Opening of Tartrate Acetals Using Dialkylboron Bromide. Evidence for Stereoselectivity Downstream from Ring Fission.

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General. Melting points were determined on an electrothermal melting point apparatus and are uncorrected. NMR spectra were recorded on a Bruker AC200 or Bruker AMX 400 spectrometer and were referenced to TMS as internal standard. IR spectra were recorded on a Perkin-Elmer 781 spectrophotometer. CI and EI mass spectra were recorded on an MF 50 TATC instrument operating at 70 eV. Optical rotations were measured on a Perkin-Elmer 241 MC polarimeter at the sodium D line with a 1 dm path length, 1 mL cell. Capillary GC analyses were performed on a Shimadzu GC-9AM instrument using a 0.25 mm x 25 m chromatopac C-R3A column. Flash chromatography was performed on Merck silica gel 60 (0.040-0.063 mm) using nitrogen pressure. Analytical thin-layer chromatography (TLC) was carried out on precoated (0.25 mm) Merck silica gel F-254 plates. All reactions were conducted under a positive nitrogen atmosphere in oven-dried glassware using standard syringe techniques. Tetrahydrofuran (THF) and ether were distilled from sodium/benzophenone immediately prior to use. Dichloromethane (CH₂Cl₂), HMPA, (iPr)₂EtN and diisopropylamine were distilled from calcium hydride. Methanol was distilled from magnesium

General procedure for the preparation of tartrate acetals. To a mixture of aldehyde (10.0 mmol) and trimethylorthoformate (10.0 mmol) at 0 was added p-toluenesulfonic acid (0.5 mmol) in one portion. After stirring for 1 hour the mixture was diluted with benzene (60 mL), dimethyl tartrate¹ was added (11.0 mmol) and the mixture refluxed overnight using a Soxhlet packed with molecular sieves to remove methanol.² The solution was then cooled to room temperature and diluted with ether. Washing with saturated NaHCO₃ and brine was followed by drying over MgSO₄ and flash chromatography to afford the desired acetal. Physical properties and analytical data are given below. Yields: **11**, 70%; **12**, 48%; **15**, 88%; **23**, 95 %; **26**, 41%; **30**, 75%; **45**, 71%.

(4R, 5R)-2-nonyl-1,3-dioxolane-4,5-dicarboxylic acid dimethyl ester (11). Oil; [α]_D -30.1 (c 1.25, CHCl₃); IR (neat) 2960, 2930, 2860, 1755, 1440, 1220, 1145, 1090 cm⁻¹; ¹H NMR (200 MHz, CDCl₃) δ 5.23 (t, J = 4.8 Hz, 1H), 4.78 (d, J_{AB} = 4.0 Hz, 1H), 4.70 (d, J_{AB} = 4.0 Hz, 1H), 3.82 (s, 6H), 1.9-1.75 (m, 2H), 1.5-1.2 (m, 14H), 0.87 (t, J = 6.4 Hz, 3H); ¹³C NMR (100 MHz, C₆D₆) δ 170.3, 169.6, 108.3, 77.7, 77.5, 52.0, 51.9, 34.2, 32.3, 29.9, 29.8, 29.7, 24.3, 23.1, 14.3; HRMS calcd for C₁₆H₂₇O₆

(M - H)⁺ 315.1807, found 315.1784; Anal. Calcd for C₁₆H₂₈O₆: C, 60.74; H, 8.92. Found: C, 60.40; H, 9.01.

(4R, 5R)-2-cyclohexyl-1,3-dioxolane-4,5-dicarboxylic acid dimethyl ester (13). White solid; mp 37-38 ; [α]_D -28.3 (c 1.93, CHCl₃); IR (neat) 2940, 2860, 1750, 1440, 1220, 1140, 1100 cm⁻¹; ¹H NMR (200 MHz, CDCl₃) δ 4.97 (d, J = 5.0 Hz, 1H), 4.76 (d, J_{AB} = 4.4 Hz, 1H), 4.68 (d, J_{AB} = 4.4 Hz, 1H), 3.81 (s, 6H), 1.9-1.6 (m, 6H), 1.4-1.05 (m, 5H); ¹³C NMR (100 MHz, C₆D₆) δ 170.2, 169.4, 110.8, 77.5, 77.4, 51.9, 51.8, 41.7, 27.4, 26.5, 25.8; HRMS calcd for C₁₃H₂₁O₆ (M + H)⁺ 273.1338, found 273.1312; Anal. Calcd for C₁₃H₂₀O₆: C, 57.34; H, 7.40. Found: C, 57.27; H, 7.52.

(4R, 5R)-2-(1-methylethyl)-1,3-dioxolane-4,5-dicarboxylic acid dimethyl ester (15). Oil; [α]_D -48.9 (c 1.50, CHCl₃); IR (neat) 2980, 2880, 1750, 1440, 1225, 1130, 1110 cm⁻¹; ¹H NMR (200 MHz, CDCl₃) δ 5.00 (d, J = 5.0 Hz, 1H), 4.78 (d, J_{AB} = 4.1 Hz, 1H), 4.69 (d, J_{AB} = 4.1 Hz, 1H), 3.82 (s, 3H), 3.81 (s, 3H), 2.15-1.9 (m, 1H), 1.00 (d, J = 6.8 Hz, 3H), 0.99 (d, J = 6.8 Hz, 3H); ¹³C NMR (50 MHz, C₆D₆) δ 170.2, 169.4, 111.5, 77.6, 77.5, 51.9, 51.8, 32.2, 16.8; MS (CI) 233 (MH⁺); HRMS calcd for C₁₀H₁₇O₆ (M + H)⁺ 233.1025, found 233.1049; Anal. Calcd. for C₁₀H₁₆O₆: C, 51.72; H, 6.94. Found: C, 51.35; H, 7.07.

(4R, 5R)-2-methyl-1,3-dioxolane-4,5-dicarboxylic acid dimethyl ester (23). Oil; [α]_D -70.8 (c 1.07, CHCl₃); IR (neat) 3000, 2980, 1760, 1440, 1225, 1155, 1125, 1090 cm⁻¹; ¹H NMR (200 MHz, CDCl₃) δ 5.38 (q, J = 4.9 Hz, 1H), 4.78 (d, J_{AB} = 4.0 Hz, 1H), 4.70 (d, J_{AB} = 4.0 Hz, 1H), 3.83 (s, 6H), 1.51 (d, J = 4.9 Hz, 3H); ¹³C NMR (50 MHz, C₆D₆) δ 170.2, 169.6, 105.1, 77.8, 77.6, 52.0, 51.8, 19.8; MS (CI) 205 (M+H); HRMS calcd for C₆H₁₃O₆ (M+H) 205.0641, found 205.0489.

(2R, 3R)-2-nonyl-1,3-dioxolane-4,5-dicarboxylic acid bis(dimethyl amide) (26). Oil; [α]_D -41.3 (c 1.25, CHCl₃); IR (neat) 2980, 2930, 1650, 1500, 1470, 1400, 1260, 1190, 1150, 1130, 1090 cm⁻¹; ¹H NMR (200 MHz, CDCl₃) δ 5.26 (d, J_{AB} = 5.6 Hz, 1H), 5.18 (d, J_{AB} = 5.6 Hz, 1H), 4.94 (d, J = 5.0 Hz, 1H), 3.19 (s, 3H), 3.18 (s, 3H), 2.98 (s, 6H), 1.95-1.79 (m, 1H), 0.95 (d, J = 6.8 Hz, 3H), 0.94 (d, J = 6.8 Hz, 3H); ¹³C NMR (50 MHz, C₆D₆) δ 168.8, 167.1, 110.1, 77.2, 75.4, 36.4, 36.2, 35.2, 32.1, 16.9, 16.8; MS (EI) 258 (M+); HRMS calcd for C₁₂H₂₂N₂O₄ 258.1579, found 258.1578; Anal. Calcd. for C₁₂H₂₂N₂O₄: C, 55.80; H, 8.58; N, 10.84. Found: C, 55.61; H, 8.67; N, 10.65.

(4R, 5R)-2-nonyl-4,5-dimethyl-1,3-dioxolane (30). Oil; [α]_D +11.4 (c 1.01, CHCl₃); IR (neat) 2930, 2840, 1460, 1380, 1330, 1150, 1120 cm⁻¹; ¹H NMR (200 MHz, CDCl₃) δ 5.03 (t, J = 4.7 Hz, 1H), 3.7-3.5 (m, 2H), 1.7 - 1.1 (m, 22 H), 0.87 (t, J = 6.2 Hz,

- (1) All acetals were prepared from Dimethyl L-tartrate with the following exceptions: **29** from Dimethyl D-Tartrate. **46** from L-Tartaric acid bis(dimethyl amide). **50** from (R, R)-2,3-Butanediol. **64** from *meso* Dimethyl Tartrate.
- (2) Alternatively the mixture was refluxed for one hour and then distilled. Methanol co-distills with benzene at 60-65 . The reaction is complete when the temperature reaches 80 .

3H); MS (CI) 229 (MH⁺); Anal. Calcd. for C₁₄H₂₈O₂: C, 73.63; H, 12.36. Found: C, 73.53; H, 12.76.

(±)-*cis*-2-methyl-1,3-dioxolane-4,5-dicarboxylic acid dimethyl ester (**45**). 2.5 : 1 Mixture of isomers (separable by flash chromatography). **Less polar isomer**: Oil; IR (neat) 3000, 2980, 2900, 1760, 1440, 1420, 1300, 1220, 1150, 1130, 1080 cm⁻¹; ¹H NMR (200 MHz, CDCl₃) δ 5.62 (q, J = 4.8 Hz, 1H), 4.89 (s, 2H), 3.74 (s, 6H), 1.45 (d, J = 4.8 Hz, 3H); ¹³C NMR (50 MHz, C₆D₆) δ 169.5, 104.9, 75.9, 51.7, 19.3; MS (CI) 205 (MH⁺). **More polar isomer**: Oil; R_f 0.21 (33 % EtOAc in hexanes); IR (neat) 3000, 2980, 2900, 1760, 1440, 1420, 1305, 1220, 1150, 1130, 1085 cm⁻¹; ¹H NMR (200 MHz, CDCl₃) δ 5.26 (q, J = 4.9 Hz, 1H), 4.75 (s, 2H), 3.76 (s, 6H), 1.59 (d, J = 4.9 Hz, 3H); ¹³C NMR (50 MHz, C₆D₆) δ 168.3, 104.4, 77.2, 51.8, 19.9; MS (CI) 205 (MH⁺). In subsequent reactions the mixture was used.

(2R, 3R)-2-nonyl-1,3-dioxolane-4,5-dicarboxylic acid bis(1-methylethyl) ester (**24**). Decyl aldehyde (1.09 g, 7.0 mmol), diisopropyl L-tartrate (1.64 g, 7.0 mmol) and p-toluenesulfonic acid (135 mg, 0.7 mmol) were refluxed in benzene (80 mL) using a Dean-Stark apparatus to remove water. After 6 h the solution was cooled to room temperature, diluted with ether and washed with saturated Na₂CO₃ and brine. After drying (MgSO₄) and removal of solvent, flash chromatography gave the desired product **24** (835 mg, 32 %). Oil; [α]_D²⁵ -34.6° (c 1.22, CHCl₃); IR (neat) 2980, 2930, 2860, 1750, 1740, 1465, 1455, 1375, 1280, 1210, 1140, 1105 cm⁻¹; ¹H NMR (200 MHz, CDCl₃) δ 5.23 (t, J = 4.8 Hz, 1H), 5.12 (septet, J = 6.3 Hz, 2H), 4.66 (d, J_{AB} = 4.2 Hz, 1H), 4.58 (d, J_{AB} = 4.2 Hz, 1H), 1.85-1.74 (m, 2H), 1.60-1.15 (m, 14H), 1.30 (d, J = 6.3 Hz, 12H), 0.88 (t, J = 6.1 Hz, 3H); ¹³C NMR (50 MHz, C₆D₆) δ 169.6, 168.7, 108.3, 78.0, 69.2, 34.2, 32.2, 29.9, 29.8, 29.7, 24.2, 23.0, 21.4, 14.3; MS (EI) 371 (MH⁺); HRMS calcd for C₂₀H₃₇O₆ 371.2434, found 371.2439; Anal. Calcd for C₂₀H₃₆O₆: C, 64.49; H, 9.74. Found: C, 64.31; H, 9.93.

(4S, 5S)-2-nonyl-4,5-(methoxymethyl)-1,3-dioxolane (**28**). A solution of decylaldehyde (651 mg, 4.17 mmol), 1,4-dimethoxythreitol (688 mg, 4.58 mmol) and p-toluenesulfonic acid (40 mg, 0.2 mmol) was refluxed in benzene (30 mL) with azeotropic removal of water. The solution was then diluted with ether, washed with sat NaHCO₃ and dried (MgSO₄). Flash chromatography gave the desired acetal **28** (870 mg, 72 %). Oil; [α]_D -8.8° (c 1.04, CHCl₃); IR (neat) 2930, 2860, 1460, 1140, cm⁻¹; ¹H NMR (200 MHz, CDCl₃) δ 5.03 (t, J = 4.6 Hz, 1H), 4.02 - 3.85 (m, 2H), 3.6 - 3.45 (m, 4H), 3.40 (s, 3H), 3.39 (s, 3H), 1.73 - 1.55 (m, 2H), 1.5 - 1.1 (m, 14H), 0.87 (t, J = 6.1 Hz, 3H); MS (CI) 289 (MH⁺); Anal. Calcd. for C₁₆H₃₂O₄: C, 66.63; H, 11.18. Found: C, 66.26; H, 11.36.

General procedure for the preparation of mixed acetals (33, 35, 37, 39, 41, 43). **Method A**: To a cold (-78 °C) solution of acetaldehyde dimethyl acetal (1 equiv.) in CH₂Cl₂ was added a solution of Me₂BBr in CH₂Cl₂ (1.2 equiv., ca 1.5 M) and the resulting solution stirred at -78 °C for 10 min. Et(iPr)₂N (2.5 equiv.) was then added followed by a solution of the appropriate alcohol (1 equiv.). After 1h at -78 °C, the solution was poured into sat. NaHCO₃ and extracted with EtOAc. The organic phase was washed with brine, dried (MgSO₄) and concentrated in vacuo. Flash chromatography gave the desired products. **Method B**: A solution of methylvinylether was prepared by sparging methylvinylether into a cold 0 °C solution of triethanolamine (ca. 40 mg) in CH₂Cl₂ (20 mL). Typically 1 to 3 g was collected. A portion of this solution (1.3 equiv.) was added to a solution of tartrate alcohol in CH₂Cl₂ (0.1 M) at 0 °C. Camphorsulfonic acid (0.02 equiv.) was then added and stirring continued until TLC indicated that the reaction was complete (30 min). The mixture was then diluted with ether and washed with saturated NaHCO₃

and brine and dried (MgSO₄). Flash chromatography afforded the desired acetal. Physical properties and analytical data are given below. Yields: **33**, 99% (method B); **35**, 84% (method B); **37**, 89% (method B); **39**, 99% (method B); **41**, 89% (method B); **43**, 83% (method A).

(2R, 3R)-2-benzyloxy-3-((1-methoxyethyl)oxy)-1,4-butanedioic acid dimethyl ester (**33**). Prepared from (2R, 3R)-2-benzyloxy-3-hydroxy-1,4-butanedioic acid dimethyl ester³ as a 1 : 1 mixture of isomers. Oil; IR (neat) 3000, 2960, 1760, 1740, 1460, 1440, 1400, 1280, 1210, 1150, 1090 cm⁻¹; ¹H NMR (200 MHz, CDCl₃) (**isomer A**) δ 7.26 - 7.38 (m, 5H), 4.90 (d, J = 12.3 Hz, 1H), 4.82 (q, J = 5.4 Hz, 1H), 4.69 (d, J = 3.2 Hz, 1H), 4.42 (d, J = 12.3 Hz, 1H), 4.41 (d, J = 3.2 Hz, 1H), 3.80 (s, 3H), 3.60 (s, 3H), 3.21 (s, 3H), 1.36 (d, J = 5.4 Hz, 3H); (**isomer B**) δ 7.26 - 7.38 (m, 5H), 4.87 (d, J = 12.2 Hz, 1H), 4.71 (q, J = 5.4 Hz, 1H), 4.53 (d, J = 3.9 Hz, 1H), 4.45 (d, J = 12.2 Hz, 1H), 4.37 (d, J = 3.9 Hz, 1H), 3.79 (s, 3H), 3.63 (s, 3H), 3.33 (s, 3H), 1.28 (d, J = 5.4 Hz, 3H); ¹³C NMR (100 MHz, C₆D₆, mixture of isomers) δ 169.8, 169.7, 169.5, 137.9, 128.4, 128.4, 127.9, 102.3, 100.1, 79.8, 79.2, 76.7, 75.4, 73.3, 73.2, 52.5, 51.5, 50.7, 19.1, 18.9; HRMS calcd for C₁₆H₂₂O₇ (M + H)⁺: 327.1477, found 327.1477; Anal. Calcd for C₁₆H₂₂O₇: C, 58.89; H, 6.79. Found: C, 58.60; H, 6.81.

(2S, 3R)-2-methoxy-3-((1-methoxyethyl)oxy)-butanoic acid dimethyl ester (**35**). Prepared from (2S, 3R)-2-methoxy-3-hydroxy-butanoic acid dimethyl ester (see below) as a 1 : 1 mixture of isomers. Oil; IR (neat) 3000, 2940, 1750, 1450, 1390, 1270, 1200, 1130, 1090 cm⁻¹; ¹H NMR (200 MHz, CDCl₃) δ 4.78 - 4.67 (m, 1H), 4.15 - 3.95 (m, 1H), 3.8 - 3.65 (m, 4H), 3.45 - 3.25 (m, 6H), 1.3 - 1.2 (m, 6H); ¹³C NMR (50 MHz, C₆D₆) δ 171.3, 171.1, 101.8, 99.6, 78.9, 77.8, 77.6, 77.0, 57.1, 56.9, 52.1, 51.4, 51.1, 19.1, 15.3; MS (CI, NH₃) 224 (M + NH₄)⁺.

(2S, 3R)-3-methoxy-2-((1-methoxyethyl)oxy)-butanoic acid dimethyl ester (**37**). Prepared from (2S, 3R)-3-methoxy-2-hydroxy-butanoic acid dimethyl ester (see below) as a 3 : 2 mixture of isomers. Oil; IR (neat) 3000, 2940, 1700, 1440, 1400, 1210, 1090 cm⁻¹; ¹H NMR (200 MHz, CDCl₃) δ 4.8 - 4.68 (m, 1H), 4.23, 4.03 (d, J = 4.0 Hz; d, J = 5.3 Hz, 1H), 3.80 - 3.60 (m, 4H), 3.4 - 3.2 (m, 6H), 1.40 - 1.15 (m, 6H); ¹³C NMR (50 MHz, C₆D₆) δ 170.7, 101.5, 98.9, 54.9, 54.5, 73.7, 71.7, 58.3, 58.1, 51.3, 51.0, 19.9, 17.4, 16.2; MS (CI, NH₃) 224 (M + NH₄)⁺.

(±)-*trans*-2-fluoro-3-((1-methoxyethyl)oxy)-1,4-butanedioic acid dimethyl ester (**39**). Prepared from *trans*-2-fluoro-3-hydroxy-1,4-butanedioic acid dimethyl ester⁴ (see below) as a 2 : 1 mixture of isomers. Oil; IR (neat) 3000, 2960, 1770, 1745, 1440, 1400, 1280, 1210, 1140, 1080 cm⁻¹; ¹H NMR (200 MHz, CDCl₃) (**major isomer**) δ 5.34 (dd, J = 46.8, 2.5 Hz, 1H), 4.88 (q, J = 5.3 Hz, 1H), 4.76 (dd, J = 29.6, 2.5 Hz, 1H), 3.81 (s, 3H), 3.22 (s, 3H), 1.35 (d, J = 5.4 Hz, 3H); (**minor isomer**) δ 5.28 (dd, J = 47.1, 3.1 Hz, 1H), 4.73 (q, J = 5.3 Hz, 1H), 4.61 (dd, J = 27.2, 2.9 Hz, 1H), 3.84 (s, 3H), 3.35 (s, 3H), 1.29 (d, J = 5.4 Hz, 3H); ¹³C NMR (100 MHz, C₆D₆, mixture of isomers) δ 168.7, 168.7, 168.6, 168.6, 167.1, 167.0, 166.9, 166.7, 102.3, 100.0, 90.4, 90.1, 88.4, 88.1, 75.1, 74.9, 74.1, 73.9, 52.8, 51.9, 50.7, 18.9, 18.6; HRMS calcd for C₈H₁₂FO₅ (M - CH₃)⁺: 223.0618, found 223.0606.

(±)-*trans*-3-methyl-2-((1-methoxyethyl)oxy)-1,4-butanedioic acid dimethyl ester (**41**). Prepared from (±)-*trans*-3-hydroxy-2-methylbutanedioic acid dimethyl ester (prepared using the procedure previously described⁵ for the diethyl ester) as a 2 : 1 mixture of isomers. Oil; IR (neat) 3000, 2960, 1700, 1470, 1440,

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1400, 1270, 1210, 1150, 1090 cm^{-1} ; ^1H NMR (200 MHz, CDCl_3) δ 4.78, 4.69 (q, $J = 5.3$; q, $J = 5.1$ Hz, 1H), 4.62, 4.45 (d, $J = 4.85$; d, $J = 5.0$ Hz, 1H), 3.74 (s), 3.70 (s, 3H), 3.32 (s), 3.25 (s, 3H), 3.05 - 2.90 (m, 1H), 1.34 - 1.18 (m, 6H); ^{13}C NMR (50 MHz, C_6D_6) δ 172.9, 171.6, 102.0, 100.0, 76.3, 74.9, 52.5, 51.4, 51.2, 43.0, 42.7, 19.0, 11.6; MS (CI, NH_3) 252 ($\text{M} + \text{NH}_4$) $^+$; HRMS calcd for $\text{C}_9\text{H}_{15}\text{O}_6$ ($\text{M} - \text{CH}_3$) $^+$ 219.0869, found 219.0941.

(2S, 3R)-*cis*-2-fluoro-3-((1-methoxyethyl)oxy)-1,4-butanedioic acid dimethyl ester (43). Prepared from *cis*-2-fluoro-3 hydroxy-1,4-butanedioic acid dimethyl ester (see below) as a 2 : 1 mixture of isomers. Oil; IR (neat) 3000, 2980, 1770, 1745, 1440, 1400, 1300, 1215, 1130, 1090 cm^{-1} ; ^1H NMR (200 MHz, CDCl_3) δ 5.45 - 5.43 (m), 5.23 - 5.18 (m, 1H), 4.95 - 4.65 (m, 2H), 3.83 - 3.79 (m, 6H), 3.37 (s), 3.32 (s, 3H), 1.36 - 1.20 (m, 3H); ^{13}C NMR (50 MHz, C_6D_6) δ 168.3, 168.1, 166.9, 166.5, 101.8, 100.4, 91.6, 91.2, 87.8, 87.4, 74.4, 73.9, 52.8, 51.9, 51.9, 50.9, 19.0, 18.9; MS (CI) 256 ($\text{M} + \text{NH}_4$); HRMS calcd for $\text{C}_8\text{H}_{12}\text{RO}_5$ ($\text{M} - \text{CH}_3$) $^+$: 223.0618, found 223.0625; Anal. Calcd for $\text{C}_9\text{H}_{13}\text{FO}_6$: C, 45.38; H, 6.35. Found: C, 44.98; H, 6.13.

(4R, 5R)-2-(1-methylethyl)-1,3-dioxolane-4,5-dicarboxylic acid bis(*tert*-butyl)ester (49). To a solution of acetal 15 (3.4 g, 14.7 mmol) in MeOH (30 mL) was added powdered KOH (2.1 g, 37 mmol) and the resulting solution stirred at room temperature overnight. The mixture was concentrated and then dissolved in a minimum of water and cooled to 0 $^\circ\text{C}$. Concentrated HCl was added until the pH was 1-2 (pH paper) and then the solution was extracted with EtOAc (3 X 50 mL). Drying (MgSO_4) and removal of solvent gave 3.0 g (100 %) of a diacid which was used without further purification. $[\alpha]_D^{25} -46.6^\circ$ (c 1.46, EtOAc); IR (CHCl_3) 3300, 3010, 3000, 1740, 1420, 1220, 1110 cm^{-1} ; ^1H NMR (200 MHz, CDCl_3) δ 5.02 (d, $J = 5.1$ Hz, 1H), 4.89 (d, $J_{\text{AB}} = 3.9$ Hz, 1H), 4.81 (d, $J_{\text{AB}} = 3.9$ Hz, 1H), 2.04 - 1.91 (m, 1H), 1.02 (d, $J = 6.8$ Hz, 3H), 1.01 (d, $J = 6.8$ Hz, 3H); HRMS calcd for $\text{C}_8\text{H}_{12}\text{NaO}_6$: 227.0537, found 227.0525. To a suspension of this acid (3.0 g, 14.7 mmol) in CH_2Cl_2 (60 mL) was added Me_3COH (4.15 mL, 44.1 mmol) and DMAP (200 mg). After stirring for ca 5 min the suspension had cleared. DCC was then added (6.0 g, 29.4 mmol) and the mixture stirred at room temperature for 3 days whereupon it was diluted with ether (100 mL) and filtered. Concentration of the filtrate and flash chromatography of the residue gave ester 49 (3.67 g, 79 %). White solid; mp 69-70 $^\circ\text{C}$; $[\alpha]_D^{25} -41.7^\circ$ (c 1.20, CHCl_3); IR (CHCl_3) 3000, 2970, 1745, 1370, 1210, 1160, 1110 cm^{-1} ; ^1H NMR (200 MHz, CDCl_3) δ 5.00 (d, $J = 4.9$ Hz, 1H), 4.51 (d, $J_{\text{AB}} = 4.6$, 1H), 4.44 (d, $J_{\text{AB}} = 4.6$, 1H), 2.05 - 1.90 (m, 1H), 1.50 (s, 18H), 1.01 (d, $J = 6.9$, 3H), 1.00 (d, $J = 6.9$, 3H); ^{13}C NMR (100 MHz, C_6D_6) δ 169.3, 168.3, 111.5, 81.8, 81.7, 78.5, 78.4, 32.3, 27.8, 16.9; MS (CI, CH_4) 205 ($\text{M} + \text{H} - \text{tBu}$) $^+$; Anal. Calcd for $\text{C}_{16}\text{H}_{22}\text{O}_6$: C, 60.76; H, 8.86. Found: C, 60.92; H, 9.04.

(4R, 5R)-2-(1-methylethyl)-1,3-dioxolane-4,5-dicarboxylic acid dimethyl- d_3 ester (64). Prepared in 85 % yield from 15 using a procedure similar to that described above for 49 using CD_3OD in place of *tert*-butanol. Oil; $[\alpha]_D^{25} -46.5^\circ$ (c 1.73, CHCl_3); IR (neat) 2980, 2940, 2880, 2260, 2200, 2130, 2080, 1750, 1470, 1410, 1370, 1300, 1240, 1100 cm^{-1} ; ^1H NMR (200 MHz, CDCl_3) δ 5.00 (d, $J = 4.9$ Hz, 1H), 4.80 (d, $J_{\text{AB}} = 4.1$ Hz, 1H), 4.71 (d, $J_{\text{AB}} = 4.1$ Hz, 1H), 2.05-1.89 (m, 1H), 1.00 (d, $J = 6.9$ Hz, 3H), 0.99 (d, $J = 6.8$ Hz, 3H); ^{13}C NMR (50 MHz, C_6D_6) δ 170.2, 169.5, 111.5, 77.6, 77.5, 32.2, 16.9; MS (EI) 237 ($\text{M} - \text{H}$) $^+$; HRMS calcd for $\text{C}_{10}\text{H}_9\text{D}_6\text{O}_6$ ($\text{M} - \text{H}$) $^+$ 237.1245, found 237.1251; Anal. Calcd. for $\text{C}_{10}\text{H}_{10}\text{D}_6\text{O}_6$: C, 50.41; H, 6.77. Found: C, 50.48; H, 6.83.

General procedure for Me_2BBr promoted opening of tartrate acetals by higher order cuprates. A solution of Me_2BBr (ca 1.5 M, 1.25 equiv.) in CH_2Cl_2 was added dropwise to a cold (-78 $^\circ\text{C}$) solution of acetal in CH_2Cl_2 (0.1 M). The resulting mixture was stirred at room temperature for 1h before being cooled to -30 $^\circ\text{C}$ and stirred at this temperature for 15 min. A solution of $\text{Me}_2\text{Cu}(\text{CN})\text{Li}_2$ (3 equiv.) in THF (0.25 M) was then introduced via cannula (5 min addition) and the resulting solution stirred at -30 $^\circ\text{C}$ for 1h before being quenched with MeOH (10 equiv.). The mixture was then poured into an aqueous solution of NH_4Cl : NH_4OH (4 : 1), diluted with EtOAc and stirred at room temperature for 15 min. Brine was added, the phases separated and the aqueous layer extracted with EtOAc. The combined organic extracts were washed with brine and dried (MgSO_4) and concentrated *in vacuo*. The crude material was purified by flash chromatography. Diastereomeric ratios were determined by capillary gas chromatography. Physical properties and analytical data of products so obtained are listed below (where possible the isomers were separated and characterized. Major isomers were obtained by further chromatography. Samples of minor isomers were obtained by repeating the reaction and maintaining the temperature at -78 $^\circ\text{C}$ throughout).

(2R, 3R)-3-((undecan-2-yl)oxy)-2-hydroxy-1,4-butanedioic acid dimethyl ester (12ab). 12a: White solid; mp 26-27 $^\circ\text{C}$; $[\alpha]_D^{25} +23.2^\circ$ (c 0.91, CHCl_3); IR (neat) 3500, 2960, 2930, 2860, 1760, 1745, 1460, 1400, 1260, 1200, 1140, 1100 cm^{-1} ; ^1H NMR (200 MHz, CDCl_3) δ 4.58 (dd, $J = 9.1$, 2.2 Hz, 1H), 4.35 (d, $J = 2.2$ Hz, 1H), 3.81 (s, 3H), 3.80 (s, 3H), 3.5-3.4 (m, 1H), 3.03 (d, $J = 9.1$ Hz, 1H), 1.62 - 1.07 (m, 16H), 1.17 (d, $J = 6.2$ Hz, 3H), 0.87 (t, $J = 6.2$ Hz, 3H); ^{13}C NMR (50 MHz, C_6D_6) δ 171.7, 170.4, 78.5, 77.4, 73.1, 51.9, 51.7, 35.9, 32.3, 30.2, 30.0, 29.7, 25.4, 23.0, 20.2, 14.3; MS (FAB) 333 ($\text{M} + \text{H}$) $^+$; Anal. Calcd for $\text{C}_{17}\text{H}_{32}\text{O}_6$: C, 61.42; H, 9.70. Found: C, 61.24; H, 9.94. 12b: Oil; $[\alpha]_D^{25} +33.3^\circ$ (c 0.84, CHCl_3); IR (neat) 3500, 2960, 2930, 2850, 1760, 1745, 1470, 1440, 1270, 1210, 1140, 1100 cm^{-1} ; ^1H NMR (200 MHz, CDCl_3) δ 4.60 (dd, $J = 9.3$, 2.1 Hz, 1H), 4.37 (dd, $J = 2.1$ Hz, 1H), 3.80 (s, 3H), 3.79 (s, 3H), 3.6-3.4 (m, 1H), 3.02 (d, $J = 9.3$ Hz, 1H), 1.66-1.14 (m, 16H), 1.01 (d, $J = 5.9$ Hz, 3H), 0.87 (t, $J = 6.8$ Hz, 3H); ^{13}C NMR (50 MHz, C_6D_6) δ 171.7, 170.0, 77.2, 75.6, 73.2, 51.9, 51.6, 37.5, 32.3, 30.1, 29.8, 25.8, 23.1, 18.5, 14.3; MS (CI) 350 ($\text{M} + \text{NH}_4$); Anal. Calcd for $\text{C}_{17}\text{H}_{32}\text{O}_6$: C, 61.42; H, 9.70. Found: C, 61.14; H, 9.89.

(2R, 3R)-3-((1-cyclohexylethyl)oxy)-2-hydroxy-1,4-butanedioic acid dimethyl ester (14ab). 14a: White solid; $[\alpha]_D^{25} +41.2^\circ$ (c 0.73, CHCl_3); IR (CHCl_3) 3560, 2990, 2920, 2860, 1760, 1450, 1435, 1400, 1200, 1140, 1090 cm^{-1} ; ^1H NMR (200 MHz, CDCl_3) δ 4.57 (dd, $J = 9.3$, 2.2 Hz, 1H), 4.38 (d, $J = 2.2$ Hz, 1H), 3.82 (s, 3H), 3.80 (s, 3H) 3.30 - 3.20 (m, 1H), 3.03 (d, $J = 9.3$ Hz, 1H), 1.82 - 0.82 (m, 11H), 1.12 (d, $J = 6.5$ Hz, 3H); ^{13}C NMR (50 MHz, C_6D_6) δ 171.7, 170.4, 81.3, 78.9, 73.1, 51.9, 51.6, 42.3, 29.2, 27.4, 26.9, 26.7, 16.5; MS (CI, CH_4) 289 ($\text{M} + \text{H}$) $^+$; Anal. Calcd for $\text{C}_{14}\text{H}_{24}\text{O}_6$: C, 58.32; H, 8.39. Found: C, 58.36; H, 8.68. 14b: White solid; $[\alpha]_D^{25} +39.4^\circ$ (c 0.67, CHCl_3); IR (CHCl_3) 3650, 2930, 2860, 1755, 1450, 1440, 1200, 1140, 1095 cm^{-1} ; ^1H NMR (200 MHz, CDCl_3) δ 4.60 (d, $J = 6.6$ Hz, 1H), 4.38 (d, $J = 2.3$ Hz, 1H), 3.79 (s, 3H), 3.78 (s, 3H), 3.35 (quint, $J = 6.0$ Hz, 1H) 3.02 (m, 1H), 1.89 - 0.88 (m, 11H), 0.94 (d, $J = 6.1$ Hz, 3H); ^{13}C NMR (50 MHz, C_6D_6) δ 171.7, 169.8, 78.9, 76.8, 73.2, 51.8, 51.5, 43.9, 28.9, 28.6, 27.0, 26.6, 14.8; MS (CI) 289 ($\text{M} + \text{H}$); Anal. Calcd for $\text{C}_{14}\text{H}_{24}\text{O}_6$: C, 58.32; H, 8.39. Found: C, 58.20; H, 8.60.

(2R, 3R)-3-((3-methylbutan-2-yl)oxy)-2-hydroxy-1,4-butanedioic acid dimethyl ester (16ab). 16a: Oil; $[\alpha]_D^{25} +34.5^\circ$ (c 0.85, CHCl_3); IR (neat) 3500, 2960, 1760, 1740, 1440, 1270,

1210, 1150, 1100 cm^{-1} ; ^1H NMR (200 MHz, CDCl_3) δ 4.57 (dd, $J = 9.2, 2.1$ Hz, 1H), 4.38 (d, $J = 2.2$ Hz, 1H), 3.81 (s, 6H), 3.28 (dq, $J_q = 6.3$, $J_d = 4.6$ Hz, 1H), 3.04 (d, $J = 9.2$ Hz, 1H), 1.81 - 1.69 (m, 1H), 1.10 (d, $J = 6.4$ Hz, 3H), 0.82 (d, $J = 9.3$ Hz, 3H), 0.79 (d, $J = 9.2$ Hz, 3H); ^{13}C NMR (50 MHz, C_6D_6) δ 171.8, 170.4, 81.6, 78.8, 73.0, 51.9, 51.7, 31.5, 18.5, 16.5, 15.3; HRMS calcd for $\text{C}_{11}\text{H}_{21}\text{O}_6$ ($\text{M} + \text{H}^+$) 249.1338, found 249.1319; Anal. Calcd for $\text{C}_{11}\text{H}_{20}\text{O}_6$: C, 53.22; H, 8.12. Found: C, 52.98; H, 8.20. **16b**: Oil; $[\alpha]_D +49.3^\circ$ (c 1.60, CHCl_3); IR (neat) 3500, 2960, 1760, 1440, 1270, 1200, 1140, 1100 cm^{-1} ; ^1H NMR (200 MHz, CDCl_3) δ 4.54 (dd, $J = 8.9, 2.6$ Hz, 1H), 4.38 (d, $J = 2.4$ Hz, 1H), 3.80 (s, 6H), 3.44 - 3.32 (m, 1H), 3.02 (d, $J = 9.0$ Hz, 1H), 1.89 - 1.71 (m, 1H), 0.94 (d, $J = 6.2$ Hz, 3H), 0.89 (d, $J = 6.8$ Hz, 3H), 0.88 (d, $J = 6.8$ Hz, 3H); ^{13}C NMR (50 MHz, C_6D_6) δ 171.7, 169.9, 79.4, 76.9, 73.1, 51.8, 51.5, 33.7, 18.3, 17.8, 14.2; MS (CI) 266 ($\text{M} + \text{NH}_4$); Anal. Calcd for $\text{C}_{11}\text{H}_{20}\text{O}_6$: C, 53.22; H, 8.12. Found: C, 53.52; H, 8.22.

(2R, 3R)-3-((octan-2-yl)oxy)-2-hydroxy-1,4-butanedioic acid dimethyl ester (18ab). **18a**: Oil; $[\alpha]_D +24.8^\circ$ (c 1.87, CHCl_3); IR (neat) 3500, 2980, 2920, 2840, 1750, 1460, 1440, 1380, 1260, 1200, 1140, 1100 cm^{-1} ; ^1H NMR (200 MHz, CDCl_3) δ 4.58 (dd, $J = 9.1, 2.3$ Hz, 1H), 4.36 (d, $J = 2.3$ Hz, 1H), 3.81 (s, 3H), 3.80 (s, 3H), 3.5 - 3.35 (m, 1H), 3.07 (d, $J = 9.1$ Hz, 1H), 1.55 - 1.15 (m, 10H), 1.17 (d, $J = 6.2$ Hz, 3H), 0.87 (d, $J = 6.8$ Hz, 3H); ^{13}C NMR (50 MHz, C_6D_6) δ 171.7, 170.4, 78.5, 77.4, 73.1, 51.9, 51.7, 35.8, 32.2, 29.9, 25.3, 23.0, 20.2, 14.3; MS (CI) 291 ($\text{M} + \text{H}$); Anal. Calcd for $\text{C}_{14}\text{H}_{26}\text{O}_6$: C, 57.91; H, 9.03. Found: C, 57.61; H, 9.10. **18b**: Oil; $[\alpha]_D +34.2^\circ$ (c 1.62, CHCl_3); IR (neat) 3500, 2960, 2940, 2820, 1750, 1460, 1430, 1370, 1330, 1260, 1140, 1100 cm^{-1} ; ^1H NMR (200 MHz, CDCl_3) δ 4.62 (dd, $J = 9.4, 2.3$ Hz, 1H), 4.38 (d, $J = 2.3$ Hz, 1H), 3.81 (s, 3H), 3.80 (s, 3H), 3.6 - 3.4 (m, 1H), 3.04 (d, $J = 9.4$ Hz, 1H), 1.65 - 1.15 (m, 10H), 1.01 (d, $J = 6.1$ Hz, 3H), 0.88 (d, $J = 6.5$ Hz, 3H); ^{13}C NMR (50 MHz, C_6D_6) δ 171.7, 169.9, 77.1, 75.6, 73.2, 51.8, 51.5, 37.5, 32.2, 29.8, 25.7, 23.0, 18.4, 14.3; MS (CI) 291 ($\text{M} + \text{H}$); Anal. Calcd for $\text{C}_{14}\text{H}_{26}\text{O}_6$: C, 57.91; H, 9.03. Found: C, 57.97; H, 9.13.

(2R, 3R)-3-((tetradecan-5-yl)oxy)-2-hydroxy-1,4-butanedioic acid dimethyl ester (19ab). **> 20** : 1 Mixture of isomers: Oil; IR (neat) 3550, 2960, 2930, 2860, 1760, 1740, 1440, 1260, 1200, 1140, 1100 cm^{-1} ; ^1H NMR (200 MHz, CDCl_3) δ 4.57 (dd, $J = 9.4, 2.2$ Hz, 1H), 4.38 (d, $J = 2.2$ Hz, 1H), 3.80 (s, 6H), 3.4 - 3.3 (m, 1H), 3.02 (d, $J = 9.3$ Hz, 1H), 1.63 - 1.09 (m, 22H), 0.94-0.82 (m, 6H); ^{13}C NMR (50 MHz, C_6D_6) δ 171.7, 170.1, 80.0, 77.7, 73.2, 51.9, 51.5, 34.0, 32.7, 32.3, 30.4, 30.0, 29.8, 27.7, 24.9, 23.3, 23.0, 14.3; MS (CI) 373 ($\text{M} + \text{H}$); HRMS calcd for $\text{C}_{20}\text{H}_{39}\text{O}_6$ ($\text{M} + \text{H}^+$) 375.2746, found 375.2706; Anal. Calcd for $\text{C}_{20}\text{H}_{38}\text{O}_6$: C, 64.14; H, 10.23. Found: C, 64.03; H, 10.53.

(2R, 3R)-3-((2-methylheptan-3-yl)oxy)-2-hydroxy-1,4-butanedioic acid dimethyl ester (60ab). **12** : 1 Mixture of isomers: Oil; IR (neat) 3500, 2960, 2880, 1760, 1740, 1470, 1435, 1260, 1200, 1140, 1090 cm^{-1} ; ^1H NMR (200 MHz, CDCl_3) δ 4.57 (dd, $J = 9.6, 2.2$ Hz, 1H), 4.42-4.39 (m, 1H), 3.80 (s, 3H), 3.79 (s, 3H), 3.25-3.17 (m, 1H), 3.08 - 3.00 (m, 1H), 1.92 - 1.72 (m, 1H), 1.6 - 1.2 (m, 6H), 0.98 - 0.75 (m, 9H); ^{13}C NMR (50 MHz, C_6D_6) δ 171.8, 170.1, 84.4, 84.3, 77.6, 77.4, 73.2, 51.9, 51.5, 43.5, 42.3, 30.7, 29.4, 28.9, 28.3, 27.4, 23.3, 18.5, 18.3, 17.8, 16.4, 14.3, 14.2; MS (CI) 308 ($\text{M} + \text{NH}_4$); Anal. Calcd for $\text{C}_{14}\text{H}_{26}\text{O}_6$: C, 57.91; H, 9.03. Found: C, 58.28; H, 9.16.

(2R, 3R)-3-((hexan-2-yl)oxy)-2-hydroxy-1,4-butanedioic acid dimethyl ester (32ab). **32a**: Oil; $[\alpha]_D +42.0^\circ$ (c 1.17, CHCl_3); IR (neat) 3500, 2960, 2940, 2880, 1760, 1440, 1260, 1205, 1140, 1100 cm^{-1} ; ^1H NMR (200 MHz, CDCl_3) δ 4.61 (dd, $J = 9.3, 2.2$ Hz, 1H), 4.36 (d, $J = 2.2$ Hz, 1H), 3.81 (s, 3H), 3.79 (s,

3H), 3.55 - 3.42 (m, 1H), 3.02 (d, $J = 9.3$ Hz, 1H), 1.73 - 1.16 (m, 6H), 1.13 (d, $J = 6.1$ Hz, 3H), 0.92-0.85 (m, 3H); ^{13}C NMR (50 MHz, C_6D_6) δ 171.8, 170.1, 77.2, 75.6, 73.1, 51.9, 51.6, 37.1, 27.8, 23.1, 18.4, 14.3; HRMS calcd for $\text{C}_{12}\text{H}_{23}\text{O}_6$ ($\text{M} + \text{H}^+$) 263.1494, found 263.1462; Anal. Calcd. for $\text{C}_{12}\text{H}_{22}\text{O}_6$: C, 54.93; H, 8.45. Found: C, 54.69; H, 8.52. **32b**: Oil; $[\alpha]_D +25.0^\circ$ (c 0.87, CHCl_3); IR (neat) 3500, 2960, 2940, 2870, 1760, 1430, 1250, 1200, 1140, 1090 cm^{-1} ; ^1H NMR (200 MHz, CDCl_3) δ 4.58 (dd, $J = 9.1, 2.2$ Hz, 1H), 4.35 (d, $J = 2.2$ Hz, 1H), 3.81 (s, 6H), 3.50 - 3.38 (m, 1H), 3.04 (d, $J = 9.2$ Hz, 1H), 1.65 - 1.06 (m, 6H), 1.16 (d, $J = 6.2$ Hz, 3H), 0.89 (t, $J = 6.3$ Hz, 3H); ^{13}C NMR (50 MHz, C_6D_6) δ 171.7, 170.4, 78.5, 77.3, 73.1, 51.9, 51.7, 35.5, 27.3, 23.2, 20.2, 14.2; MS (CI) 280 ($\text{M} + \text{NH}_4$); HRMS calcd for $\text{C}_{12}\text{H}_{23}\text{O}_6$ ($\text{M} + \text{H}^+$) 263.1494, found 263.1443; Anal. Calcd for $\text{C}_{12}\text{H}_{22}\text{O}_6$: C, 54.95; H, 8.45. Found: C, 54.57; H, 8.65.

(2R, 3R)-3-((1-phenyldecyl)oxy)-2-hydroxy-1,4-butanedioic acid dimethyl ester (20ab). **14** : 1 Mixture of isomers: IR (neat) 3500, 2920, 2840, 1750, 1450, 1440, 1260, 1200, 1130, 1090 cm^{-1} ; ^1H NMR (200 MHz, CDCl_3) δ 7.41-7.17 (m, 5H), 4.56 (dd, $J = 8.8, 2.4$ Hz, 1H), 4.33 (dd, $J = 2.4$ Hz, 1H), 4.23 (t, $J = 6.8$ Hz, 1H), 3.88 (s, 3H), 3.57 (s, 3H), 3.12 (d, $J = 8.8$ Hz, 1H), 1.95-1.75 (m, 1H), 1.70-1.50 (m, 1H), 1.4-1.0 (m, 14H), 0.87 (t, $J = 6.9$ Hz, 3H); ^{13}C NMR (50 MHz, CDCl_3) δ 171.8, 169.8, 140.5, 128.2, 128.1, 127.3, 84.8, 77.9, 72.4, 52.7, 52.1, 36.7, 31.8, 31.7, 29.5, 29.3, 25.7, 22.6, 14.1; MS (CI) 393 ($\text{M} + \text{H}$), 267 ($\text{M} - \text{C}_9\text{H}_{19}$); HRMS calcd for $\text{C}_{13}\text{H}_{15}\text{O}_6$ ($\text{M} - \text{C}_9\text{H}_{19}$) 267.0868, found 267.0875; Anal. Calcd for $\text{C}_{22}\text{H}_{34}\text{O}_6$: C, 66.98; H, 8.69. Found: C, 66.67; H, 8.80.

(2R, 3R)-3-((1-dodecen-3-yl)oxy)-2-hydroxy-1,4-butanedioic acid dimethyl ester (21ab). **21a**: Oil; $[\alpha]_D -2.3^\circ$ (c 1.04, CHCl_3); IR (neat) 3500, 2920, 2860, 1760, 1740, 1440, 1260, 1200, 1140, 1090 cm^{-1} ; ^1H NMR (200 MHz, CDCl_3) δ 5.82 - 5.64 (m, 1H), 5.23 - 5.05 (m, 2H), 4.56 (dd, $J = 8.7, 2.3$ Hz, 1H), 4.28 (d, $J = 2.3$ Hz, 1H), 3.83 (s, 3H), 3.76 (s, 3H), 3.70 - 3.55 (m, 1H), 3.04 (d, $J = 8.8$ Hz, 1H), 1.76 - 1.09 (m, 16H), 0.87 (t, $J = 6.1$ Hz, 3H); ^{13}C NMR (50 MHz, C_6D_6) δ 171.9, 170.1, 139.1, 117.1, 84.6, 78.6, 73.1, 51.9, 51.6, 35.3, 32.3, 30.0, 29.7, 25.6, 23.1, 14.3; MS (CI) 362 ($\text{M} + \text{NH}_4$); HRMS calcd for $\text{C}_{18}\text{H}_{32}\text{O}_6$ (M^+) 344.2198, found 344.2169; Anal. Calcd for $\text{C}_{18}\text{H}_{32}\text{O}_6$: C, 62.77; H, 9.36. Found C, 62.91; H, 9.35. **21b**: Oil; $[\alpha]_D +22.8^\circ$ (c 0.53, CHCl_3); IR (CHCl_3) 3560, 2920, 2860, 1755, 1440, 1270, 1140, 1090 cm^{-1} ; ^1H NMR (200 MHz, CDCl_3) δ 5.50 - 5.06 (m, 3H), 4.62 - 4.56 (m, 1H), 4.36 (d, $J = 2.2$ Hz, 1H), 3.80 (m, 7H), 3.04 - 2.99 (m, 1H), 1.81 - 1.11 (m, 16H), 0.87 (t, $J = 6.0$ Hz, 3H); ^{13}C NMR (50 MHz, C_6D_6) δ 171.7, 169.8, 138.2, 118.4, 81.5, 76.4, 72.9, 51.8, 51.6, 35.8, 32.3, 30.0, 29.7, 25.4, 23.1, 14.3; MS (CI) 362 ($\text{M} + \text{NH}_4$); HRMS calcd for $\text{C}_{18}\text{H}_{32}\text{O}_6$ (M^+) 344.2198, found 344.2181.

(2R, 3R)-3-((undecan-2-yl)oxy)-2-hydroxy-1,4-butanedioic acid bis(1-methylethyl) ester (25). **25** : 1 Mixture of isomers: Oil; IR (neat) 3500, 2980, 2920, 2860, 1750, 1465, 1455, 1385, 1370, 1260, 1200, 1140, 1100 cm^{-1} ; ^1H NMR (200 MHz, CDCl_3) δ 5.12 (octet, $J = 6.3$ Hz, 2H), 4.50 (dd, $J = 9.0, 2.2$ Hz, 1H), 4.29 (d, $J = 2.2$ Hz, 1H), 3.6-3.4 (m, 1H), 3.05 (d, $J = 9.0$ Hz, 1H), 1.7-1.2 (m, 16 H), 1.30 (d, $J = 6.3$ Hz, 12H), 1.18 (d, $J = 6.2$ Hz, 3H), 0.88 (t, $J = 6.2$ Hz, 3H); ^{13}C NMR (50 MHz, C_6D_6) δ 171.0, 169.6, 78.5, 77.2, 73.3, 69.9, 68.6, 36.2, 32.2, 30.2, 30.0, 29.7, 25.7, 23.0, 21.7, 20.9, 14.3; MS (EI) 389 (M^+); HRMS calcd for $\text{C}_{21}\text{H}_{41}\text{O}_6$ 389.2903, found 389.2894; Anal. Calcd for $\text{C}_{21}\text{H}_{40}\text{O}_6$: C, 64.92; H, 10.38. Found: C, 65.01; H, 10.70.

(2R, 3R)-3-((undecan-2-yl)oxy)-2-hydroxy-4,5-dicarboxylic acid bis(dimethyl amide) (27): **25** : 1 Mixture of isomers: IR (neat) 3400, 2960, 2920, 2870, 1650, 1500, 1460, 1400, 1380, 1260, 1080 cm^{-1} ; ^1H NMR (200 MHz, CDCl_3) δ 4.71 (dd, $J = 6.8,$

3.2 Hz, 1H), 4.38 (d, J = 3.2 Hz, 1H), 3.97 (d, J = 6.8 Hz, 1H), 3.28 (s, 3H), 3.3-3.1 (m, 1H), 3.12 (s, 3H), 2.99 (s, 3H), 2.97 (s, 3H), 1.8-1.5 (m, 1H), 1.05 (d, J = 6.3 Hz, 3H), 0.87 (d, J = 6.0 Hz, 3H), 0.83 (d, J = 6.7 Hz, 3H); ^{13}C NMR (50 MHz, C_6D_6) δ 171.1, 170.9, 81.9, 81.7, 71.0, 37.3, 36.3, 36.0, 35.4, 32.8, 18.3, 17.6, 15.9; MS (CI) 275 (M+H), 230, 202; HRMS calcd for $\text{C}_{10}\text{H}_{20}\text{NO}_3$ (M-CONMe₂) 202.1443, found 202.1446; Anal. Calcd for $\text{C}_{13}\text{H}_{26}\text{N}_2\text{O}_4$: C, 56.91; H, 9.55; N, 10.21. Found: C, 56.54; H, 9.39; N, 9.87.

(2S, 3S)-3-((undecan-2-yl)oxy)-2-hydroxy-1,4-methoxybutane (29). 2 : 1 Mixture of isomers. Oil; IR (neat) 3480, 2940, 1460, 1130 cm^{-1} ; ^1H NMR (200 MHz, CDCl_3) δ 3.83 (b, 1H), 3.6-3.3 (m, 13H), 2.5 (b, 1H), 1.6-1.1 (m, 19H), 0.95-0.8 (m, 3H); MS (CI) 305 (MH⁺); HRMS calcd for $\text{C}_{17}\text{H}_{37}\text{O}_4$ (M + H)⁺: 305.2692, found 305.2676; Anal. Calcd for $\text{C}_{17}\text{H}_{36}\text{O}_4$: C, 67.06; H, 11.92. Found: C, 67.00; H, 12.16.

(2S, 3S)-3-((undecan-2-yl)oxy)-3-hydroxybutane (31). 1 : 1 Mixture of isomers. Oil; IR (neat) 3500, 2960, 2920, 2860, 1460, 1380, 1090 cm^{-1} ; ^1H NMR (200 MHz, CDCl_3) δ 3.6-3.4 (m, 2H), 3.25-3.10 (m, 1H), 2.7 (b, 1H), 1.7-0.7 (m, 28H); MS (CI) 245 (MH⁺); HRMS calcd for $\text{C}_{15}\text{H}_{33}\text{O}_2$ (M + H)⁺: 245.2480, found 245.2473; Anal. Calcd for $\text{C}_{15}\text{H}_{32}\text{O}_2$: C, 73.71; H, 13.20. Found: C, 73.93; H, 13.54.

(2R, 3R)-2-benzyloxy-3-((hexan-2-yl)oxy)-1,4-butanedioic acid dimethyl ester (34). Acetal 33 (119.6 mg, 0.37 mmol) was treated with Me_2BBr and $\text{Bu}_2\text{Cu}(\text{CN})\text{Li}_2$ to afford adduct 34 (19.9 mg, 14 %) as a 7 : 1 mixture of isomers. Oil; IR (neat) 2960, 1765, 1735, 1460, 1440, 1275, 1205, 1155, 1105 cm^{-1} ; ^1H NMR (200 MHz, CDCl_3) δ 7.38-7.22 (m, 5H), 4.87 (d, J = 12.2 Hz, 1H), 4.39 (m, 3H), 3.77 (s, 3H), 3.62 (s, 3H), 3.5-3.4 (m, 1H), 1.7-0.85 (m, 12H); ^{13}C NMR (50 MHz, CDCl_3) δ 170.2, 169.9, 137.0, 128.3, 128.3, 127.9, 78.6, 77.4, 76.8, 73.1, 52.1, 51.9, 36.5, 27.5, 22.7, 18.5, 14.0; MS (CI) 353 (MH⁺), 269 (M-C₆H₁₂); HRMS calcd for $\text{C}_{19}\text{H}_{29}\text{O}_6$ (M + H)⁺ 353.1964, found 353.1997; Anal. Calcd for $\text{C}_{19}\text{H}_{28}\text{O}_6$: C, 64.75; H, 8.01. Found: C, 64.76; H, 8.23.

(2S, 3R)-2-methoxy-3-((hexan-2-yl)oxy)-butanoic acid methyl ester (36). Acetal 35 (78.4 mg, 0.38 mmol) was treated with Me_2BBr and $\text{Bu}_2\text{Cu}(\text{CN})\text{Li}_2$ to afford adduct 36 (37.7 mg, 43 %) as a 1 : 1 mixture of isomers. Oil; IR (neat) 2960, 2930, 1700, 1460, 1380, 1340, 1275, 1200, 1100 cm^{-1} ; ^1H NMR (200 MHz, CDCl_3) δ 3.85-3.67 (m, 5H), 3.5-3.37 (m, 4H), 1.53-0.82 (m, 15H); ^{13}C NMR (50 MHz, C_6D_6) δ 171.9, 171.5, 81.2, 80.1, 78.0, 77.8, 76.9, 75.3, 57.1, 51.0, 37.3, 36.2, 27.9, 27.8, 23.1, 20.5, 19.0, 15.5, 14.3; MS (CI, CH₄) 233 (M + H)⁺.

(2S, 3R)-3-methoxy-2-((hexan-2-yl)oxy)-butanoic acid methyl ester (38). Acetal 37 (78.0 mg, 0.38 mmol) was treated with Me_2BBr and $\text{Bu}_2\text{Cu}(\text{CN})\text{Li}_2$ to afford adduct 38 (47.8 mg, 54 %) as a 1 : 1 mixture of isomers. Oil; IR (neat) 2960, 2930, 1755, 1470, 1270, 1200, 1165, 1100 cm^{-1} ; ^1H NMR (200 MHz, CDCl_3) δ 3.95-3.60 (m, 5H), 3.45-3.25 (m, 4H), 1.65-0.80 (m, 15H); ^{13}C NMR (50 MHz, C_6D_6) δ 170.9, 85.1, 85.9, 75.1, 74.1, 73.6, 58.3, 58.2, 51.0, 37.3, 28.1, 23.1, 20.7, 20.2, 17.6, 16.4, 14.3; MS (CI, CH₄) 233 (M + H)⁺; Anal. Calcd. for $\text{C}_{12}\text{H}_{24}\text{O}_4$: C, 62.04; H, 10.41. Found: 62.22; H, 10.81.

(±)-trans-2-fluoro-3-((hexan-2-yl)oxy)-1,4-butanedioic acid dimethyl ester (40). Acetal 39 (86.0 mg, 0.38 mmol) was treated with Me_2BBr and $\text{Bu}_2\text{Cu}(\text{CN})\text{Li}_2$ to afford adduct 40 (7.1 mg, 7 %) as a 7 : 1 mixture of isomers. Oil; IR (CHCl₃) 2960, 2940, 1770, 1740, 1440, 1280, 1150, 1090 cm^{-1} ; ^1H NMR (200 MHz, CDCl_3) δ 5.31 (dd, J = 47.1, 2.7 Hz, 1H), 4.47 (dd, J = 30.1, 2.7 Hz, 1H), 3.83 (s, 3H), 3.81 (s, 3H), 3.60-3.48 (m, 1H), 1.71-0.80 (m, 9H), 1.05 (d, J = 6.5 Hz, 3H); MS (CI, CH₄) 265 (M+H)⁺.

(±)-trans-2-methyl-3-((hexan-2-yl)oxy)-1,4-butanedioic acid dimethyl ester (42). Acetal 41 (62.0 mg, 0.26 mmol) was treated with Me_2BBr and $\text{Bu}_2\text{Cu}(\text{CN})\text{Li}_2$ to afford 41 (28.5 mg, 41 %) as a 1.6 : 1 mixture of isomers. Oil; IR (neat) 2960, 1750, 1460, 1430, 1270, 1200, 1150, 1100 cm^{-1} ; ^1H NMR (200 MHz, CDCl_3) δ 3.95-3.85 (m, 1H), 3.82-3.60 (m, 4H), 3.36(s), 3.35 (s, 3H), 1.65-0.80 (m, 15H); ^{13}C NMR (50 MHz, C_6D_6) δ 173.0, 172.2, 171.8, 78.2, 77.1, 76.9, 75.2, 51.3, 51.2, 43.1, 42.9, 37.2, 35.8, 27.9, 27.6, 23.1, 23.0, 20.3, 18.7, 14.2, 11.7, 11.5; MS (CI, CH₄) 261 (M + H)⁺.

(2S, 2R)-cis-2-fluoro-3-((hexan-2-yl)oxy)-1,4-butanedioic acid dimethyl ester (44). Acetal 43 (86.0 mg, 0.38 mmol) was treated with Me_2BBr and $\text{Bu}_2\text{Cu}(\text{CN})\text{Li}_2$ to afford adduct 44 (22.0 mg, 22 %) as a 1.6 : 1 mixture of isomers. Oil; IR (neat) 2960, 2930, 1770, 1745, 1440, 1300, 1270, 1220, 1140 cm^{-1} ; ^1H NMR (200 MHz, CDCl_3) δ 5.41-5.38 (m), 5.18-5.13 (m, 1H), 4.53-4.38 (m, 1H), 3.82-3.78 (m, 3H), 3.69-3.54 (m, 1H), 1.70-1.10 (m, 9H), 0.93-0.85 (m, 3H); MS (CI, CH₄) 265 (M + H)⁺.

(±)-1,4-cis-2-((hexan-2-yl)oxy)-3-hydroxy-1,4-butanedioic acid dimethyl ester (46). Acetal 45 (77.6 mg, 0.38 mmol) was treated with Me_2BBr and $\text{Bu}_2\text{Cu}(\text{CN})\text{Li}_2$ to afford adduct 46 (28.9 mg, 29 %) as a 1.6 : 1 mixture of isomers. Oil; IR (neat) 3500, 2960, 2940, 2870, 1750, 1440, 1380, 1340, 1250, 1210, 1130, 1110 cm^{-1} ; ^1H NMR (100 MHz, CDCl_3) δ 4.60-4.55 (m, 1H), 4.35-4.25 (m, 1H), 3.79, 3.76 (s, 3H), 3.77, 3.76 (s, 3H), 3.63-3.50 (m, 1H), 3.14-3.07 (m, 1H), 1.69-1.20 (m, 6H), 1.17, 1.11 (d, J = 6.2, J = 6.1 Hz, 3H), 0.94-0.85 (m, 3H); ^{13}C NMR (50 MHz, C_6D_6) δ 171.8, 170.2, 169.9, 79.9, 78.8, 78.0, 76.3, 72.7, 72.6, 52.0, 51.5, 51.3, 37.0, 36.0, 27.8, 27.7, 23.0, 20.3, 18.9, 14.3; MS (CI, CH₄) 263 (M+1)⁺; Anal. Calcd for $\text{C}_{12}\text{H}_{22}\text{O}_6$: C, 54.95; H, 8.45. Found: C, 54.70; H, 8.43.

(2R, 3R)-3-((3-methylbutan-2-yl)oxy)-2-hydroxy-1,4-butanedioic acid dimethyl-d₃ ester (66). 66a: Oil; $[\alpha]^{25}_{\text{D}}$ +32.9° (c 2.04, CHCl₃); IR (neat) 3500, 2980, 2860, 2260, 2190, 2130, 2090, 1750, 1470, 1390, 1280, 1230, 1210, 1140, 1080 cm^{-1} ; ^1H NMR (200 MHz, CDCl_3) δ 4.59 (dd, J = 9.2, 2.2 Hz, 1H), 4.38 (d, J = 2.2 Hz, 1H) 3.33-3.24 (m, 1H), 3.07 (d, J = 9.3 Hz, 1H), 1.80-1.71 (m, 1H), 1.11 (d, J = 6.4 Hz, 3H), 0.84 (d, J = 6.9 Hz, 3H), 0.79 (d, J = 6.8 Hz, 3H); ^{13}C NMR (50 MHz, C_6D_6) δ 171.8, 170.4, 81.5, 78.8, 73.1, 31.5, 18.5, 16.5, 15.4; MS (CI) 272 (M+NH₄); Anal. Calcd. for $\text{C}_{11}\text{H}_{14}\text{D}_6\text{O}_6$: C, 51.95; H, 7.93. Found: C, 52.18; H, 7.73. 66b: Oil; $[\alpha]^{25}_{\text{D}}$ +42.8° (c 1.01, CHCl₃); IR (neat) 3500, 2960, 2860, 2260, 2200, 2140, 2090, 1750, 1470, 1380, 1280, 1230, 1210, 1140, 1100, 1090 cm^{-1} ; ^1H NMR (200 MHz, CDCl_3) δ 4.62 (dd, J = 9.6, 2.4 Hz, 1H), 4.39 (d, J = 2.4 Hz, 1H), 3.42-3.37 (m, 1H), 3.04 (d, J = 9.6 Hz, 1H), 1.87-1.77 (m, 1H), 0.95 (d, J = 6.2 Hz, 3H), 0.90 (d, J = 6.8 Hz, 3H), 0.88 (d, J = 6.8 Hz, 3H); ^{13}C NMR (50 MHz, C_6D_6) δ 171.7, 169.9, 79.4, 76.9, 73.1, 33.8, 18.3, 17.8, 14.3; MS (CI) 272 (M+NH₄).

General procedure for Me_2BBr promoted opening of tartrate acetals using thiophenol. Preparation of compounds. A solution of Me_2BBr (ca 1.5M, 1.25 equiv.) in CH_2Cl_2 was added dropwise to a cold (-78 °C) solution of acetal in CH_2Cl_2 (0.1 M). The resulting solution was stirred at ambient temperature for 1h before being cooled to -78 °C and stirred at that temperature for 15 min. $\text{Et}(\text{iPr})_2\text{N}$ (4 equiv.) or Et_3N (4 equiv.) was then added dropwise followed immediately by a solution of PhSH in CH_2Cl_2 (1.0 M). It is imperative that the PhSH solution be injected as rapidly as possible. After stirring for 1h at -78 °C, the solution was poured into a solution of NaHCO_3 in water and stirred 15 min. Extraction with EtOAc was followed by washing with brine and drying over MgSO_4 . Flash chromatography

afforded the pure products. Physical properties and analytical data are given below.

(2R, 3R)-3-((1-thiophenyl-1-cyclohexylmethyl)oxy)-2-hydroxy-1,4-butanedioic acid dimethyl ester (22). **22a:** White solid; mp 61 °C; $[\alpha]_D^{25} -58.4^\circ$ (c 1.19, CHCl₃); IR (CHCl₃) 3550, 3000, 2930, 2860, 1750, 1460, 1440, 1260, 1200, 1130, 1100, 1080 cm⁻¹; ¹H NMR (200 MHz, CDCl₃) δ 7.60 - 7.45 (m, 2H), 7.35 - 7.25 (m, 3H), 4.57 (s, 1H), 4.54 (dd, J = 7.5, 2.4 Hz, 1H), 4.45 (d, J = 6.8 Hz, 1H), 3.78 (s, 3H), 3.75 (s, 3H), 3.02 (d, J = 8.8 Hz, 1H), 2.0 - 1.6 (m, 6H), 1.3 - 1.0 (m, 5H); ¹³C NMR (100.6 MHz, CDCl₃) δ 171.5, 169.8, 133.9, 133.0m 128.9, 127.6, 98.0, 78.3, 72.0, 52.7, 52.4, 42.9, 29.6, 29.3, 26.2, 25.9; MS (EI) 273 (M - SPh)⁺; Anal. Calcd for C₁₉H₂₆O₆S: C, 59.64; H, 6.85. Found: C, 59.78; H, 6.96. **22b:** Colorless crystals; mp 69 °C; $[\alpha]_D^{25} +37.7^\circ$ (c 0.70, CHCl₃); IR (CHCl₃) 3550, 3000, 2930, 2880, 1755, 1590, 1480, 1440, 1400, 1130, 1110, 1090 cm⁻¹; ¹H NMR (200 MHz, CDCl₃) δ 7.39 - 7.25 (m, 5H), 4.95 (d, J = 2.2 Hz, 1H), 4.89 (d, J = 4.8 Hz, 1H), 4.62 (dd, J = 9.4, 2.2 Hz, 1H), 3.82 (s, 3H), 3.63 (s, 3H), 3.02 (d, J = 9.4 Hz, 1H), 1.9 - 1.5 (m, 6H), 1.4 - 1.1 (m, 5H); ¹³C NMR (100.6 MHz, CDCl₃) δ 171.4, 169.0, 135.2, 132.1, 129.1, 127.2, 95.5, 75.4, 72.0, 52.9, 52.1, 43.8, 28.9, 28.8, 26.3, 26.0; MS (EI) 273 (M - SPh)⁺; Anal. Calcd for C₁₉H₂₆O₆S: C, 59.64; H, 6.85. Found: C, 59.78; H, 6.96.

General procedures for the removal of tartrate auxiliary. **Method A:** To a solution of substrate (0.5 mmol) and Et₃N (3 equiv.) in CH₂Cl₂ (0.1 M) was added methanesulfonyl chloride (1.5 eq). After stirring for 30 min, DBU was added (10 equiv.) and the solution stirred at 0 °C until TLC indicated that the reaction was complete (30 min). The solution was then diluted with ether, washed with water, 10 % HCl, saturated NaHCO₃, brine; dried (MgSO₄) and concentrated *in vacuo*. The residue was then taken up in methanol (2 ml), NaOMe added (1 ml of a 25 % solution in MeOH) and the resulting solution refluxed 30 min. Brine was added (20 ml) after cooling to room temperature and the solution extracted with EtOAc (5 X). Drying (MgSO₄) and concentration were followed by flash chromatography to afford the pure alcohols. **Method B:** To a mixture of substrate (ca 0.5 mmol), alcohol (10 equiv.) and HMPA (6.0 equiv.) was added 0.1 M SmI₂⁶ in THF.⁷ When TLC indicated that the reaction was complete (30 min to 6h) the septum was removed and the mixture stirred to destroy excess SmI₂ (blue solution becomes yellow). The mixture was then diluted with ether and washed with 10 % HCl, 10 % Na₂S₂O₃, sat. NaHCO₃ and brine and dried (MgSO₄). Flash chromatography afforded the pure alcohols.

(2R)-Undecan-2-ol. From adduct **12a** (80 mg, 0.24 mmol) was obtained (2R)-Undecan-2-ol (27 mg, 65%) using method B. $[\alpha]_D^{30} -5.6^\circ$ (c 1.35, MeOH); $[\alpha]_D^{25} -5.2^\circ$ (c 1.43, EtOH). Reported⁸ for R isomer $[\alpha]_D -8.11^\circ$ (EtOH). From adduct **12b** (81 mg, 0.24 mmol) was obtained alcohol (2S)-Undecan-2-ol (25 mg, 60%) using method B. $[\alpha]_D^{30} +5.7^\circ$ (c 1.1, CHCl₃); $[\alpha]_D^{25} +5.9^\circ$ (c 2.13, EtOH).

(1R)-1-cyclohexylethanol. From adduct **14a** (165 mg, 0.57 mmol) was obtained (1R)-1-cyclohexylethanol (38 mg, 82%) using method B. $[\alpha]_D^{30} -2.54^\circ$ (c 1.26, CHCl₃); $[\alpha]_D^{25} -3.6^\circ$ (c 1.14, EtOH); Reported⁹ for S isomer $[\alpha]_D +5.5^\circ$ (neat).

(3R)-3-Methylheptan-3-ol. From adduct **60a** (95 mg, 0.33 mmol) was obtained (3R)-3-Methylheptan-3-ol (34 mg, 79%)

using method B. $[\alpha]_D^{30} +21.5^\circ$ (c 1.14, CHCl₃). Reported^{9,10} for R isomer $[\alpha]_D +23.34^\circ$ (EtOH).

(2R)-Octan-2-ol. From adduct **18** (86 mg, 0.30 mmol) was obtained (2R)-Octan-2-ol (28 mg, 72%) using method B. $[\alpha]_D^{30} -6.4^\circ$ (c 1.02, CHCl₃). Reported¹¹ for R isomer $[\alpha]_D -9.5^\circ$ (neat). This compound was converted to the Mosher ester¹² using the R acid.
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General procedure for the preparation samples of bromo-ether for NMR observations. To a cooled (-78 °C) solution of the appropriate acetal (ca 10 - 20 mg) in CD₂Cl₂ (500 μ L) in an NMR tube (equipped with a septum cap) was carefully added a solution of Me₂BBr (1.2 equiv.) in CD₂Cl₂ so as to minimize mixing. After a short delay (1 to 2 min) to ensure that the temperature was uniform throughout the sample, the tube shaken briefly and then was placed in the NMR probe which had been set at the appropriate temperature (see text). ¹H and ¹³C chemical shifts are reported relative to CD₂Cl₂ (¹H: 5.32 ppm, ¹³C: 53.8 ppm). ¹¹B chemical shifts were determined relative to BF₃·OEt₂ (external standard).

(2R, 3R)-3-((1-bromo-1-decanyl)oxy)-2-hydroxy-1,4-butanedioic acid dimethyl ester. Recorded at -50 °C. **Major isomer:** ¹H NMR (400 MHz, CD₂Cl₂) δ 5.95 (t, J = 5.3 Hz, 1H), 5.12 (d, J_{AB} = 2.6 Hz, 1H), 4.89 (d, J_{AB} = 2.6 Hz, 1H), 3.72 (s, 6H), 2.19-2.12 (m, 2H), 1.25-1.10 (m, 14H), 0.81 (t, J = 5.7 Hz, 3H), 0.33 (br, 6H); ¹³C NMR (100 MHz, CD₂Cl₂) δ 168.2, 167.6, 95.8, 77.5, 74.0, 52.9, 52.9, 40.2, 31.8, 29.6, 29.4, 28.8, 25.8, 22.7, 14.1. **Minor isomer:** ¹H NMR (400 MHz, CD₂Cl₂) δ 5.83 (dd, J = 7.7, 4.1 Hz, 1H), 5.05 (d, J_{AB} = 3.6 Hz, 1H), 4.70 (d, J_{AB} = 3.6 Hz, 1H), 3.73-3.70 (m, 6H), 2.19-2.12 (m, 2H), 1.30-1.10 (m, 14H), 0.81 (t, J = 5.7 Hz, 3H), 0.33 (br, 6H); ¹³C NMR (100 MHz, CD₂Cl₂) δ 168.4, 167.7, 95.8, 80.6, 74.4, 52.9, 52.9, 40.9, 31.8, 29.3, 29.4, 28.8, 26.6, 22.7, 14.0.

(2R, 3R)-3-((1-bromo-1-cyclohexylmethyl)oxy)-2-hydroxy-1,4-butanedioic acid dimethyl ester. Recorded at -50 °C. **Major isomer:** ¹H NMR (400 MHz, CD₂Cl₂) δ 5.89 (d, J = 3.8 Hz, 1H), 5.11 (d, J_{AB} = 2.8 Hz, 1H), 4.93 (d, J_{AB} = 2.8 Hz, 1H), 3.71 (s, 6H), 1.90-1.55 (m, 6H), 1.28-1.06 (m, 5H), 0.32 (br, 6H); ¹³C NMR (100 MHz, CD₂Cl₂) δ 168.2, 167.5, 101.5, 77.3, 74.1, 52.8, 52.8, 45.5, 28.5, 28.1, 25.8, 25.3. **Minor isomer:** ¹H NMR (400 MHz, CD₂Cl₂) δ 5.68 (d, J = 5.8 Hz, 1H), 5.04 (d, J_{AB} = 3.5 Hz, 1H), 4.71 (d, J_{AB} = 3.5 Hz, 1H), 3.71 (s, 6H), 1.90-1.55 (m, 6H), 1.23-1.06 (m, 5H), 0.32 (br, 6H); ¹³C NMR (100 MHz, CD₂Cl₂) δ 168.4, 167.8, 102.2, 80.6, 74.3, 52.8, 52.8, 46.0, 29.5, 28.5, 25.7, 25.3.

(2R, 3R)-3-((1-bromo-2-methylpropanyl)oxy)-2-hydroxy-1,4-butanedioic acid dimethyl ester. Recorded at -78 °C. **Major isomer:** ¹H NMR (400 MHz, CD₂Cl₂) δ 5.95 (d, J = 2.9 Hz, 1H), 5.11 (J_{AB} = 3.0 Hz, 1H), 4.95 (d, J_{AB} = 3.0 Hz, 1H), 3.71 (s, 6H), 2.08-1.96 (m, 1H), 0.85 (d, J = 6.3 Hz, 3H), 0.84 (d, J = 6.7 Hz, 3H), 0.28-0.17 (m, 6H); ¹³C NMR (100 MHz, CD₂Cl₂) δ 168.2, 167.5, 102.5, 77.3, 74.1, 52.8, 52.7, 35.9, 18.4, 17.0. **Minor isomer:** ¹H NMR (400 MHz, CD₂Cl₂) δ 5.71 (d, J = 5.1 Hz, 1H), 5.05 (d, J_{AB} = 3.8 Hz, 1H), 4.70 (d, J_{AB} = 3.8 Hz, 1H), 3.71 (s, 6H), 2.08-1.96 (m, 1H), 0.88-0.84 (m, 6H), 0.28-0.17 (m, 6H); ¹³C NMR (100 MHz, CD₂Cl₂) δ 168.5, 167.7, 102.7, 80.6, 74.3, 53.0, 52.9, 36.9, 18.6, 18.0. ¹¹B NMR (128.4 MHz, CD₂Cl₂) mixture of isomers) 54.7.

(2R, 3R)-3-((1-bromoethyl)oxy)-2-hydroxy-1,4-butanedioic acid dimethyl ester. Recorded at -50 °C. **Major isomer:** ¹H NMR (400 MHz, CD₂Cl₂) δ 6.02 (d, 5.3 Hz, 1H), 5.11 (d, J_{AB} =

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2.4 Hz, 1H), 4.87 (d, J_{AB} = 2.4 Hz, 1H), 3.73 (s, 3H), 3.72 (s, 3H), 2.02 (d, J = 5.4 Hz, 3H), 0.32 (br, 6H); ^{13}C NMR (100 MHz, CD_2Cl_2) δ 168.2, 90.6, 77.6, 73.9, 53.9, 52.9, 27.5. **Minor isomer:** ^1H NMR (400 MHz, CD_2Cl_2) δ 5.97 (d, J = 5.3 Hz, 1H), 5.06 (d, J_{AB} = 3.3 Hz, 1H), 4.72 (d, J_{AB} = 3.3 Hz, 1H), 3.73-3.71 (m, 6H), 1.92 (d, J = 5.4 Hz, 3H), 0.32 (br, 6H); ^{13}C NMR (100 MHz, CD_2Cl_2) δ 168.5, 167.5, 91.0, 80.1, 74.4, 53.0, 52.8, 27.6.

(5R)-2-(1-methylethyl)-5-(1-(R)-hydroxyacetic acid)-1,3-dioxolan-4-one (1,1-dimethylethyl) ester (50ab). To a solution of ester **74** (316 mg, 1 mmol) in CH_2Cl_2 (10 mL) at -78°C was added Me_2BBr (0.68 mL, 1.2 mmol). After stirring at -78°C for 5 min, the solution was warmed to room temperature for 20 min then poured into sat NaHCO_3 . After extraction with ether the organic phase was dried (MgSO_4), concentrated and purified by flash chromatography to afford pure **50ab** (105 mg, 39 %) as an inseparable mixture of isomers (lactones **50a** and **50b** were obtained in pure form from the corresponding silyl ethers **51a** and **51b** by treatment with $\text{HF}\cdot\text{py}$). **50a:** White solid, mp $72-74^\circ\text{C}$; $[\alpha]_D^{+64.4}$ (c 4.69, CHCl_3); IR (CHCl_3) 3510, 3020, 2995, 2970, 1800, 1735, 1475, 1460, 1430, 1410, 1300, 1165, 1140 cm^{-1} ; ^1H NMR (400 MHz, CDCl_3) δ 5.27 (d, J = 5.6, Hz, 1H), 4.64-4.63 (m, 1H), 4.47 (dd, J = 6.7, 1.8 Hz, 1H), 3.12 (d, J = 6.7 Hz, 1H), 2.02 - 1.98 (m, 1H), 1.53 (s, 9H), 1.01 (d, J = 8.8 Hz, 3H), 0.99 (d, J = 8.4, 3H); ^{13}C NMR (100 MHz, CDCl_3) δ 169.9, 169.7, 108.4, 83.9, 76.4, 69.4, 32.4, 27.8, 15.9, 15.8; MS (Cl , CH_4) 261 ($M + \text{H}$) $^+$; Anal. Calcd for $\text{C}_{12}\text{H}_{20}\text{O}_6$: C, 55.35; H, 7.75. Found: C, 55.30; H, 7.89. **50b:** White solid, mp $97-98^\circ\text{C}$; $[\alpha]_D^{+63.7}$ (c 0.96, CHCl_3); IR (CHCl_3) 3500, 2980, 2940, 1800, 1735, 1470, 1455, 1400, 1370, 1280, 1160, 1130, 1100 cm^{-1} ; ^1H NMR (400 MHz, CDCl_3) δ 5.56 (dd, J = 4.7, 1.4 Hz, 1H), 4.65 - 4.63 (m, 1H), 4.45 (dd, J = 5.0, 1.6 Hz, 1H), 3.26 (d, J = 4.8 Hz, 1H), 1.96 - 1.92 (m, 1H), 1.52 (s, 9H), 0.97 (d, J = 6.8 Hz, 6H); ^{13}C NMR (100 MHz, CDCl_3) δ 170.6, 170.1, 110.8, 84.3, 76.4, 71.4, 33.0, 27.9, 15.6, 15.4; MS (Cl , NH_3) 278 ($M + \text{NH}_4$) $^+$, 205 ($M - \text{C}_4\text{H}_9$); Anal. Calcd for $\text{C}_{12}\text{H}_{20}\text{O}_6$: C, 55.37; H, 7.74. Found: C, 55.21; H, 7.90.

(5R)-2-(1-methylethyl)-5-(1R-1-((1,1-triethylsilyl)oxy) -acetic acid)-1,3-dioxolan-4-one (1,1-dimethylethyl) ester (51ab): To a solution of alcohols **50ab** (120 mg, 0.46 mmol) and imidazole (70 mg, 0.92 mmol) in DMF (3 mL) was added Et_3SiCl (0.12 mL, 0.69 mmol). After stirring at room temperature for 2 h, TLC indicated the reaction was completed. The solution was diluted with ether and washed with water (10 mL) and brine, dried over MgSO_4 and concentrated in vacuo. Flash chromatography gave the pure products (**51a**: 38 mg, 22 %; **51b**: 107 mg, 62 %). **51a:** Oil; $[\alpha]_D^{+78.1}$ (c 1.17, CHCl_3); IR (CHCl_3) 2980, 2890, 1800, 1760, 1470, 1460, 1370, 1230, 1160, 1100 cm^{-1} ; ^1H NMR (400 MHz, CDCl_3) δ 4.76 (dd, J = 5.2, 0.8 Hz, 1H), 4.55 (d, J = 2.2, 1H), 4.05 (dd, J = 2.2, 0.9 Hz, 1H), 1.91 - 1.86 (m, 1H), 1.35 (s, 9H), 1.02 (t, J = 3.5 Hz, 9H), 0.86 (dd, J = 6.6, 6.6 Hz, 6H), 0.73 - 0.67 (m, 6H); ^{13}C NMR (100 MHz, C_6D_6) δ 170.0, 168.8, 108.4, 81.7, 77.6, 72.0, 32.9, 27.9, 16.1, 15.9, 6.9, 5.0; MS (Cl , NH_3) 392 ($M + \text{NH}_4$) $^+$; Anal. calcd for $\text{C}_{18}\text{H}_{34}\text{O}_6\text{Si}$: C, 57.72; H, 9.15. Found: C, 57.28; H, 9.29. **51b:** Oil; $[\alpha]_D^{+70.6}$ (c 5.12, CHCl_3); IR (CHCl_3) 2980, 2890, 1800, 1760, 1480, 1410, 1400, 1380, 1350, 1320, 1160, 1100, 1020 cm^{-1} ; ^1H NMR (400 MHz, CDCl_3) δ 5.69 (dd, J = 4.4, 1.2 Hz, 1H), 4.76 (dd, J = 1.9, 1.3 Hz, 1H), 4.65 (d, J = 1.9 Hz, 1H), 1.68 - 1.66 (m, 1H), 1.38 (s, 9H), 1.08 (t, J = 3.4 Hz, 9H), 0.81 - 0.71 (m, 12H); ^{13}C NMR (100 MHz, C_6D_6) δ 170.6, 168.6, 110.7, 81.8, 78.3, 73.8, 32.9, 27.9, 15.6, 15.3, 6.9, 5.0; MS (Cl , NH_4) 392 ($M + \text{NH}_4$) $^+$; Anal. Calcd for $\text{C}_{18}\text{H}_{34}\text{O}_6\text{Si}$: C, 57.72; H, 9.15. Found: C, 57.49; H, 9.39.

(2S, 3R)-2-methoxy-3-hydroxy-butanoic acid dimethyl ester and (2S, 3R)-3-methoxy-2-hydroxy-butanoic acid dimethyl

ester. An ethereal solution of CH_2N_2 was added in portions to an ice cold solution of methyl 2,3-dihydroxybutanoate (Prepared by hydrolysis of the commercially available acetonide) (3.30 g, 24.6 mmol) and SnCl_2 (466 mg, 2.46 mmol) in CH_3CN . After each portion was added, the reaction was checked by TLC. When starting material could no longer be detected the solvents were removed in vacuo and the residue taken up in a 1 : 1 mixture of EtOAc and hexanes. Filtration through silica gel was followed by concentration and flash chromatography using TLC grade silica to afford the (2S, 3R)-2-methoxy-3-hydroxy-butanoic acid dimethyl ester **i** (1.28 g, 35 %) and (2S, 3R)-3-methoxy-2-hydroxy-butanoic acid dimethyl ester **ii** (1.20 g, 33 %). **i:** Oil; $[\alpha]_D^{+6.6}$ (c 1.22, CHCl_3); IR (neat) 3500, 2990, 2940, 1750, 1440, 1280, 1210, 1155, 1095 cm^{-1} ; ^1H NMR (200 MHz, CDCl_3) δ 4.05 (b, 1H), 3.82 (s, 3H), 3.79 - 3.66 (m, 1H), 3.32 (s, 3H), 2.85 (b, 1H), 1.26 (d, J = 6.5 Hz, 3H); MS (Cl , CH_4) 149 ($M + \text{H}$) $^+$. **ii:** Oil; $[\alpha]_D^{-76.4}$ (c 0.955, CHCl_3); IR (neat) 3500, 2990, 2940, 1750, 1460, 1440, 1270, 1200, 1140, 1100 cm^{-1} ; ^1H NMR (200 MHz, CDCl_3) δ 4.04 - 3.90 (m, 1H), 3.78 (s, 3H), 3.60 (d, J = 5.4, 1H), 3.45 (s, 3H), 2.3 (b, 1H), 1.21 (d, J = 6.5 Hz, 3H); MS (Cl , CH_4) 149 ($M + \text{H}$) $^+$.

($\pm$)-trans-2-fluoro-3-hydroxy-1,4-butanedioic acid dimethyl ester. To a cold (-78°C) solution of meso-dimethyl tartrate (Prepared from the commercially available acid by CH_2N_2 treatment) (2.50 g, 14.0 mmol) in CH_2Cl_2 was added dropwise DAST (2.26 g, 14 mmol). The mixture was stirred at -78°C for 20 min and then at room temperature until TLC indicated the reaction was complete (19h). Water (10 mL) was added and the mixture was transferred to a separatory funnel and diluted with EtOAc (300 mL) and water (75 mL). After the phases were separated, the aqueous phase was extracted with EtOAc. The combined organic extracts were washed with brine and dried over MgSO_4 . Flash chromatography afforded trans-2-fluoro-3-hydroxy-1,4-butanedioic acid dimethyl ester (1.06 g, 42 %). Oil; IR (neat) 3500, 2980, 1750, 1440, 1280, 1220, 1140, 1080 cm^{-1} ; ^1H NMR (200 MHz, CDCl_3) δ 5.25 (dd, J = 47.0, 1.7 Hz, 1H), 4.68 (ddd, J = 30.3, 7.5, 1.7 Hz, 1H), 3.88 (s, 3H), 3.87 (s, 3H), 3.16 (d, J = 7.5 Hz, 1H); MS (Cl , CH_4) 181 ($M + \text{H}$) $^+$.

(2S, 3R)-cis-2-fluoro-3-((1-methoxyethyl)oxy)-1,4-butanedioic acid dimethyl ester. To a cold (-78°C) solution of dimethyl L-tartrate (2.50 g, 14.0 mmol) in CH_2Cl_2 (71 mL) was added dropwise DAST (2.26 g, 14.0 mmol). The mixture was stirred at -78°C for 20 min and then at room temperature until TLC indicated the reaction was complete (19 h). Water (10 mL) was added and the mixture was transferred to a separatory funnel and diluted with EtOAc (300 mL) and water (75 mL). After the phases were separated, the aqueous phase was extracted with EtOAc. The combined organic extracts were washed with brine and dried over MgSO_4 . Flash chromatography afforded cis-2-fluoro-3-hydroxy-1,4-butanedioic acid dimethyl ester. (1.62g, 64 %). Oil; $[\alpha]_D^{-35.8}$ (c 1.185, CHCl_3); IR (neat) 3500, 2960, 1750, 1445, 1300, 1260, 1230, 1125 cm^{-1} ; ^1H NMR (200 MHz, CDCl_3) δ 5.26 (dd, J = 49.3, 2.2 Hz, 1H), 4.71 (ddd, J = 22.9, 5.7, 2.2 Hz, 1H), 3.86 (s, 3H), 3.83 (s, 3H), 3.26 (d, J = 5.7 Hz, 1H); MS (Cl , CH_4) 181 ($M + \text{H}$) $^+$.