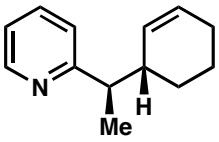
Supporting Information for

Palladium-Catalyzed Regio-, Diastereo-, and Benzylic Allylation of 2-Substituted Pyridines

Barry M. Trost and David Thaisrivongs
Department of Chemistry, Stanford University, Stanford, California 94305-5080

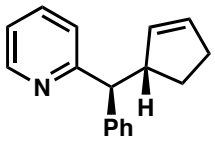
Material and Methods. All reactions were performed in flame- or oven-dried glassware with magnetic stirring under a nitrogen or argon atmosphere using freshly distilled solvents. All other commercial reagents were used without purification unless otherwise noted. Air and moisture-sensitive liquids and solutions were transferred via stainless steel syringe or cannula and introduced into the reaction vessel through rubber septa. Reactions conducted below room temperature were cooled by an external bath: dry ice in acetone for –78 °C or ice in water for 0 °C. Thin-layer chromatography was performed on EMD silica gel 60 F_{254} plates (0.25 mm); visualization of the developed chromatogram was performed by fluorescence quenching and staining with aqueous ceric ammonium molybdate, *p*-anisaldehyde, or potassium permanganate. Organic solutions were concentrated by rotary evaporation below 40 °C at *ca.* 25 mm Hg. Chromatographic purification of products was accomplished using forced-flow chromatography on Silicycle silica gel (particle size 0.040-0.063 mm). All isolated and characterized compounds were >95% pure as judged by ^{1}H NMR spectroscopic analysis. Optical rotations were measured on a Jasco DIP-1000 digital polarimeter using 5 cm glass cells with a sodium 589 nm filter and are reported as $[\alpha]^{25}_{D}$, concentration (g/100 mL), and solvent. Melting points were determined on a Thomas Hoover Capillary Melting Point Apparatus and are uncorrected. ^{1}H and ^{13}C NMR spectroscopy were performed on a Varian Unity Inova NMR operating at 500 and 125 MHz, respectively. Chemical shifts are reported in ppm relative to residual protio solvent signals; all ^{13}C NMR spectra are proton decoupled. Data for ^{1}H are reported as chemical shift (δ ppm), multiplicity (s = singlet, d = doublet, t = triplet, q = quartet, quint = quintet, sex = sextet, sept = septet, oct = octet, m = multiplet, app. = apparent), coupling constant, integration); data for ^{13}C are reported in terms of chemical shift. Infrared spectroscopic data was recorded on sodium chloride plates as thin films on a Thermo Scientific Nicolet IR100 FT-IR spectrometer. Mass spectrometry data were collected on a Micromass Q-Tof API-US mass spectrometer (Waters Corporation, Milford, MA). Chiral HPLC analysis was performed on a Thermo Separation Products Spectra Series P-100 using Chiralcel® and Chiralpak® columns.

General Procedure for the Asymmetric Allylic Alkylation of Allylic Pivaloyl Esters with 2-Substituted Pyridyl Nucleophiles. A reaction vial equipped with a stir bar was charged with the pyridyl nucleophile (0.185 mmol). To a second reaction vial equipped with a stir bar was added $[(\eta^3\text{-}C_3H_5)PdCl]_2$ (1.13 mg, 0.00308 mmol) and (*S*,*S*)-anthracenyl Trost ligand (6.00 mg, 0.00738 mmol). The vials were sealed, connected with a cannula, and evacuated and filled with Ar three times. Dioxane (degassed by sparging with Ar for 30 min, 0.25 mL) was added to the vial containing the nucleophile, followed by $BF_3{\bullet}OEt_2$ (19.7 μL, 0.160 mmol) and additional dioxane (0.25 mL); dioxane (1 mL) was also added to the vial containing the precatalyst mixture. After stirring for 30 min, the allylic pivaloyl ester (0.123 mmol) was added to the reaction followed by LiHMDS (1.0 M in THF, 369 μL, 0.369 mmol). [LiHMDS was prepared by adding *n*-BuLi (2.40 M in hexanes, 833 μL, 2.0 mmol) dropwise to a solution of HMDS (467 μL, 2.20 mmol) in THF (700 μL) at −78 °C. After 15 min, the slurry was warmed to 0 °C and stirred for 15 min.] The solution was cooled to 0 °C, *n*-BuLi (2.40 M in hexanes, 61.5 μL, 0.123 mmol) was added dropwise, and the reaction warmed to room temperature. The preformed catalyst was then added via cannula to the mixture and the reaction stirred for 10 h unless otherwise noted. The solution was concentrated in vacuo and the crude material dissolved in 10 mL MeOH, heated to 55 °C, and stirred for 2 h. After cooling to rt, Et_3N (1 mL) was added and the reaction concentrated in vacuo. The crude material was loaded onto silica gel and purified by flash chromatography on silica gel.

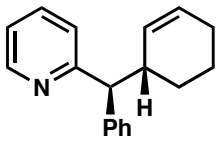


2-((*R*)-1-((*S*)-cyclohex-2-enyl)ethyl)pyridine (3a). The reaction was performed with 21.3 μL (0.185 mmol) of 2-ethylpyridine for 33 h. The crude material was purified by flash chromatography on silica gel (pretreated with 2% Et_3N in hexanes; eluted with 1% Et_3N in EtOAc:hexanes = 1:19) to give the product (19.7 mg, >19:1 dr, 86% yield) as a colorless oil. R_f = 0.45 (silica gel, EtOAc:hexanes = 2:8); $[\alpha]^{25}_D$ = –48.7° (*c* = 1.00, $CHCl_3$); IR (thin film) ν_{max} = 3017, 2929, 1589, 1569, 1473, 1433, 785.8, 748.6, 722.4, 668.7 cm^{-1}; ^1H NMR (500 MHz, $CDCl_3$) δ 8.55 (dq, *J* = 1.0, 5.0 Hz, 1H), 7.60 (dt, *J* = 1.5, 7.5 Hz, 1H), 7.13 (dt, *J* = 0.5, 8.0 Hz, 1H), 7.10 (dq, *J* = 1.5, 5.0 Hz, 1H), 5.63 (dq, *J* = 3.0, 10 Hz, 1H), 5.30 (app.d, *J* = 11 Hz, 1H), 2.78 (dq, *J* = 7.0, 14 Hz, 1H), 2.50-2.57 (m, 1H), 1.93-1.97 (m, 2H), 1.71-1.80 (m, 2H), 1.46-1.56 (m, 1H), 1.32-1.37 (m, 1H), 1.28 (d, *J* = 7.0 Hz, 1H); ^{13}C NMR (125 MHz, $CDCl_3$) δ 165.6, 149.1, 136.2, 130.5, 127.8, 122.5, 121.1, 46.89, 40.88, 26.16,

25.33, 21.86, 17.25; HRMS-ESI (*m*/*z*): $[M + H]^+$ calcd for $C_{13}H_{18}N$, 188.1439; found, 188.1440; Chiral HPLC: Chiralcel® OJ column, isopropanol:heptane = 2:98, 0.80 mL/min, λ = 254 nm; t_R = 6.45 (major), 7.21 (minor): 94% ee.

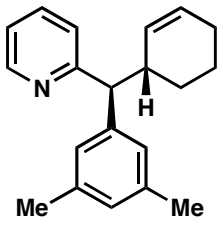


2-((*S*)-((*S*)-cyclopent-2-enyl)(phenyl)methyl)pyridine (3b). The reaction was performed with 29.7 μL (0.185 mmol) of 2-benzylpyridine. The crude material was purified by flash chromatography on silica gel (pretreated with 2% Et_3N in hexanes; eluted with 1% Et_3N in EtOAc:hexanes = 1:19) to give the product (27.5 mg, 11:1 dr, 95% yield) as a colorless oil. R_f = 0.48 (silica gel, EtOAc:hexanes = 2:8); $[\alpha]^{25}_D$ = –40.6° (*c* = 1.00, $CHCl_3$); IR (thin film) ν_{max} = 3056, 3026, 2005, 2927, 2849, 1588, 1569, 1493, 1470, 1453, 1432, 764.2, 746.8, 721.1, 700.2, 641.6, 605.8 cm^{-1}; ^1H NMR (500 MHz, $CDCl_3$) δ 8.57 (ddd, *J* = 1.0, 1.5, 4.5 Hz, 1H), 7.55 (dt, *J* = 2.0, 7.5 Hz, 1H), 7.42 (dd, *J* = 1.5, 8.5 Hz, 2H), 7.28 (app.tt, *J* = 1.5, 7.5 Hz, 2H), 7.18 (app.qt, *J* = 1.0, 7.0 Hz, 2H), 7.07 (ddd, *J* = 1.0, 4.5, 7.5 Hz, 1H), 7.75 (dq, *J* = 2.0, 6.0 Hz, 1H), 5.43 (dq, *J* = 2.0, 6.0 Hz, 1H), 3.76-3.80 (m, 2H), 2.33-2.41 (m, 1H), 2.25-2.31 (m, 1H), 1.89-2.01 (m, 1H), 1.38-1.52 (m, 1H); ^{13}C NMR (125 MHz, $CDCl_3$) δ 163.6, 149.4, 143.3, 136.4, 133.8, 131.6, 128.44, 128.42, 126.4, 123.1, 121.3, 60.12, 50.15, 31.90, 28.99; HRMS-ESI (*m*/*z*): $[M + H]^+$ calcd for $C_{17}H_{18}N$, 236.1439; found, 236.1439; Chiral HPLC: Chiralpak® IA column, isopropanol:heptane = 0.1:99.9, 1.0 mL/min, λ = 254 nm; t_R = 13.1 (major), 14.4 (minor): 88% ee.

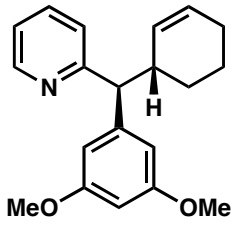


2-((*S*)-((*S*)-cyclohex-2-enyl)(phenyl)methyl)pyridine (3c). The reaction was performed with 29.7 μL (0.185 mmol) of 2-benzylpyridine. The crude material was purified by flash chromatography on silica gel (pretreated with 2% Et_3N in hexanes; eluted with 1% Et_3N in EtOAc:hexanes = 1:19) to give the product (30.5 mg, 6:1 dr, 99% yield) as a colorless oil. R_f = 0.53 (silica gel, EtOAc:hexanes = 2:8); $[\alpha]^{25}_D$ = +30.0° (*c* = 1.00, $CHCl_3$); IR (thin film) ν_{max} = 3023, 2924, 1588, 1569, 1493, 1470, 1452, 1432, 1148, 1050, 994.5, 747.2, 722.9, 700.0, 679.8, 657.7 cm^{-1}; ^1H NMR (500 MHz, $CDCl_3$) δ 8.60 (ddd, *J* = 1.0, 1.5, 4.5 Hz, 1H), 7.55 (dt, *J* = 2.0, 7.5 Hz, 1H), 7.42 (dd, *J* = 1.0, 8.0 Hz, 2H), 7.27 (t, *J* = 7.5 Hz, 2H), 7.22 (d, *J* = 7.5 Hz, 1H), 7.17 (dt, *J* = 1.0, 7.5 Hz, 1H), 7.07 (ddd, *J* = 1.0, 5.0, 7.5 Hz, 1H), 5.66 (dq, *J* = 3.5, 10 Hz, 1H), 5.35 (dq, *J* = 2.0, 11 Hz, 1H), 3.75 (d, *J* = 12 Hz, 1H), 3.23-3.29 (m, 1H), 1.97-2.01 (m, 1H), 1.69-1.75 (m, 1H), 1.48-1.58 (m, 1H), 1.16-1.26 (m,

1H); ^{13}C NMR (125 MHz, $CDCl_3$) δ 162.9, 149.4, 142.7, 136.4, 130.0, 128.4, 128.4, 128.3, 126.4, 123.8, 121.3, 59.92, 39.09, 27.77, 25.51, 21.32; HRMS-ESI (*m*/*z*): $[M + H]^+$ calcd for $C_{18}H_{20}N$, 250.1596; found, 250.1588; Chiral HPLC: Chiralcel® OD column, isopropanol:heptane = 2:98, 0.80 mL/min, λ = 254 nm; t_R = 10.8 (minor), 11.3 (major): 96% ee.

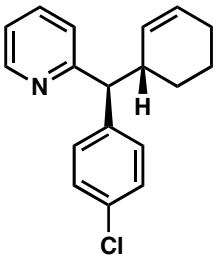


2-((*S*)-((*S*)-cyclohex-2-enyl)(3,5-dimethylphenyl)methyl)pyridine (3d). The reaction was performed with 36.5 μL (0.185 mmol) of 2-(3,5-dimethylbenzyl)pyridine. The crude material was purified by flash chromatography on silica gel (pretreated with 2% Et_3N in hexanes; eluted with 1% Et_3N in EtOAc:hexanes = 1:9) to give the product (34.1 mg, >19:1 dr, 99% yield) as a yellow oil. R_f = 0.51 (silica gel, EtOAc:hexanes = 2:8); $[\alpha]^{25}_D$ = +34.4° (*c* = 2.00, $CHCl_3$); IR (thin film) ν_{max} = 3019, 2920, 2859, 1588, 1568, 1470, 1447, 1432, 1147, 1048, 994.7, 747.3, 725.4, 706.4, 686.5, 617.4 cm^{-1}; ^{1}H NMR (500 MHz, $CDCl_3$) δ 8.59 (dd, *J* = 1.0, 4.5 Hz, 1H), 7.55 (dt, *J* = 2.0, 8.0 Hz, 1H), 7.23 (d, *J* = 8.0 Hz, 1H), 7.07 (dt, *J* = 1.0, 5.0 Hz, 1H), 7.09 (s, 2H), 6.81 (s, 1H), 5.65 (dq, *J* = 3.5, 9.5 Hz, 1H), 5.34 (dd, *J* = 2.0, 10 Hz, 1H), 3.68 (d, *J* = 12 Hz, 1H), 3.19-3.25 (m, 1H), 2.27 (s, 6H), 1.97-2.01 (m, 2H), 1.70-1.76 (m, 1H), 1.49-1.60 (m, 2H), 1.17-1.26 (m, 1H); ^{13}C NMR (125 MHz, $CDCl_3$) δ 163.2, 149.4, 142.6, 137.8, 136.4, 130.2, 128.2, 126.1, 123.7, 121.2, 59.90, 38.89, 27.83, 25.54, 21.36; HRMS-ESI (*m*/*z*): $[M + H]^+$ calcd for $C_{20}H_{24}N$, 278.1909; found, 278.1903; Chiral HPLC: Chiralcel® AD column, isopropanol:heptane = 2:98, 0.80 mL/min, λ = 254 nm; t_R = 6.23 (major), 7.54 (major): 94% ee.

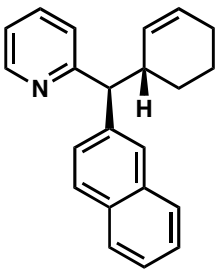


2-((*S*)-((*S*)-cyclohex-2-enyl)(3,5-dimethoxyphenyl)methyl)pyridine (3e). The reaction was performed with 42.4 μL (0.185 mmol) 2-(3,5-dimethoxybenzyl)pyridine. The crude material was purified by flash chromatography on silica gel (pretreated with 2% Et_3N in hexanes; eluted with 1% Et_3N in EtOAc:hexanes = 1:9) to give the product (36.1 mg, 8:1 dr, 95% yield) as a yellow oil. R_f = 0.30 (silica gel, EtOAc:hexanes = 2:8); $[\alpha]^{25}_D$ = +32.5° (*c* = 2.00, $CHCl_3$); IR (thin film) ν_{max} = 2932, 2835, 1592, 1466, 1430, 1311, 1203, 1156, 1063, 829.9, 748.6, 700.0 cm^{-1}; ^{1}H NMR (500 MHz, $CDCl_3$) δ 8.59 (dt, *J* = 1.0, 5.0 Hz, 1H), 7.55 (dt, *J* = 1.5, 7.5 Hz, 1H), 7.22 (d, *J* = 7.5 Hz, 1H), 7.08 (ddd, *J* = 0.5, 4.5, 8.0 Hz, 1H), 6.60 (d, *J* = 2.0 Hz, 2H), 6.28 (t, *J* = 2.5 Hz, 1H), 5.64 (dq, *J* = 3.5, 10 Hz, 1H), 5.32 (dd, *J* = 2.0, 10 Hz, 1H), 3.76 (s,

6H), 3.68 (d, J = 21 Hz, 1H), 3.18-3.24 (m, 1H), 1.96-2.00 (m, 2H), 1.69-1.76 (m, 1H), 1.57-1.63 (m, 1H), 1.49-1.56 (m, 1H), 1.19-1.27 (m, 1H); ^{13}C NMR (125 MHz, $CDCl_3$) δ 162.7, 160.7, 149.4, 145.2, 136.4, 130.0, 128.3, 123.8, 121.4, 106.5, 98.06, 60.10, 55.31, 38.97, 27.68, 25.51, 21.32; HRMS-ESI (m/z): $[M + Na]^+$ calcd for $C_{20}H_{23}NO_2Na$, 332.1626; found, 332.1626; Chiral HPLC: Chiralcel® OD column, isopropanol:heptane = 2:98, 0.80 mL/min, λ = 254 nm; t_R = 7.65 (major), 9.67 (minor): 98% ee.

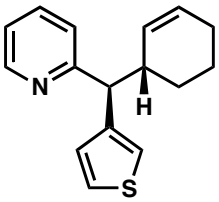


2-((*S*)-(4-chlorophenyl)((*S*)-cyclohex-2-enyl)methyl)pyridine (3f). The reaction was performed with 37.8 μL (0.185 mmol) of 2-(4-chlorobenzyl)pyridine. The crude material was purified by flash chromatography on silica gel (pretreated with 2% Et_3N in hexanes; eluted with 1% Et_3N in EtOAc:hexanes = 1:19) to give the product (31.0 mg, 15:1 dr, 89% yield) as a yellow oil. R_f = 0.54 (silica gel, EtOAc:hexanes = 2:8); $[\alpha]^{25}_D$ = +36.0° (c = 2.00, $CHCl_3$); IR (thin film) ν_{max} = 3021, 2925, 2859, 2835, 1589, 1569, 1488, 1470, 1433, 1409, 1148, 1089, 1049, 1015, 994.6, 875.1, 808.8, 772.0, 747.4, 725.3, 678.5, 652.9, 629.3 cm^{-1}; ^{1}H NMR (500 MHz, $CDCl_3$) δ 8.59 (dq, J = 1.0, 5.0 Hz, 1H), 7.56 (dt, J = 2.0, 8.0 Hz, 1H), 7.37 (d, J = 8.5 Hz, 2H), 7.23 (d, J = 8.5 Hz, 2H), 7.19 (dt, J = 1.0, 8.0 Hz, 1H), 7.09 (ddd, J = 1.0, 5.0, 7.5 Hz, 1H), 5.66 (dq, J = 3.5, 9.5 Hz, 1H), 5.30 (dq, J = 2.0, 11 Hz, 1H), 3.71 (d, J = 12 Hz, 1H), 3.17-3.24 (m, 1H), 1.96-2.01 (m, 2H), 1.68-1.75 (m, 1H), 1.48-1.56 (m, 2H), 1.14-1.21 (m, 1H); ^{13}C NMR (125 MHz, $CDCl_3$) δ 162.4, 149.6, 141.2, 136.5, 132.2, 129.7, 128.5, 123.8, 121.5, 59.23, 39.20, 27.71, 25.47, 21.28; HRMS-ESI (m/z): $[M + H]^+$ calcd for $C_{18}H_{19}NCl$, 284.1206; found, 284.1194; Chiral HPLC: Chiralcel ® AD column, isopropanol:heptane = 2:98, 1.0 mL/min, λ = 254 nm; t_R = 31.6 (minor), 39.7 (minor): 96% ee.

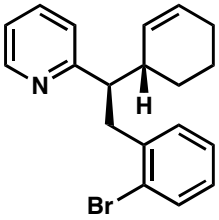


2-((*S*)-((*S*)-cyclohex-2-enyl)(naphthalen-2-yl)methyl)pyridine (3g). The reaction was performed with 40.6 μL (0.185 mmol) of 2-(naphthalen-2-ylmethyl)pyridine. The crude material was purified by flash chromatography on silica gel (pretreated with 2% Et_3N in hexanes; eluted with 1% Et_3N in EtOAc:hexanes = 1:19) to give the product (33.3 mg, 12:1 dr, 90% yield) as a yellow oil. R_f = 0.55 (silica gel, EtOAc:hexanes = 2:8); $[\alpha]^{25}_D$ = +62.3° (c = 2.00, $CHCl_3$); IR (thin film) ν_{max} = 3055, 3019, 2924, 2858, 2835, 1588, 1568, 1507, 1471, 1432, 1148, 994.6,

906.5, 814.2, 746.7, 680.7 cm^{-1}; ^1H NMR (500 MHz, $CDCl_3$) δ 8.62 (dq, *J* = 1.0, 5.0 Hz, 1H), 7.83 (s, 1H), 7.75-7.81 (m, 2H), 7.63 (dd, *J* = 2.0, 8.5 Hz, 1H), 7.55 (dt, *J* = 2.0, 8.0 Hz, 1H), 7.39-7.45 (m, 3H), 7.29 (dt, *J* = 1.0, 8.0 Hz, 1H), 7.08 (ddd, *J* = 1.0, 5.0, 7.5 Hz, 1H), 5.69 (dq, *J* = 3.5, 9.5 Hz, 1H), 5.42 (dq, *J* = 2.0, 10 Hz, 1H), 3.93 (d, *J* = 12 Hz, 1H), 3.63-3.42 (m, 1H), 1.99-2.03 (m, 2H), 1.69-1.76 (m, 1H), 1.49-1.59 (m, 2H), 1.21-1.28 (m, 1H); ^{13}C NMR (125 MHz, $CDCl_3$) δ 162.85, 149.54, 140.3, 136.4, 133.6, 132.4, 130.1, 128.4, 128.1, 127.8, 127.6, 126.9, 126.5, 125.9, 125.4, 123.9, 121.3, 60.06, 38.89, 27.85, 25.53, 21.33; HRMS-ESI (*m*/*z*): $[M + H]^+$ calcd for $C_{22}H_{22}N$, 300.1752; found, 300.1748; Chiral HPLC: Chiralcel ® OD column, isopropanol:heptane = 0.5:99.5, 1.0 mL/min, λ = 254 nm; t_R = 23.87 (major), 30.33 (minor): 98% ee.

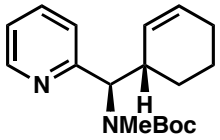


2-((*S*)-((*S*)-cyclohex-2-enyl)(thiophen-3-yl)methyl)pyridine (3h). The reaction was performed with 32.4 μL (0.185 mmol) of 2-(thiophen-3-ylmethyl)pyridine. The crude material was purified by flash chromatography on silica gel (pretreated with 2% Et_3N in hexanes; eluted with 1% Et_3N in EtOAc:hexanes = 1:19) to give the product (20.7 mg, >19:1 dr, 66% yield) as a yellow oil. R_f = 0.55 (silica gel, EtOAc:hexanes = 2:8); $[\alpha]^{25}_D$ = +21.6° (*c* = 1.00, $CHCl_3$); IR (thin film) ν_{max} = 3019, 2924, 2857, 1588, 1569, 1470, 1432, 1411, 1148, 1050, 994.0, 839.1, 772.4, 747.3, 726.3, 705.7, 669.5 cm^{-1}; ^1H NMR (500 MHz, $CDCl_3$) δ 8.59 (d, *J* = 5.0 Hz, 1H), 7.57 (dt, *J* = 2.0, 7.5 Hz, 1H), 7.20-7.26 (m, 2H), 7.14-7.16 (m, 2H), 7.09 (dd, *J* = 5.0, 6.8 Hz, 1H), 5.64 (dq, *J* = 3.5, 10 Hz, 1H), 5.29 (dd, *J* = 2.5, 10 Hz, 1H), 3.92 (d, *J* = 11 Hz, 1H), 3.10-3.16 (m, 1H), 1.96-2.00 (m, 2H), 1.69-1.76 (m, 1H), 1.57-1.65 (m, 1H), 1.49-1.57 (m, 1H), 1.19-1.30 (m, 1H); ^{13}C NMR (125 MHz, $CDCl_3$) δ 162.7, 149.5, 143.4, 136.4, 129.7, 128.4, 127.7, 125.3, 123.6, 121.4, 121.1, 92.06, 68.61, 55.21, 39.72, 27.75, 25.48, 21.30; HRMS-ESI (*m*/*z*): $[M + H]^+$ calcd for $C_{16}H_{18}NS$, 256.1160; found, 256.1159; Chiral HPLC: Chiralcel ® AD column, isopropanol:heptane = 0.5:99.5, 1.0 mL/min, λ = 254 nm; t_R = 19.22 (major), 21.39 (minor): 99% ee.

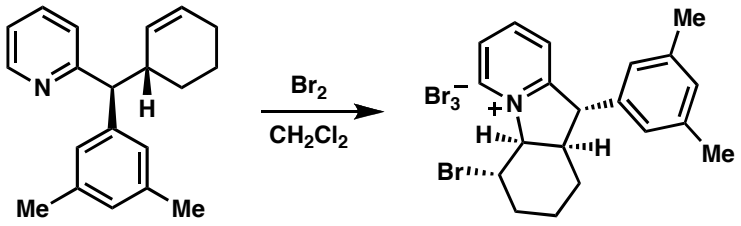


2-((*R*)-2-(2-bromophenyl)-1-((*S*)-cyclohex-2-enyl)ethyl)pyridine (3i). The reaction was performed with 48.5 μL (0.185 mmol) of 2-(2-bromophenethyl)pyridine. The crude material was purified by flash chromatography on silica gel (pretreated with 2% Et_3N in hexanes; eluted with

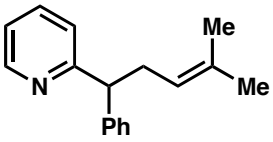
1% Et_3N in EtOAc:hexanes = 1:9) to give the product (38.0 mg, 4:1 dr, 90% yield) as a colorless oil. R_f = 0.39 (silica gel, EtOAc:hexanes = 2:8); $[\alpha]^{25}_D$ = +57.7° (*c* = 1.00, $CHCl_3$); IR (thin film) ν_{max} = 3019, 2928, 2858, 1674, 1589, 1568, 1471, 1435, 1148, 1048, 1024, 995.3, 748.2, 722.9, 700.0, 658.8 cm^{-1}; ^1H NMR (500 MHz, $CDCl_3$) δ 8.59 (app.dq, *J* = 1.0, 4.5 Hz, 1H), 7.44 (ddd, *J* = 2.0, 3.0, 4.0 Hz, 1H), 7.38 (dt, *J* = 2.0, 7.5 Hz, 1H), 7.03 (ddd, *J* = 1.5, 5.0, 7.5 Hz, 1H), 6.88-6.95 (m, 2H), 6.75 (dt, *J* = 1.0, 8.0 Hz, 1H), 6.62-6.64 (m, 1H), 5.63 (dq, *J* = 2.5, 10 Hz, 1H), 5.28-5.31 (m, 1H), 3.41 (dd, *J* = 3.5, 13 Hz, 1H), 2.72-2.77 (m, 2H), 3.02-3.18 (m, 2H), 1.94-2.00 (m, 2H), 1.79-1.85 (m, 1H), 1.52-1.66 (m, 2H); ^{13}C NMR (125 MHz, $CDCl_3$) δ 162.7, 149.2, 140.1, 135.7, 132.6, 131.5, 130.0, 129.0, 127.4, 126.7, 124.8, 124.6, 121.3, 52.53, 40.04, 38.68, 26.96, 25.39, 21.78; HRMS-ESI (*m*/*z*): $[M + H]^+$ calcd for $C_{19}H_{21}NBr$, 342.0857; found, 342.0846; Chiral HPLC: Chiralcel® OD column, isopropanol:heptane = 2:98, 0.80 mL/min, λ = 254 nm; t_R = 7.65 (major), 9.67 (minor): 98% ee.



***tert*-butyl (*R*)-((*S*)-cyclohex-2-enyl)(pyridin-2-yl)methyl(methyl)carbamate (3j).** The reaction was performed with 41.1 μL (0.185 mmol) of *tert*-butyl methyl(pyridin-2-ylmethyl)carbamate. The crude material was purified by flash chromatography on silica gel (pretreated with 2% Et_3N in hexanes; eluted with 1% Et_3N in EtOAc:hexanes = 1:9) to give the product (26.0 mg, 13:1 dr, 70% yield) as a colorless oil. R_f = 0.40 (silica gel, EtOAc:hexanes = 2:8); $[\alpha]^{25}_D$ = +42.3° (*c* = 2.00, $CHCl_3$); IR (thin film) ν_{max} = 3009, 2974, 2931, 1691, 1590, 1570, 1474, 1436, 1391, 1366, 1325, 1291, 1250, 1147, 1102, 1049, 995.5, 883.4, 792.6, 763.1, 749.5, 725.6, 702.2, 680.1, 618.4 cm^{-1}; ^1H NMR (500 MHz, $CDCl_3$) δ 8.58 (d, *J* = 4.0 Hz, 1H), 7.63 (dt, *J* = 1.5, 7.5 Hz, 1H), 7.22 (d, *J* = 7.5 Hz, 1H), 7.18 (t, *J* = 5.5 Hz, 1H), 5.64 (app.s, 1H), 5.17 (d, *J* = 13 Hz, 1H), 4.94 (d, *J* = 12 Hz, 1H), 3.14-3.21 (m, 1H), 2.73 (d, *J* = 15 Hz, 3H), 2.01 (app.s, 2H), 1.68-1.88 (m, 2H), 1.54-1.67 (m, 1H), 1.48 (d, *J* = 31 Hz, 9H), 1.47 (s, 1H); ^{13}C NMR (125 MHz, $CDCl_3$) δ 148.9, 136.6, 129.0, 128.0, 125.4, 124.8, 122.4, 79.85, 79.45, 63.39, 62.23, 33.91, 28.54, 25.40, 20.90, 20.49; HRMS-ESI (*m*/*z*): $[M + Na]^+$ calcd for $C_{18}H_{26}N_2O_2Na$, 325.1892; found, 325.1899; Chiral HPLC: Chiralpak ® IC column, isopropanol:heptane = 2:98, 0.80 mL/min, λ = 254 nm; t_R = 13.76 (minor), 16.80 (minor): >98% ee.



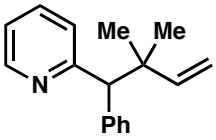
This bromocyclization was conducted under conditions adapted from those reported by Tunge.[1] Bromine (934 μL of a 1.0 M solution in CH_2Cl_2, 0.934 mmol) was added to a solution of 2-((*S*)-((*S*)-cyclohex-2-enyl)(3,5-dimethylphenyl)methyl)pyridine (25.9 mg, 0.0934 mmol) in benzene (1.56 mL) at ca. 10 °C, after which the reaction was allowed to warm to ambient temperature. After 10 minutes, the solution was concentrated to afford the crude product (100% conversion by ^{1}H NMR, >19:1 dr). Red cuboidal crystals suitable for X-ray diffraction were obtained by slow vapor diffusion of pentane into a solution of the pyridinium salt in CH_2Cl_2 at ambient temperature. M.p.: 162-156°C; R_f = 0.14 (silica gel, MeOH: CH_2Cl_2 = 1:9); $[\alpha]^{25}_D$ = –3.77° (*c* = 0.24, $CHCl_3$); IR (thin film) ν_{max} = 3434, 3400, 3306, 2921, 2859, 1626, 1495, 1156 cm^{-1}. For thermal ellipsoid representation and additional crystal and structural refinement data, see S12. Intriguingly, the absolute stereochemistry of this product is opposite that which has been demonstrate for "soft" nucleophiles.[2]



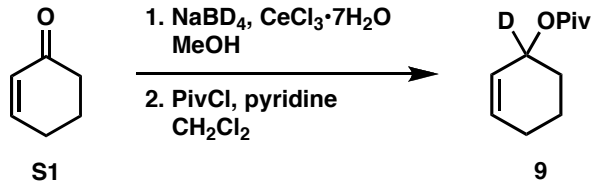
2-(4-methyl-1-phenylpent-3-enyl)pyridine (7). The reaction was performed with 41.1 μL (0.185 mmol) of 2-benzylpyridine and 23.3 μL (0.123 mmol) of 3-methylbut-2-enyl pivalate (**5**). The crude material was purified by flash chromatography on silica gel (pretreated with 2% Et_3N in hexanes; eluted with 1% Et_3N in EtOAc:hexanes = 1:19) to give the product (21.7 mg, 74% yield, >19:1 linear:branched) as a yellow oil. R_f = 0.62 (silica gel, EtOAc:hexanes = 2:8); $[\alpha]^{25}_D$ = –26.4° (*c* = 1.00, $CHCl_3$); IR (thin film) ν_{max} 3061, 3026, 2967, 2913, 1589, 1569, 1495, 1471, 1452, 1432, 745.8, 699.4 cm^{-1}; ^{1}H NMR (500 MHz, $CDCl_3$) δ 8.57 (app.dq, *J* = 1.0, 5.0 Hz, 1H), 7.55 (dt, *J* = 2.0, 8.0 Hz, 1H), 7.34 (app.d, *J* = 8.0 Hz, 2H), 7.27 (app.t, *J* = 5.0 Hz, 2H), 7.18 (tt, *J* = 1.5, 8.5 Hz, 1H), 7.15 (d, *J* = 12 Hz, 1H), 7.08 (ddd, *J* = 1.0, 5.0, 6.5 Hz, 1H), 5.05 (tt, *J* = 1.5, 7.0 Hz, 1H), 4.08 (t, *J* = 7.5 Hz, 1H), 2.94 (ddd, *J* = 7.0, 7.0, 15 Hz, 1H), 2.77 (ddd, *J* = 7.0, 7.0, 15 Hz,

[1] Waetzig, S. R.; Tunge, J. A. *J. Am. Chem. Soc.* **2007**, *129*, 4138.
[2] Trost, B. Am.; Machacke, M. R.; Aponick, A. Acc. Chem. Res. **2006**, *39*, 747.

1H), 1.60 (s, 3H), 1.56 (s, 3H); ^{13}C NMR (125 MHz, $CDCl_3$) δ 163.8, 149.3, 143.8, 136.4, 133.0, 128.4, 128.2, 126.36, 122.92, 122.4, 121.3, 53.97, 33.72, 25.78, 17.93; HRMS-ESI (*m*/*z*): [M + H]$^+$ calcd for $C_{17}H_{20}N$, 238.1596; found, 238.1590; Chiral HPLC: Chiralcel ® OD column, isopropanol:heptane = 0.5:99.5, 0.80 mL/min, λ = 254 nm; t_R = 16.37 (major), 18.09 (minor): 89% ee. [Note: **L1** and **L2** give enantioenriched products of the opposite absolute stereochemistry.]



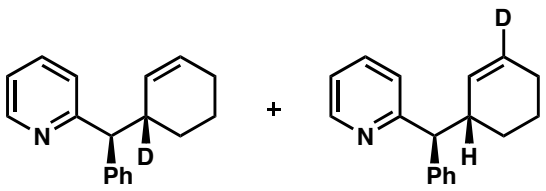
2-(2,2-dimethyl-1-phenylbut-3-enyl)pyridine (8). The reaction was performed with 41.1 μL (0.185 mmol) of 2-benzylpyridine and 24.7 μL (0.123 mmol) of 2-methylbut-3-en-2-yl pivalate (**6**). The crude material was purified by flash chromatography on silica gel (pretreated with 2% Et_3N in hexanes; eluted with 1% Et_3N in EtOAc:hexanes = 1:19) to give the product (18.7 mg, 64% yield, >19:1 branched:linear) as a yellow oil. R_f = 0.54 (silica gel, EtOAc:hexanes = 2:8); $[\alpha]^{25}_D$ = –31.5° (*c* = 1.00, $CHCl_3$); IR (thin film) ν_{max} = 2965, 1587, 1470, 1432, 1378, 1361, 1149, 997.2, 911.6, 745.7, 702.9 cm^{-1}; ^{1}H NMR (500 MHz, $CDCl_3$) δ 8.61 (dt, *J* = 1.0, 4.5 Hz, 1H), 7.59 (d, *J* = 7.5 Hz, 2H), 7.56 (dt, *J* = 2.0, 7.5 Hz, 1H), 7.30 (app.q, *J* = 7.0 Hz, 3H), 7.23 (d, *J* = 7.5 Hz, 1H), 7.11 (dd, *J* = 5.0, 8.0 Hz, 1H), 6.19 (dd, *J* = 11, 18 Hz, 1H), 5.01 (dd, *J* = 1.0, 11 Hz, 1H), 4.91 (dd, *J* = 1.5, 18 Hz, 1H), 3.98 (s, 1H), 1.15 (s, 3H), 1.14 (s, 3H); ^{13}C NMR (125 MHz, $CDCl_3$) δ 160.2, 148.8, 146.5, 140.7, 135.7, 130.6, 127.6, 126.4, 124.7, 121.2, 111.6, 64.66, 41.07, 26.81, 26.17; HRMS-ESI (*m*/*z*): [M + H]$^+$ calcd for $C_{17}H_{20}N$, 238.1596; found, 238.1596; Chiral HPLC: Chiralcel ® OD column, isopropanol:heptane = 0.1:99.9, 0.80 mL/min, λ = 254 nm; t_R = 12.82 (minor), 13.36 (major): 63% ee. [Note: Both **L1** and **L2** give enantioenriched products of the same absolute stereochemistry.]



Deuterium-labeled substrate (9). $NaBD_4$ (87.0 mg, 2.08 mmol) was slowly added to a solution of cyclohex-2-enone (**S1**, 200 μL, 2.08 mmol) and $CeCl_3$•$7H_2O$ (774 mg, 2.08 mmol) in MeOH

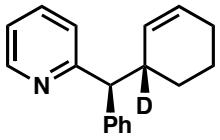
(3.5 mL) at ambient temperature. After 10 min, the reaction was diluted with E_2O (10 mL) and then quenched by the slow addition of H_2O (20 mL). The layers were separated and the product further extracted with E_2O (2 × 10 mL). The combined organic layers were dried over $MgSO_4$, filtered, and concentrated in vacuo to give the crude allylic alcohol as a clear oil, which was carried on without further purification.

Pivaloyl chloride (256 μL, 2.08 mmol) was slowly added to a solution of the allylic alcohol in pyridine (1.5 mL) and CH_2Cl_2 (1.5 mL) at 0 °C. The reaction was allowed to warm to ambient temperature and stirred for 24 hours. The mixture was diluted with CH_2Cl_2 (10 mL) and quenched by the addition of sat. aq. NH_4Cl (10 mL). The layers were separated and the product further extracted with CH_2Cl_2 (2 × 10 mL). The combined organic layers were dried over $MgSO_4$, filtered, and concentrated in vacuo. The crude material was purified by flash chromatography on silica gel (EtOAc:hexanes = 1:19) to give the product (233 mg, 61% yield over two steps) as a pale yellow oil. R_f = 0.61 (silica gel, EtOAc:hexanes = 2:8); IR (thin film) ν_{max} = 2977, 2874, 1810, 1724, 1480, 1461, 1396, 1368, 1291, 1265, 1157, 1124, 1080, 1044, 1006, 941.7 cm^{-1}; ^1H NMR (500 MHz, $CDCl_3$) δ 5.94 (dt, *J* = 3.5, 10 Hz, 1H), 5.68 (dt, *J* = 2.0, 10 Hz, 1H), 5.21-5.22 (m, 18% residual ^1H), 2.05-2.12 (m, 1H), 1.95-2.02 (m, 1H), 1.81-1.87 (m, 1H), 1.69-1.77 (m, 2H), 1.58-1.67 (m, 2H), 1.19 (s, 9H); ^{13}C NMR (125 MHz, $CDCl_3$) δ 174.1, 132.5, 125.9, 40.28, 38.75, 28.21, 26.59, 24.99, 18.93.



Products 10 and 11. The reaction was performed at half the usual scale with 14.9 μL (0.0925 mmol) of 2-benzylpyridine. The crude material was purified by flash chromatography on silica gel (pretreated with 2% Et_3N in hexanes; eluted with 1% Et_3N in EtOAc:hexanes = 1:19) to give the product (15.2 mg, 9:1 dr, 99% yield with (*R*,*R*)-**L1** and 14.3 mg, 9:1 dr, 93% yield with (*S*,*S*)-**L1**) as a colorless oil. R_f = 0.53 (silica gel, EtOAc:hexanes = 2:8); $[\alpha]^{25}_D$ = +34.7° (*c* = 1.00, $CHCl_3$); IR (thin film) ν_{max} = 3060, 3023, 2924, 2857, 1588, 1569, 1493, 1470, 1452, 1432, 766.2, 747.0, 700.3, 663.2, 590.4 cm^{-1}; ^1H NMR (500 MHz, $CDCl_3$) δ 8.59 (app.dd, *J* = 1.0, 5.0 Hz, 1H), 7.56 (app.t, *J* = 6.5 Hz, 1H), 7.42 (d, *J* = 7.5 Hz, 2H), 7.27 (t, *J* = 7.5 Hz, 2H), 7.23 (d, *J* = 8.5 Hz, 1H), 7.17 (tt, *J* = 1.0, 7.0 Hz, 1H), 7.09 (app.t, *J* = 5.0, Hz, 1H), 5.66 (dt, *J* = 3.5, 10 Hz, 1H),

5.32-5.34 (m, 1H), 3.75 (s, 1H), 3.22-3.28 (m, 1H), 1.97-2.00 (m, 1H), 1.69-1.74 (m, 1H), 1.48-1.59 (m, 2H), 1.15-1.31 (m, 2H); ^{13}C NMR (125 MHz, $CDCl_3$) δ 163.0, 149.5, 142.8, 136.4, 130.0, 128.8, 128.44, 128.38, 126.4, 123.8, 121.3, 59.84, 39.05, 27.64, 25.52, 21.28. Chiral HPLC: Chiralpak® IC column, isopropanol:heptane = 2:98, 1.0 mL/min, λ = 254 nm; with (*R*,*R*)-**L1**: t_R = 5.23 (major), 5.81 (minor): 90% ee and with (*S*,*S*)-**L1**: t_R = 5.20 (minor), 5.68 (major): 91% ee.



Product *rac*-11. The reaction was performed at half the usual scale with 14.9 μL (0.0925 mmol) of 2-benzylpyridine. The crude material was purified by flash chromatography on silica gel (pretreated with 2% Et_3N in hexanes; eluted with 1% Et_3N in EtOAc:hexanes = 1:19) to give the product (14.9 mg, 9:1 dr, 97% yield) as a colorless oil. R_f = 0.53 (silica gel, EtOAc:hexanes = 2:8); IR (thin film) ν_{max} = 3023, 2925, 2857, 1588, 1569, 1493, 1471, 1452, 1432, 747.3, 700.19, 664.5, 605.2 cm^{-1}; ^{1}H NMR (500 MHz, $CDCl_3$) δ 8.60 (ddd, *J* = 0.5, 1.5, 5.5 Hz, 1H), 7.55 (dt, *J* = 2.0, 7.5 Hz, 1H), 7.42 (dd, *J* = 1.0, 8.5 Hz, 2H), 7.27 (t, *J* = 7.5 Hz, 2H), 7.23 (d, *J* = 8.0 Hz, 1H), 7.17 (dt, *J* = 1.5, 7.0 Hz, 1H), 7.07 (ddd, *J* = 1.0, 6.0, 6.5 Hz, 1H), 5.66 (dt, *J* = 3.5, 10 Hz, 1H), 5.34 (dq, *J* = 1.0, 11 Hz, 1H), 3.75 (s, 1H), 3.22-3.28 (m, 22% ^{1}H), 1.97-2.01 (m, 2H), 1.69-1.74 (m, 2H), 1.48-1.56 (m, 2H); ^{13}C NMR (125 MHz, $CDCl_3$) δ 162.9, 149.5, 142.8, 136.4, 130.0, 128.8, 128.45, 128.38, 126.4, 123.8, 121.3, 67.98, 59.84, 27.64, 25.52, 21.28.

Crystallographic Information for Bromocyclization Product

Data collection. A crystal (approximate dimensions 0.35 x 0.25 x 0.15mm^3) was placed onto the tip of a 0.1 mm diameter glass capillary and mounted on a CCD area detector diffractometer for a data collection at 173(2) K.[3] A preliminary set of cell constants was calculated from reflections harvested from three sets of 20 frames. These initial sets of frames were oriented such that orthogonal wedges of reciprocal space were surveyed. This produced initial orientation matrices determined from 141 reflections. The data collection was carried out using MoKα radiation (graphite monochromator) with a frame time of 20 seconds and a detector distance of 4.8 cm. A randomly oriented region of reciprocal space was surveyed to the extent of one sphere and to a resolution of 0.77 Å. Four major sections of frames were collected with 0.30° steps in ω at four different ϕ settings and a detector position of –28° in 2θ. The intensity data were corrected for absorption and decay (SADABS).[4] Final cell constants were calculated from 2990 strong reflections from the actual data collection after integration (SAINT).[5] Refer to Table 1 for additional crystal and refinement information.

Structure solution and refinement.[6] The structure was solved using Bruker SHELXTL[7] and refined using Bruker SHELXTL.[5] The space group $P2_12_12_1$ was determined based on systematic absences and intensity statistics. A direct-methods solution was calculated which provided most non-hydrogen atoms from the E-map. Full-matrix least squares / difference Fourier cycles were performed which located the remaining non-hydrogen atoms. All non-hydrogen atoms were refined with anisotropic displacement parameters. All hydrogen atoms were placed in ideal positions and refined as riding atoms with relative isotropic displacement parameters. The final full matrix least squares refinement converged to $R1 = 0.0265$ and $wR2 = 0.0573$ (F^2, all data).

Data collection and structure solution were conducted at the X-Ray Crystallographic Laboratory, 193 Kolthoff Hall, Department of Chemistry, University of Minnesota. All calculations were performed using Pentium computers using the current SHELXTL suite of programs.

---

[3] SMART V5.054, Bruker Analytical X-ray Systems, Madison, WI (2001).

[4] An empirical correction for absorption anisotropy, Blessing, R. *Acta Cryst.* **1995**, A51, 33.

[5] SAINT+ V6.45, Bruker Analytical X-Ray Systems, Madison, WI (2003).

[6] (a) Altomare, A.; Burla, M. C.; Camalli, M.; Cascarano, G.; Giacovazzo, C.; Guagliardi, A.; Moliterni, A. G. G.; Polidori, G.; Spagna, R. Sir97. *J. Appl. Cryst.* **1998**, *32*, 115. (b) Burla, M. C.; Camalli, M.; Carrozzini, B.; Cascarano, G. L.; Giacovazzo, C.; Polidori, G.; Spagna, R. Sir2002: A new direct methods program for automatic solution and refinement of crystal structures. *J. Appl. Cryst.* **2003**, *manuscript in preparation*. (c) Spek, A. L.; *Acta. Cryst.* **1990**, A46, C34. (d) Spek, A. L. PLATON, A Multipurpose Crystallographic Tool. **2000**, Utrecht University, Utrecht, The Netherlands.

[7] SHELXTL V6.14, Bruker Analytical X-Ray Systems, Madison, WI (2000).

Figure S1. ORTEP Drawing of Bromocyclization Product

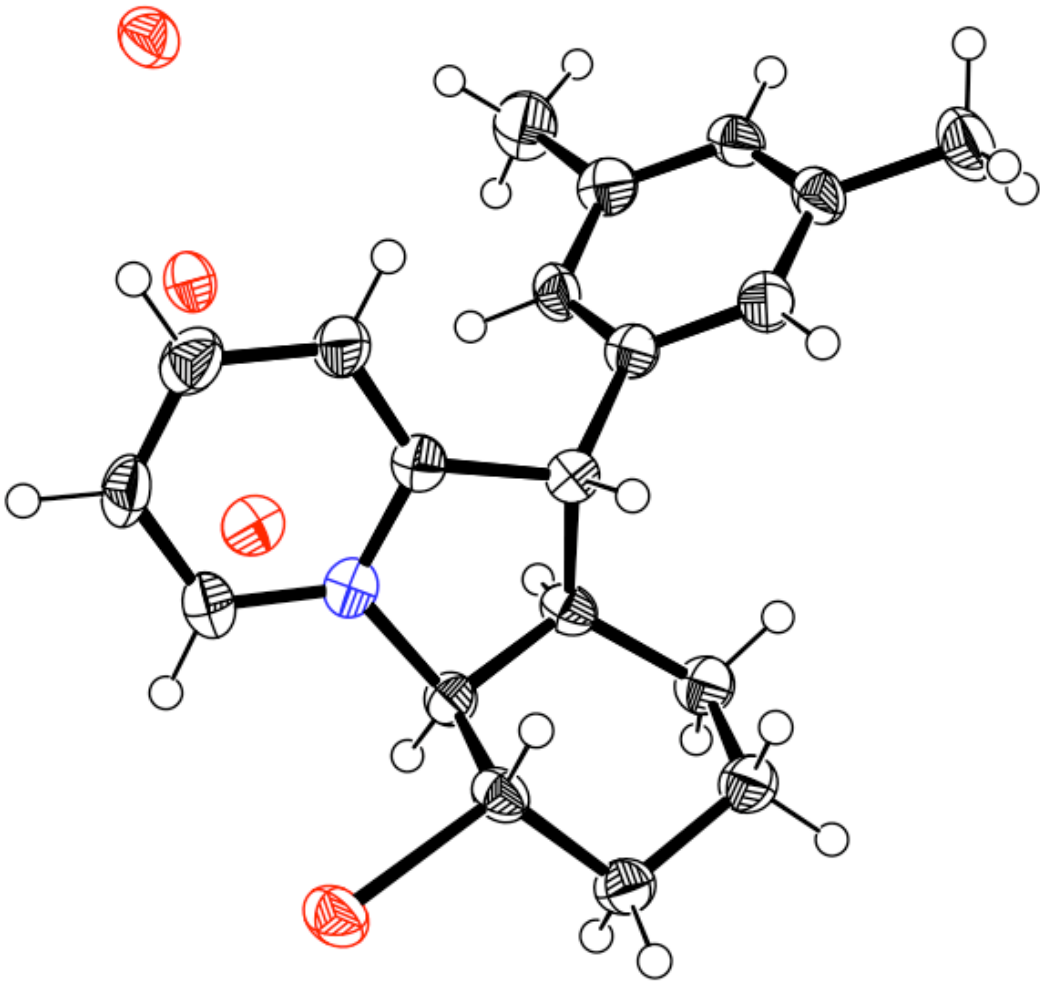


Table S1. Crystal data and structure refinement for bromocyclization product.

Empirical formula	$C_{20}H_{23}Br_4N$	
Formula weight	597.03	
Temperature	173(2) K	
Wavelength	0.71073 Å	
Crystal system	Orthorhombic	
Space group	$P2_12_12_1$	
Unit cell dimensions	a = 7.966(2) Å	α = 90°
	b = 8.544(2) Å	β = 90°
	c = 31.115(8) Å	γ = 90°
Volume	2117.8(9) Å^3	
Z	4	
Density (calculated)	1.873 Mg/m^3	
Absorption coefficient	7.605 mm^{-1}	
F(000)	1160	
Crystal color, morphology	Orange, Block	
Crystal size	0.35 x 0.25 x 0.15 mm^3	
Theta range for data collection	2.47 to 27.50°	
Index ranges	$-10 \le h \le 10, 0 \le k \le 11, 0 \le l \le 40$	
Reflections collected	24641	
Independent reflections	4838 [R(int) = 0.0402]	
Observed reflections	4371	
Completeness to theta = 27.50°	99.6%	
Absorption correction	Multi-scan	
Max. and min. transmission	0.3950 and 0.1760	
Refinement method	Full-matrix least-squares on F^2	
Data / restraints / parameters	4838 / 0 / 228	
Goodness-of-fit on F^2	1.077	
Final R indices [I>2sigma(I)]	$R1$ = 0.0265, $wR2$ = 0.0552	
R indices (all data)	$R1$ = 0.0331, $wR2$ = 0.0573	
Absolute structure parameter	-0.004(10)	
Largest diff. peak and hole	0.629 and -0.316 e.Å^{-3}	

Table S2. Atomic coordinates (x 10^4) and equivalent isotropic displacement parameters ($Å^2$x 10^3) for bromocyclization product. U_{eq} is defined as one third of the trace of the orthogonalized U_{ij} tensor.

	x	y	z	U_{eq}
C1	4248(4)	5215(4)	6022(1)	27(1)
C2	2651(4)	4303(4)	5913(1)	28(1)
Br1	2865(1)	3302(1)	5348(1)	36(1)
C3	2278(5)	3127(4)	6264(1)	32(1)
C4	1848(5)	4067(4)	6670(1)	33(1)
C5	3358(5)	5021(4)	6815(1)	34(1)
C6	4124(4)	6027(4)	6462(1)	27(1)
C7	3191(4)	7586(4)	6358(1)	26(1)
C8	3776(4)	7901(4)	5908(1)	26(1)
C9	3755(5)	9258(4)	5670(1)	33(1)
C10	4452(5)	9249(5)	5258(1)	39(1)
C11	5146(5)	7902(5)	5095(1)	37(1)
C12	5137(4)	6548(5)	5338(1)	33(1)
N1	4430(3)	6587(3)	5731(1)	27(1)
C13	3552(5)	8885(4)	6681(1)	27(1)
C14	5114(4)	9602(4)	6689(1)	30(1)
C15	5474(5)	10776(4)	6982(1)	35(1)
C16	4251(5)	11177(4)	7282(1)	33(1)
C17	2689(5)	10454(4)	7286(1)	33(1)
C18	2344(5)	9318(4)	6981(1)	33(1)
C19	7157(6)	11610(5)	6970(1)	48(1)
C20	1399(6)	10890(5)	7624(1)	50(1)
Br2	8691(1)	7103(1)	6023(1)	38(1)
Br3	8530(1)	10079(1)	5847(1)	32(1)
Br4	8161(1)	12965(1)	5725(1)	41(1)

Table S3. Bond lengths (Å) and angles (°) for bromocyclization product.

C(1)-N(1)	1.488(4)
C(1)-C(2)	1.530(5)
C(1)-C(6)	1.539(5)
C(1)-H(1A)	1.0000
C(2)-C(3)	1.515(4)
C(2)-Br(1)	1.963(3)
C(2)-H(2A)	1.0000
C(3)-C(4)	1.535(5)
C(3)-H(3A)	0.9900
C(3)-H(3B)	0.9900
C(4)-C(5)	1.521(5)
C(4)-H(4A)	0.9900
C(4)-H(4B)	0.9900
C(5)-C(6)	1.522(5)
C(5)-H(5A)	0.9900
C(5)-H(5B)	0.9900
C(6)-C(7)	1.559(4)
C(6)-H(6A)	1.0000
C(7)-C(8)	1.502(4)
C(7)-C(13)	1.524(4)
C(7)-H(7A)	1.0000
C(8)-N(1)	1.354(4)
C(8)-C(9)	1.375(5)
C(9)-C(10)	1.397(5)
C(9)-H(9A)	0.9500
C(10)-C(11)	1.374(5)
C(10)-H(10A)	0.9500
C(11)-C(12)	1.383(5)
C(11)-H(11A)	0.9500
C(12)-N(1)	1.345(5)
C(12)-H(12A)	0.9500
C(13)-C(14)	1.387(5)
C(13)-C(18)	1.391(5)
C(14)-C(15)	1.387(5)

C(14)-H(14A)	0.9500
C(15)-C(16)	1.392(5)
C(15)-C(19)	1.518(6)
C(16)-C(17)	1.390(5)
C(16)-H(16A)	0.9500
C(17)-C(18)	1.386(5)
C(17)-C(20)	1.516(5)
C(18)-H(18A)	0.9500
C(19)-H(19A)	0.9800
C(19)-H(19B)	0.9800
C(19)-H(19C)	0.9800
C(20)-H(20A)	0.9800
C(20)-H(20B)	0.9800
C(20)-H(20C)	0.9800
Br(2)-Br(3)	2.6045(8)
Br(3)-Br(4)	2.5121(8)
N(1)-C(1)-C(2)	110.3(3)
N(1)-C(1)-C(6)	101.1(3)
C(2)-C(1)-C(6)	112.0(3)
N(1)-C(1)-H(1A)	111.0
C(2)-C(1)-H(1A)	111.0
C(6)-C(1)-H(1A)	111.0
C(3)-C(2)-C(1)	109.9(3)
C(3)-C(2)-Br(1)	112.0(2)
C(1)-C(2)-Br(1)	110.4(2)
C(3)-C(2)-H(2A)	108.1
C(1)-C(2)-H(2A)	108.1
Br(1)-C(2)-H(2A)	108.1
C(2)-C(3)-C(4)	106.9(3)
C(2)-C(3)-H(3A)	110.3
C(4)-C(3)-H(3A)	110.3
C(2)-C(3)-H(3B)	110.3
C(4)-C(3)-H(3B)	110.3
H(3A)-C(3)-H(3B)	108.6
C(5)-C(4)-C(3)	110.3(3)
C(5)-C(4)-H(4A)	109.6

C(3)-C(4)-H(4A)	109.6
C(5)-C(4)-H(4B)	109.6
C(3)-C(4)-H(4B)	109.6
H(4A)-C(4)-H(4B)	108.1
C(4)-C(5)-C(6)	114.0(3)
C(4)-C(5)-H(5A)	108.8
C(6)-C(5)-H(5A)	108.8
C(4)-C(5)-H(5B)	108.8
C(6)-C(5)-H(5B)	108.8
H(5A)-C(5)-H(5B)	107.7
C(5)-C(6)-C(1)	114.4(3)
C(5)-C(6)-C(7)	116.2(3)
C(1)-C(6)-C(7)	103.3(3)
C(5)-C(6)-H(6A)	107.5
C(1)-C(6)-H(6A)	107.5
C(7)-C(6)-H(6A)	107.5
C(8)-C(7)-C(13)	115.2(3)
C(8)-C(7)-C(6)	101.5(3)
C(13)-C(7)-C(6)	113.3(3)
C(8)-C(7)-H(7A)	108.8
C(13)-C(7)-H(7A)	108.8
C(6)-C(7)-H(7A)	108.8
N(1)-C(8)-C(9)	119.0(3)
N(1)-C(8)-C(7)	110.5(3)
C(9)-C(8)-C(7)	130.5(3)
C(8)-C(9)-C(10)	118.9(4)
C(8)-C(9)-H(9A)	120.5
C(10)-C(9)-H(9A)	120.5
C(11)-C(10)-C(9)	120.2(4)
C(11)-C(10)-H(10A)	119.9
C(9)-C(10)-H(10A)	119.9
C(10)-C(11)-C(12)	119.8(3)
C(10)-C(11)-H(11A)	120.1
C(12)-C(11)-H(11A)	120.1
N(1)-C(12)-C(11)	118.6(3)
N(1)-C(12)-H(12A)	120.7

C(11)-C(12)-H(12A)	120.7
C(12)-N(1)-C(8)	123.4(3)
C(12)-N(1)-C(1)	125.0(3)
C(8)-N(1)-C(1)	111.6(3)
C(14)-C(13)-C(18)	119.4(3)
C(14)-C(13)-C(7)	120.1(3)
C(18)-C(13)-C(7)	120.4(3)
C(13)-C(14)-C(15)	121.1(3)
C(13)-C(14)-H(14A)	119.4
C(15)-C(14)-H(14A)	119.4
C(14)-C(15)-C(16)	118.4(4)
C(14)-C(15)-C(19)	120.4(4)
C(16)-C(15)-C(19)	121.2(3)
C(17)-C(16)-C(15)	121.6(3)
C(17)-C(16)-H(16A)	119.2
C(15)-C(16)-H(16A)	119.2
C(18)-C(17)-C(16)	118.9(3)
C(18)-C(17)-C(20)	120.8(4)
C(16)-C(17)-C(20)	120.3(3)
C(17)-C(18)-C(13)	120.6(3)
C(17)-C(18)-H(18A)	119.7
C(13)-C(18)-H(18A)	119.7
C(15)-C(19)-H(19A)	109.5
C(15)-C(19)-H(19B)	109.5
H(19A)-C(19)-H(19B)	109.5
C(15)-C(19)-H(19C)	109.5
H(19A)-C(19)-H(19C)	109.5
H(19B)-C(19)-H(19C)	109.5
C(17)-C(20)-H(20A)	109.5
C(17)-C(20)-H(20B)	109.5
H(20A)-C(20)-H(20B)	109.5
C(17)-C(20)-H(20C)	109.5
H(20A)-C(20)-H(20C)	109.5
H(20B)-C(20)-H(20C)	109.5
Br(4)-Br(3)-Br(2)	174.81(2)

Table S4. Anisotropic displacement parameters ($Å^2$ x 10^3) for bromocyclization product. The anisotropic displacement factor exponent takes the form: $-2\pi^2[h^2a^{*2}U_{11} + ... + 2\ h\ k\ a^*\ b^*\ U_{12}]$

	U_{11}	U_{22}	U_{33}	U_{23}	U_{13}	U_{12}
C1	32(2)	27(2)	23(2)	3(1)	-1(1)	3(1)
C2	34(2)	27(2)	22(2)	-3(1)	-3(1)	5(1)
Br1	50(1)	33(1)	26(1)	-4(1)	-3(1)	4(1)
C3	38(2)	28(2)	30(2)	1(1)	-2(2)	-2(2)
C4	43(2)	30(2)	27(2)	4(1)	0(2)	1(2)
C5	47(2)	32(2)	23(2)	6(1)	-5(2)	4(2)
C6	29(2)	27(2)	25(2)	-3(1)	-5(1)	3(1)
C7	25(2)	27(2)	26(2)	1(1)	-2(1)	0(1)
C8	25(2)	30(2)	24(2)	-1(1)	-4(1)	-2(2)
C9	41(2)	33(2)	24(2)	2(1)	-2(2)	-1(2)
C10	50(2)	39(2)	29(2)	7(2)	-4(2)	-6(2)
C11	43(2)	47(2)	21(2)	5(2)	3(2)	-7(2)
C12	30(2)	41(2)	28(2)	-4(2)	4(2)	0(2)
N1	23(1)	32(2)	26(2)	3(1)	-3(1)	0(1)
C13	32(2)	28(2)	21(2)	2(1)	-4(2)	2(2)
C14	34(2)	35(2)	20(2)	-1(1)	3(1)	4(2)
C15	41(2)	35(2)	28(2)	1(2)	-7(2)	-1(2)
C16	52(2)	28(2)	18(2)	-2(1)	-3(2)	7(2)
C17	45(2)	34(2)	21(2)	2(1)	3(2)	12(2)
C18	32(2)	35(2)	31(2)	4(2)	2(2)	6(2)
C19	52(2)	52(2)	40(2)	-9(2)	-1(2)	-15(2)
C20	62(3)	55(3)	33(2)	-2(2)	14(2)	16(2)
Br2	32(1)	39(1)	45(1)	3(1)	-3(1)	1(1)
Br3	28(1)	40(1)	30(1)	-2(1)	1(1)	2(1)
Br4	43(1)	40(1)	39(1)	-1(1)	3(1)	9(1)

Table S5. Hydrogen coordinates (x 10^4) and isotropic displacement parameters (Å^{2}x 10^3) for bromocyclization product.

	x	y	z	U(eq)
H1A	5259	4524	6007	33
H2A	1696	5062	5899	33
H3A	3268	2454	6316	38
H3B	1321	2454	6181	38
H4A	894	4777	6610	40
H4B	1507	3343	6903	40
H5A	4228	4297	6925	41
H5B	3013	5707	7056	41
H6A	5291	6303	6554	32
H7A	1956	7381	6354	31
H9A	3273	10186	5784	39
H10A	4447	10178	5090	47
H11A	5630	7901	4816	44
H12A	5620	5610	5231	40
H14A	5950	9283	6489	36
H16A	4490	11965	7489	39
H18A	1272	8831	6976	39
H19A	7249	12210	6703	72
H19B	8064	10836	6983	72
H19C	7243	12321	7216	72
H20A	1435	12021	7674	75
H20B	1649	10336	7892	75
H20C	277	10594	7523	75

Table S6. Torsion angles (°) for bromocyclization product.

N1-C1-C2-C3	-168.1(3)
C6-C1-C2-C3	-56.3(4)
N1-C1-C2-Br1	67.9(3)
C6-C1-C2-Br1	179.7(2)
C1-C2-C3-C4	66.2(4)
Br1-C2-C3-C4	-170.6(2)
C2-C3-C4-C5	-63.7(4)
C3-C4-C5-C6	52.0(4)
C4-C5-C6-C1	-41.6(4)
C4-C5-C6-C7	78.7(4)
N1-C1-C6-C5	160.7(3)
C2-C1-C6-C5	43.2(4)
N1-C1-C6-C7	33.4(3)
C2-C1-C6-C7	-84.0(3)
C5-C6-C7-C8	-157.2(3)
C1-C6-C7-C8	-31.1(3)
C5-C6-C7-C13	78.6(4)
C1-C6-C7-C13	-155.2(3)
C13-C7-C8-N1	140.0(3)
C6-C7-C8-N1	17.2(3)
C13-C7-C8-C9	-39.0(5)
C6-C7-C8-C9	-161.8(4)
N1-C8-C9-C10	-1.8(5)
C7-C8-C9-C10	177.2(3)
C8-C9-C10-C11	0.0(6)
C9-C10-C11-C12	0.6(6)
C10-C11-C12-N1	0.5(6)
C11-C12-N1-C8	-2.4(5)
C11-C12-N1-C1	176.9(3)
C9-C8-N1-C12	3.1(5)
C7-C8-N1-C12	-176.1(3)
C9-C8-N1-C1	-176.3(3)
C7-C8-N1-C1	4.5(4)
C2-C1-N1-C12	-85.1(4)

C6-C1-N1-C12	156.2(3)
C2-C1-N1-C8	94.2(3)
C6-C1-N1-C8	-24.4(3)
C8-C7-C13-C14	-44.8(4)
C6-C7-C13-C14	71.4(4)
C8-C7-C13-C18	137.8(3)
C6-C7-C13-C18	-105.9(4)
C18-C13-C14-C15	-2.0(5)
C7-C13-C14-C15	-179.3(3)
C13-C14-C15-C16	2.6(5)
C13-C14-C15-C19	-176.6(3)
C14-C15-C16-C17	-1.2(5)
C19-C15-C16-C17	177.9(4)
C15-C16-C17-C18	-0.7(5)
C15-C16-C17-C20	178.5(3)
C16-C17-C18-C13	1.4(5)
C20-C17-C18-C13	-177.9(3)
C14-C13-C18-C17	-0.1(5)
C7-C13-C18-C17	177.3(3)