_3\text{SeNa}$: 409.1258]

Ester 6b : β -Hydroxy ketone **1a** (63 mg, 0.396 mmol) and phosphino aldehyde **5b** (137 mg, 0.396 mmol) were dissolved in anhydrous THF (7.1 ml) under argon atmosphere. The stirred solution was cooled to $-10\text{ }^\circ\text{C}$, shielded from light, and 0.8 mL (0.079 mmol) of a 0.1 M stock solution of freshly prepared SmI_2 in THF was added dropwise. After 1 h, the reaction mixture was quenched by the addition of Et_2O and saturated aqueous NaHCO_3 . The aqueous layer was extracted with Et_2O (2 X 20 mL) and the organic layers were washed with brine (3 mL), dried over MgSO_4 , filtered, and concentrated *in vacuo*. Flash chromatography, using ethyl acetate-hexane (1:9 to 1:6) as elutant, provided **6b** (166 mg, 83% yield) as a colorless oil : IR (film) 3511 (m, br), 3053 (m), 2961 (s), 1728 (s), 1599 (w), 1465 (s), 1435 (s), 1368 (s), 1183 (s), 1119 (s), 1000 (m), 810 (m), 744 (s), 670 (s) cm^{-1} ; ^1H NMR (500 MHz, CDCl_3) δ 7.37-7.17 (m, 14H), 4.97 (ddd, J = 10.5, 5.4, 2.5 Hz, 1H), 3.18 (ddd, J = 10.4, 5.5, 2.4 Hz, 1H), 2.68 (t, J = 7.2 Hz, 2H), 2.42 (t, J = 7.1 Hz, 2H), 1.89-1.82 (m, 1H), 1.77-1.53 (m, 7H), 0.95 (d, J = 6.9 Hz, 6H), 0.93 (d, J = 6.8 Hz, 6H); ^{13}C NMR (125 MHz, CDCl_3) δ 174.74, 142.80 (s, 2C), 137.47 (d, $^1J_{\text{pc}}$ = 10.9 Hz, 2C), 134.06 (d, $^1J_{\text{pc}}$ = 10.0 Hz, 1C), 133.87 (d, $^2J_{\text{pc}}$ = 20.0 Hz, 2C), 133.59 (d, $^2J_{\text{pc}}$ = 19.4 Hz, 4C), 128.55 (m, 3C), 128.37 (d, $^3J_{\text{pc}}$ = 6.7 Hz, 4C), 75.94, 71.86, 36.36, 35.32, 34.28, 33.53, 32.20, 30.66, 24.74, 18.78 (2C), 17.88, 17.68; ^{31}P NMR (145.73 MHz, CDCl_3) δ -5.85; high resolution mass spectrum m/z 527.2688 [(M+Na) $^+$; calcd for $\text{C}_{32}\text{H}_{41}\text{O}_3\text{PNa}$: 527.2691]

Ester 6c : β -Hydroxy ketone **1a** (87.0 mg, 0.550 mmol) and *N*-morpholino aldehyde **5c** (94.1 mg, 0.550 mmol) were dissolved in anhydrous THF (10 ml) under argon atmosphere. The stirred solution was cooled to $-10\text{ }^{\circ}\text{C}$, shielded from light, and 1.10 mL (0.110 mmol) of a 0.1 M stock solution of freshly prepared Sml_2 in THF was added dropwise. The reaction was held at this temperature ($-10\text{ }^{\circ}\text{C}$) for 1 h, then was allowed to rise to $0\text{ }^{\circ}\text{C}$, stirring continued for 30 min. The reaction mixture was quenched by the addition of CH_2Cl_2 and saturated aqueous NaHCO_3 . The aqueous layer was extracted with CH_2Cl_2 (2 X 20 mL) and the combined organic layers were dried over MgSO_4 , filtered, and concentrated *in vacuo*. Flash chromatography on silica gel, using acetone- CH_2Cl_2 (1:20 to 1:6) as elutant, provided **6c** (145 mg, 80% yield) as a colorless oil : IR (film) 3502 (m, br), 2962 (vs), 2875 (s), 2806 (m), 1717 (s), 1472 (m), 1389 (m), 1322 (w), 1285 (s), 1186 (s), 1117 (vs), 1012 (m), 866 (m) cm^{-1} ; ^1H NMR (500 MHz, CDCl_3) δ 4.93 (ddd, $J = 10.7$, 5.0, 2.4 Hz, 1H), 3.63 (t, $J = 4.63$, 1H), 3.23-3.21 (m, 1H), 3.05 (d, $J = 4.2$ Hz, 1H), 2.56-2.50 (m, 4H), 2.49 (s, 2H), 1.86-1.83 (m, 1H), 1.67-1.50 (m, 4H), 1.20 (s, 6H), 0.95 (d, $J = 6.7$ Hz, 3H), 0.940 (d, $J = 6.8$ Hz, 3H), 0.936(d, $J = 6.7$ Hz, 3H), 0.91 (d, $J = 6.8$ Hz, 3H); ^{13}C NMR (125 MHz, CDCl_3) δ 178.55, 75.84, 71.59, 67.08, 55.63, 44.74, 36.14, 33.51, 32.19, 24.18, 24.13, 18.79, 18.69, 17.95, 17.56; high resolution mass spectrum m/z 352.2449 [(M+Na) $^+$]; calcd for $\text{C}_{18}\text{H}_{35}\text{NO}_4\text{Na}$: 352.2464]

Ester 6d : β -Hydroxy ketone **1a** (182.3 mg, 1.15 mmol) and stannyl aldehyde **5d** (3-4 : 1 E/Z mixture) (430.0 mg, 1.15 mmol) were dissolved in anhydrous THF (20.7 ml) under argon atmosphere. The stirred solution was cooled to $-10\text{ }^{\circ}\text{C}$, shielded from light, and 2.30 mL (0.230 mmol) of a 0.1 M stock solution of freshly prepared Sml_2 in THF was added dropwise. After 1 h, the reaction mixture was quenched by the addition of Et_2O and saturated aqueous NaHCO_3 . The aqueous layer was extracted with Et_2O (2 X 30 mL) and the combined organic layers were washed with brine (5 mL), dried over MgSO_4 , filtered, and concentrated *in vacuo*. Flash chromatography, using ethyl ether-hexane (1: 15) as elutant, provided **6d** (538.7 mg, 88% yield) as 3.8 : 1 E/Z mixture , both as colorless oils.

(E)-MAJOR : IR (film) 3529 (m, br), 2959 (vs), 2927 (vs), 2872 (s), 1715 (s), 1599 (m), 1465 (m), 1419 (m), 1376 (m), 1340 (m), 1263 (m), 1184 (m), 1146 (m), 1071 (m), 1047 (m), 1000 (m), 960 (m), 874 (w), 838 (w), 691 (m) cm^{-1} ; ^1H NMR (500 MHz, CDCl_3) δ 6.04-5.88 (m, 2H), 4.94 (ddd, J = 10.7, 5.4, 2.3 Hz, 1H), 3.18-3.14 (m, 1H), 2.82 (d, J = 4.2 Hz, 1H), 2.47-2.34 (m, 4H), 1.86-1.79 (m, 1H), 1.68-1.40 (m, 9H), 1.37-1.26 (m, 6H), 0.94-0.74 (m, 27H); ^{13}C NMR (125 MHz, CDCl_3) δ 174.45, 146.57, 128.87, 75.98, 71.83, 34.75, 36.38, 33.56, 32.66, 32.16, 29.03, 27.20, 18.80, 18.77, 17.88, 17.68, 13.61, 9.38; high resolution mass spectrum m/z 555.2821 $[(\text{M}+\text{Na})^+]$; calcd for $\text{C}_{26}\text{H}_{52}\text{O}_3\text{SnNa}$: 555.2836]

(Z)-MINOR : IR (film) 3529 (m, br), 2959 (vs), 2927 (vs), 2872 (s), 1715 (s), 1599 (m), 1465 (m), 1419 (m), 1376 (m), 1340 (m), 1263 (m), 1184 (m), 1146 (m), 1071 (m), 1047 (m), 1000 (m), 960 (m), 874 (w), 838 (w), 691 (m) cm^{-1} ; ^1H NMR (500 MHz, CDCl_3) δ 6.50-6.45 (m, 1H), 6.04-5.88 (m, 1H), 4.94 (ddd, J = 10.7, 5.4, 2.3 Hz, 1H), 3.18-3.14 (m, 1H), 2.81 (d, J = 4.2 Hz, 1H), 2.47-2.34 (m, 4H), 1.86-1.79 (m, 1H), 1.68-1.40 (m, 9H), 1.37-1.26 (m, 6H), 0.94-0.74 (m, 27H); ^{13}C NMR (125 MHz, CDCl_3) δ 174.11, 146.21, 130.34, 76.07, 71.83, 34.75, 36.46, 33.72, 32.66, 32.31, 29.13, 27.22, 18.80, 18.77, 17.88, 17.65, 13.61, 10.19; high resolution mass spectrum m/z 555.2821 $[(\text{M}+\text{Na})^+]$; calcd for $\text{C}_{26}\text{H}_{52}\text{O}_3\text{SnNa}$: 555.2836]

Ester 6e : β -Hydroxy ketone **1a** (50.6 mg, 0.320 mmol) and aldehyde (+)-**5e** (140 mg, 0.320 mmol) were dissolved in anhydrous THF (6.40 ml) under argon atmosphere. The stirred solution was cooled to $-10\text{ }^\circ\text{C}$, shielded from light, and 0.640 mL (0.064 mmol) of a 0.1 M stock solution of freshly prepared Sml_2 in THF was added dropwise. After 1 h, the reaction mixture was quenched by the addition of Et_2O and saturated aqueous NaHCO_3 . The aqueous layer was extracted with Et_2O (2 X 20 mL) and the combined organic layers were washed with brine (5 mL), dried over MgSO_4 , filtered, and concentrated *in vacuo*. Flash chromatography, using ethyl acetate-hexane (1: 8 to 1:4) as elutant, provided **6e** as a diastereomeric mixture (134 mg, 70% yield) as colorless oils : high resolution mass spectrum m/z 617.3351 $[(\text{M}+\text{Na})^+]$; calcd for $\text{C}_{29}\text{H}_{58}\text{O}_6\text{S}_2\text{SiNa}$: 617.3342]