Supporting Information

Asymmetric Synthesis of γ-Hydroxy α,β-Unsaturated Aldehydes *via* Enantioselective Direct Addition of 2-Propargyl Acetate to Aldehydes

(Cover & 11 pages)

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General Procedures: All reactions were performed using oven dried glassware under a dry argon atmosphere with magnetic stirring, unless otherwise specified. Toluene was distilled and dried before use (≤ 20 ppm H_2O as determined by Karl Fischer titration). Anhydrous dimethylformamide (DMF) was stored over 4Å molecular sieves and used without further purification. Methanol was used without further purification. Triethylamine was freshly distilled from KOH prior to use. Reagents were purchased from either *Aldrich* or *Fluka* and used without prior purification except commercial aldehydes which were distilled before use. Propargyl acetate **7**,[1] 2-(*tert*-butyldimethylsilyloxy)ethanal **6**,[2] (*S*)-2-(*tert*-butyldimethylsilyloxy)propanal **4**,[3] and tris(dibenzylidenacetone)dipalladium (chloroform)[4] were synthesized according to literature procedures. Zinc triflate was purchased from *Fluka* at ≥ 98% purity. Chromatographic purification of products was accomplished using forced flow chromatography on *Fluka* Silica Gel 60 according to the method of Still.[5] NMR spectra were recorded on a *Varian Mercury 300* operating at 300 MHz, 75 MHz, and 282 MHz for ^{1}H, ^{13}C and ^{19}F respectively, and referenced to the internal solvent signals. The designation b refers to broad signals whenever applicable. IR spectra were recorded on a *Perkin Elmer Spectrum RX I FT-IR* spectrometer as a thin film unless otherwise noted. Optical rotations were measured on a *Jasco DIP-1000* digital polarimeter. Thin layer chromatography was performed using *Merck* Silica Gel 60 F_{254} TLC plates and visualized either with ultraviolet light or stained with $KMnO_4$ stain. Enantiomeric excesses were determined via ^{19}F NMR of the corresponding (*R*)-Mosher esters. Combustion analysis were performed by the Mikroelementar-analytisches Laboratorium at the ETH, Zürich.

Intermolecular Enantioselective Addition of Propargyl Acetate to Aldehydes

General Method (A): Zinc trifluoromethanesulfonate (1.1 mmol) and (+)-*N*-methylephedrine (1.2 mmol) were mixed and suspended in dry toluene (3 mL) under a dry argon atmosphere. The suspension was treated with a dropwise addition of dry triethylamine (1.2 mmol) at room temperature to afford a turbid milky reaction

[1] Harvey, D. F.; Lund, K. P.; Neil, D. A. *J. Am. Chem. Soc.* **1992**, *114*, 8424.
[2] (a) Jones, K.; Storey, M. D. *Tetrahedron* **1993**, *49*, 4901; (b) Provencal, D. P.; Gardelli, C.; Lafontaine, J. A.; Leahy, J. W. *Tetrahedron Lett.* **1995**, *36*, 6033.
[3] Yoshikawa, N.; Yamada, Y. M. A.; Das, J.; Sasai, H.; Shibasaki, M. *J. Am. Chem. Soc.* **1999**, *121*, 4168.
[4] Ukai, T.; Kawazura, H.; Ishii, Y.; Bonnet, J. J.; Ibers, J. A. *J. Organomet. Chem.* **1974**, *65*, 253.
[5] Still, W. C.; Ammon, H. L.; DeShong, P. *J. Am. Chem. Soc.* **1995**, *117*, 5166.

mixture which was stirred at room temperature for 2 h. A solution of propargyl acetate **7** (1.2 mmol) in dry toluene (2 mL) was added dropwise at room temperature. After 15 min. the aldehyde (1 mmol) was added dropwise at room temperature. The resulting reaction mixture was stirred at room temperature for 4-5 h. Tlc-examination (SiO_2; hexanes:ethyl acetate = 3/1) revealed the presence of a spot corresponding to the addition product. The reaction was quenched with sat. aq. NH_4Cl solution followed by extraction with ether (4x30 mL). The combined ether extracts were washed with sat. aq. NH_4Cl solution (30 mL), brine (2x30 mL), then dried ($MgSO_4$) and concentrated. The remaining oily residue was purified by flash chromatography (SiO_2; hexanes:ethyl acetate = 3/1) to afford the pure addition product **8-11** as a clear colourless oil.

(4R)-(+)-4-Hydroxy-5-methyl-2-hexynyl Acetate (**8**)*:* The product was afforded in 95% yield and 96% ee. $[\alpha]_D^{25.8}$=+1.0º (c=1.1, $CHCl_3$). ^{1}H NMR ($CDCl_3$, 300 MHz): δ 4.71 (*d*, *J*=1.5, 2H); 4.20 (*bs*, 1H); 2.08 (*s*, 3H); 1.98 (*bs*, 1H); 1.85 (*m*, 1H); 1.00 (*d*, *J*=3.9, 3H); 0.98 (*d*, *J*=3.9, 3H). ^{13}C NMR ($CDCl_3$, 75 MHz): δ 170.3, 86.5, 79.5, 67.8, 52.3, 34.3, 20.7, 18.0, 17.4. IR (thin film): cm^{-1} 3436, 2965, 1748, 1380, 1229, 1028. Low res. MS: m/z 169 (0.4), 152 (3), 137 (4), 127 (100), 110 (17), 95 (16), 91 (24), 85 (19), 68 (38), 43 (28). Ion spec. high res. MALDI: MNa^+ = 193.084 (calcd. for $C_9H_{14}O_3$ = 193.0835).

(4R)-(-)-4-Cyclohexyl-4-hydroxy-2-butynyl Acetate (**9**): The product was afforded in 88% yield and 97% ee. $[\alpha]_D^{25.8}$=-2.7º (c=1.085, $CHCl_3$). ^{1}H NMR ($CDCl_3$, 300 MHz): δ 4.71 (*d*, *J*=1.8, 2H); 4.18 (*bd*, *J*=6.0, 1H); 2.09 (*s*, 3H); 1.46-1.99 (*m*, 8H); 0.96-1.34 (*m*, 4H). ^{13}C NMR ($CDCl_3$, 75 MHz): δ 170.3, 86.9, 79.5, 67.1, 52.4, 43.9, 28.5, 28.1, 26.3, 25.8, 20.8. IR (thin film): cm^{-1} 3432, 2929, 2854, 1745, 1676, 1451, 1379, 1360, 1230, 1146, 1027, 734. Low res. MS: m/z 192 (3), 166 (8), 150 (13), 137 (15), 132 (13), 127 (9), 117 (14), 111 (12), 91 (14), 68 (100), 55 (33), 43 (16). Analysis for $C_{12}H_{19}O_3$: C = 68.20 %; H = 9.22 % (calcd. C = 68.22 %; H = 9.06 %).

(4R)-(+)-4-Hydroxy-6,6-dimethyl-2-heptynyl Acetate (**10**)*:* The product was afforded in 68% yield and 97% ee. $[\alpha]_D^{25.8}$=+12.7º (c=1.015, $CHCl_3$). ^{1}H NMR ($CDCl_3$, 300 MHz): δ 4.69 (*d*, *J*=2.1, 2H); 4.49 (*bq*, *J*=6.1, 1H); 2.09 (*s*, 3H); 1.87 (*bd*, *J*=5.1, 1H);

1.68 (*d*, *J*=6.6, 2H); 0.97 (*s*, 9H). ^{13}C NMR ($CDCl_3$, 75 MHz): δ 170.3, 89.1, 78.6, 60.2, 52.3, 51.2, 30.1, 29.9, 20.8. IR (thin film): cm^{-1} 3436, 2955, 2870, 1749, 1477, 1437, 1379, 1366, 1231, 1026, 734. Low res. MS: m/z 197 (0.15), 180 (4), 165 (13), 138 (17), 127 (100), 105 (39), 95 (52), 85 (44), 68 (28), 57 (76), 43 (50). Analysis for $C_{11}H_{19}O_3$: C=66.26 %; H = 9.69 % (calcd. C = 66.30 %; H = 9.61 %).

(4R,5S)-(+)-5-tert-Butyldimethylsilyloxy-4-hydroxy-2-hexynyl Acetate (**11**)*:* The product was afforded in 70% yield and 26:1 dr using ^{19}F NMR ($CDCl_3$, 282 MHz) of the corresponding (*R*)-MTPA ester : δ -71.46 (*s*, 96.27F); -71.76 (*s*, 3.73F). $[\alpha]_D^{25.8}$=+23.7º (c=0.55, $CHCl_3$). ^{1}H NMR ($CDCl_3$, 300 MHz): δ 4.70 (*d*, *J*=1.8, 2H); 4.10 (*tt*, *J*=1.7/5.5, 1H); 3.87 (*m*, 1H); 2.62 (*d*, *J*=5.7, 1H); 2.08 (*s*, 3H); 1.22 (*d*, *J*=6.0, 3H); 0.90 (*s*, 9H); 0.11 (*s*, 3H); 0.10 (*s*, 3H). ^{13}C NMR ($CDCl_3$, 75 MHz): δ 170.2, 85.9, 79.2, 71.7, 67.2, 52.2, 25.8, 20.7, 20.1, 18.0, -4.4, -4.8. IR (thin film): cm^{-1} 3474, 2931, 2888, 2858, 1749, 1473, 1378, 1361, 1227, 1134, 1107, 1028, 962, 886, 836, 778, 666. Low res. MS: m/z 204 (4), 161 (20), 144 (100), 131 (20), 115 (50), 105 (26), 77 (20), 66 (7), 43 (7). Analysis for $C_{14}H_{26}O_4Si$: C = 58.72 %; H = 9.30 % (calcd. C = 58.70 %; H = 9.15).

General Method (B):

(4R)-(+)-4-Hydroxy-4-phenyl-2-butynyl Acetate (**12**)*:* Zinc trifluoromethanesulfonate (4.2 mmol) and (+)-*N*-methylephedrine (3.2 mmol) were mixed and suspended in dry toluene (4 mL) under a dry argon atmosphere. The suspension was treated with a dropwise addition of dry triethylamine (3.2 mmol) at room temperature to afford a turbid milky reaction mixture which was stirred at room temperature for 2 h. A solution of propargyl acetate **7** (3.2 mmol) in dry toluene (2 mL) was added dropwise at room temperature. After 15 min. benzaldehyde **5** (1 mmol) was added in one portion at room temperature. The resulting reaction mixture was stirred at room temperature overnight (16 h.). The reaction was quenched with sat. aq. NH_4Cl solution followed by extraction with ether (4x30 mL). The combined ether extracts were washed with sat. aq. NH_4Cl solution (30 mL), brine (2x30 mL), then dried ($MgSO_4$) and concentrated. The remaining oily residue was purified by flash chromatography (SiO_2; hexanes:ethyl acetate = 3/1) to afford the product as a clear yellow oil in 57% yield and 97% ee. $[\alpha]_D^{25.8}$=+1.8º (c=0.51, $CHCl_3$). ^{1}H NMR

($CDCl_3$, 300 MHz): δ 7.48-7.56 (*m*, 2H); 7.30-7.44 (*m*, 3H); 5.51 (*bs*, 1H); 4.76 (*d*, *J*=1.8, 2H); 2.31 (*bs*, 1H); 2.10 (*s*, 3H). ^{13}C NMR ($CDCl_3$, 75 MHz): δ 170.3, 140.0, 128.7, 128.6, 126.6, 86.3, 80.7, 64.6, 52.3, 20.8. IR (thin film): cm^{-1} 3428, 3065, 2940, 2242, 1744, 1647, 1598, 1581, 1494, 1451, 1379, 1226, 1030, 969, 914, 734, 700. Low res. MS: m/z 199 (0.34), 185 (7), 169 (41), 159 (100), 131 (14), 117 (84), 75 (39), 59 (3), 43 (5). Analysis for $C_{12}H_{12}O_3$: C = 70.52%; H = 5.93 % (C = 70.58 %; H = 5.92 %).

General Method (C):

(4R)-(+)-5-tert-Butyldimethylsilyloxy-4-hydroxy-2-pentynyl Acetate (**13**)*:* Zinc trifluoromethanesulfonate (2 mmol) and (+)-*N*-methylephedrine (2.2 mmol) were mixed and suspended in dry toluene (14 mL) under a dry argon atmosphere. The suspension was treated with a dropwise addition of dry triethylamine (2.2 mmol) at room temperature to afford a turbid milky reaction mixture which was stirred at room temperature for 2 h. A solution of propargyl acetate **7** (2.2 mmol) in dry toluene (6 mL) was added dropwise at room temperature. After 30 min. a solution of the 2-(*tert*-butyldimethylsilyloxy)ethanal **6** (1 mmol) in dry toluene (4 mL) was added dropwise at room temperature over 24 h. The reaction was quenched with sat. aq. NH_4Cl solution followed by extraction with ether (4x30 mL). The combined ether extracts were washed with sat. aq. NH_4Cl solution (30 mL), brine (2x30 mL), then dried ($MgSO_4$) and concentrated. The remaining oily residue was purified by flash chromatography (SiO_2; hexanes:ethyl acetate = 3/1) to afford the pure addition product as a clear colourless oil in 54% yield and 88% ee. $[\alpha]_D^{25.8}$=+11.4º (c=0.49, $CHCl_3$). ^{1}H NMR ($CDCl_3$, 300 MHz): δ 4.70 (*d*, *J*=1.8, 2H); 4.43 (*m*, 1H); 3.77 (*dd*, *J*=3.6/9.9, 1H); 3.65 (*dd*, *J*=6.9/9.9, 1H); 2.63 (*d*, *J*=5.1, 1H); 2.09 (*s*, 3H); 0.91 (*s*, 9H); 0.10 (*s*, 3H); 0.09 (*s*, 3H). ^{13}C NMR (75 MHz, $CDCl_3$): δ 170.3, 84.72, 79.4, 66.7, 63.1, 52.2, 25.8, 20.7, 18.3, -5.3. IR (thin film): cm^{-1} 3446, 2930, 2858, 1750, 1472, 1379, 1361, 1226, 1122, 1028, 838, 779. Low res. MS: m/z 241 (0.26), 215 (0.52), 197 (4), 185 (3), 173 (6), 155 (50), 117 (100), 89 (31), 75 (63), 59 (4), 43 (7), 28 (4). Analysis for $C_{13}H_{24}O_4Si$: C = 57.34 %; H = 8.79 % (calcd. C = 57.32; H = 8.88 %).

tert-Butyldiphenylsilyl Protected Propargyl Alcohols: *tert*-Butyldiphenylsilyl chloride (1.2 mmol) was added dropwise to a stirred solution of the propargyl alcohol **8-13** (1 mmol) and imidazole (2.5 mmol) in DMF (0.75 mL) at 0°C under a dry argon atmosphere. The resulting reaction mixture was stirred at 0°C for 1 h then at room temperature over two successive nights. The reaction was poured onto ice-water then extracted with ether (3x30 mL). After drying ($MgSO_4$) and concentration the remaining oily residue was flash chromatographed (SiO_2; hexanes:ethyl acetate = 20/1) afforded the pure product **15-20** as a clear colourless oil.

(4R)-(+)-4-tert-Butyldiphenylsilyloxy-5-methyl-2-hexynyl Acetate (**15**)*:* The product was afforded in 90% yield. $[\alpha]_D^{25.8}$=+79.3º (c=1.15, $CHCl_3$). ^{1}H NMR ($CDCl_3$, 300 MHz): δ 7.65-7.78 (*m*, 4H); 7.30-7.45 (*m*, 6H); 4.48 (*dd*, *J*=0.6/1.5, 2H); 4.20 (*td*, *J*=1.8/4.9, 1H); 2.04 (*s*, 3H); 1.86 (*m*, 1H); 1.08 (*s*, 9H); 1.00 (*d*, *J*=6.9, 3H); 0.90 (*d*, *J*=6.9, 3H). ^{13}C NMR ($CDCl_3$, 75 MHz): δ 170.2, 136.1, 135.9, 133.8, 133.6, 129.7, 129.5, 127.6, 127.3, 86.8, 79.6, 69.0, 52.3, 35.0, 26.9, 20.8, 19.4, 18.1, 17.3. IR (thin film): cm^{-1} 3072, 3050, 2962, 2932, 2895, 2859, 1751, 1590, 1472, 1428, 1378, 1360, 1223, 1190, 1154, 1113, 1076, 1028, 823, 702, 613. Ion spec. high res. MALDI: MNa^+ = 431.202 (Calcd. for $C_{25}H_{32}O_3Si$ = 431.2013).

(4R)-(+)-4-tert-Butyldiphenylsilyloxy-4-cyclohexyl-2-butynl Acetate (**16**)*:* The product was afforded in 90% yield. $[\alpha]_D^{25.8}$=+47.5º (c=1.005, $CHCl_3$). ^{1}H NMR (300 MHz, $CDCl_3$): δ 7.49-7.58 (*m*, 4H); 7.32-7.50 (*m*, 6H); 4.46 (*bs*, 2H); 4.19 (*td*, *J*=1.5/5.4, 1H); 2.03 (*s*, 3H); 1.48-1.90 (*m*, 6H); 1.06-1.22 (*m*, 5H); 1.08 (*s*, 9H). ^{13}C NMR ($CDCl_3$, 75 MHz): δ 170.2, 136.2, 136.0, 133.6, 129.7, 129.5, 127.6, 127.2, 87.2, 79.7, 68.4, 52.3, 44.7, 28.5, 28.0, 27.0, 26.5, 26.0, 20.8, 19.4, 14.2. IR (thin film): cm^{-1} 3072, 3850, 2931, 2856, 1750, 1590, 1472, 1450, 1428, 1376, 1360, 1224, 1188, 1112, 1072, 1027, 957, 898, 824, 740, 702, 611. Ion spec. high res. MALDI: MNa^+ = 471.233 (Calcd. for $C_{28}H_{36}O_3Si$ = 471.2326).

(4R)-(+)-4-tert-Butyldiphenylsilyloxy-6,6-dimethyl-2-heptynyl Acetate (**17**)*:* The product was afforded in 95% yield. $[\alpha]_D^{25.8}$=+64.3º (c=0.76, $CHCl_3$). ^{1}H NMR (300 MHz, $CDCl_3$): δ 7.69-7.76 (*m*, 4H); 7.34-7.46 (*m*, 6H); 4.43 (*bs*, 2H); 4.41-4.45 (*m*, 1H); 2.02 (*s*, 3H); 1.76 (*dd*, *J*=7.6/14.0, 1H); 1.67 (*dd*, *J*=5.1/13.8, 1H); 1.06 (*s*, 9H);

0.84 (*s*, 9H). ^{13}C NMR (75 MHz, $CDCl_3$): δ 170.2, 136.1, 136.00, 133.9, 133.6, 129.7, 129.5, 127.6, 127.3, 89.4, 79.4, 61.6, 52.3, 51.8, 29.9, 29.8, 26.9, 20.7, 19.2. IR (thin film): cm^{-1} 3072, 2956, 2859, 1752, 1590, 1473, 1428, 1362, 1223, 1112, 1072, 1028, 998, 822, 738, 702, 612. Ion spec. high res. MALDI: MNa^+ = 459.232 (Calcd. for $C_{27}H_{36}O_3Si$ = 459.2326).

(4R,5S)-(+)-5-tert-Butyldimethylsilyloxy-4-tert-butyldiphenylsilyloxy-2-hexynyl Acetate (**18**)*:* The product was afforded in 94% yield. $[\alpha]_D^{25.8}$=+36.4º (c=0.5, $CHCl_3$). ^{1}H NMR (300 MHz, $CDCl_3$): δ 7.66-7.76 (*m*, 4H); 7.34-7.45 (*m*, 6H); 4.55 (*d*, *J*=2.1, 2H); 4.30 (*td*, *J*=1.7/4.8, 1H); 3.71 (*m*, 1H); 2.05 (*s*, 3H); 1.27 (*d*, *J*=6.3, 3H); 1.08 (*s*, 9H); 0.80 (*s*, 9H); -0.09 (*s*, 3H); -0.18 (*s*, 3H). ^{13}C NMR (75 MHz, $CDCl_3$): δ 170.2, 136.1, 135.8, 133.4, 129.8, 129.7, 127.7, 127.4, 85.7, 79.4, 70.4, 68.3, 52.4, 26.9, 25.8, 20.8, 19.3, 18.1, 18.0, -4.8, -4.9. IR (thin film): cm^{-1} 3072, 2932, 2891, 2858, 1752, 1590, 1273, 1428, 1378, 1361, 1222, 1113, 1026, 1006, 969, 836, 777, 740, 702, 612. Ion spec. high res. MALDI: MNa^+ = 547.267 (Calcd. for $C_{30}H_{44}O_4Si_2$ = 547.2670).

(4R)-(+)-4-tert-Butyldiphenylsilyloxy-4-phenyl-2-butynyl Acetate (**19**)*:* The product was afforded in 88% yield. $[\alpha]_D^{25.8}$=+23.1º (c=0.615, $CHCl_3$). ^{1}H NMR (300 MHz, $CDCl_3$): δ 7.77-7.80 (*m*, 2H); 7.58-7.62 (*m*, 2H); 7.28-7.49 (*m*, 11H); 5.43 (*t*, *J*=1.6, 1H); 4.55 (*d*, *J*=2.1, 2H); 2.04 (*s*, 3H); 1.08 (*s*, 9H). ^{13}C NMR (75 MHz, $CDCl_3$): δ 141.1, 136.1, 135.9, 133.3, 133.0, 129.8, 129.8, 128.4, 127.9, 127.6, 127.5, 126.3, 87.4, 80.0, 65.7, 52.3, 26.8, 20.8, 19.4. IR (thin film): cm^{-1} 3071, 2932, 2858, 1749, 1589, 1493, 1472, 1451, 1428, 1377, 1224, 1138, 1113, 1061, 1027, 970, 923, 825, 742, 700, 610. Ion spec. high res. MALDI: MNa^+ = 465.186 (Calcd. for $C_{28}H_{30}O_3Si$ = 465.1856).

(4R)-(+)-5-tert-Butyldimethylsilyloxy-4-tert-butyldiphenylsilyloxy-2-pentynyl Acetate (**20**)*:* The product was afforded in 58% yield. $[\alpha]_D^{25.8}$=+43.0º (c=1.08, $CHCl_3$). ^{1}H NMR (300 MHz, $CDCl_3$) : δ 7.68-7.77 (*m*, 4H); 7.33-7.45 (*m*, 6H); 4.51 (*d*, *J*=1.8, 2H); 4.41-4.46 (*m*, 1H); 3.73 (*dd*, *J*=6.9/9.9, 1H); 3.67 (*dd*, *J*=5.7/9.9, 1H); 2.05 (*s*, 3H); 1.07 (*s*, 9H); 0.87 (*s*, 9H); 0.03 (*s*, 3H); 0.02 (*s*, 3H). ^{13}C NMR (75 MHz, $CDCl_3$) : δ 170.2, 136.1, 136.0, 133.5, 133.3, 129.7, 129.6, 127.5, 127.4, 86.2, 79.3,

67.5, 65.2, 52.2, 26.9, 25.9, 20.7, 19.3, 18.4, -5.3, -5.4. IR (thin film): cm^{-1} 3072, 3050, 2931, 2858, 1752, 1590, 1472, 1428, 1377, 1361, 1222, 1113, 1028, 965, 940, 868, 836, 779, 739, 702, 666, 613. Ion spec. high res. MALDI: MNa^+ = 533.252 (Calcd. for $C_{29}H_{42}O_4Si_2$ = 533.2514).

Palladium Catalyzed Redox and Acetate Addition: Tris(dibenzylideneacetone) dipalladium (chloroform) (0.021 mmol) and triphenylphosphine (0.23 mmol) were dissolved in dry toluene (10 mL) at room temperature. After 10 min. a clear yellow reaction mixture was formed. This was followed by a dropwise addition of 100% acetic acid (1.75 mmol) at room temperature. After 20 min. a solution of the silyl protected propargyl alcohol derivative **15-20** (1 mmol) in dry toluene (2 mL) was added at room temperature. The resulting reaction mixture was heated to reflux for 48 h. The reaction mixture was cooled to room temperture and the volatiles evaporated under reduced pressure. The remaining yellow oily residue was flash chromatographed (SiO_2; hexanes:ethyl acetate = 10/1) to afford the diacetate **21-26** as a clear yellow oil.

(4R)-(+)-4-tert-Butyldiphenylsilyloxy-5-methyl-2-hexenyl-1,1-diacetate (**21**)*:* The product was afforded in 85% yield. $[\alpha]_D^{25.8}$=+31.1º (c=0.665, $CHCl_3$). ^{1}H NMR ($CDCl_3$, 300 MHz): δ 7.58-7.68 (*m*, 4H); 7.30-7.46 (*m*, 6H); 7.00 (*dd*, *J*=0.9/6.4, 1H); 5.94 (*ddd*, *J*=0.9/6.6/15.6, 1H); 5.43 (*ddd*, *J*=1.2/6.3/15.6, 1H); 4.00 (*ddd*, *J*=1.2/4.5/6.3, 1H); 2.04 (*s*, 6H); 1.65-1.79 (*m*, 1H); 1.06 (*s*, 9H); 0.82 (*d*, *J*=6.9, 3H); 0.77 (*d*, *J*=7.2, 3H). ^{13}C NMR ($CDCl_3$, 75 MHz): δ 168.6, 137.0, 136.0, 135.9, 134.0, 129.6, 129.5, 127.5, 127.4, 124.3, 89.1, 77.6, 34.3, 27.0, 20.9, 19.5, 18.2, 16.9. IR (thin layer): cm^{-1} 3072, 2961, 2932, 2858, 1765, 1656, 1622, 1590, 1472, 1428, 1370, 1243, 1205, 1111, 1053, 1008, 965, 822, 740, 702, 608. Ion spec. high res. MALDI: MNa^+ = 491.223 (Calcd. for $C_{27}H_{36}O_5Si$ = 491.2224).

(4R)-(+)-4-tert-Butyldiphenylsilyloxy-4-cyclohexyl-2-butenyl-1,1-diacetate (**22**)*:* The product was afforded in 75% yield. $[\alpha]_D^{25.8}$=+9.0º (c=0.25, $CHCl_3$). ^{1}H NMR ($CDCl_3$, 300 MHz): δ 7.58-7.67 (*m*, 4H); 7.30-7.43 (*m*, 6H); 6.98 (*dd*, *J*=0.8/5.8, 1H); 5.92 (*ddd*, *J*=0.9/6.8/15.5, 1H); 5.36 (*ddd*, *J*=1.1/6.2/15.7, 1H); 3.96 (*ddd*, *J*=0.9/5.4/6, 1H); 2.04 (*s*, 3H); 2.03 (*s*, 3H); 1.56-1.74 (*m*, 7H); 1.20-1.48 (*m*, 3H); 1.05 (*s*, 9H).

^{13}C NMR ($CDCl_3$, 75 MHz): δ 168.6, 162.7, 137.6, 136.0, 135.9, 129.6, 129.5, 127.5, 127.3, 124.0, 89.0, 62.6, 44.4, 28.7, 27.8, 27.1, 26.6, 26.3, 20.9, 19.5, 18.4. IR (thin film): cm^{-1} 3072, 2930, 2856, 1766, 1590, 1472, 1450, 1428, 1371, 1240, 1204, 1112, 1065, 1007, 965, 898, 822, 780, 741, 702, 608. Ion spec. high res. MALDI: MNa^+ = 531.254 (Calcd. for $C_{30}H_{40}O_5Si$ = 531.2537).

(4R)-(+)-4-tert-Butyldiphenylsilyloxy-6,6-dimethyl-2-heptenyl-1,1-diacetate (**23**)*:* The product was afforded in 83% yield. $[\alpha]_D^{25.8}$=+37.6º (c=0.24, $CHCl_3$). ^{1}H NMR (300 MHz, $CDCl_3$): δ 7.61-7.69 (*m*, 4H); 7.31-7.60 (*m*, 6H); 6.98 (*dd*, *J*=0.8/6.2, 1H); 5.97 (*ddd*, *J*=0.9/7.5/15.6, 1H); 5.31 (*ddd*, *J*=0.9/5.8/15.6, 1H); 4.22 (*m*, 1H); 2.03 (*s*, 3H); 2.02 (*s*, 3H); 1.60 (*dd*, *J*=4.8/14.1, 1H); 1.47 (*dd*, *J*=8.1/13.8, 1H); 1.03 (*s*, 9H); 0.74 (*s*, 9H). ^{13}C NMR (75 MHz, $CDCl_3$): δ 168.5, 140.6, 136.1, 134.0, 129.7, 129.5, 127.5, 127.4, 123.0, 110.0, 88.9, 71.6, 51.7, 30.2, 29.8, 27.0, 20.8, 20.8, 19.2. IR (thin layer): cm^{-1} 2956, 2859, 1766, 1473, 1428, 1368, 1241, 1204, 1112, 1043, 1008, 963, 822, 739, 703. Ion spec. high res. MALDI: MNa^+ = 519.254 (Calcd. for $C_{29}H_{40}O_5Si$ = 519.2537).

(4R,5S)-(-)-5-tert-Butyldimethylsilyloxy-4-tert-butyldiphenylsilyloxy-2-hexenyl-1,1-diacetate (**24**)*:* The product was afforded in 73% yield. $[\alpha]_D^{25.8}$=-3.9º (c=0.58, $CHCl_3$). ^{1}H NMR (300 MHz, $CDCl_3$): δ 7.60-7.68 (*m*, 4H); 7.32-7.45 (*m*, 6H); 7.16 (*d*, *J*=6, 1H); 6.12 (*dd*, *J*=4.4/15.8, 1H); 5.80 (*ddd*, *J*=1.6/6.2/15.8, 1H); 4.20 (*dt*, *J*=1.5/4.6, 1H); 3.56 (*m*, 1H); 2.09 (*s*, 3H); 2.07 (*s*, 3H); 1.08 (*s*, 9H); 1.01 (*d*, *J*=6.0, 3H); 0.74 (*s*, 9H); -0.21 (*s*, 3H); -0.32 (*s*, 3H). ^{13}C NMR (75 MHz, $CDCl_3$): δ 168.7, 168.6, 135.8, 135.6, 133.9, 133.4, 129.9, 129.7, 127.7, 127.6, 124.3, 89.4, 75.0, 70.0, 27.1, 25.7, 20.9, 20.9, 19.4, 17.8, 16.9, -5.0, -5.2. IR(thin film): cm^{-1} 3072, 3051, 2931, 2892, 2858, 1766, 1590, 1472, 1428, 1372, 1243, 1204, 1109, 1007, 884, 836, 777, 741, 702, 666, 610. Ion spec. high res. MALDI: MNa^+ = 607.289 (Calcd. for $C_{32}H_{48}O_6Si_2$ = 607.2882).

(4R)-(-)-4-tert-Butyldiphenylsilyloxy-4-phenyl-2-butenyl-1,1-diacetate (**25**)*:* The product was afforded in 42% yield. $[\alpha]_D^{25.8}$=-17.6º (c=0.425, $CHCl_3$). ^{1}H NMR (300 MHz, $CDCl_3$): δ 7.65-7.68 (*m*, 2H); 7.18-7.48 (*m*, 13H); 7.05 (*d*, *J*=6.0, 1H); 6.05 (*ddd*, *J*=0.8/5.6/15.3, 1H); 5.65 (*ddd*, *J*=1.6/5.8/15.5, 1H); 5.16 (*m*, 1H); 2.052 (*s*,

3H); 2.046 (*s*, 3H); 1.06 (*s*, 9H). ^{13}C NMR (75 MHz, $CDCl_3$): δ 168.6, 142.0, 139.6, 139.2, 135.9, 133.6, 133.2, 129.7, 129.6, 128.3, 127.6, 127.4, 126.4, 122.2, 88.7, 75.2, 26.9, 20.9, 19.4. IR (thin film): cm^{-1} 3071, 2932, 2892, 2858, 1766, 1590, 1491, 1472, 1454, 1428, 1371, 1241, 1203, 1112, 1045, 1007, 963, 846, 822, 742, 701, 606. Ion spec. high res. MALDI: MNa^+ = 525.207 (Calcd. for $C_{30}H_{34}O_5Si$ = 525.2068).

(4R)-(+)-5-tert-Butyldimethylsilyloxy-4-tert-butyldiphenylsilyloxy-2-pentenyl-1,1-diacetate (**26**)*:* The product was afforded in 55% yield. $[\alpha]_D^{25.8}$=+8.8º (c=0.635, $CHCl_3$). ^{1}H NMR (300 MHz, $CDCl_3$) : δ 7.61-7.74 (*m*, 4H); 7.31-7.45 (*m*, 6H); 7.09 (*d*, *J*=6.3, 1H); 6.05 (*ddd*, *J*=0.9/5.6/15.8, 1H); 5.66 (*ddd*, *J*=1.5/6.2/15.6, 1H); 4.22 (*m*, 1H); 3.53 (*dd*, *J*=5.6/9.8, 1H); 3.40 (*dd*, *J*=7.2/9.9, 1H); 2.06 (*s*, 3H); 2.06 (*s*, 3H); 1.07 (*s*, 9H); 0.80 (*s*, 9H); -0.08 (*s*, 3H); -0.12 (*s*, 3H). ^{13}C NMR (75 MHz, $CDCl_3$): δ 168.6, 137.3, 136.0, 135.9, 134.8, 133.9, 133.6, 129.7, 129.7, 127.7, 127.6, 127.5, 123.8, 88.9, 73.2, 66.8, 27.0, 26.6, 25.8, 20.9, 19.3, 18.2, -5.5. IR (thin film): cm^{-1} 3072, 3050, 2931, 2894, 2858, 1765, 1656, 1622, 1590, 1472, 1428, 1372, 1244, 1204, 1113, 1046, 1008, 964, 837, 778, 741, 703, 608. Ion spec. high res. MALDI: MNa^+ = 593.272 (Calcd. for $C_{31}H_{46}O_6Si_2$ = 593.2725).

Hydrolysis of the Diacetates to the Corresponding Aldehydes: Dry triethylamine (3.2 mmol) was added to a stirred solution of the silyl protected diacetate **21-26** (1 mmol) in methanol (15 mL) at room temperature. The reaction mixture was stirred overnight at room temperature (unless otherwise stated). All volatiles were evaporated at reduced pressure and the remaining oily residue was flash chromatographed (SiO_2; hexanes:ethyl acetate = 10/1) to afford the α,β-unsaturated aldehyde **27-32** as a clear yellow oil.

(4R)-(+)-4-tert-Butyldiphenylsilyloxy-5-methyl-2-hexenal (**27**)*:* The product was afforded in 94% yield. $[\alpha]_D^{25.8}$=+33.1º (c=0.405, $CHCl_3$). ^{1}H NMR ($CDCl_3$, 300 MHz): δ 9.38 (*d*, *J*=8.1, 1H); 7.58-7.67 (*m*, 4H); 7.31-7.45 (*m*, 6H); 6.62 (*dd*, *J*=5.8/15.8, 1H); 6.04 (*ddd*, *J*=1.4/8.0/15.6, 1H); 4.28 (*ddd*, *J*=1.4/4.8/5.7, 1H); 1.81 (*m*, 1H); 1.09 (*s*, 9H); 0.87 (*d*, *J*=6.9, 3H); 0.83 (*d*, *J*=6.6, 3H). ^{13}C NMR ($CDCl_3$, 75 MHz): δ 193.4, 157.1, 135.9, 133.6, 132.3, 129.9, 127.7, 127.6, 77.3, 34.4, 27.0, 19.4, 18.2, 16.9. IR (thin film): cm^{-1} 3072, 2961, 2932, 2858, 1694, 1590, 1472, 1428,

1390, 1368, 1303, 1187, 1112, 1075, 998, 978, 940, 822, 741, 702, 611. Ion spec. high res. MALDI: MNa^+ = 389.190 (calcd. For $C_{23}H_{30}O_2Si$ = 389.1907).

(4R)-(+)-4-tert-Butyldiphenylsilyloxy-4-cyclohexyl-2-butenal (**28**)*:* The product was afforded in 97% yield. $[\alpha]_D^{25.8}$=+1.4º (c=0.53, $CHCl_3$). ^{1}H NMR ($CDCl_3$, 300 MHz): δ 9.35 (*d*, *J*=8.1, 1H); 7.57-7.67 (*m*, 4H); 7.31-7.44 (*m*, 6H); 6.62 (*dd*, *J*=6.2/15.4, 1H); 5.98 (*ddd*, *J*=1.4/8.1/15.4, 1H); 4.24 (*m*, 1H); 1.30-1.80 (*m*, 7H); 1.09 (*s*, 9H); 0.80-1.20 (*m*, 4H). ^{13}C NMR ($CDCl_3$, 75 MHz): δ 193.5, 157.9, 135.9, 131.9, 129.9, 127.6, 127.6, 44.5, 28.7, 27.8, 27.1, 26.5, 26.3, 26.1, 19.5. IR (thin film): cm^{-1} 3072, 2928, 2855, 1960, 1890, 1694, 1590, 1487, 1472, 1450, 1428, 1391, 1362, 1263, 1190, 1111, 1029, 1007, 976, 951, 898, 823, 740, 702, 611. Ion spec. high res. MALDI: MNa^+ = 429.222 (calcd. for $C_{26}H_{34}O_2Si$ = 429.2220).

(4R)-(+)-4-tert-Butyldiphenylsilyloxy-6,6-dimethyl-2-heptenal (**29**)*:* The reaction was stirred at 45 °C. The product was afforded in 87% yield. $[\alpha]_D^{25.8}$=+23.0º (c=0.135, $CHCl_3$). ^{1}H NMR (300 MHz, $CDCl_3$) : δ 9.35 (*d*, *J*=7.8, 1H); 7.59-7.69 (*m*, 4H); 7.32-7.45 (*m*, 6H); 6.69 (*dd*, *J*=6.6/15.6, 1H); 5.94 (*ddd*, *J*=1.0/7.9/15.7, 1H); 4.47 (*m*, 1H); 1.68 (*dd*, *J*=4.6/14.2, 1H); 1.53 (*dd*, *J*=8.0/14.0, 1H); 1.06 (*s*, 9H); 0.77 (*s*, 9H). ^{13}C NMR (75 MHz, $CDCl_3$) : δ 193.9, 160.0, 136.0, 135.9, 133.5, 130.5, 130.0, 127.7, 127.6, 71.2, 51.7, 30.3, 27.0, 19.3. IR (thin film): cm^{-1} 3072, 2957, 2858, 1698, 1472, 1428, 1364, 1262, 1112, 822, 739, 702. Ion spec. high res. MALDI: MNa^+ = 417.221 (calcd. for $C_{25}H_{34}O_2Si$ = 417.2220).

(4R,5S)-(-)-5-tert-Butyldimethylsilyloxy-4-tert-butyldiphenylsilyloxy-2-hexenal (**30**)*:* The product was afforded in 99% yield. $[\alpha]_D^{25.8}$=-30.6º (c=0.69, $CHCl_3$). ^{1}H NMR (300 MHz, $CDCl_3$): δ 9.58 (*d*, *J*=8.1, 1H); 7.57-7.68 (*m*, 4H); 7.34 (*m*, 6H); 6.95 (*dd*, *J*=3.4/15.4, 1H); 6.49 (*ddd*, *J*=1.6/8.1/15.8, 1H); 4.46 (*m*, 1H); 3.61 (*m*, 1H); 1.09 (*s*, 9H); 1.02 (*d*, *J*=6.3, 3H); 0.75 (*s*, 9H); -0.21 (*s*, 3H); -0.30 (*s*, 3H). ^{13}C NMR (300 MHz, $CDCl_3$): δ 193.7, 157.0, 135.8, 135.7, 132.9, 132.7, 130.1, 130.1, 127.9, 127.8, 75.3, 70.0, 27.0, 25.7, 19.4, 17.8, 17.1, -5.0, -5.2. IR (thin film): cm^{-1} 3073, 2931, 2894, 2858, 1697, 1590, 1472, 1428, 1378, 1258, 1106, 1007, 952, 882, 825, 777, 740, 702, 611. Ion spec. high res. MALDI: MNa^+ = 505.257 (calcd. for $C_{28}H_{42}O_3Si$ = 505.2565).

(4R)-(-)-4-tert-Butyldiphenylsilyloxy-4-phenyl-2-butenal (**31**)*:* The product was afforded in 88% yield. $[\alpha]_D^{25.8}$=-34.2º (c=0.35, $CHCl_3$). ^{1}H NMR (300 MHz, $CDCl_3$) : δ 9.45 (*d*, *J*=7.8, 1H); 7.63-7.66 (*m*, 2H); 7.16-7.47 (*m*, 13H); 6.74 (*dd*, *J*=4.6/15.4, 1H); 6.30 (*ddd*, *J*=1.4/8.0/15.5, 1H); 5.36 (*dd*, *J*=1.5/4.8, 1H); 1.08 (*s*, 9H). ^{13}C NMR (75 MHz, $CDCl_3$) : δ 193.7, 158.4, 140.6, 135.8, 135.8, 133.1, 132.7, 130.1, 129.8, 129.4, 128.6, 128.0, 127.8, 127.5, 126.6, 75.1, 26.9, 19.4. IR (thin film): cm^{-1} 3071, 2931, 2893, 2858, 1961, 1892, 1694, 1590, 1490, 1472, 1454, 1428, 1391, 1362, 1290, 1190, 1105, 1027, 974, 822, 741, 699, 608, 566. Ion spec. high res. MALDI: MNa^+ = 423.176 (calcd. for $C_{26}H_{28}O_2Si$ = 423.0408).

(4R)-(-)-5-tert-Butyldimethylsilyloxy-4-tert-butyldiphenylsilyloxy-2-pentenal (**32**)*:* The product was afforded in 77% yield. $[\alpha]_D^{25.8}$=-4.8º (c=0.515, $CHCl_3$). ^{1}H NMR (300 MHz, $CDCl_3$): δ 9.50 (*d*, *J*=8.1, 1H); 7.59-7.72 (*m*, 4H); 7.33-7.45 (*m*, 6H); 6.87 (*dd*, *J*=4.2/15.6, 1H); 6.31 (*ddd*, *J*=0.9/8.1/15.6, 1H); 4.45 (*m*, 1H); 3.55 (*dd*, *J*=5.2/9.8, 1H); 3.45 (*dd*, *J*=8.2/9.4, 1H); 1.09 (*s*, 9H); 0.80 (*s*, 9H); -0.10 (*s*, 3H); -0.14 (*s*, 3H). ^{13}C NMR (75 MHz, $CDCl_3$): δ 193.8, 158.0, 151.4, 135.8, 135.8, 133.1, 133.0, 130.1, 130.0, 129.96, 129.91, 127.8, 127.7, 119.9, 73.0, 66.4, 27.0, 25.8, 19.3, 18.2, -5.5. IR (thin film): cm^{-1} 3072, 3050, 2931, 2894, 2858, 1698, 1590, 1472, 1391, 1362, 1258, 1113, 1006, 978, 939, 837, 779, 740, 702, 668, 613. Ion spec. high res. MALDI: MNa^+ = 491.241 (calcd. for $C_{27}H_{40}O_3Si_2$ = 491.2408).