Supporting Information

Anti-1,2-Diols via Ni-Catalyzed Reductive Coupling of Alkynes and α -Oxyaldehydes

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Experimental Procedures and Data for New Compounds.

General Information. Unless otherwise noted, all reactions in organic solvents were performed under an oxygen-free atmosphere of argon with rigid exclusion of moisture from reagents and glassware. Ni(cod)₂ and (*S*)-(+)-neomenthyldiphenylphosphine ((*S*)-NMDPP) were purchased from Strem Chemicals, Inc. and used without further purification. (*R*)-(-)-Neomenthyldiphenylphosphine ((*R*)-NMDPP) was synthesized as previously described for the antipode by instead starting from (+)-menthol.¹ Triethylborane (98%) was purchased from Aldrich Chemical Co. and used without further purification. 1,3-Dimethylimidazolidin-2-one (DMI) and dichloromethane were distilled from calcium hydride. Tetrahydrofuran and Et₂O were distilled from a blue solution of sodium benzophenone ketyl. Ethyl acetate was distilled from magnesium sulfate. Analytical thin layer chromatography (TLC) was performed using EM Science silica gel 60 F254 plates. The developed chromatograms were analyzed by UV lamp (254 nm) and ethanolic phosphomolybdic acid (PMA), cerium molybdate (CAM) or aqueous potassium permanganate (KMnO₄). Liquid chromatography was performed using a forced flow (flash chromatography) of the indicated solvent system on Silicycle Silica Gel (230-400 mesh).² Preparatory thin layer chromatography was performed using Analtech silica gel UV254 1000 micron plates. HPLC was performed on a Hewlett-Packard 1100 chromatograph equipped with a variable wavelength detector and Chiralcel OD, AD, or OJ column. GC analysis was performed on a Varian CP-3800 gas chromatograph fitted with Chiraldex B-PH, B-DA, and G-TA capillary columns. Temperatures were maintained using a Thermo Neslab CC-65 cryocool immersion cooler equipped with Cryotrol temperature controller. ¹H and ¹³C NMR spectra were recorded in deuteriochloroform

(CDCl₃), unless otherwise noted, on a Varian Mercury 300 MHz, a Bruker Avance 400 MHz or a Varian Inova 500 MHz spectrometer. Chemical shifts in ¹H NMR spectra are reported in parts per million (ppm) on the δ scale from an internal standard of residual chloroform (7.27 ppm). Data are reported as follows: chemical shift, multiplicity (s = singlet, d = doublet, t = triplet, q = quartet, m = multiplet, app = apparent and br = broad), coupling constant in hertz (Hz), and integration. Chemical shifts of ¹³C NMR spectra are reported in ppm from the central peak of CDCl₃ (77.2 ppm) on the δ scale. Infrared (IR) spectra were recorded on a Perkin-Elmer 2000 FT-IR. High Resolution mass spectra (HRMS) were obtained on a Bruker Daltonics APEXII 3 Tesla Fourier Transform Mass Spectrometer by Dr. Li Li of the Massachusetts Institute of Technology Department of Chemistry Instrumentation Facility. Optical rotations were measured on a Perkin-Elmer 241 polarimeter at 589 nm. Data are reported as follows: [α]_λ^{temp}, concentration (c g/100 mL), and solvent.

(2R)-2-Cyclohexyl-2-methoxymethoxy-ethanol (6): To the stirring solution of (1R)-1-cyclohexyl-ethane-1,2-diol³ (25 mmol, 3.61 g) in dichloromethane (95 mL), were added DL-camphor sulfonic acid (2 mmol, 0.466 g) and trimethyl orthoformate (37.5 mmol, 4.1 mL). The solution was stirred 24 h at ambient temperature. Triethylamine (25 mL) was added, and the solution was concentrated. The residue was purified by flash chromatography on silica gel (30% EtOAc/Hex) to afford a mixture of diastereomeric cyclic orthoesters. The mixture (17.6 mmol) was dissolved in dichloromethane (180 mL) and cooled to -78 °C. Diisobutylaluminum hydride (70 mmol, 70 mL of 1 M solution in hexane) was added slowly, and the solution was stirred 1.5 h at -78 °C. The reaction was warmed to 0 °C and stirred 1.5 h. Methanol (10 mL) was added dropwise to quench the reaction. Ether and a saturated solution of Rochelle's salt were added, and the solution

was stirred at ambient temperature until it became clear. The solution was extracted with ether (2 x 500 mL), dried over magnesium sulfate, and concentrated. Silica gel chromatography (60% EtOAc/Hex) afforded the title compound (2.92 g, 62% yield). R_f 0.38 (60% EtOAc/Hex). ^1H NMR (500 MHz, CDCl_3) δ 4.76 (d, J = 6.5 Hz, 1H); 4.65 (d, J = 6.5 Hz, 1H); 3.66 (ddd, J = 12, 9, 3 Hz, 1H); 3.57 (ddd, J = 12, 9, 3 Hz, 1H); 3.45 (s, 3H); 3.30 (dt, J = 7, 3 Hz, 1H); 3.13 (dd, J = 9, 3 Hz, 1H); 1.62-1.82 (m, 5H); 1.48-1.58 (m, 1H); 1.00- 1.29 (m, 5H). ^{13}C NMR (125 MHz, CDCl_3) δ 98.0, 87.8, 64.0, 55.9, 40.4, 29.4, 28.9, 26.6, 26.4, 26.4. IR (film): 3442, 2926, 2852, 1450, 1210, 1141, 1103, 1035, 918 cm^{-1} . HRMS ESI (m/z): $[\text{M}+\text{Na}]^+$ calcd for $\text{C}_{10}\text{H}_{20}\text{O}_3\text{Na}$, 211.1305; found 211.1302. $[\alpha]_D = -64.0$ (c 0.5, CHCl_3).

2a

(*R*)-Cyclohexyl-methoxymethoxy-acetaldehyde (2a): To a stirring solution of (*2R*)-2-cyclohexyl-2-methoxymethoxy-ethanol (**6**) (4 mmol, 0.753 g) in dichloromethane (100 mL), was added Dess-Martin reagent⁴ (4.2 mmol, 1.7 g). The reaction was stirred 0.5 h at room temperature and concentrated. Silica gel chromatography (30% EtOAc/Hex) afforded the title compound (674 mg, 91% yield). R_f 0.51 (30% EtOAc/Hex). ^1H NMR (500 MHz, CDCl_3) δ 9.64 (d, J = 2.5 Hz, 1H); 4.72 (d, J = 7 Hz, 1H); 4.67 (J = 7 Hz, 1H); 3.68 (dd, J = 6, 2.5 Hz, 1H); 3.41 (s, 3H); 1.62-1.83 (m, 5H); 1.11-1.25 (m, 5H). ^{13}C NMR (125 MHz, CDCl_3) δ 203.9, 97.2, 86.7, 56.2, 39.7, 29.1, 28.0, 26.3, 26.3, 26.2. IR (film): 2930, 2855, 2825, 2718, 1733, 1451, 1404, 1379, 1290, 1273, 1213, 1158, 1143, 1107, 1084, 1039, 961, 919, 889, 774, 730 cm^{-1} . HRMS ESI (m/z): $[\text{M}+\text{Na}]^+$ calcd for $\text{C}_{10}\text{H}_{18}\text{O}_3\text{Na}$, 209.1148; found 209.1149. $[\alpha]_D = 70.0$ (c 2.0, CHCl_3).

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(2R)-2-Methoxymethoxy-octan-1-ol (7): To the stirring solution of (2R)-octane-1,2-diol³ (29 mmol, 4.32 g) in dichloromethane (100 mL), were added DL-camphor sulfonic acid (2.4 mmol, 0.559 g) and trimethyl orthoformate (45 mmol, 4.9 mL). The solution was stirred 24 h at ambient temperature. Triethylamine (29 mL) was added, and the solution was concentrated. The residue was purified by flash chromatography on silica gel (30% EtOAc/Hex) to afford a mixture of diastereomeric cyclic orthoesters. The mixture (28 mmol) was dissolved in dichloromethane (280 mL) and cooled to -78°C . Diisobutylaluminium hydride (112 mmol, 112 mL of 1 M solution in hexane) was added slowly, and the solution was stirred 1.5 h at -78°C . The reaction was warmed to 0°C and stirred 1.5 h. Methanol (15 mL) was added dropwise to quench the reaction. Ether and a saturated solution of Rochelle's salt were added, and the solution was stirred at ambient temperature until it became clear. The solution was extracted with ether (2 x 500 mL), dried over magnesium sulfate, and concentrated. Silica gel chromatography (50% EtOAc/Hex) afforded the primary alcohol (3.87 g, 66% yield). R_f 0.32 (50% EtOAc/Hex). ^1H NMR (500 MHz, CDCl_3) δ 4.75 (d, $J = 7$ Hz, 1H); 4.70 (d, $J = 7$ Hz, 1H); 3.48-3.63 (m, 3H), 3.44 (s, 3H), 3.08 (dd, $J = 8, 4$ Hz, 1H); 1.24-1.57 (m, 10H); 0.89 (t, $J = 7$ Hz, 3H). ^{13}C NMR (125 MHz, CDCl_3) δ 97.2, 82.7, 66.0, 55.9, 32.0, 31.9, 29.5, 25.7, 22.8, 14.3. IR (film): 3446, 2929, 2858, 1457, 1212, 1153, 1104, 1038, 918 cm^{-1} . HRMS ESI (m/z): $[\text{M}+\text{Na}]^+$ calcd for $\text{C}_{10}\text{H}_{22}\text{O}_3\text{Na}$, 213.1461; found 213.1466. $[\alpha]_{\text{D}} = -44.9$ (c 1.07, CHCl_3).

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(2R)-Cyclohexyl-2-(4-methoxybenzyloxy)-ethanol (8): To the stirring solution of (1R)-1-cyclohexyl-ethane-1,2-diol (16 mmol, 2.32 g) in dichloromethane (64 mL), were added pyridinium *p*-toluenesulfonate (1.28 mmol, 0.32 mg) and *p*-Anisaldehyde dimethyl acetal (16 mmol, 2.7 mL). The solution was stirred 24 h at ambient temperature. Triethylamine

(20 mL) was added, and the solution was concentrated. The residue was purified by flash chromatography on silica gel (30% EtOAc/Hex) to afford a mixture of diastereomeric cyclic acetal. The mixture (14 mmol) was dissolved in dichloromethane (140 mL) and cooled to $-78\text{ }^{\circ}\text{C}$. Diisobutylaluminum hydride (54 mmol, 54 mL of 1 M solution in hexane) was added slowly, and the solution was stirred 1.5 h at $-78\text{ }^{\circ}\text{C}$. The reaction was warmed to $0\text{ }^{\circ}\text{C}$ and stirred 1.5 h. Methanol (5 mL) was added dropwise to quench the reaction. Ether and a saturated solution of Rochelle's salt were added, and the solution was stirred at ambient temperature until it became clear. The solution was extracted with ether (2 x 250 mL), dried over magnesium sulfate, and concentrated. Silica gel chromatography (25% EtOAc/Hex) afforded the title compound (3.07 g, 73% yield). R_f 0.25 (25% EtOAc/Hex). ^1H NMR (500 MHz, CDCl_3) δ 7.27-7.30 (m, 2H); 6.89-6.91 (m, 2H); 4.56 (d, $J = 11$ Hz, 1H); 4.49 (d, $J = 11$ Hz, 1H); 3.82 (s, 3H); 3.71 (dd, $J = 11, 3$ Hz, 1H); 3.59 (dd, $J = 11, 7$ Hz); 3.25 (dt, $J = 7, 3$ Hz, 1H); 1.61-1.91 (m, 7H); 0.96- 1.29 (m, 5H). ^{13}C NMR (125 MHz, CDCl_3) δ 159.4, 130.8, 129.6, 114.0, 84.3, 72.3, 61.9, 55.4, 39.3, 29.4, 28.9, 26.7, 26.4, 26.4. IR (film): 3432, 2999, 2926, 2852, 1613, 1586, 1614, 1465, 1450, 1421, 1395, 1340, 1302, 1248, 1173, 1150, 1111, 1092, 1075, 1037, 931, 891, 923, 755, 668, 637 cm^{-1} . HRMS ESI (m/z): $[\text{M}+\text{Na}]^+$ calcd for $\text{C}_{16}\text{H}_{24}\text{O}_3\text{Na}$, 287.1618; found 287.1621. $[\alpha]_{\text{D}} = -11.4$ (c 2.2, CHCl_3).

2b

(*R*)-Cyclohexyl-(4-methoxybenzyloxy)-acetaldehyde (2b): To a stirring solution of (*2R*)-2-cyclohexyl-2-(4-methoxy-benzyloxy)-ethanol (**8**) (1 mmol, 264 mg) in dichloromethane (25 mL), was added Dess-Martin reagent (1.05 mmol, 445 mg). The reaction was stirred 0.5 h at room temperature and concentrated. Silica gel chromatography (30% EtOAc/Hex) afforded the title compound (230 mg, 88% yield). R_f 0.54 (30% EtOAc/Hex). ^1H NMR (500 MHz, CDCl_3) δ 9.63 (d, $J = 3$ Hz, 1H); 7.26-7.29 (m, 2H); 6.88-6.90 (m, 2H); 4.60 (d, $J = 12$ Hz, 1H); 4.42 (d, $J = 12$ Hz); 3.81 (s, 3H); 3.47 (dd, $J = 6, 3$ Hz, 1H); 1.61-1.79 (m, 6H); 1.13-1.26 (m, 5H). ^{13}C NMR (125 MHz, CDCl_3)

δ 205.0, 159.6, 129.9, 129.7, 114.1, 87.6, 72.8, 55.5, 39.7, 28.9, 28.2, 26.3, 26.2, 26.1. IR (film): 3000, 2929, 2854, 2711, 1730, 1613, 1586, 1514, 1464, 1451, 1423, 1372, 1303, 1249, 1212, 1174, 1112, 1090, 1073, 1060, 1035, 931, 889, 822, 752, 710 cm^{-1} . HRMS ESI (m/z): $[\text{M}+\text{Na}]^+$ calcd for $\text{C}_{16}\text{H}_{24}\text{O}_3\text{Na}$, 285.1461; found 285.1461. $[\alpha]_{\text{D}} = 25.4$ (c 1.85, CHCl_3).

Standard Procedure for Catalytic Reductive Couplings of Aldehydes and Alkynes:

An oven-dried 10 mL, round-bottom flask was charged with $\text{Ni}(\text{cod})_2$ (0.03 mmol, 8.75 mg) and (*S*)-(+)-neomenthyldiphenylphosphine (0.06 mmol, 19.5 mg) in a glove box and subsequently placed under an argon atmosphere. Ethyl acetate (1.5 mL), DMI (1.5 mL), and triethylborane (0.6 mmol, 87 μL ,) were added, and the solution was cooled to -10°C . To the stirring solution was added the aldehyde (0.45 mmol) and the solution was allowed to stir for 5 min before the alkyne (0.3 mmol) was added. The reaction mixture was stirred for 20 h maintaining the temperature at -10°C . The solution was quenched by the addition of 3 M NaOH (1 mL) and 30% H_2O_2 (3 drops). The resulting mixture was extracted with ether, dried over MgSO_4 , filtered through a plug of silica, and concentrated in vacuo. Diastereoselectivity was determined by ^1H NMR of the crude reaction residue. The residue was then purified by flash column chromatography.

3a

(*E*)-(1*R*,2*S*)-1-Cyclohexyl-1-methoxymethoxy-3-methyl-4-phenyl-but-3-en-2-ol (3a):

The reductive coupling of 1-phenyl-1-propyne (**1a**) (0.3 mmol, 38 μL) and (**2a**) (0.45 mmol, 84 mg) was performed under the standard procedure. The residue was purified by FCC (10% EtOAc/Hex) to afford the title compound (79 mg, 87% yield, 90:10 d.r.). R_f 0.11 (10% EtOAc/Hex). ^1H NMR (300 MHz, CDCl_3) δ 7.22-7.41 (m, 5H); 6.57 (s, 1H);

4.76 (d, $J = 11$ Hz, 1H); 4.60 (d, $J = 11$ Hz, 1H); 4.30 (br s, 1H); 3.48 (m, 1H); 3.45 (s, 3H); 3.16-3.18 (m, 1H); 1.90-1.99 (m, 1H); 1.92 (s, 3H); 1.52-1.82 (m, 5H); 1.05-1.30 (m, 5H). ^{13}C NMR (75 MHz, CDCl_3) δ 137.9, 137.9, 129.3, 128.3, 127.7, 126.6, 98.9, 87.9, 77.0, 56.4, 39.7, 30.8, 28.4, 26.6, 26.5, 26.4, 14.8. IR (film): 3446, 3081, 3055, 3023, 2927, 2852, 1560, 1492, 1449, 1363, 1295, 1266, 1240, 1210, 1146, 1106, 1032, 971, 919, 862, 751, 699 cm^{-1} . HRMS ESI (m/z): $[\text{M}+\text{Na}]^+$ calcd for $\text{C}_{19}\text{H}_{28}\text{O}_3\text{Na}$, 327.1931; found 327.1944. $[\alpha]_{\text{D}} = -28.1$ (c 8.8, CHCl_3).

3b

(*E*)-(1*R*,2*S*)-1-Cyclohexyl-1-methoxymethoxy-3-methyl-4-naphthalen-1-yl-but-3-en-2-ol (3b): The reductive coupling of 1-prop-1-ynynaphthalene (**1b**) (0.3 mmol, 50 mg) and (**2a**) (0.45 mmol, 84 mg) was performed under the standard procedure. Silica gel chromatography (10% EtOAc/Hex) afforded the title compound (99 mg, 93% yield, 83:17 d.r.). R_f 0.20 (10% EtOAc/Hex). ^1H NMR (500 MHz, CDCl_3) δ 7.99- 8.00 (m, 1H); 7.86-7.88 (m, 1 H); 7.77 (d, $J = 8$ Hz, 1H); 7.45-7.50 (m, 3H); 7.35 (d, $J = 8$ Hz, 1H); 7.01 (s, 1H); 4.83 (d, $J = 6$ Hz, 1H); 4.65 (d, $J = 6$ Hz, 1H); 4.49 (t, $J = 5$ Hz, 1H); 3.55 (dd, $J = 7$, 5 Hz, 1H); 3.49 (s, 3H); 3.45 (d, $J = 5$ Hz, 1H); 2.08 (br d, $J = 12$ Hz, 1H); 1.66-1.89 (m, 5H), 1.79 (s, 3H); 1.10-1.39 (m, 6H). ^{13}C NMR (125 MHz, CDCl_3) δ 139.5, 135.2, 133.7, 132.2, 128.7, 127.2, 126.8, 125.9, 125.9, 125.7, 125.5, 125.4, 99.0, 88.4, 76.7, 56.5, 39.9, 30.8, 28.8, 26.7, 26.5, 26.4, 15.1. IR (film): 3440, 2925, 2851, 1591, 1508, 1449, 1210, 1144, 1102, 1029, 971, 918, 784 cm^{-1} . HRMS ESI (m/z): $[\text{M}+\text{Na}]^+$ calcd for $\text{C}_{23}\text{H}_{30}\text{O}_3\text{Na}$, 377.2087; found 377.2083. $[\alpha]_{\text{D}} = -3.3$ (c 2.7, CHCl_3).

3c

(1*R*,2*S*)-1-Cyclohexyl-1-methoxymethoxy-3-[1-phenyl-meth-(*E*)-ylidene]-pentan-2-ol

(3c): The reductive coupling of 1-phenyl-1-butyne (**1c**) (0.3 mmol, 43 μ L) and (**2a**) (0.45 mmol, 84 mg) was performed under the standard procedure. Silica gel chromatography (10% EtOAc/Hex) afforded the title compound (52 mg, 54% yield, >95:5 d.r.). R_f 0.14 (10% EtOAc/Hex). ^1H NMR (500 MHz, CDCl_3) δ 7.22-7.36 (m, 5H); 6.68 (s, 1H); 4.77 (d, $J = 7$ Hz, 1H); 4.63 (d, $J = 7$ Hz, 1H); 4.44 (br s, 1H); 3.51 (t, $J = 5$ Hz, 1H); 3.45 (s, 3H); 2.89 (d, $J = 3.5$ Hz); 2.48-2.54 (m, 1H); 2.13-2.19 (m, 1H); 2.00 (br d, 1H); 1.65-1.77 (m, 5H); 1.12-1.28 (m, 5H); 1.13 (t, $J = 7.5$ Hz, 3H). ^{13}C NMR (125 MHz, CDCl_3) δ 143.6, 138.1, 128.9, 128.5, 126.8, 126.6, 98.3, 86.6, 75.1, 56.4, 39.4, 31.2, 28.3, 26.7, 26.7, 26.5, 22.5, 14.2. IR (film): 3457, 2928, 2852, 1493, 1449, 1240, 1144, 1104, 1032, 919, 749, 699 cm^{-1} . HRMS ESI (m/z): $[\text{M}+\text{Na}]^+$ calcd for $\text{C}_{20}\text{H}_{30}\text{O}_3\text{Na}$, 341.2087; found 341.2083. $[\alpha]_D = -7.7$ (c 0.91, CHCl_3).

3d

(*E*)-(1*R*,2*S*)-1-Cyclohexyl-3-cyclopropyl-1-methoxymethoxy-4-phenyl-but-3-en-2-ol

(3d): The reductive coupling of cyclopropylethynylbenzene (**1d**) (0.3 mmol, 43 mg) and (**2a**) (0.45 mmol, 84 mg) was performed under the standard procedure. Silica gel chromatography (10% EtOAc/Hex) afforded the title compound (61 mg, 62% yield, >95:5 d.r.). R_f 0.14 (10% EtOAc/Hex). ^1H NMR (500 MHz, CDCl_3) δ 7.21-7.46 (m, 5H); 6.82 (s, 1H); 4.79 (d, $J = 6.5$ Hz, 1H); 4.66 (d, $J = 6.5$ Hz, 1H); 4.32 (t, $J = 4.5$ Hz, 1H); 3.611 (t, $J = 4.5$ Hz, 1H); 3.45 (s, 3H); 2.85 (d, $J = 5$ Hz, 1H); 2.00 (d, $J = 12$ Hz, 1H); 1.56-1.78 (m, 6H); 1.10-1.29 (m, 5H); 0.68-0.79 (m, 2H); 0.36-0.49 (m, 2H). ^{13}C NMR (125 MHz, CDCl_3) δ 140.7, 137.7, 129.6, 128.3, 128.0, 126.6, 98.2, 86.7, 74.4, 56.4, 39.4, 31.2, 28.5,

26.7, 26.6, 26.5, 12.4, 8.3, 7.2. IR (film): 3456, 2927, 2852, 1493, 1448, 1144, 1104, 1031, 919, 760, 697 cm^{-1} . HRMS ESI (m/z): $[\text{M}+\text{Na}]^+$ calcd for $\text{C}_{21}\text{H}_{30}\text{O}_3\text{Na}$, 353.2087; found 353.2089. $[\alpha]_{\text{D}} = 2.13$ (c 6.1, CHCl_3).

3e

(3*S*,4*R*)-4-Cyclohexyl-3-hydroxy-4-methoxymethoxy-2-[1-phenyl-meth-(*E*)-ylidene]-butyl-carbamic acid *tert*-butyl ester (3e): The reductive coupling of (3-phenyl-prop-2-ynyl)-carbamic acid *tert*-butyl ester (**1e**) (0.3 mmol, 69 mg) and (**2a**) (0.45 mmol, 84 mg) was performed under the standard procedure. Silica gel chromatography (10% EtOAc/Hex) afforded the title compound (75 mg, 60% yield, 95:5 d.r.). R_f 0.13 (10% EtOAc/Hex). ^1H NMR (500 MHz, CDCl_3) δ 7.22-7.37 (m, 5H); 6.72 (s, 1H); 5.14 (bs, 1H); 4.76 (d, $J = 7$ Hz, 1H); 4.37 (d, $J = 5.5$ Hz, 1H); 4.01 (br s, 2H); 3.47 (t, $J = 5.5$ Hz, 1H); 1.95 (m, 1H); 1.61-1.79 (m, 5H), 1.43 (s, 9H); 1.05-1.40 (m, 5H). ^{13}C NMR (125 MHz, CDCl_3) δ 156.4, 138.1, 136.7, 132.1, 128.8, 128.6, 127.4, 98.9, 87.7, 79.6, 75.7, 56.4, 39.8, 38.3, 30.7, 28.6, 28.0, 26.6, 26.5, 26.3. IR (film): 3376, 2929, 2852, 1690, 1507, 1450, 1392, 1366 1250, 1168, 1044, 920, 700 cm^{-1} . HRMS ESI (m/z): $[\text{M}+\text{Na}]^+$ calcd for $\text{C}_{24}\text{H}_{37}\text{NO}_5\text{Na}$, 442.2564; found 442.2568. $[\alpha]_{\text{D}} = -30$ (c 0.4, CHCl_3).

3f

(1*R*,2*S*)-1-cyclohexyl-1-(4-methoxy-benzyloxymethoxy)-3-[1-phenyl-meth-(*E*)-ylidene]-pentan-2-ol (3f): In the reductive coupling of 1-phenyl-1-butyne (**1c**) (0.3 mmol, 39 mg) and (**2b**) (118 mg, 0.45 mmol), the standard procedure was used. Silica gel chromatography (10% EtOAc/Hex) afforded the title compound (87 mg, 74% yield, >95:5

d.r.). R_f 0.15 (10% EtOAc/Hex). ^1H NMR (500 MHz, CDCl_3) δ 7.33-7.36 (m, 2H); 7.22-7.28 (m, 5H); 6.86-6.89 (m, 2H); 6.73 (s, 1H); 4.57 (d, $J = 11$ Hz, 1H); 4.51 (d, $J = 11$ Hz, 1H); 4.49 (d, $J = 5.5$ Hz, 1H); 3.81 (s, 3H); 3.38 (dd, $J = 5.5, 3.5$ Hz, 1H); 2.48-2.55 (m, 1H); 2.264 (br s, 1H); 2.03-2.10 (m, 1H); 1.98 (m, 1H); 1.57-1.76 (m, 5H); 1.16-1.39 (m, 5H); 1.11 (t, $J = 7.5$ Hz, 3H). ^{13}C NMR (125 MHz, CDCl_3) δ 159.3, 143.9, 138.1, 130.8, 129.6, 128.8, 128.4, 126.5, 126.0, 113.9, 85.1, 74.1, 73.6, 55.5, 39.5, 31.5, 27.5, 26.9, 26.7, 26.6, 22.7, 14.1. IR (film): 3462, 2927, 2851, 1612, 1514, 1449, 1302, 1248, 1173, 1074, 1035, 822, 749, 699 cm^{-1} . HRMS ESI (m/z): $[\text{M}+\text{Na}]^+$ calcd for $\text{C}_{26}\text{H}_{34}\text{O}_3\text{Na}$, 417.2406; found 417.2400. $[\alpha]_D = -17.1$ (c 1.17, CHCl_3).

(1R,2S)-1-Methoxymethoxy-1-phenyl-3-[1-phenyl-meth-(*E*)-ylidene]-pentan-2-ol (3g):

The reductive coupling of 1-phenyl-1-butyne (**1c**) (0.3 mmol, 39 mg) and (**2c**) (0.45 mmol, 81 mg) was performed under the standard procedure. Silica gel chromatography (10% EtOAc/Hex) afforded the title compound (35 mg, 39% yield, >95:5 d.r.) and the *syn* diastereomer (18 mg, 18%, >95:5 d.r.) for a combined yield of 57%. R_f 0.15 (10% EtOAc/Hex). ^1H NMR (500 MHz, CDCl_3) δ 7.14-7.37 (m, 10H); 6.33 (s, 1H); 4.77 (d, $J = 5.5$ Hz, 1H); 4.62 (d, $J = 6.5$ Hz, 1H); 4.60 (d, $J = 6.5$ Hz, 1H); 4.55 (dd, $J = 5.5, 2.5$ Hz, 1H); 3.36 (s, 3H); 2.42-2.49 (m, 1H); 2.15-2.22 (m, 1H); 2.05 (d, $J = 2.5$ Hz, 1H); 1.17 (t, $J = 7.5$ Hz, 3H). ^{13}C NMR (125 MHz, CDCl_3) δ 142.8, 137.8, 137.5, 128.7, 128.5, 128.4, 128.3, 128.3, 127.5, 126.6, 94.6, 80.3, 77.4, 56.0, 22.8, 14.0. IR (film): 3463, 3028, 2963, 2887, 1599, 1494, 1454, 1377, 11211, 1149, 1101, 1034, 969, 919, 747, 699 cm^{-1} . HRMS ESI (m/z): $[\text{M}+\text{Na}]^+$ calcd for $\text{C}_{20}\text{H}_{24}\text{O}_3\text{Na}$, 335.1618; found 335.1618. $[\alpha]_D = -10.0$ (c 3.2, CHCl_3).

3h

(4*S*,5*R*)-5-Methoxymethoxy-3-[1-phenyl-meth-(*E*)-ylidene]-undecan-4-ol (3h): The reductive coupling of 1-phenyl-1-butyne (**1c**) (0.3 mmol, 39 mg) and (**2d**) (0.45 mmol, 87 mg) was performed under the standard procedure. Silica gel chromatography (10% EtOAc/Hex) afforded the title compound as a 4:1 mixture of diastereomers determined by ¹H NMR (83 mg, 86% yield, 80:20 d.r.). *R_f* 0.15 (10% EtOAc/Hex). ¹H NMR (500 MHz, CDCl₃) δ 7.20-7.38 (m, 6.7H); 6.68 (s, 1H); 6.56 (s, 0.3H); 4.82 (d, *J* = 7 Hz, 1H); 4.76 (d, *J* = 7 Hz, 0.3H); 4.72 (d, *J* = 7 Hz, 0.3H); 4.71 (d, *J* = 7 Hz, 1H); 4.49 (d, *J* = 3 Hz, 1H); 4.41 (d, *J* = 3 Hz, 0.3H); 3.76 (dt, *J* = 7.3 Hz); 3.64 (dt, *J* = 7.3 Hz, 0.3H); 3.457 (s, 3H); 3.443 (s, 0.9H); 3.30 (dd, *J* = 3.5 Hz, 0.3H); 2.60 (br s, 1H); 2.51 (m, 1H); 2.43 (m, 0.3H); 2.25 (m, 0.3H); 2.06 (m, 1H); 1.40-1.65 (m, 2.6H); 1.25-1.36 (m, 10.4H); 1.13 (t, *J* = 7.5 Hz, 0.9H); 1.12 (t, *J* = 7.5 Hz, 3H); 0.89 (t, *J* = 7 Hz, 0.9 H); 0.88 (t, *J* = 7 Hz, 3H). ¹³C NMR (125 MHz, CDCl₃) δ 143.6, 142.3, 138.0, 137.9, 128.9, 128.9, 128.5, 128.4, 127.7, 126.7, 126.6, 125.8, 97.7, 96.5, 82.8, 80.5, 78.1, 74.9, 56.2, 56.2, 32.3, 32.1, 32.0, 29.6, 28.6, 26.2, 25.6, 22.9, 22.8, 22.5, 22.0, 14.3, 14.3, 14.1, 13.8. IR (film): 3463, 3056, 2955, 2858, 1600, 1576, 1494, 1378, 1305, 1213, 1132, 1098, 919, 781, 748, 699 cm⁻¹. HRMS ESI (*m/z*): [M+Na]⁺ calcd for C₂₀H₃₂O₃Na, 343.2244; found 343.2243.

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