



Supporting Information

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Asymmetric Catalytic Coupling of Organoboranes, Alkynes, and Imines Possessing A Removable (Trialkylsilyloxy)ethyl Group — Direct Access to Enantiomerically Pure Primary Allylic Amines

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Unless stated otherwise, all compounds were purchased from commercial suppliers (Aldrich, Alfa Aesar, or Strem) and used without further purification. THF, Et₂O and toluene were distilled from sodium/benzophenone ketyl. MeOH was distilled from magnesium methoxide. All other anhydrous grade solvents were purchased from Aldrich Chemical Co. Triethylborane was obtained neat and solutions were prepared using freshly distilled, thoroughly degassed solvents. Imines were prepared by condensation of aldehydes and amines in the presence of molecular sieves, and then purified by distillation or crystallization.

Analytical thin layer chromatography (TLC) was performed on silica gel 60 F₂₅₄ aluminum plates precoated with a fluorescent indicator. TLC plates were analyzed with UV light, stained with 12-molybdophosphoric (PMA) stain and developed by heating for 10 sec with a heat gun. Flash chromatography was performed using silica gel 60 (40-63 μm) from Silicycle. All ¹H and ¹³C NMR spectra were recorded using Bruker 400 MHz or Varian 500 MHz spectrometers at ambient temperature. IR spectra were recorded as a thin film between NaCl plates on a Perkin-Elmer Model 2000 FTIR instrument. 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. High resolution mass spectra (HRMS) were obtained on a Bruker Daltonics APEXII 3 Tesla Fourier Transform Mass Spectrometer of the Massachusetts

Institute of Technology Department of Chemistry Instrumentation Facility.

(R)-Ferrocenyl(2-*i*-propylphenyl)phenylphosphane (1d)

The *P*-chiral ferrocenyl phosphane (**1d**) was prepared from ephedrine-based oxazaphospholidine complex in 5% overall yield over four steps in >97% ee. (Colby, E. A.; Jamison, T.F. *J. Org. Chem.* **2003**, 68, 156-166).

R_f (10:1 hexane/EtOAc) = 0.65.

^1H NMR (CDCl_3 , 400 MHz): δ 7.48 (m, 2H), 7.35 (m, 3H), 7.28 (m, 2H), 7.08 (m, 1H), 6.99 (m, 1H), 4.43 (m, 1H), 4.38 (m, 2H), 4.11 (s, 5H), 3.81 (m, 1H), 3.63(sep, J = 6.9 Hz, 1H), 1.31(d, J = 6.8 Hz, 3H), 0.76 (d, J = 6.8 Hz, 3H).

^{13}C NMR (CDCl_3 , 100 MHz): δ 152.2 (d, J = 22.0 Hz), 138.3 (d, J = 7.6 Hz), 137.5 (d, J = 11.2 Hz), 134.5 (d, J = 19.9 Hz), 132.6, 128.9, 128.8, 128.3 (d, J = 7.5 Hz), 125.7, 125.3 (d, J = 4.0 Hz), 76.5 (d, J = 6.0 Hz), 74.5 (d, J = 29.0 Hz), 72.1, 71.4 (d, J = 6.59 Hz), 70.6, 69.3 (s, 5C), 31.3 (d, J = 24.3 Hz), 23.9 (d, J = 28.0 Hz).

^{31}P NMR (CDCl_3 , 121 MHz): δ -25.7 (s).

IR (film, CH_2Cl_2): 3053, 2959, 2246, 1586, 1470, 1435, 1160, 1106, 1026, 909, 819, 761, 741 cm^{-1} .

HRMS (ESI): m/z calcd for $\text{C}_{25}\text{H}_{26}\text{FeP}$ 414.1194, found 414.1149.

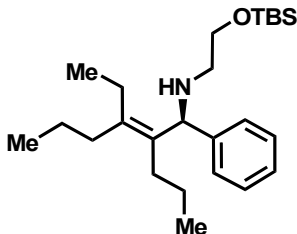
Enantiomeric excess: >97% ee, HPLC analysis of phosphane borane complex (Chiralcel AD, isocratic 1ml/min, hexane/2-propanol 99.5:0.5, t_R [(*R*)-**1d**] = 10.7 min, t_R [(*S*)-**1d**] = 12.5 min).

$[\alpha]_D = -36.4$ (c 0.71, CHCl_3).

Standard Experimental Procedure for Asymmetric, Catalytic Three-component Coupling of Alkynes, Imines and Triethylborane (Table 2).

In a glovebox, an oven-dried 50mL flask was charged with Ni(cod)₂ (7 mg, 0.025 mmol) and (*R*)-Ferrocenyl(2-*i*-propylphenyl)phenylphosphane **1d** (10.5 mg, 0.025 mmol), teflon coated stir bar and then sealed with a rubber septum. The flask was removed from the glovebox and placed under Ar atmosphere. Distilled MeOH (2.5 mL) was added followed by 100 μL of 3M solution of Et₃B in MeOAc. After 2 min, the imine (0.5 mmol) and alkyne (0.2 mmol) were added, and the mixture was stirred 10 min. Additional alkyne (0.80 mmol) and Et₃B in MeOAc (1.20 mmol, 400 μL) were added in four equal portions every 10 min. The mixture was stirred 12 h at room temperature and opened to air for 10 min. Concentration in vacuo and silica gel chromatography (hexanes: EtOAc) yielded allylic amines **2** and **3a-k**. Unless otherwise stated, yields refer to combined isolated yield with greater than >95% purity by ¹H NMR.

(S)-[2-(*tert*-Butyl-dimethyl-silanyloxy)-ethyl]-(3-ethyl-1-phenyl-2-propyl-hex-2-enyl)-amine (2)



In the three-component coupling of 4-octyne (1.0 mmol, 150 μ L), benzyldiene-[2-(*tert*-butyl-dimethyl-silanyloxy)-ethyl]-amine (0.5 mmol, 135 μ L), and Et₃B (1.5 mmol, 3M in MeOAc), the standard procedure was used. Silica gel chromatography afforded the allylic amine **2** (172 mg, 85% yield). R_f 0.69 (10:1 hexanes: EtOAc).

¹H NMR (CDCl₃, 400 MHz): δ 7.40 (m, 2H), 7.29 (m, 2H), 7.20 (m, 1H), 4.78 (s, 1H), 3.77 (app t, *J* = 4.60 Hz, 2H), 2.67 (m, 2H), 2.27 (q, *J* = 7.39 Hz, 2H), 2.13 (m, 2H), 1.87 (m, 1H), 1.75 (m, 2H), 1.44 (m, 2H), 1.08 (t, *J* = 7.52 Hz, 3H), 0.94 (m, 12H), 0.65 (m, 4H), 0.11 (s, 3H), 0.10 (s, 3H).

^{13}C NMR (CDCl_3 , 100 MHz): δ 143.7, 138.9, 135.2, 128.1, 127.4, 126.3, 62.9, 62.3, 50.1, 34.2, 30.6, 26.1, 24.2, 24.1, 22.2, 18.5, 15.1, 14.7, 14.6, -5.07, -5.10.

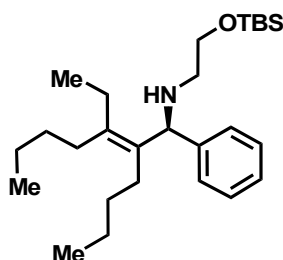
IR (film, CH_2Cl_2): 3337, 3025, 2958, 2930, 1463, 1256, 1082, 835, 776 cm^{-1} .

HRMS (ESI): m/z calcd for $\text{C}_{25}\text{H}_{45}\text{NOSi}$ 403.3343, found $(\text{M}+\text{H})^+$ 404.3335.

Enantiomeric excess: 89% ee, HPLC analysis (Chiralcel OD, isocratic 0.4ml/min, hexane/2-propanol 99.5:0.5, t_R [(*R*)] = 10.0 min, t_R [(*S*)] = 10.7 min).

$[\alpha]_{\text{D}} = -57.8$ (c 6.4, CHCl_3).

(*S*)-[2-(*tert*-Butyl-dimethyl-silanyloxy)-ethyl]-(2-butyl-3-ethyl-1-phenyl-hept-2-enyl)-amine (3a**)**



In the three-component coupling of 5-decyne (1.0 mmol, 179 μL), benzyldiene-[2-(*tert*-butyl-dimethyl-silanyloxy)-ethyl]-amine (0.5 mmol, 135 μL), and Et_3B (1.5 mmol, 3M in MeOAc), the standard procedure was used. Silica gel chromatography afforded the allylic amine **3a** as colorless oil (180 mg, 83% yield). R_f = 0.72 (90:10 hexanes: EtOAc).

^1H NMR (CDCl_3 , 400 MHz): δ 7.41 (m, 2H), 7.30 (m, 2H), 7.22 (m, 1H), 4.80 (s, 1H), 3.77 (app t, J = 5.24 Hz, 2H), 2.69 (m, 2H), 2.29 (m, 2H), 2.05 (m, 2H), 1.89 (m, 1H), 1.76 (m, 2H), 1.38 (m, 4H), 1.12 (m, 6H), 0.93 (m, 12H), 0.73 (t, J = 7.23 Hz, 3H), 0.61 (m, 1H), 0.10 (s, 3H), 0.09 (s, 3H).

^{13}C NMR (CDCl_3 , 100 MHz): δ 143.5, 138.9, 135.0, 128.1, 127.4, 126.3, 62.9, 62.3, 50.1, 32.9, 31.7, 31.3, 27.8, 26.1, 24.3, 23.6, 23.4, 18.5, 14.6, 14.3, 13.9, -5.07, -5.11.

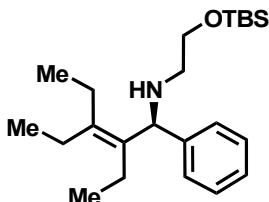
IR (film, CH_2Cl_2): 3337, 3061, 3025, 2958, 2957, 1491, 1463, 1378, 1256, 1125, 1081, 1061, 963, 835, 777, 701 cm^{-1} .

HRMS (ESI): m/z calcd for $\text{C}_{27}\text{H}_{49}\text{NOSi}$ 432.3656, found $(\text{M}+\text{H})^+$ 432.3635.

Enantiomeric excess: 89% ee, HPLC analysis (Chiralcel OD, isocratic 0.4ml/min, hexane/2-propanol 99.5:0.5, t_R [(*R*)] = 8.4 min, t_R [(*S*)] = 9.1 min).

$[\alpha]_D = -45.8$ (c 6.4, CHCl_3).

(*S*)-[2-(*tert*-Butyl-dimethyl-silanyloxy)-ethyl]-(2,3-diethyl-1-phenyl-pent-2-enyl)-amine (3b**)**



In the three-component coupling of 3-hexyne (1.0 mmol, 114 μL), benzyldiene-[2-(*tert*-butyl-dimethyl-silanyloxy)-ethyl]-amine (0.5 mmol, 135 μL), and Et_3B (1.5 mmol, 3M in MeOAc), the standard procedure was used. Silica gel chromatography afforded the allylic amine **3b** (169 mg, 89% yield). R_f = 0.67 (90:10 hexanes: EtOAc).

^1H NMR (CDCl_3 , 400 MHz): δ 7.42 (m, 2H), 7.30 (m, 2H), 7.20 (m, 1H), 4.80 (s, 1H), 3.77 (dd, J = 5.00, 5.50 Hz, 2H), 2.69 (m, 2H), 2.28 (q, J = 7.54 Hz, 2H), 2.10 (m, 2H), 1.95 (m, 1H), 1.83 (m, 1H), 1.70 (bs, 1H), 1.10 (t, J = 7.53 Hz, 3H), 1.02 (t, J = 7.48 Hz, 3H), 0.91 (s, 9H), 0.61 (t, J = 7.53 Hz, 3H), 0.09 (s, 3H), 0.08 (s, 3H).

¹³C NMR (CDCl₃, 100 MHz): δ 143.5, 140.2, 135.6, 128.1, 127.4, 126.3, 62.9, 62.3, 50.0, 26.1, 24.7, 23.8, 20.6, 18.5, 15.4, 14.6, 13.6, -5.05, -5.09.

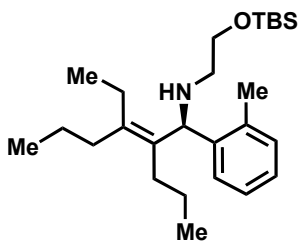
IR (film, CH₂Cl₂): 3337, 3026, 2960, 2931, 2872, 1463, 1451, 1255, 1082, 835, 777 cm⁻¹.

HRMS (ESI): m/z calcd for $C_{23}H_{41}NOSi$ 376.3030, found $(M+H)^+$ 376.3043.

Enantiomeric excess: 83% ee, HPLC analysis (Chiralcel OD, isocratic 0.3ml/min, hexane/2-propanol 99.6:0.4, t_R [(*R*)] = 13.3 min, t_R [(*S*)] = 14.6 min).

$$[\alpha]_{\text{D}} = -60.7 \text{ (} c \text{ 2.8, CHCl}_3 \text{)}.$$

(S)-[2-(*tert*-Butyl-dimethyl-silanyloxy)-ethyl]-(3-ethyl-2-propyl-1-*o*-tolyl-hex-2-enyl)-amine (3c)



In the three-component coupling of 4-octyne (1.0 mmol, 150 μ L), [2-(*tert*-butyldimethyl-silanyloxy)-ethyl]-(2-methyl-benzylidene)-amine (0.5 mmol, 139 μ L), and Et₃B (1.5 mmol, 3M in MeOAc), the standard procedure was used. Silica gel chromatography afforded the allylic amine **3c** (154 mg, 74% yield). *R*_f = 0.57 (90:10 hexanes: EtOAc).

¹H NMR (CDCl₃, 400 MHz): δ 7.73 (d, *J* = 7.42 Hz, 1H), 7.21 (t, *J* = 7.46 Hz, 1H), 7.13 (dt, *J* = 1.34, 7.32 Hz, 1H), 7.07 (d, *J* = 7.17 Hz, 1H), 4.72 (s, 1H), 3.74 (t, *J* = 5.02 Hz, 2H), 2.62 (m, 2H), 2.41 (m, 1H), 2.23 (m, 1H), 2.18 (s, 3H), 2.04 (t, *J* = 7.95 Hz, 2H), 1.76 (m, 2H), 1.57 (bs, 1H), 1.41 (m, 3H), 1.09 (t, *J* = 7.54 Hz, 3H), 0.91 (m, 12H), 0.58 (t, *J* = 7.24 Hz, 3H), 0.4 (m, 1H), 0.08 (s, 3H), 0.07 (s, 3H).

^{13}C NMR (CDCl_3 , 100 MHz): δ 140.8, 139.4, 136.8, 133.9, 130.0, 127.2, 126.2, 125.7, 62.9, 60.4, 50.4, 33.8, 31.2, 26.1, 24.0, 23.5, 22.2, 19.7, 18.5, 14.8, 14.7, 13.9, -5.07, -5.09.

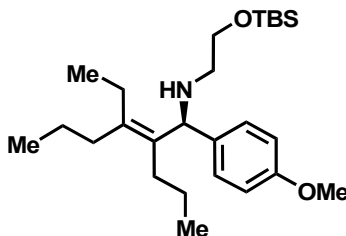
IR (film, CH_2Cl_2): 3345, 2957, 2930, 2870, 1462, 1255, 1091, 1059, 833, 776, 745 cm^{-1} .

HRMS (ESI): m/z calcd for $\text{C}_{26}\text{H}_{47}\text{NOSi}$ 418.3500, found 418.3496.

Enantiomeric excess: enantiomeric excess was measured on the trifluoro-acetamide of the deprotected primary allylic amine [*N*-(3-Ethyl-2-propyl-1-*o*-tolyl-hex-2-enyl)-2,2,2-trifluoro-acetamide] 85% ee, HPLC analysis (Chiralcel AD, isocratic 1 ml/min, hexane/2-propanol 99.5:0.5, t_R [(*R*)] = 4.4 min, t_R [(*S*)] = 5.5 min).

$[\alpha]_D = -44.7$ (c 3.8, CHCl_3).

(*S*)-[2-(*tert*-Butyl-dimethyl-silanyloxy)-ethyl]-[3-ethyl-1-(4-methoxy-phenyl)-2-propyl-hex-2-enyl]-amine (3d)



In the three-component coupling of 4-octyne (1.0 mmol, 150 μL), [2-(*tert*-butyl-dimethyl-silanyloxy)-ethyl]-(4-methoxy-benzylidene)-amine (0.5 mmol, 147 μL), and Et_3B (1.5 mmol, 3M in MeOAc), the standard procedure was used. Silica gel chromatography afforded the allylic amine **3d** (162 mg, 75% yield). R_f = 0.37 (90:10 hexanes: EtOAc).

^1H NMR (CDCl_3 , 400 MHz): δ 7.31 (m, 2H), 6.84 (m, 2H), 4.73 (s, 1H), 3.80 (s, 3H), 3.76 (dd, J = 4.64, 5.73 Hz, 2H), 2.67 (m, 2H), 2.24 (m, 2H), 2.02 (m, 2H), 1.83 (m, 1H), 1.74 (m, 1H), 1.65(bs, 1H), 1.43 (m, 2H), 1.07 (t, J = 7.52 Hz, 3H), 0.91 (m, 12H), 0.69 (m, 4H), 0.08 (s, 3H), 0.07 (s, 3H).

^{13}C NMR (CDCl_3 , 100 MHz): δ 158.2, 138.7, 135.7, 135.3, 128.3, 113.4, 62.9, 61.6, 55.4, 50.0, 34.2, 30.5, 26.1, 24.1, 24.0, 22.2, 18.5, 15.1, 14.7, 14.6, -5.07, -5.10.

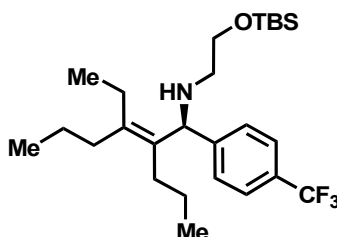
IR (film, CH_2Cl_2): 3334, 2957, 2931, 2870, 1610, 1584, 1509, 1464, 1246, 1103, 1074, 1040, 834, 777 cm^{-1} .

HRMS (ESI): m/z calcd for $\text{C}_{26}\text{H}_{47}\text{NO}_2\text{Si}$ 434.3449, found 434.3444.

Enantiomeric excess: 82% ee, HPLC analysis (Chiralcel AD, isocratic 0.4ml/min, hexane/2-propanol 99.5:0.5, t_R [(*R*)] = 8.7 min, t_R [(*S*)] = 11.2 min).

$[\alpha]_D = -48.9$ (c 9.2, CHCl_3).

(*S*)-[2-(*tert*-Butyl-dimethyl-silanyloxy)-ethyl]-[3-ethyl-2-propyl-1-(4-trifluoromethyl-phenyl)-hex-2-enyl]-amine (3e)



In the three-component coupling of 4-octyne (1.0 mmol, 150 μL), [2-(*tert*-butyl-dimethyl-silanyloxy)-ethyl]-(4-trifluoromethyl-benzylidene)-amine (0.5 mmol, 143 μL), and Et_3B (1.5 mmol, 3M in MeOAc), the standard procedure was used. Silica gel chromatography afforded the allylic amine **3e** (214 mg, 91% yield). R_f = 0.82 (90:10 hexanes: EtOAc).

^1H NMR (CDCl_3 , 400 MHz): δ 7.49 (m, 4H), 4.76 (s, 1H), 3.72 (dd, J = 4.10, 6.44 Hz, 2H), 2.68 (m, 1H), 2.57 (m, 1H), 2.22 (m, 2H), 1.99 (m, 2H), 1.81 (m, 1H), 1.63 (m, 2H), 1.41 (m, 2H), 1.04 (t, J = 7.52 Hz, 3H), 0.87 (m, 13H), 0.65 (m, 4H), 0.05 (s, 3H), 0.04 (s, 3H).

^{13}C NMR (CDCl_3 , 100 MHz): δ 148.1, 139.9, 134.4, 128.6, 127.7, 126.0, 125.00, 62.8, 62.4, 50.1, 34.2, 30.6, 26.1, 24.3, 24.1, 22.2, 18.5, 15.0, 14.7, 14.6, -5.08, -5.12.

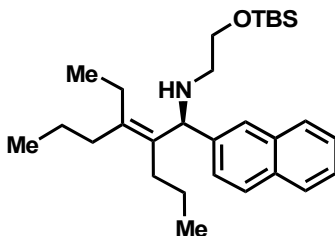
IR (film, CH_2Cl_2): 3338, 2959, 2931, 2871, 1618, 1464, 1325, 1256, 1163, 1126, 1068, 1017, 833, 777 cm^{-1} .

HRMS (ESI): m/z calcd for $\text{C}_{26}\text{H}_{44}\text{F}_3\text{NOSi}$ 472.3217, found 472.3229.

Enantiomeric excess: 85% ee, HPLC analysis (Chiralcel AD, isocratic 0.4ml/min, hexane/2-propanol 99.1:0.1, t_R [(*R*)] = 7.8 min, t_R [(*S*)] = 9.6 min).

$[\alpha]_D = -65.8$ (c 2.4, CHCl_3).

(*S*)-[2-(*tert*-Butyl-dimethyl-silanyloxy)-ethyl]-(3-ethyl-1-naphthalen-2-yl-2-propyl-hex-2-enyl)-amine (3f)



In the three-component coupling of 4-octyne (1.0 mmol, 150 μL) and [2-(*tert*-butyl-dimethyl-silanyloxy)-ethyl]-naphthalen-2-ylmethylene-amine (0.5 mmol, 157 mg), and Et_3B (1.5 mmol, 3M in MeOAc), the standard procedure was used. Silica gel chromatography afforded the allylic amine **3f** (204 mg, 90% yield). R_f = 0.38 (90:10 hexanes: EtOAc).

^1H NMR (CDCl_3 , 400 MHz): δ 7.94 (s, 1H), 7.83 (app dd, J = 7.75, 10.45 Hz, 2H), 7.76 (d, J = 8.53 Hz, 1H), 7.45 (m, 3H), 4.96 (s, 1H), 3.84 (m, 2H), 2.75 (m, 2H), 2.35 (m, 2H), 2.07 (m, 2H), 1.92 (m, 1H), 1.78 (m, 1H), 1.48 (m, 2H), 1.22 (m, 1H), 1.14 (t, J = 7.50 Hz, 3H), 0.95 (m, 12H), 0.65 (m, 4H), 0.12 (s, 3H), 0.11 (s, 3H).

^{13}C NMR (CDCl_3 , 100 MHz): δ 141.2, 139.5, 134.8, 133.7, 132.6, 128.1, 127.7, 127.5, 126.6, 125.9, 125.4, 125.2, 62.8, 62.5, 50.1, 34.2, 30.6, 26.2, 24.3, 24.1, 22.2, 18.5, 15.1, 14.7, 14.6, -5.04, -5.07.

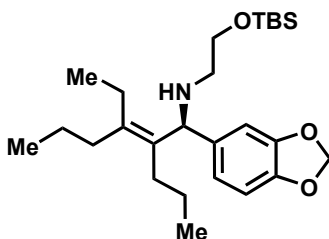
IR (film, CH_2Cl_2): 3335, 2957, 2929, 2869, 1507, 1463, 1255, 1091, 954, 834, 777 cm^{-1} .

HRMS (ESI): m/z calcd for $\text{C}_{29}\text{H}_{47}\text{NOSi}$ 454.3500, found 454.3491.

Enantiomeric excess: 73% ee, HPLC analysis (Chiralcel AD, isocratic 0.4 ml/min, hexane/2-propanol 99.5:0.5, t_R [(*R*)] = 9.8 min, t_R [(*S*)] = 11.8 min).

$[\alpha]_D = -78.7$ (c 10.8, CHCl_3).

(*S*)-(1-Benzo[1,3]dioxol-5-yl-3-ethyl-2-propyl-hex-2-enyl)-[2-(*tert*-butyl-dimethyl-silanyloxy)-ethyl]-amine (3g**)**



In the three-component coupling of 4-octyne (1.0 mmol, 150 μL), benzo[1,3]dioxol-5-ylmethylene-[2-(*tert*-butyl-dimethyl-silanyloxy)-ethyl]-amine (0.5 mmol, 154 mg), and Et_3B (1.5 mmol, 3M in MeOAc), the standard procedure was used. Silica gel chromatography afforded the allylic amine **3g** (212 mg, 95% yield). R_f = 0.46 (90:10 hexanes: EtOAc).

^1H NMR (CDCl_3 , 400 MHz): δ 6.93 (d, J = 1.28 Hz, 1H), 6.87 (d, J = 8.10 Hz, 1H), 6.75 (d, J = 8.02 Hz, 1H), 5.93 (s, 2H), 4.68 (s, 1H), 3.75 (t, J = 5.11 Hz, 2H), 2.65 (m, 2H), 2.23 (q, J = 7.51 Hz, 2H), 2.01 (m, 2H), 1.86 (m, 1H), 1.72 (m, 1H), 1.59 (bs, 1H), 1.43

(m, 2H), 1.22 (m, 1H), 1.07 (t, $J = 7.52$ Hz, 3H), 0.91 (m, 12H), 0.72 (m, 4H), 0.08 (s, 3H), 0.07 (s, 3H).

^{13}C NMR (CDCl_3 , 100 MHz): δ 147.6, 145.9, 138.9, 137.8, 135.2, 120.2, 108.0, 107.9, 100.9, 62.9, 62.0, 50.0, 34.2, 30.5, 26.1, 24.2, 24.1, 22.2, 18.5, 15.1, 14.7, 14.6, -5.08, -5.11.

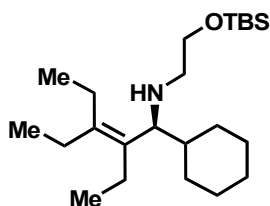
IR (film, CH_2Cl_2): 3335, 2957, 2930, 2870, 1503, 1486, 1471, 1251, 1236, 1086, 1042, 940, 835, 810, 777 cm^{-1} .

HRMS (ESI): m/z calcd for $\text{C}_{26}\text{H}_{45}\text{NO}_3\text{Si}$ 448.3241, found 448.3239.

Enantiomeric excess: 73% ee, HPLC analysis (Chiralcel AD, isocratic 0.4 ml/min, hexane/2-propanol 99.5:0.5, t_R [(*R*)] = 8.9 min, t_R [(*S*)] = 12.3 min).

$[\alpha]_D = -48.7$ (c 15.6, CHCl_3).

(*S*)-[2-(*tert*-Butyl-dimethyl-silanyloxy)-ethyl]-(1-cyclohexyl-2,3-diethyl-pent-2-enyl)-amine (3h)



In the three-component coupling of 3-hexyne (2.0 mmol, 228 μL), [2-(*tert*-butyl-dimethyl-silanyloxy)-ethyl]-cyclohexylmethylene-amine (1 mmol, 270 μL), and Et_3B (1.5 mmol, 3M in MeOAc), the standard procedure was used. Silica gel chromatography afforded the allylic amine **3h** (202 mg, 53% yield). $R_f = 0.81$ (95:5 hexanes: EtOAc).

^1H NMR (CDCl_3 , 400 MHz): δ 3.65 (m, 2H), 3.16 (d, $J = 3.16$ Hz, 1H), 2.57 (m, 1H), 2.42 (m, 1H), 2.08 (m, 7H), 1.9 (m, 1H), 1.62 (m, 5H), 1.2 (m, 5H), 0.98 (m, 6H), 0.91 (t, $J = 7.54$ Hz, 3H), 0.88 (s, 9H), 0.76 (m, 1H), 0.03 (s, 6H).

^{13}C NMR (CDCl_3 , 100 MHz): δ 140.9, 133.2, 64.3, 62.9, 49.9, 41.2, 31.3, 31.0, 26.9, 26.8, 26.7, 26.6, 26.1, 24.4, 22.9, 18.4, 15.6, 13.8, 13.6, -5.11, -5.14.

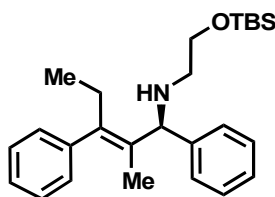
IR (film, CH_2Cl_2): 3361, 2959, 2928, 2854, 1463, 1449, 1255, 1094, 834, 776 cm^{-1} .

HRMS (ESI): m/z calcd for $\text{C}_{23}\text{H}_{47}\text{NOSi}$ 382.3500, found 382.3492.

Enantiomeric excess: 51% ee, chiral GC analysis. Column: β -cyclodextrin dialkyl B-DA, 20m* .25mm, isocratic 3.5 ml/min, 105 $^\circ\text{C}$, t_R (major) = 148 min, t_R (minor) = 152 min. (Analysis performed on Trifluoroacetate derivative of amino-alcohol: Treat product with TBAF, followed by Tf_2O , Et_3N)

$[\alpha]_D = -6.3$ (c 26.8, CHCl_3).

(*S*)-[2-(*tert*-Butyl-dimethyl-silanyloxy)-ethyl]-(2-methyl-1,3-diphenyl-pent-2-enyl)-amine (3i**)**



In the three-component coupling of 1-phenyl-1-propyne (1.0 mmol, 125 μL), benzylidene-[2-(*tert*-butyl-dimethyl-silanyloxy)-ethyl]-amine (0.5 mmol, 135 μL), and Et_3B (1.5 mmol, 3M in MeOAc), the standard procedure was used. Silica gel chromatography afforded the allylic amines **3i** (92 mg, 45% yield and 80:20 regioisomer, major shown). $R_f = 0.34$ (10:1 hexanes: EtOAc).

^1H NMR (CDCl_3 , 400 MHz): δ 7.56 (m, 2H), 7.39 (m, 4H), 7.29 (m, 2H), 7.16 (m, 2H), 5.05 (s, 1H), 3.91 (dd, $J = 4.51, 6.28$ Hz, 2H), 2.89 (m, 1H), 2.81 (m, 1H), 2.68 (q, $J = 7.45$ Hz, 2H), 1.33 (s, 3H), 1.05 (t, $J = 7.43$ Hz, 3H), 0.98 (s, 9H), 0.16 (2s, 6H).

^{13}C NMR (CDCl_3 , 100 MHz): δ 143.8, 143.1, 140.8, 132.0, 129.1, 128.3, 128.2, 127.1, 126.6, 126.3, 62.8, 61.5, 49.7, 27.3, 26.1, 18.5, 14.2, 13.7, -5.02, -5.06.

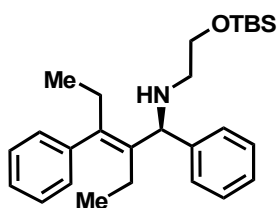
IR (film, CH_2Cl_2): 3329, 3058, 3024, 2929, 2956, 2857, 1945, 1600, 1492, 1471, 1462, 1377, 1360, 1256, 1085, 960, 836, 776 cm^{-1} .

HRMS (ESI): m/z calcd for $\text{C}_{26}\text{H}_{39}\text{NOSi}$ 410.2874, found 410.2872.

Enantiomeric excess: 84% ee, HPLC analysis (Chiralcel OD, isocratic 0.6ml/min, hexane/2-propanol 99.5:0.5, t_R [(*R*)] = 8.9 min, t_R [(*S*)] = 10.1 min).

$[\alpha]_D = -26.4$ (c 17.8, CHCl_3).

(*S*)-[2-(*tert*-Butyl-dimethyl-silanyloxy)-ethyl]-(2-ethyl-1,3-diphenyl-pent-2-enyl)-amine (3j)



In the three-component coupling of 1-phenyl-1-butyne (1.0 mmol, 142 μL), benzyldiene-[2-(*tert*-butyl-dimethyl-silanyloxy)-ethyl]-amine (0.5 mmol, 135 μL), and Et_3B (1.5 mmol, 3M in MeOAc), the standard procedure was used. Silica gel chromatography afforded the allylic amine **3j** as a single regioisomer (132 mg, 62% yield). $R_f = 0.41$ (95:5 hexanes: EtOAc).

^1H NMR (CDCl_3 , 400 MHz): δ 7.52 (m, 2H), 7.35 (m, 4H), 7.25 (m, 2H), 7.14 (m, 2H), 4.99 (s, 1H), 3.85 (dd, $J = 4.42, 6.32$ Hz, 2H), 2.88 (m, 1H), 2.79 (m, 1H), 2.60 (m, 2H), 1.85 (m, 2H), 1.69 (m, 1H), 1.00 (t, $J = 7.49$ Hz, 3H), 0.95 (s, 9H), 0.47 (t, $J = 7.53$ Hz, 3H), 0.13 (2s, 6H).

^{13}C NMR (CDCl_3 , 100 MHz): δ 143.7, 143.4, 141.5, 138.4, 129.0, 128.3, 128.1, 127.3, 126.6, 126.2, 62.9, 62.2, 50.2, 27.8, 26.2, 22.1, 18.5, 14.9, 13.5, -5.02, -5.06.

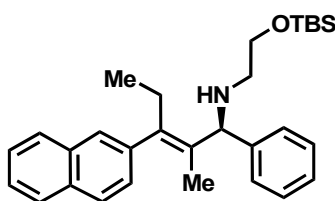
IR (film, CH_2Cl_2): 3337, 3058, 3024, 2959, 2930, 2857, 1599, 1491, 1462, 1256, 1081, 835, 777, 702 cm^{-1} .

HRMS (ESI): m/z calcd for $\text{C}_{27}\text{H}_{41}\text{NOSi}$ 424.3030, found 424.3018.

Enantiomeric excess: 71% ee, HPLC analysis (Chiralcel OD, isocratic 0.5ml/min, hexane/2-propanol 99.5:0.5, t_R [(*R*)] = 8.1 min, t_R [(*S*)] = 9.9 min).

$[\alpha]_D = -31.6$ (c 3.8, CHCl_3).

(*S*)-[2-(*tert*-Butyl-dimethyl-silanyloxy)-ethyl]-(2-methyl-3-naphthalen-2-yl-1-phenyl-pent-2-enyl)-amine (3k)



In the three-component coupling of 2-prop-1-ynyl-naphthalene (0.5 mmol, 83 mg), benzylidene-[2-(*tert*-butyl-dimethyl-silanyloxy)-ethyl]-amine (0.25 mmol, 68 μL), and Et_3B (1.5 mmol, 3M in MeOAc), the standard procedure was used. Silica gel chromatography afforded the allylic amines **3k** (regioselectivity: 85:15, 48 mg, 42% yield). $R_f = 0.34$ (90:10 hexanes: EtOAc).

¹H NMR (CDCl₃, 400 MHz): δ 7.84 (m, 3H), 7.52 (m, 5H), 7.41 (m, 2H), 7.29 (m, 2H), 5.08 (s, 1H), 3.90 (app t, *J* = 5.20 Hz, 2H), 2.92 (m, 1H), 2.81 (m, 1H), 2.75 (q, *J* = 7.46 Hz, 2H), 1.93 (bs, 1H), 1.34 (s, 3H), 1.05 (t, *J* = 7.49 Hz, 3H), 0.97 (s, 9H), 0.15 (s, 3H), 0.14 (s, 3H).

¹³C NMR (CDCl₃, 100 MHz): δ 143.1, 141.3, 140.7, 133.5, 132.6, 132.2, 128.4, 127.9, 127.8, 127.7, 127.4, 127.1, 126.7, 126.1, 125.6, 62.9, 61.6, 49.8, 27.3, 26.2, 18.6, 14.3, 13.8, -5.00, -5.03.

IR (film, CH₂Cl₂): 3329, 3055, 2955, 2928, 2856, 1598, 1462, 1450, 1255, 1085, 835, 820, 778, 747, 701 cm⁻¹.

HRMS (ESI): *m/z* calcd for C₃₀H₄₁NOSi 460.3030, found 460.3033.

Enantiomeric excess: 70% ee, HPLC analysis (Chiralcel OD, isocratic 0.4ml/min, hexane/2-propanol 99.5:0.5, *t_R* [(*R*)] = 12.9 min, *t_R* [(*S*)] = 15.3 min).

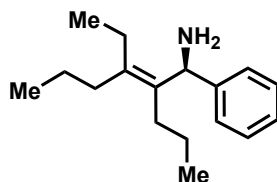
[α]_D = -23.3 (*c* 3.0, CHCl₃).

Standard Experimental Procedure for Deprotection of N-(*tert*-butyldimethyl)silyloxy ethyl (TBSOCH₂CH₂-) allylic amines

Tetrabutylammoniumfluoride (TBAF 1M solution in THF, 150 mol%) was added to a solution of allylic amine product (1M in THF) at 0 °C and mixture stirred for 30 min. 5 mL H₂O was added, and extracted with ether. Concentration under vacuo afforded the β-amino alcohol product. Without further purification, this product was dissolved in MeOH (0.2 M) and 40 % aq MeNH₂ (300 mol%), and solution of H₅IO₆ in water (360 mol%, 0.2M) were sequentially added. Reaction mixture was stirred 5 hr and then concentrated under vacuo. Add saturated NaHCO₃ solution to pH 9.0 and extract with CH₂Cl₂. Organic layer was concentrated in vacuo and silica gel chromatography (hexanes:

EtOAc) yielded primary allylic amines **4a-e**. Unless otherwise stated, yields refer to combined isolated yield with greater than >95% purity by ^1H NMR. Enantioselectivity was measured with HPLC (Chiralcel OD) on the corresponding trifluoroacetamide derivatives of primary allylic amines.

(S)-3-Ethyl-1-phenyl-2-propyl-hex-2-enylamine (4a)



^1H NMR (CDCl_3 , 400 MHz): δ 7.39 (m, 2H), 7.31 (m, 2H), 7.21 (m, 1H), 5.14 (s, 1H), 2.42 (m, 2H), 2.23 (m, 2H), 2.03 (m, 2H), 1.91 (ddd, $J = 4.73, 12.03, 16.81$ Hz, 1H), 1.75 (ddd, $J = 4.97, 11.65, 16.72$ Hz, 1H), 1.45 (m, 3H), 1.23 (m, 1H), 1.07 (t, $J = 7.53$ Hz, 3H), 0.934 (t, $J = 7.35$ Hz, 3H), 0.88 (m, 1H), 0.75 (t, $J = 7.22$ Hz, 3H).

^{13}C NMR (CDCl_3 , 100 MHz): δ 144.7, 138.3, 136.4, 128.2, 126.6, 126.4, 55.2, 34.4, 30.6, 24.8, 24.3, 22.2, 15.1, 14.8, 14.7.

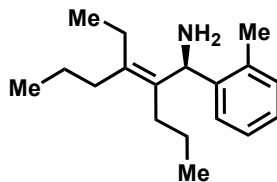
IR (film, CH_2Cl_2): 3376 (d), 3026, 2959, 2930, 2870, 1602, 1466, 1450, 1027 cm^{-1} .

HRMS (ESI): m/z calcd for $\text{C}_{17}\text{H}_{27}\text{N}+\text{Na}$ 268.2036, found 268.2043.

Enantiomeric excess: 89% ee, HPLC analysis (Chiralcel OD, isocratic 1 ml/min, hexane/2-propanol 99.5:0.5, t_R [(R)] = 5.0 min, t_R [(S)] = 9.7 min).

$[\alpha]_D = -80.0$ (c 10.0, CHCl_3).

(S)-3-Ethyl-2-propyl-1-*o*-tolyl-hex-2-enylamine (4b)



^1H NMR (CDCl_3 , 400 MHz): δ 7.68 (d, $J = 7.62$, 1H), 7.24 (dt, $J = 1.16$, 7.58, Hz, 1H), 7.15 (dt, $J = 1.36$, 7.35, Hz, 1H), 7.07 (d, $J = 7.27$, 1H), 5.15 (s, 1H), 2.42 (m, 2H), 2.21 (m, 4H), 2.04 (m, 2H), 1.81 (m, 2H), 1.46 (m, 5H), 1.11 (t, $J = 7.54$ Hz, 3H), 1.10 (m, 1H), 0.93 (t, $J = 7.35$ Hz, 3H), 0.59 (t, $J = 7.22$ Hz, 3H).

^{13}C NMR (CDCl_3 , 100 MHz): δ 142.6, 138.8, 136.2, 134.5, 130.0, 126.4, 126.0, 125.9, 52.7, 33.9, 30.8, 23.8, 23.7, 22.2, 20.0, 14.9, 14.7, 14.1.

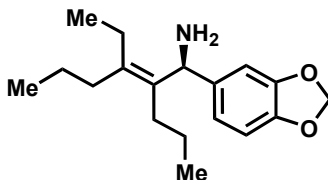
IR (film, CH_2Cl_2): 3379 (d), 2959, 2930, 2870, 1604, 1464, 1036, 742 cm^{-1} .

HRMS (ESI): m/z calcd for $\text{C}_{18}\text{H}_{29}\text{N}+\text{H}$ 260.2373, found 260.2361.

Enantiomeric excess: 85% ee, HPLC analysis (Chiralcel OD, isocratic 0.4ml/min, hexane/2-propanol 99.5:0.5, t_R [(*R*)] = 4.4 min, t_R [(*S*)] = 5.5 min).

$[\alpha]_{\text{D}} = -73.8$ (c 8.4, CHCl_3).

(S)-1-Benzo[1,3]dioxol-5-yl-3-ethyl-2-propyl-hex-2-enylamine (4c)



^1H NMR (CDCl_3 , 400 MHz): δ 6.88 (m, 2H), 6.75 (dd, $J = 0.75, 7.65$ Hz, 1H), 5.94 (s, 2H), 5.03 (s, 1H), 2.20 (m, 2H), 2.03 (m, 2H), 1.91 (ddd, $J = 4.79, 12.04, 16.82$ Hz, 1H), 1.74 (ddd, $J = 4.98, 11.84, 16.81$ Hz, 1H), 1.45 (m, 4H), 1.25 (m, 1H), 1.06 (t, $J = 7.54$ Hz, 3H), 0.96 (m, 1H), 0.94 (t, $J = 7.32$ Hz, 3H), 0.77 (t, $J = 7.27$ Hz, 3H).

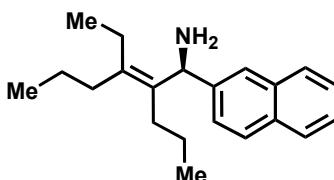
^{13}C NMR (CDCl_3 , 100 MHz): δ 147.6, 146.0, 138.9, 138.2, 136.4, 119.4, 107.9, 107.5, 101.0, 54.9, 34.4, 30.5, 24.9, 24.3, 22.2, 15.1, 14.8, 14.7.

IR (film, CH_2Cl_2): 3382 (d), 2958, 2930, 2870, 1502, 1486, 1234, 1040, 940, 810 cm^{-1} .

HRMS (ESI): m/z calcd for $\text{C}_{18}\text{H}_{27}\text{NO}_2 + \text{H}$ 290.2115, found 290.2123.

Enantiomeric excess: 73% ee, HPLC analysis (Chiralcel OD, isocratic 1ml/min, hexane/2-propanol 99.5:0.5, t_R [(*R*)] = 7.4 min, t_R [(*S*)] = 14.7 min).

(S)-3-Ethyl-1-naphthalen-2-yl-2-propyl-hex-2-enylamine (4d)



^1H NMR (CDCl_3 , 400 MHz): δ 7.94 (s, 1H), 7.84 (m, 2H), 7.76 (d, $J = 8.55$ Hz, 1H), 7.45 (m, 3H), 5.29 (s, 1H), 2.30 (m, 2H), 2.08 (m, 2H), 1.96 (ddd, $J = 4.82, 12.1, 16.9$

Hz, 1H), 1.76 (ddd, $J = 4.96, 11.8, 16.8$ Hz, 1H), 1.93 (bs, 2H), 1.50 (m, 2H), 1.27 (m, 1H), 1.12 (t, $J = 7.53$ Hz, 3H), 0.97 (t, $J = 7.35$ Hz, 3H), 0.89 (m, 1H), 0.69 (t, $J = 7.29$ Hz, 3H).

^{13}C NMR (CDCl_3 , 100 MHz): δ 142.3, 138.7, 136.2, 133.6, 132.5, 128.1, 127.7, 127.6, 126.1, 126.0, 125.5, 124.3, 55.4, 34.4, 30.7, 24.8, 24.4, 22.2, 15.1, 14.9, 14.7.

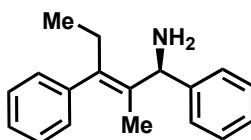
IR (film, CH_2Cl_2): 3377(d), 2959, 2929, 2869, 1602, 1506, 1466, 1455, 1374, 1058, 855, 817, 754 cm^{-1} .

HRMS (ESI): m/z calcd for $\text{C}_{21}\text{H}_{29}\text{N}+\text{H}$ 296.2373, found 296.2389.

Enantiomeric excess: 76% ee, HPLC analysis (Chiralcel OD, isocratic 1 ml/min, hexane/2-propanol 99.5:0.5, t_R [(*R*)] = 7.5 min, t_R [(*S*)] = 17.4 min).

$[\alpha]_D = -123.3$ (c 9.0, CHCl_3).

(*S*)-2-Methyl-1,3-diphenyl-pent-2-enylamine (4e)



^1H NMR (CDCl_3 , 400 MHz): δ 7.48 (m, 2H), 7.36 (m, 4H), 7.26 (m, 2H), 7.15 (m, 2H), 5.30 (s, 1H), 2.60 (q, $J = 7.52$ Hz, 2H), 1.60 (bs, 1H), 1.31 (s, 1H), 1.01 (t, $J = 7.51$ Hz, 3H)

^{13}C NMR (CDCl_3 , 100 MHz): δ 144.1, 143.6, 139.6, 133.5, 129.0, 128.4, 128.2, 126.6, 126.4, 126.3, 54.8, 27.3, 14.3, 14.0.

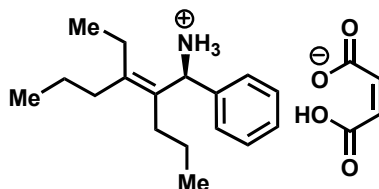
IR (film, CH_2Cl_2): 3375 (d), 3024, 2965, 2930, 2870, 1599, 1492, 1449, 1462, 1376, 1028, 766, 750 cm^{-1} .

HRMS (ESI): m/z calcd for $C_{18}H_{21}N+Na$ 274.1566, found 274.1566.

Enantiomeric excess: 84% ee, HPLC analysis (Chiralcel OD, isocratic 0.7 ml/min, hexane/2-propanol 99.5:0.5, t_R [(*R*)] = 17.2 min, t_R [(*S*)] = 23.5 min).

$[\alpha]_D = -27.8$ (c 1.8, $CHCl_3$).

Maleic Acid Salt of 4a



White crystals from ether at 0° C.

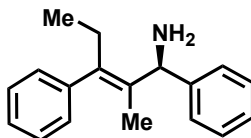
1H NMR ($CDCl_3$, 400 MHz): δ 8.56 (bs, 3H), 7.32 (m, 5H), 5.99 (s, 2H), 5.54 (s, 1H), 2.37 (m, 1H), 2.07 (m, 5H), 1.42 (m, 2H), 1.20 (m, 1H), 1.08 (t, $J = 7.50$ Hz, 3H), 0.93 (t, $J = 7.29$ Hz, 3H), 0.72 (m, 4H).

^{13}C NMR ($CDCl_3$, 100 MHz): δ 170.2, 145.0, 136.7, 135.8, 129.0, 128.6, 128.3, 126.3, 55.2, 34.1, 30.2, 24.5, 23.9, 21.8, 14.8, 14.7, 14.2.

Enantiomeric excess: Recrystallized maleic salt was treated with saturated $NaHCO_3$ solution and extracted with CH_2Cl_2 . Corresponding triflamide was made to measure enantiomeric excess. ee >99% ee, HPLC analysis (Chiralcel OD, isocratic 1 ml/min, hexane/2-propanol 99.5:0.5, t_R [(*R*)] = 5.0 min, t_R [(*S*)] = 9.7 min).

$[\alpha]_D = -59.4$ (c 3.2, $CHCl_3$).

Determination of absolute configuration via mosher ester analysis.



Primary allylic amine **4e** (6 mg, 0.03 mmol, 73% ee) was dissolved in CH₂Cl₂ (1 mL). (*R*)-Mosher's chloride (11.5 μL, 0.06 mmol), cat DMAP (~1 mg) and Et₃N (15 μL, 0.1 mmol) were added sequentially, and the reaction was stirred at room temperature for 5 hr. Reaction was diluted with 5 mL CH₂Cl₂ and washed with saturated NaHCO₃ solution. The organic layer was dried and concentrated, then subjected to silica gel chromatography (hexanes: EtOAc = 99: 1) to yield mixture of diastereomers (6 mg, ~85:15 diastereoselectivity). Shielding of the H and deshielding of the alkenyl group in the major diastereomer suggests an absolute configuration of (*S*).