The Palladium Catalyzed Asymmetric Addition of Oxindoles and Allenes: an Atom-Economical Versatile Method for the Construction of Chiral Indole Alkaloids

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Supplementary Material

Part A: Experimental Section

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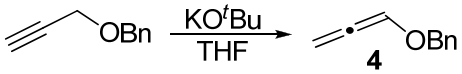
General. Melting points were determined using a Thomas-Hoover melting point apparatus and are uncorrected. ^{1}H NMR spectra were recorded on Varian GEM-300 (300 MHz), Varian Mercury (400 MHz), or Unity Inova (500 MHz) spectrometers. Chemical shifts are reported in ppm from tetramethylsilane with the solvent resonance as an internal standard ($CHCl_3$: 7.24 ppm). Data are reported as follows: chemical shift, multiplicity (s = singlet, d = doublet, t = triplet, q = quartet, p = pentet, h = hextet, br = broad, m = multiplet), coupling constants (Hz), and integration. ^{13}C NMR spectra were recorded on Varian GEM-300 (75 MHz), Varian Mercury (100 MHz), or Unity Inova (125 MHz) instruments with complete proton decoupling. Chemical shifts are reported in ppm from tetramethylsilane with the solvent as the internal standard ($CDCl_3$: 77.0 ppm). High-resolution mass spectrometry was acquired by the Vincent Coates Foundation Mass Spectrometry Laboratory, Stanford University Mass Spectrometry (http://mass-spec.stanford.edu) on a Micromass Q-Tof API-US mass spectrometer (Waters Corporation, Milford, MA) or by the Mass Spectrometry Resource, School of S2 Pharmacy, University of California-San Francisco, on a Kratos MS9 spectrometer at an ionizing current of 98 mA and an ionizing voltage of 70 eV. Elemental analyses (EA) were performed by M-H-W Laboratories, Phoenix, AZ. Infrared (IR) spectra were obtained on a Thermo Scientific Nicolet IR100 FT-IR spectrophotometer or a Perkin-Elmer Paragon 500 FT-IR spectrophotometer. Optical rotations were measured using a JASCP DIP-1000 digital polarimeter. Chiral High Performance Liquid Chromatography (HPLC) was performed on a Thermo Separation Products Spectra Series P-100 or 200 using Chiralcel® columns.

Liquid chromatography was performed using forced flow (flash chromatography) on EM Science silica gel (0.040-0.063 μm grade). Thin layer chromatography (TLC) was performed on 0.2 mm coated commercial silica gel plates (E. Merck, DC-Plasrikfolien, kieselgel 60 F254). Visualization was achieved using UV light, phosphomolybdic acid in ethanol, potassium permanganate in water, or ammonium cerium(IV) nitrate and ammonium molybdate in sulfuric acid solution, each followed by heating.

All reactions were carried out under an atmosphere of nitrogen or argon in oven-dried glassware with magnetic stirring, unless otherwise indicated. Some solvents were freshly purified by passage through two activated alumina columns using dry nitrogen using a solvent purification system designed by J. C. Meyer of Glass Contour before use: acetonitrile, methylene chloride, toluene, benzene, triethylamine, dimethylformamide, tetrahydrofuran, pyridine, and diethyl ether. Methanol was distilled from magnesium methoxide. Solvents for Pd-catalyzed reactions were degassed by freeze-thaw techniques under vacuum. Tris(dibenzylideneacetone)dipalladium(0) monochloroform complex, $Pd_2(dba)_3$•$CHCl_3$, was prepared by the procedure of Ibers.[1] Ligands (*R*,*R*)-**L1**, (*R*,*R*)-**L2**, (*R*,*R*)-**L3**, and (*R*,*R*)-**L4** were prepared by literature procedures.[2] Allenes were prepared by base catalyzed isomerization of the corresponding propargylic ether or sulfonamide using KO^{t}Bu by the known method.[3] All other reagents were used as obtained unless otherwise noted.

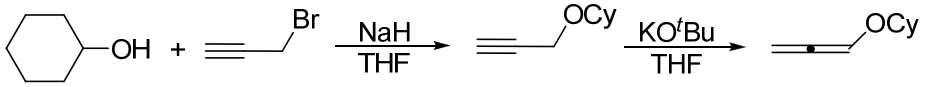
Representative allene synthesis, preparation of allene 4:[3]



At room temperature, 4.3 g (38 mmol) of *t*-BuOK was added into a solution of 22 g (130 mmol) of benzyl propargyl ether in 10 ml of THF. The suspension was stirred at room temperature for 3 h, then filtered through a celite pad and washed with 50 ml of Et_2O. The combined solution was concentrated *in vacuo* and purified by

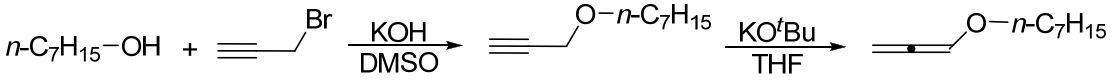
[1] Ukai, T.; Kawazura, H.; Ishii, Y.; Bonnet, J. J.; Ibers, J. A. *J. Organomet. Chem.* **1974**, *65*, 253.
[2] (a) Trost, B. M.; Vanvranken, D. L.; Bingel, C. *J. Am. Chem. Soc.* **1992**, *114*, 9327. (b) Trost, B. M.; Bunt, R.; Lemoine, R.; Calkins, T. *J. Am. Chem. Soc.* **2000**, *122*, 5968.
[3] Trost, B. M.; Xie, J. *J. Am. Chem. Soc.* **2008**, *130*, 6231.

silica gel chromatography (1% Et_2O in petroleum ether) to afford 18 g (82%) of **4** as a light yellowish liquid. R_f = 0.84 (5% Et_2O/pet. ether). *Density* = 1.01 g/cm^3. FTIR (neat): 3034, 2925, 2868, 1953, 1726, 1454, 1442, 1349, 1190, 1043, 893, 737, 698 cm^{-1}. ^{1}H NMR (500 MHz, $CDCl_3$): δ 7.35 – 7.20 (m, 5H), 6.85 (dd, *J* = 6.3 Hz, 1H), 5.48 (d, *J* = 6.1 Hz, 2H), 4.62 (s, 2H). ^{13}C NMR (126 MHz, $CDCl_3$): δ 196.5, 132.5, 123.6, 123.1, 123.0, 116.8, 86.4, 65.8.



NaH (1.2 g, 30.0 mmol, 60 wt% in mineral oil) was added slowly into a solution of cyclohexanol (2.50 ml, 24 mmol) in 100 ml THF at 0 °C. After stirring for 5 min at 0 °C, propargyl bromide (80 wt% in toluene, 2.16 ml, 2.88 g, 19.4 mmol) was added and the solution was allowed to slowly warmed to room temperature. After stirring was continued for 3 h, the reaction was quenched with saturated aq. NH_4Cl (30 ml) followed by extraction with Et_2O (3 × 20 ml). The combined organic layers were washed with brine (25 ml), dried over anhydrous $MgSO_4$, filtered, and concentrated *in vacuo*. Purification of the yellowish liquid by flash chromatography (5% diethyl ether in petroleum ether, silica gel) gave 2.2 g (80%) of the desired cyclohexyl propargyl ether as a colorless liquid (2.2 g, 80%). R_f = 0.75 (10% ether / pet. ether). FTIR(neat): 3034, 2925, 2868, 1953, 1726, 1454, 1442, 1349, 1190, 1043, 893, 737, 698 cm^{-1}. ^{1}H NMR (500 MHz, $CDCl_3$): δ 4.18 – 4.17 (m, 2H), 3.49 – 3.45 (m, 1H), 2.40 – 2.39 (m, 1H), 1.96 – 1.90 (m, 2H), 1.76 –1.72 (m, 2H), 1.56 – 1.52 (m, 1H), 1.34 – 1.19 (m, 5H). ^{13}C NMR (126 MHz, $CDCl_3$): δ 80.5, 76.5, 73.5, 54.8, 31.8, 25.6, 23.9.

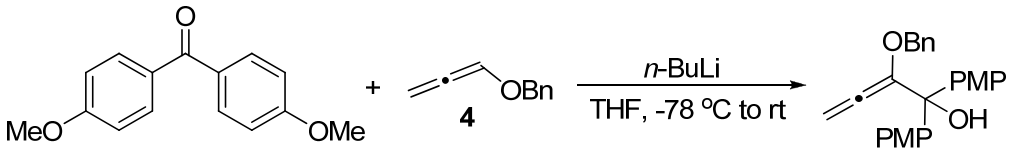
At room temperature, *t*-BuOK (100 mg, 0.894 mmol) was added to a solution of the cyclohexyl propargyl ether (618mg, 4.47 mmol) in 4 ml THF. The suspension was stirred at room temperature for 3 h, then diluted with Et_2O and filtered through a celite pad, washing with 20 ml of Et_2O. The solution was then concentrated *in vacuo* and purified by flash chromatography (1% diethyl ether in petroleum ether) to afford 420 mg (68%) of the desired allenyl cyclohexyl ether as a light yellowish liquid. R_f = 0.23 (pet. ether). IR(neat): 2934, 2858, 1953, 1446, 1335, 1049, 1023, 888, 857 cm^{-1}. ^{1}H NMR (500 MHz, $CDCl_3$): δ 6.61 (t, *J* = 6.0 Hz, 1H), 5.36 (d, *J* = 6.0 Hz, 2H), 3.66 – 3.62 (m, 1H), 1.90 – 1.87 (m, 2H), 1.76 – 1.70 (m, 2H), 1.54 – 1.49 (m, 1H), 1.43 – 1.36 (m, 2H), 1.30 – 1.20 (m, 3H). ^{13}C NMR (126 MHz, $CDCl_3$): δ 201.7, 119.7, 89.2, 76.3, 31.7, 25.5, 23.6.



To a suspension of 10.9 g (195 mmol) of KOH in 130 mL of DMSO under Ar at 0 °C was added 9.18 mL (7.55 g, 65.0 mmol) of *n*-heptanol. This mixture was stirred for 10 min, and 7.24 mL (9.66 g, 65.0 mmol) of propargyl bromide (80 wt% in toluene) was then added giving a dark brown/black solution. The mixture was allowed to warm to room temperature and stirred for 24 h. The reaction was poured into 260 mL of H_2O and extracted with Et_2O (3 x 150 mL). The combined organic layers were washed with H_2O (4 x 80 mL), brine (1 x), and dried with $MgSO_4$. Purification of the crude oil using silica gel chromatography (gradient, 1:0 to 30:1 pet. ether:Et_2O) afforded 4.64 g (46%) of the desired propargylic ether as a yellow oil. R_f = 0.21 (50:1 pet. ether:Et_2O). ^{1}H NMR (400 MHz, $CDCl_3$): δ 4.10 (d, *J* = 2.4 Hz, 2H), 3.48 (t, *J* = 6.4 Hz, 2H), 2.38 (t, *J* = 2.4

Hz, 1H), 1.56 (p, J = 7.2 Hz, 2H), 1.11-1.40 (m, 8H), 0.85 (t, J = 6.8 Hz, 3H). ^{13}C NMR (100 MHz, $CDCl_3$): δ 80.02, 73.96, 70.26, 57.95, 31.76, 29.48, 29.07, 26.02, 22.57, 14.03. FTIR (thin film): 3311 (m), 2930 (s), 2857 (s), 1468 (m), 1356 (m), 1272 (w), 1104 (s), 1022 (w) cm^{-1}.

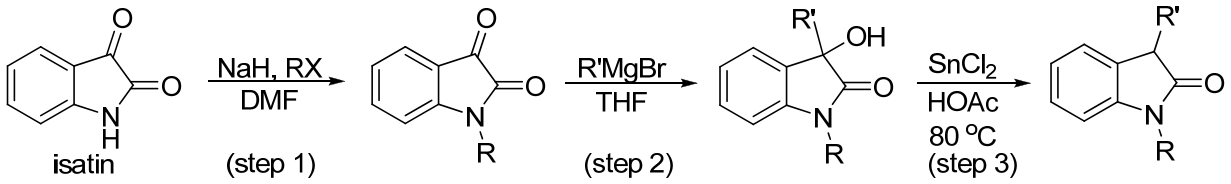
The propargyl ether (982 mg, 6.37 mmol) was then dissolved in 3.4 mL of THF under Ar, and 214 mg (1.91 mmol) of KO^{t}Bu was added. This orange slurry was stirred rapidly for 4 h, and Et_2O (20 mL) was then added. The heterogeneous mixture was filtured through celite, washing with Et_2O, and volatile material removed under reduced pressure. The resultant oil was purified by silica gel chromatography (gradient, 1:0 to 100:1 pet. ether:Et_2O) to afford 532 mg (54%) of the desired allenyl ether as a colorless oil. R_f = 0.32 (100% pet. ether). *Density* = 0.83 g/cm^3. ^{1}H NMR (400 MHz, $CDCl_3$): δ 6.70 (t, J = 6.0 Hz, 1H), 5.40 (d, J = 6.0 Hz, 2H), 3.52 (t, J = 6.4 Hz, 2H), 1.62 (p, J = 6.8 Hz, 2H), 1.15-1.40 (m, 8H), 0.86 (t, J = 7.2 Hz, 3H). ^{13}C NMR (100 MHz, $CDCl_3$): δ 201.4, 121.6, 90.28, 68.92, 31.76, 29.17, 29.06, 25.97, 22.59, 14.06. FTIR (thin film): 3042, 2930, 2858, 1953, 1468, 1446, 1380, 1351, 1202 cm^{-1}.



The procedure was adapted from the literature.[3] To a stirred solution of benzyloxyallene **4** (731 mg, 5.00 mmol) in 20 mL of THF was added dropwise a 2.5 M solution of *n*-butyllithium (2.0 mL, 5.0 mmol) in hexane at -78 °C. After stirring for 1 h at -78 °C, 4,4'-dimethoxybenzophenone (1.20 g, 5.00 mmol) was added portion-wise, and after complete addition, stirring was allowed to continue for 4 h at -78 °C. The reaction was then allowed to warm to room temperature. The resultant mixture was diluted with water and extracted with Et_2O. The combined extracts were washed with brine and dried over anhydrous Na_2SO_4. The crude residue was purified by flash chromatography on silica gel (20% ether in petroleum ether) to afford 1.7 g (88%) the desired allene. R_f = 0.30 (25% ether /pet. ether). IR (neat): 3489, 2928, 2854, 1957, 1742, 1606, 1509, 1455, 1303, 1249, 1174, 1034, 827, 734, 697, 583 cm^{-1}. ^{1}H NMR (500 MHz, $CDCl_3$): δ 7.34 – 7.23 (m, 9H), 6.82 – 6.79 (m, 4H), 5.32 (s, 2H), 4.71 (s, 2H), 3.79 (s, 6H), 3.28 (b, 1H). ^{13}C NMR (126 MHz, $CDCl_3$): δ 198.3, 158.7, 137.0, 136.6, 132.2, 128.8, 128.3, 127.8, 127.8, 112.8, 92.8, 79.5, 71.1, 55.2. HRMS (ESI+): Calc'd for $C_{14}H_{16}OS$ $[M]^+$: 388.1675. found: 388.1666.

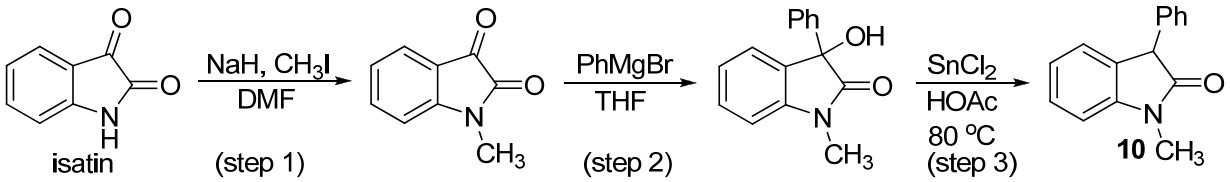
General procedure for the synthesis of oxindoles:

The majority of the *N*-alkyl substituted oxindoles used in this study were prepared by the following 3-step sequence:[4]



The *N*-Boc substituted oxindoles used in this study were prepared according to the literature.[5]

Oxindole 10:



Step 1: Isatin (2.94 g, 20.0 mmol) was dissolved in anhydrous DMF (80 ml), and the resultant solution was cooled to 0 °C, whereupon sodium hydride (60% dispersion in oil, 0.95 g, 24.0 mmol) was added in one portion and stirred for 5 minutes. Iodomethane (1.87 ml, 30.0 mmol) was added and the reaction was stirred at 0 °C for 30 min. The reaction mixture was then poured into saturated aqueous NH_4Cl and extracted with EtOAc (4 × 30 ml). The combined organic layers were washed with water (3 × 15 ml) and brine (20 ml), then dried over $MgSO_4$, filtered, and concentrated to give the crude *N*-methyl isatin product (3.2g, 100%) which was used without further purification. R_f = 0.55 (50% EtOAc / pet. ether). ^{1}H NMR (500 MHz, $CDCl_3$): δ 7.63 (dt, *J* = 7.7 Hz, *J* = 1.3 Hz, 1H), 7.54 (d, *J* = 7.5 Hz, 1H), 7.13 (dt, *J* = 7.6 Hz, *J* = 0.8 Hz, 1H), 6.94 (d, *J* = 7.9 Hz, 1H),3.25 (s, 3H). ^{13}C NMR (126 MHz, $CDCl_3$): δ 183.1, 157.9, 151.1, 138.3, 124.8, 123.5, 117.0, 109.8, 25.9. Spectral data was in agreement with that reported in the literature.[6]

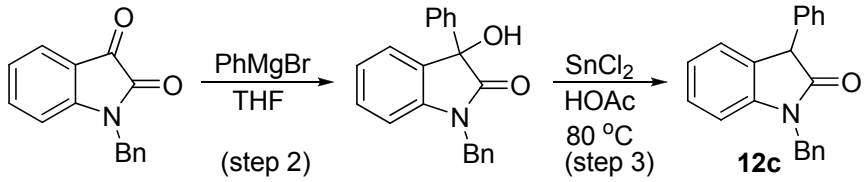
Step 2: The crude *N*-methylisatin (3.2g, 20 mmol) was dissolved in anhydrous THF (60 ml) and cooled to 0 °C followed by dropwise addition of a 2.0 M solution of PhMgBr in THF (12.0 ml, 24.0 mmol). Then, the ice-bath was removed, and the reaction was stirred under N_2 for 30 min at which point TLC analysis indicated consumption of the starting material. The reaction mixture was quenched by the addition of 5 ml of MeOH, and then poured into saturated aqueous NH_4Cl (20 ml), and extracted with ethyl acetate (3 × 20 ml). The combined organic layers were washed with brine (20 ml), dried over anhydrous $MgSO_4$, filtered, and concentrated to give the crude alcohol. R_f = 0.47 (50% EtOAc / pet. ether). ^{1}H NMR (500 MHz, $CDCl_3$): δ 7.35 – 7.22 (m, 7H), 7.03 (dt, *J* = 7.6 Hz, *J* = 1.0 Hz, 1H), 6.84 (d, *J* = 7.8 Hz, 2H), 4.46 (s, 1H), 3.13 (s, 3H). ^{13}C NMR (126 MHz,

[4] (a) Trost, B. M.; Zhang, Y. *J. Am. Chem. Soc.* **2007**, *129*, 14548. (b) Thomson, J. E.; Kyle, A. F.; Gallagher, K. A.; Lenden, P.; Concellon, C.; Morrill, L.; Miller, A. J.; Joannesse, C.; Slawin, A. M. Z.; Smith, A. D. *Synthesis* **2008**, *17*, 2805.
[5] Hamashima, Y.; Suzuki, T.; Takano, H.; Shimura, Y.; Sodeoka, M. *J. Am. Chem. Soc.* **2005**, *127*, 10164.
[6] Esmaeili, A.; Darbanian, M. *Tetrahedron* **2003**, *59*, 5545.

$CDCl_3$): δ 177.6, 143.2, 140.0, 131.7, 129.5, 128.3, 128.0, 125.3, 124.8, 123.4, 108.5, 77.9. Spectral data was in agreement with that reported in the literature.[7]

Step 3: The crude alcohol (1.2 g, 5.0 mmol) was dissolved in 30 ml of glacial acetic acid and $SnCl_2$ (1.90 g, 10.0 mmol) was added. The reaction mixture was stirred at 80 °C for 2 h at which point tlc analysis indicated consumption of the starting material. Next, the solution was cooled to room temperature, concentrated *in vacuo*, and then diluted with EtOAc (150 ml). The solution was washed with water (3 × 20 ml), saturated aqueous $NaHCO_3$ (30 ml), and brine (30 ml). The organic layer was dried with anhydrous $MgSO_4$, filtered, and concentrated *in vacuo*. The residue was purified by flash column chromatography (20% EtOAc in petroleum ether, silica gel) to afford 0.95 g of (86% over two steps) the oxindole as a light yellow solid. M.P.: 115 – 117 °C (lit. M.P. 117 – 119 °C)[**Error! Reference source not found.**]. R_f = 0.35 (50% ether / pet. ether). IR (neat): 3052, 3024, 1693, 1610, 1496, 1466, 1346, 1086, 752, 700, 642 cm^{-1}. ^1H NMR (500 MHz, $CDCl_3$): δ 7.32 – 7.23 (m, 4H), 7.20 – 7.18 (m, 2H), 7.14 (dt, *J* = 7.3 Hz, 1H), 7.04 (ddd, *J* = 7.8 Hz, *J* = 7.8 Hz, *J* = 0.8 Hz, 1H), 6.87 (d, *J* = 7.8 Hz, 1H), 4.58 (s, 1H), 3.22 (s, 3H). ^{13}C NMR (126 MHz, $CDCl_3$): δ 175.8, 144.3, 136.5, 128.7, 128.6, 128.3, 127.4, 124.8, 122.6, 108.0, 51.8, 26.3. Spectral data was in agreement with that reported in the literature.[8]

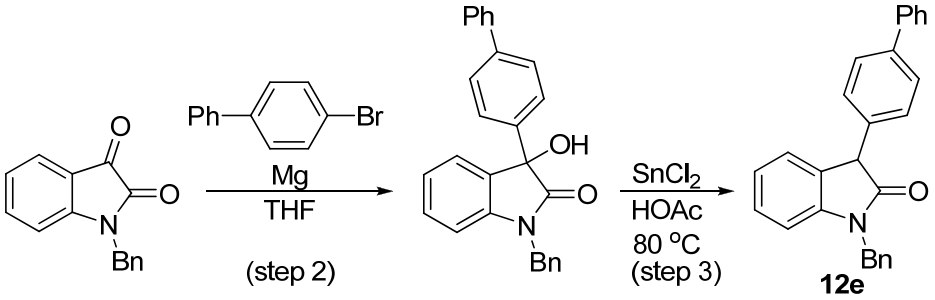
1-Benzyl-3-phenylindolin-2-one (12c):



The oxindole was prepared according to the general procedure. Step 2: The addition reaction was conducted in THF (15 ml) for 1 h, using 1-benzylisatin (778 mg, 3.28 mmol) and a 2.0 M solution of PhMgBr in THF (1.97 ml, 3.94 mmol). The crude alcohol was taken into the next step without chromatography purification. Step 3: The reduction reaction was conducted in acetic acid (20 ml) for 4 h, using $SnCl_2$ (). Purification by flash chromatography (10% ether in petroleum ether, silica gel) afforded 1-Benzyl-3-phenylindolin-2-one (785 mg, 80%) as a white solid. mp 114 – 116 °C (Lit.[9] mp 116 – 118 °C). R_f = 0.62 (25% EtOAc / pet. ether): 0.62. ^1H NMR (500 MHz, $CDCl_3$): δ 7.32 –7.24 (m, 7H), 7.23 – 7.18 (m, 3H), 7.17 – 7.09 (m, 2H), 6.98 (ddd, *J* = 7.5 Hz, *J* = 7.5 Hz, *J* = 1.0 Hz, 1H), 6.76 (d, *J* = 7.9 Hz, 1H), 4.95 (d, *J* = 15.6 Hz, 1H), 4.87 (d, *J* = 15.6 Hz, 1H), 4.66 (s, 1H). ^{13}C NMR (126 MHz, $CDCl_3$): δ 175.9, 143.4, 140.5, 140.4, 135.7, 135.6, 128.7, 128.6(2), 128.2, 127.6, 127.5, 127.2, 127.2, 126.9, 125.0, 122.7, 109.1, 51.6, 43.8. Spectral data matched that reported in the literature.[9]

[7] Batanero, B.; Barba, F. *J. Org. Chem.* **2003**, *68*, 3706.
[8] Hirose, N.; Toyoshim, S.; Sohda, S.; Kuriyama, S. *Chem. Pharm. Bull.* **1972**, *20*, 1669.
[9] Huang, A.; Kodanko, J. J.; Overman, L. E. *J. Am. Chem. Soc.* **2004**, *126*, 14043.

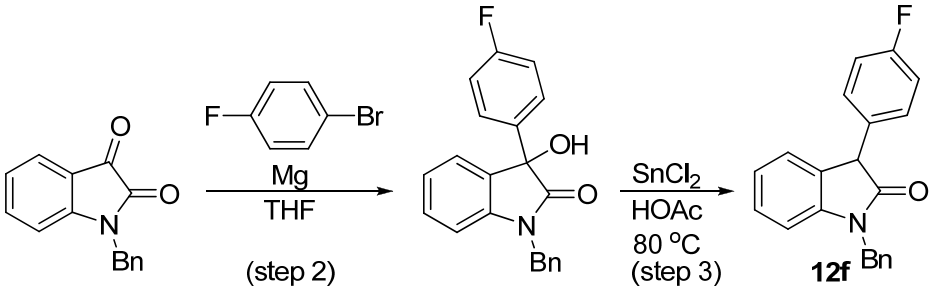
1-Benzyl-3-(biphenyl-4-yl)indolin-2-one (12e):



Step 2: In a round-bottom flask, 4-bromobiphenyl (420 mg, 1.80 mmol) was dissolved in 5 ml anhydrous THF. Mg turnings (51 mg, 2.10 mmol) were added. The reaction flask was briefly heated to initiate the reaction. The reaction mixture was then stirred under N_2 until most of the Mg turnings had disappeared. The resulting Grignard solution was cooled to 0 °C and added dropwise to a solution of 1-benzylisatin (356 mg, 1.50 mmol) in THF (5 ml). The resulting solution was stirred at 0 °C for 1h, at which point TLC analysis indicated complete consumption of the starting material, and the reaction mixture was then quenched by the addition of saturated aqueous NH_4Cl (10 ml), and extracted with EtOAc (3 × 10 ml). The combined organic layers were washed with brine (10 ml), dried over anhydrous $MgSO_4$, filtered, and concentrated *in vacuo* to give the crude alcohol. R_f = 0.12 (25% EtOAc/pet. ether). IR (neat): 3366, 3028, 1710, 1615, 1466, 1376, 1348, 1174, 1076, 738, 698. ^{1}H NMR (500 MHz, $CDCl_3$): δ 7.56 – 7.54 (m, 4H), 7.49 – 7.54 (m, 2H), 7.44 – 7.41 (m, 2H), 7.36 – 7.32 (m, 6H), 7.32 – 7.28 (m, 1H), 7.27 – 7.23 (m, 2H), 7.07 (dt, *J* = 7.6 Hz, *J* = 1.0 Hz, 1H), 5.07 (d, *J* = 15.5 Hz, 1H), 4.85 (d, *J* = 15.5 Hz, 1H), 3.43 (b, 1H). ^{13}C NMR (126 MHz, $CDCl_3$): δ 177.5, 142.7, 141.3, 140.5, 139.1, 135.4, 131.5, 129.9, 128.9, 128.8, 127.8, 127.4, 127.3, 127.1, 125.8, 125.0, 123.6, 109.8, 77.9, 44.1.

Step 3: The crude alcohol was dissolved in 30 ml of glacial acetic acid and $SnCl_2$ (569 mg, 3.0 mmol) was added. The reaction mixture was stirred at 80 °C for 2 h at which point TLC analysis indicated complete consumption of the starting material. Next, the solution was cooled to room temperature, concentrated *in vacuo*, and then diluted with EtOAc (50 ml). The solution was washed with water (3 × 10 ml), saturated aqueous $NaHCO_3$ (10 ml), and brine (10 ml). It was then dried over anhydrous $MgSO_4$, filtered, and concentrated *in vacuo*. The residue was purified by silica gel chromatography (20% EtOAc in petroleum ether) to afford 320 mg (57% over 2 steps) of oxindole **12e** as a white solid. mp 124 – 126 °C. R_f = 0.59 (25% EtOAc/pet. ether). FTIR (neat): 3366, 3028, 1710, 1615, 1466, 1376, 1348, 1174, 1076, 738, 698 cm^{-1}. ^{1}H NMR (500 MHz, $CDCl_3$): δ 7.55 – 7.52 (m, 4H), 7.39 – 7.36 (m, 2H), 7.31 – 7.14 (m, 9H), 6.98 (ddd, *J* = 7.5 Hz, *J* = 7.5 Hz, *J* = 1.0 Hz, 1H), 6.76 (d, *J* = 7.8 Hz, 1H), 4.96 (d, *J* = 15.6 Hz, 1H), 4.86 (d, *J* = 15.6 Hz, 1H), 4.70 (s, 1H). ^{13}C NMR (126 MHz, $CDCl_3$): δ 176.0, 143.5, 136.7, 135.9, 128.9, 128.8, 128.7, 128.4, 128.3, 127.6 (2), 127.3, 125.1, 122.7, 109.1, 52.0, 43.9. Elemental Analysis Calc'd for $C_{27}H_{21}NO$: C, 86.37; H, 5.64; N, 3.73; found: C, 86.60; H, 5.37; N, 3.64.

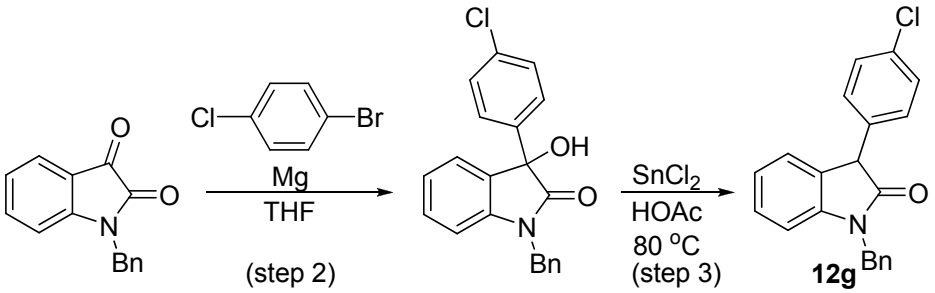
1-Benzyl-3-(4-fluorophenyl)indolin-2-one (12f):



Step 2: The alcohol was prepared according to the general procedure using *N*-benzylisatin (721 mg, 3.0 mmol), 1-bromo-4-fluorobenzene (0.40 ml, 3.60 mmol), and Mg turnings (102.1 mg, 4.2 mmol). The reaction was conducted in THF (15 ml) for 1 h. Purification by flash chromatography (25% EtOAc in petroleum ether, silica gel) afforded 727 mg (80%) of the alcohol as a solid. mp 142–144 °C. R_f = 0.25 (25% EtOAc/pet. ether). FTIR (neat): 3365, 1699, 1614, 1468, 1372, 1172, 1079, 830, 745, 696 cm^{-1}. ^1H NMR (500 MHz, $CDCl_3$): δ 7.36 – 7.33 (m, 2H), 7.31 – 7.19 (m, 7H), 7.03 (dt, *J* = 7.6 Hz, *J* = 0.9 Hz, 1H), 6.98 (dt, *J* = 7.6 Hz, *J* = 2.0 Hz, 1H), 6.77 (d, *J* = 7.9 Hz, 1H), 4.98 (d, *J* = 15.7 Hz, 1H), 4.76 (d, *J* = 15.7 Hz, 1H), 4.26 (b, 1H). ^{13}C NMR (126 MHz, $CDCl_3$): δ 177.6, 163.6, 161.6, 142.4, 135.9, 135.2, 131.5, 129.8, 128.8, 127.8, 127.4, 127.3, 127.2, 124.9, 123.7, 115.5, 115.3, 109.8, 77.5, 44.0. Elemental Analysis Calc'd for $C_{21}H_{16}FNO$: C, 79.48; H, 5.08; N, 4.41; found: C, 79.89; H, 4.89; N, 4.02.

Step 3: Oxindole **12f** was prepared according to the general procedure using from the intermediate alcohol (750 mg, 2.25 mmol) and $SnCl_2$ (853 mg, 4.50 mmol). The reaction was conducted in acetic acid (20 ml) at 80 °C for 3 h. Purification by flash chromatography (20% ether in petroleum ether, silica gel) afforded 620 mg (87%) of oxindole **12f** as a solid. mp 98–100 °C. R_f = 0.85 (25% EtOAc/pet. ether). FTIR (neat): 3032, 2920, 1707, 1613, 1489, 1455, 1350, 1180, 1009, 908, 731, 692 cm^{-1}. ^1H NMR (500 MHz, $CDCl_3$): δ 7.30 – 7.25 (m, 2H), 7.23 – 7.16 (m, 7H), 7.11 (d, *J* = 7.3 Hz, 1H), 7.01 – 6.97 (m, 3H), 6.78 (d, *J* = 7.8 Hz, 1H), 4.95 (d, *J* = 15.6 Hz, 1H), 4.85 (d, *J* = 15.6 Hz, 1H), 4.64 (s, 1H). ^{13}C NMR (126 MHz, $CDCl_3$): δ 175.7, 163.1, 161.1, 143.3, 135.7, 132.3, 129.9, 129.8, 128.6, 128.4, 128., 127.5, 127.2, 124.9, 122.7, 115.7, 115.6, 109.1, 51.0, 43.7. Elemental Analysis Calc'd for $C_{21}H_{16}FNO$ C, 79.48; H, 5.08; N, 4.41; found: C, 79.26; H, 4.98; N, 4.26.

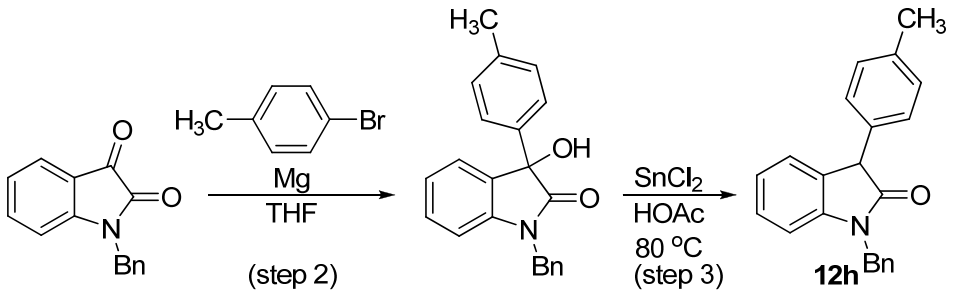
1-Benzyl-3-(4-chlorophenyl)indolin-2-one (12g):



Step 2: The alcohol was prepared according to the general procedure using *N*-benzylisatin (474 mg, 2.00 mmol), 1-bromo-4-chlorobenzene (459 mg, 2.40 mmol), and Mg turnings (68 mg, 2.8 mmol). The reaction was conducted in THF (10 ml) for 1 h. Purification by flash chromatography (20% EtOAc in petroleum ether, silica gel) afforded 550 mg (79%) of the alcohol intermediate as a solid. mp 144–146 °C. R_f = 0.38 (25% EtOAc/pet. ether). FTIR (neat): 3310, 3063, 1706, 1614, 1488, 1467, 1372, 1172, 1091, 1012, 923, 819, 752, 696 cm^{-1}. ^1H NMR (500 MHz, $CDCl_3$): δ 7.31 – 7.23 (m, 2H), 7.20 (dt, *J* = 7.8 Hz, *J* = 1.2 Hz, 2H), 7.01 (dt, *J* = 7.7 Hz, *J* = 0.9 Hz, 1H), 6.75 (d, *J* = 7.7 Hz, 1H), 4.96 (d, *J* = 15.6 Hz, 1H), 4.73 (d, *J* = 15.6 Hz, 1H), 4.55 (b, 1H). ^{13}C NMR (126 MHz, $CDCl_3$): δ 177.4, 142.3, 138.7, 135.2, 134.1, 131.5, 129.8, 128.8, 128.6, 127.8, 127.2, 126.9, 124.8, 123.7, 109.8, 77.6, 44.0. HRMS (ESI+) Calc'd for $C_{21}H_{16}ClNO_2$ $[M + Na]^+$: 372.0767, found: 372.0762.

Oxindole **12g** was prepared according to the general procedure using the alcohol (540 mg, 1.54 mmol) and $SnCl_2$ (585 mg, 3.09 mmol). Reaction was conducted in acetic acid (15 ml) at 80 °C for 3 h. Purification by flash chromatography (25% Et_2O in petroleum ether, silica gel) afforded 447 mg (87%) of **12g**. R_f = 0.68 (25% EtOAc/pet. ether). FTIR (neat): 3061, 2925, 1715, 1613, 1488, 1467, 1357, 1232, 1170, 1092, 1014, 752, 691 cm^{-1}. ^1H NMR (500 MHz, $CDCl_3$): δ 7.31 – 7.20 (m, 9H), 7.20 – 7.11 (m, 2H), 7.04 (dd, *J* = 7.6 Hz, 1H), 6.79 (d, *J* = 7.9 Hz, 1H), 4.96 (d, *J* = 15.5 Hz, 1H), 4.87 (d, *J* = 15.5 Hz, 1H), 4.66 (s, 1H). ^{13}C NMR (126 MHz, $CDCl_3$): δ 175.5, 173.4, 168.8, 143.4, 135.6, 130.1, 129.7, 129.0, 128.6, 128.4, 128.1, 127.8, 127.6, 125.0, 122.8, 109.2, 51.2, 43.8. HRMS (ESI+) Calc'd for $C_{21}H_{16}ClNO$ $[M + Na]^+$: 356.0818, found: 356.0822.

1-benzyl-3-*p*-tolylindolin-2-one (12h):

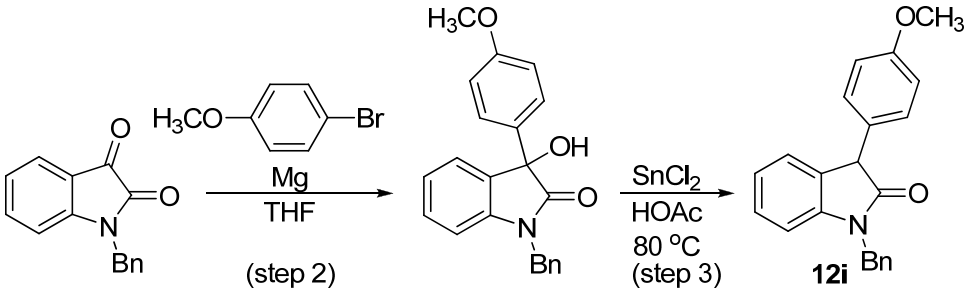


Step 2: The alcohol was prepared according to the general procedure using *N*-benzylisatin (712 mg, 3.00 mmol), 1-bromo-4-methylbenzene (616 mg, 3.60 mmol), and Mg turnings (102.1 mg, 4.2 mmol). The reaction was conducted in THF (15 ml) for 1 h. Purification by flash chromatography (20% EtOAc in petroleum ether, silica gel) afforded 760 mg (77%) of the alcohol intermediate as a solid. mp 147–149 °C. R_f = 0.44 (25% EtOAc/pet. ether). FTIR (neat): 3305, 1706, 1615, 1467, 1372, 1173, 1103, 1034, 922, 810, 748, 728, 692 cm^{-1}. ^1H NMR (500 MHz, $CDCl_3$): δ 7.30 – 7.20 (m, 8H), 7.17 (dt, *J* = 7.7 Hz, *J* = 1.1 Hz, 1H), 7.10 (d, *J* = 7.9 Hz, 1H), 6.73 (d, *J* = 7.8 Hz, 1H), 4.99 (d, *J* = 15.7 Hz, 1H), 4.74 (d, *J* = 15.6 Hz, 1H), 4.10 (b, 1H), 2.30 (s, 3H). ^{13}C NMR (126 MHz, $CDCl_3$): δ 177.8, 142.4, 137.9, 135.4, 131.9, 129.5, 129.2, 128l.8, 127.6, 127.2, 125.2, 124.9, 123.5, 109.6, 77.9, 43.9, 21.1.

Step 3: Oxindole **12h** was prepared according to the general procedure using the alcohol (700 mg, 2.13 mmol) and $SnCl_2$ (806 mg, 4.25 mmol). The reaction was conducted in acetic acid (20 ml) at 80 °C for 3 h. Purification by flash chromatography (20% Et_2O in petroleum ether, silica gel) afforded 540 mg (81%) of **12h** as a solid. mp 104–106 °C. R_f = 0.85 (25% EtOAc/pet. ether). FTIR (neat): 3061, 2923, 1714, 1613, 1509, 1488, 1466, 1357, 1224, 1158, 752, 731, 698 cm^{-1}. ^1H NMR (500 MHz, $CDCl_3$): δ 7.29 – 7.08 (m, 11H), 6.95 (ddd, *J* = 7.6 Hz, *J* = 7.6 Hz, *J* = 0.8 Hz, 1H), 6.74 (d, *J* = 7.9 Hz, 1H), 4.95 (d, *J* = 15.6 Hz, 1H), 4.83 (d, *J* =

15.6 Hz, 1H), 4.62 (s, 1H), 2.28 (s, 3H). ^{13}C NMR (126 MHz, $CDCl_3$): δ 176.0, 143.3, 137.0, 135.7, 135.5, 129.4, 128.9, 128.5, 128.1, 128.0, 127.4, 127.1, 124.8, 122.5, 108.9, 51.5, 43.6, 20.9. Elemental Analysis Calc'd for $C_{22}H_{19}NO$ C, 84.31; H, 6.11; N, 4.47; found: C, 84.14; H, 6.21; N, 4.27.

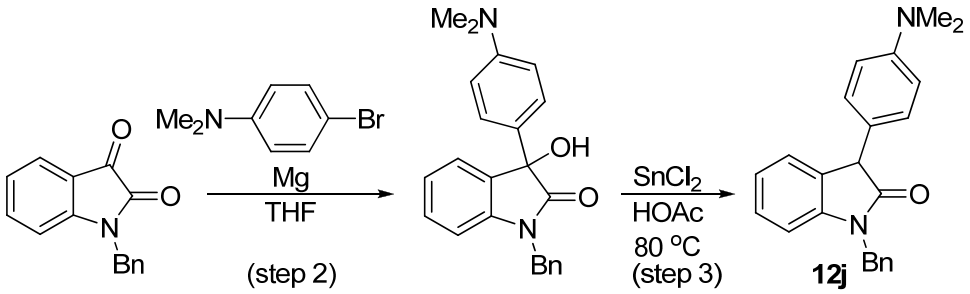
1-Benzyl-3-(4-methoxyphenyl)indolin-2-one (12i):



Step 2: The alcohol was prepared according to the general procedure using *N*-benzylisatin (712 mg, 3.00 mmol) and a 0.5 M solution of 4-MeOPhMgBr (7.2 ml, 3.60 mmol). The reaction was conducted in THF (10 ml) for 30 min. The crude alcohol was taken on to the next step without chromatography purification. R_f = 0.40 (25% EtOAc/pet. ether). ^{1}H NMR (500 MHz, $CDCl_3$): δ 7.40 – 7.24 (m, 8H), 7.19 (dt, *J* = 7.7 Hz, *J* = 1.2 Hz, 1H), 7.02 (dt, *J* = 7.6 Hz, *J* = 1.0 Hz, 1H), 6.85 – 6.82 (m, 2H), 6.74 (d, *J* = 7.8 Hz, 1H), 4.99 (d, *J* = 15.7 Hz, 1H), 4.76 (d, *J* = 15.7 Hz, 1H), 4.00 (b, 1H), 3.76 (s, 3H).

Step 3: Oxindole **12i** was prepared according to the general procedure using the crude alcohol obtained above and $SnCl_2$ (1.14 g, 6.0 mmol). The reaction was conducted in acetic acid (30 ml) at 80 °C for 3 h. Purification by flash chromatography (20% Et_2O in petroleum ether, silica gel) afforded 632 mg (64% over two steps) of **12i**. R_f = 0.61 (25% EtOAc/pet. ether). FTIR (neat): 3032, 2931, 2836, 1715, 1610, 1512, 1408, 1346, 1249, 1179, 1031, 751, 697 cm^{-1}. ^{1}H NMR (500 MHz, $CDCl_3$): δ 7.30 – 7.12 (m, 9H), 6.98 (ddd, *J* = 7.4 Hz, *J* = 7.4 Hz, *J* = 0.9 Hz, 1H), 6.88 – 6.86 (m, 2H), 6.76 (d, *J* = 7.8 Hz, 1H), 4.96 (d, *J* = 15.6 Hz, 1H), 4.86 (d, *J* = 15.6 Hz, 1H), 4.63 (s, 1H), 3.74 (s, 3H). ^{13}C NMR (126 MHz, $CDCl_3$): δ 176.3, 158.9, 143.3, 135.8, 129.3, 129.0, 128.6, 128.5, 128.1, 127.5, 124.9, 122.6, 114.2, 109.0, 55.1, 51.1, 43.7. HRMS (ESI+) Calc'd for $C_{22}H_{19}NO_2$ $[M + Na]^+$: 352.1313, found: 352.1313.

1-benzyl-3-*p*-tolylindolin-2-one (12j):

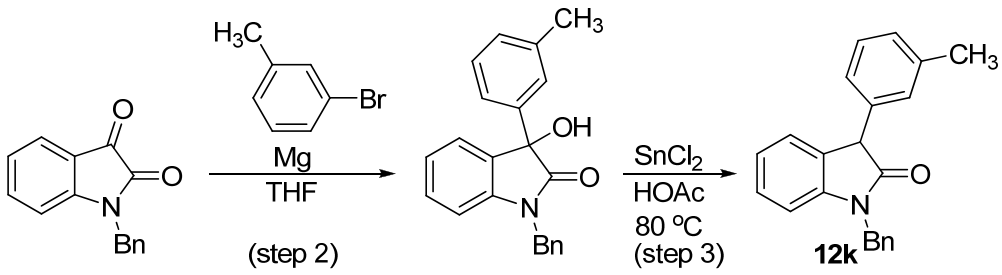


Step 2: The alcohol was prepared according to the general procedure using *N*-benzylisatin (237 mg, 1.00 mmol), 4-bromo-*N,N*-dimethylaniline (240 mg, 1.20 mmol), and Mg turnings (34.0 mg, 1.4 mmol). The reaction was conducted in THF (5 ml) for 1 h. The crude alcohol was taken on to the next step without

chromatography purification. R_f = 0.54 (50% EtOAc/pet. ether). ^{1}H NMR (500 MHz, $CDCl_3$): δ 7.35 – 7.25 (m, 8H), 7.19 (dt, *J* = 7.6 Hz, *J* = 1.1 Hz, 1H), 7.04 (dt, *J* = 7.7 Hz, *J* = 1.0 Hz,1H), 6.74 (d, *J* = 7.6 Hz, 1H), 6.69 – 6.67 (m, 2H), 5.03 (d, *J* = 15.6 Hz, 1H), 4.81 (d, *J* = 15.6 Hz, 1H), 3.25 (b, 1H), 2.93 (s, 6H). ^{13}C NMR (126 MHz, $CDCl_3$): δ 178.6, 149.4, 141.9, 136.0, 134.2, 129.9, 129.0, 128.6, 127.5, 127.3, 127.1, 125.7, 122.5, 112.4, 112.2, 109.2, 60.8, 43.8, 40.4.

Step 3: Oxindole **12j** was prepared according to the general procedure using the crude alcohol obtained above and $SnCl_2$ (379 mg, 2.0 mmol). The reaction was conducted in acetic acid (15 ml) at 80 ^{o} for 3 h. Purification by flash chromatography (20% Et_2O in petroleum ether) afforded 190 mg (55% over two steps) of oxindole **12j**. R_f = 0.45 (25% EtOAc/pet. ether). FTIR (neat): 3032, 2886, 2791, 1714, 1611, 1521, 1487, 1346, 1166, 797, 751, 698 cm^{-1}. ^{1}H NMR (500 MHz, $CDCl_3$): δ 7.31 – 7.14 (m, 7H), 7.07 (d, *J* = 8.7 Hz, 2H), 6.98 (dd, *J* = 7.5 Hz, *J* = 7.5 Hz, 1H), 6.74 (d, *J* = 7.9 Hz, 1H), 6.69 (d, *J* = 8.8 Hz, 2H), 4.97 (d, *J* = 15.6 Hz, 1H), 4.86 (d, *J* = 15.6 Hz, 1H), 4.60 (s, 1H), 2.90 (s, 6H). ^{13}C NMR (126 MHz, $CDCl_3$): δ 176.7, 150.0, 143.4, 136.0, 129.5, 128.9, 128.6, 127.9, 127.4, 127.2, 125.0, 124.2, 122.5, 112.9, 108.9, 51.1, 43.7, 40.5. HRMS (ESI+) Calc'd for $C_{23}H_{22}N_2O$ [M + Na]$^+$: 365.1630, found: 365.1615.

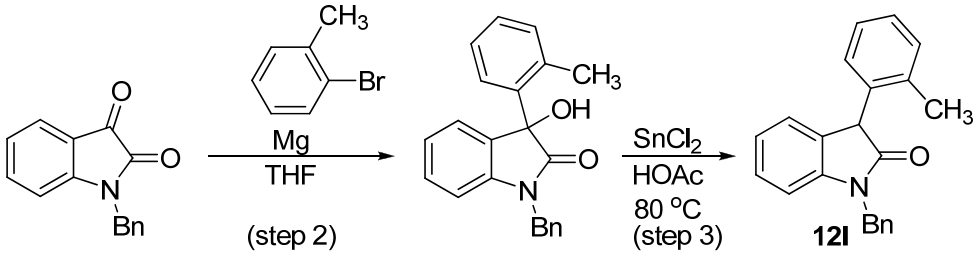
1-Benzyl-3-*m*-tolylindolin-2-one (12k):



Step 2: The alcohol was prepared according to the general procedure using *N*-benzylisatin (800 mg, 3.37 mmol), 1-bromo-3-methylbenzene (0.49 ml, 4.05 mmol), and Mg turnings (115 mg, 4.72 mmol). The reaction was conducted in THF (30 ml) for 1 h. Purification by flash chromatography (20% EtOAc in petroleum ether, silica gel) afforded 855 mg (77%) of the alcohol intermediate. R_f = 0.72 (25% EtOAc/pet. ether). FTIR (neat): 3392, 3031, 2922, 1706, 1613, 1488, 1467, 1367, 1172, 752, 704 cm^{-1}. ^{1}H NMR (500 MHz, $CDCl_3$): δ 7.25 – 7.10 (m, 10H), 7.06 – 7.04 (m, 1H), 6.94 (d, *J* = 7.6 Hz, 1H),6.70 (dd, *J* = 7.8 Hz, *J* = 2.3 Hz, 1H), 4.95 (d, *J* = 15.7 Hz, 1H), 4.71 (b, 1H), 4.66 (d, *J* = 15.7 Hz, 1H), 2.24 (s, 3H). ^{13}C NMR (126 MHz, $CDCl_3$): δ 177.9, 142.2, 140.1, 140.0, 138.0, 135.3, 132.1, 132.0, 129.3, 128.8, 128.6, 128.3, 127.5, 127.1, 125.8, 124.7, 123.4, 122.2, 109.5, 77.9, 43.7, 21.3.

Step 3: Oxindole **12k** was prepared according to the general procedure using the alcohol (700 mg, 2.13 mmol) and $SnCl_2$ (800 mg, 4.25 mmol). The reaction was conducted in acetic acid (20 ml) at 80 ^{o}C for 6 h. Purification by flash chromatography (20% Et_2O in petroleum ether, silica gel) afforded 580 mg (87%) of oxindole **12k**. R_f = 0.43 (25% EtOAc/pet. ether). FTIR (neat): 3053, 3032, 2920, 1716, 1613, 1488, 1466, 1347, 1182, 752, 730, 695 cm^{-1}. ^{1}H NMR (500 MHz, $CDCl_3$): δ 7.30 – 7.23 (m, 4H), 7.21 – 7.11 (m, 3H), 7.10 – 7.02 (m, 3H), 6.98 (d, *J* = 7.7 Hz, 1H), 6.94 (ddd, *J* = 7.6 Hz, *J* = 7.6 Hz, *J* = 0.9 Hz, 1H), 6.75 (d, *J* = 7.8 Hz, 1H), 4.95 (d, *J* = 15.6 Hz, 1H), 4.85 (d, *J* = 15.6 Hz, 1H), 4.61 (s, 1H), 2.28 (s, 3H). ^{13}C NMR (126 MHz, $CDCl_3$): δ 175.9, 143.2, 138.3, 136.5, 135.7, 128.9, 128.8, 128.6, 128.5, 128.2, 128.0, 127.4, 127.1, 125.2, 124.8, 122.5, 108.9, 51.8, 43.6, 21.2. HRMS (ESI+) Calc'd for $C_{22}H_{19}NO$ [M + H]$^+$: 314.1545, found: 314.1536.

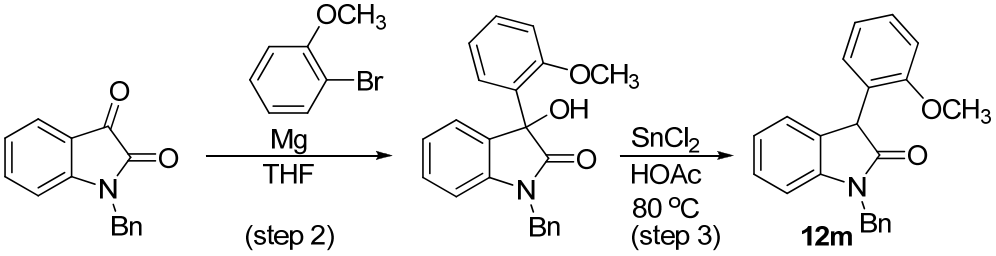
1-Benzyl-3-o-tolylindolin-2-one (12l):



Step 2: The alcohol was prepared according to the general procedure using *N*-benzylisatin (712 mg, 3.00 mmol), 1-bromo-2-methylbenzene (0.43 ml, 3.60 mmol), and Mg turnings (102 mg, 4.20 mmol). The reaction was conducted in THF (20 ml) for 1 h. Purification by flash chromatography (20% EtOAc in petroleum ether, silica gel) afforded 790 mg (80%) of the alcohol intermediate. R_f = 0.50 (25% EtOAc/pet. ether). FTIR (neat): 3375, 3031, 2922, 1698, 1614, 1466, 1371, 1170, 754, 700 cm^{-1}. ^1H NMR (500 MHz, $CDCl_3$): δ 7.96 (dd, *J* = 7.8 Hz, *J* = 1.1 Hz, 1H), 7.38 (d, *J* = 7.6 Hz, 2H), 7.34 – 7.27 (m, 4H), 7.22 (dt, *J* = 7.3 Hz, *J* = 1.2 Hz, 2H), 7.04 – 7.02 (m, 2H), 6.96 (dt, *J* = 7.6 Hz, *J* = 0.8 Hz, 1H), 6.83 (d, *J* = 7.9 Hz, 1H), 5.03 (d, *J* = 15.4 Hz, 1H), 4.86 (d, *J* = 15.4 Hz, 1H), 3.55 (b, 1H), 1.78 (s, 3H). ^{13}C NMR (126 MHz, $CDCl_3$): δ 177.1, 143.2, 137.6, 135.2, 134.5, 131.4, 130.3, 129.8, 128.8, 128.3, 127.8, 127.7, 126.1, 126.0, 124.9, 123.5, 109.5, 77.5, 44.1, 19.5.

Step 3: Oxindole **12l** was prepared according to the general procedure using the alcohol (750 mg, 2.28 mmol) and $SnCl_2$ (862 mg, 4.55 mmol). The reaction was conducted in acetic acid (23 ml) at 80 °C for 6 h. Purification by flash chromatography (20% Et_2O in petroleum ether, silica gel) afforded 610 mg (85%) of oxindole **12l**. R_f = 0.58 (25% EtOAc/pet. ether). FTIR (neat): 3062, 3031, 2926, 1714, 1612, 1487, 1466, 1346, 1184, 1163, 1080, 1030, 910, 751, 730, 699, 653 cm^{-1}. ^1H NMR (500 MHz, $CDCl_3$): δ 7.39 – 7.33 (m, 4H), 7.29 – 7.18 (m, 4H), 7.14 – 7.11 (m, 1H), 7.01 – 6.97 (m, 3H), 6.93 – 6.87 (m, 1H), 5.12 (s, 1H), 4.97 (d, *J* = 15.6 Hz, 1H), 4.94 (d, *J* = 15.6 Hz, 1H), 2.25 (s, 3H). ^{13}C NMR (126 MHz, $CDCl_3$): δ 176.1, 135.8, 130.9, 128.7, 128.0, 127.5, 127.4, 126.3, 124.6, 122.6, 109.0, 43.8. Elemental Analysis Calc'd for $C_{22}H_{19}NO$: C, 84.31; H, 6.11; N, 4.47; found: C, 84.50; H, 5.96; N, 4.41. HRMS (ESI+) Calc'd for ($C_{22}H_{19}NO$ $[M + Na]^+$: 336.1364, found: 336.1372.

1-Benzyl-3-(2-methoxyphenyl)indolin-2-one (12m):

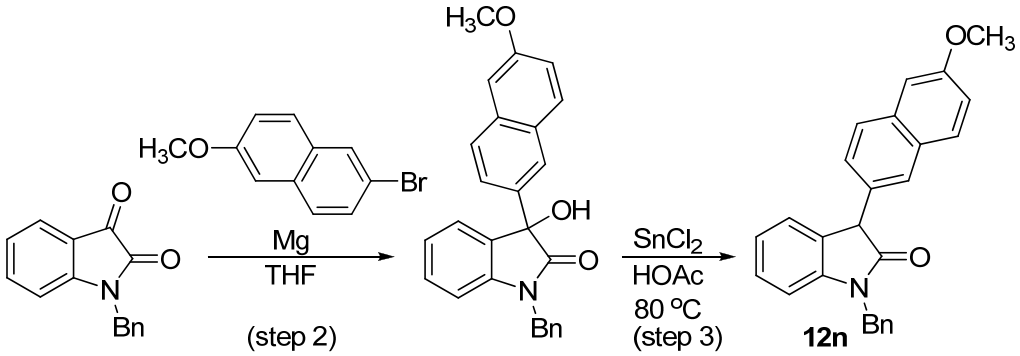


Step 2: The alcohol was prepared according to the general procedure using *N*-benzylisatin (949 mg, 4.00 mmol), 1-bromo-2-methoxybenzene (0.60 ml, 4.80 mmol), and Mg turnings (136 mg, 5.60 mmol). The reaction was conducted in THF (30 ml) for 1 h. Purification by flash chromatography (20% EtOAc in petroleum ether,

silica gel) afforded 1.11 g (80%) of the alcohol intermediate. R_f = 0.75 (50% EtOAc/pet. ether). ^{1}H NMR (500 MHz, $CDCl_3$): δ 7.75 (dd, *J* = 7.6 Hz, *J* = 1.1 Hz, 1H) 7.42 (d, *J* = 7.4 Hz, 2H), 7.33 (t, *J* = 7.5 Hz, 2H), 7.30 – 7.20 (m, 2H), 7.18 (dt, *J* = 7.7 Hz, *J* = 1.2 Hz, 1H), 7.08 (d, *J* = 7.3 Hz, 1H), 7.02 (dt, *J* = 7.6 Hz, *J* = 1.0 Hz, 1H), 6.94 (5, *J* = 7.5 Hz, 1H), 6.79 (d, *J* = 8.1 Hz, 1H), 6.78 (d, *J* = 7.8 Hz, 1H), 5.02 (d, *J* = 15.5 Hz, 1H), 4.83 (d, *J* = 15.5 Hz, 1H), 3.87 (b, 1H), 3.38 (s, 3H). ^{13}C NMR (126 MHz, $CDCl_3$): δ 177.5, 156.1, 143.4, 135.9, 130.8, 129.4, 128.7, 128.5, 127.7, 127.6, 126.9, 124.3, 122.8, 120.9, 111.6, 109.0, 76.3, 55.6, 43.9.

Step 3: Oxindole **12m** was prepared according to the general procedure using the alcohol (900 mg, 2.61 mmol) and $SnCl_2$ (986 mg, 5.21 mmol). The reaction was conducted in acetic acid (25 ml) at 80 °C for 4 h. Purification by flash chromatography (50% Et_2O in petroleum ether, silica gel) afforded 800 mg (93%) of oxindole **12m**. R_f = 0.38 (25% EtOAc/pet. ether). FTIR (neat): 3060, 2938, 2837, 1714, 1612, 1493, 1457, 1357, 1245, 1185, 1026, 751, 699 cm^{-1}. ^{1}H NMR (500 MHz, $CDCl_3$): δ 7.35 (d, *J* = 7.3 Hz, 2H), 7.23 (dd, *J* = 7.3 Hz, *J* = 7.3 Hz, 2H), 7.20 – 7.15 (m, 2H), 7.09 (d, *J* = 6.9 Hz, 1H), 7.04 (dd, *J* = 7.8 Hz, *J* = 7.8 Hz, 1H), 6.96 (d, *J* = 7.3 Hz, 1H), 6.87 – 6.81 (m, 2H), 6.78 (d, *J* = 8.2 Hz, 1H), 6.70 (d, *J* = 7.8 Hz, 1H), 5.05 (d, *J* = 15.6 Hz, 1H), 4.84 (s, 1H), 4.76 (d, *J* = 15.6 Hz, 1H), 3.47 (s, 3H). ^{13}C NMR (126 MHz, $CDCl_3$): δ 176.1, 157.0, 142.9, 135.9, 130.1, 129.3, 128.6, 128.2, 127.3, 127.2, 127.1, 125.4, 123.6, 121.9, 120.5, 111.0, 108.3, 55.0, 43.4. Elemental Analysis Calc'd for $C_{22}H_{19}NO_2$ C, 80.22; H, 5.81; N, 4.25; found: C, 80.39; H, 6.77; N, 3.99.

1-Benzyl-3-(6-methoxynaphthalen-2-yl)indolin-2-one (12n):

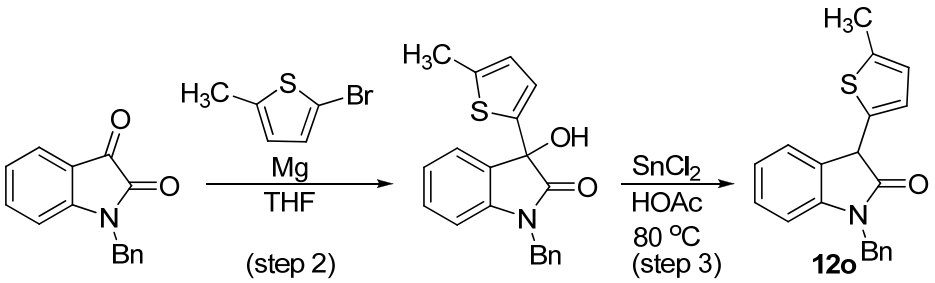


Step 2: The alcohol was prepared according to the general procedure using *N*-benzylisatin (949 mg, 4.00 mmol), 2-bromo-6-methoxynaphthalene (1.14 g, 4.80 mmol), and Mg turnings (136 mg, 5.60 mmol). The reaction was conducted in THF (30 ml) for 2.5 h. Purification by flash chromatography (20% EtOAc in petroleum ether, silica gel) afforded 810 mg (51%) of the alcohol intermediate. R_f = 0.60 (50% EtOAc/pet. ether). FTIR (neat): 3378, 3059, 2936, 1705, 1612, 1466, 1373, 1266, 1171, 1030, 755, 698 cm^{-1}. ^{1}H NMR (500 MHz, $CDCl_3$): δ 7.83 (d, *J* = 1.6 Hz, 1H), 7.65 (d, *J* = 8.8 Hz, 2H), 7.39 (dd, *J* = 8.7 Hz, *J* = 1.8 Hz, 1H), 7.;33 – 7.25 (m, 6H), 7.22 (dt, *J* = 7.7 Hz, *J* = 1.2 Hz, 1H), 7.12 (dd, *J* = 8.9 Hz, *J* = 2.5 Hz,1H), 7.07 (d, *J* = 2.4 Hz, 1H), 7.03 (dd, *J* = 7.5 Hz, *J* = 0.9 Hz,1H), 6.79 (d, *J* = 7.8 Hz, 1H), 5.05 (d, *J* = 15.5 Hz, 1H), 4.82 (d, *J* = 15.5 Hz, 1H), 3.89 (s, 3H), 3.80 (s, 1H). ^{13}C NMR (126 MHz, $CDCl_3$): δ 177.7, 158.0, 142.6, 135.4, 135.1, 134.3, 131.7, 129.7, 128.8, 128.5, 127.8, 127.4, 127.3, 125.0, 124.2, 123.6, 123.5, 119.1, 109.7, 105.5, 78.1, 55.3, 44.0.

Step 3: Oxindole **12n**was prepared according to the general procedure using the alcohol (791 mg, 2.00 mmol) and $SnCl_2$ (758 mg, 4.00 mmol). The reaction was conducted in acetic acid (30 ml) at 80 °C for 3 h. Purification by flash chromatography (25% EtOAc in petroleum ether, silica gel) afforded 560 mg (74%) of oxindole **12n**. R_f = 0.55 (25% EtOAc/pet. ether). FTIR (neat): 2926, 2853, 1706, 1607, 1487, 1345, 1261, 1164,

1030, 852, 750 cm^{-1}. ^1H NMR (500 MHz, $CDCl_3$): δ 7.70 – 7.63 (m, 3H), 7.34 – 7.28 (m, 4H), 7.26 – 7.18 (m, 3H), 7.15 – 7.08 (m, 3H), 7.00 (ddd, *J* = 7.5 Hz, *J* = 7.5 Hz, *J* = 0.9 Hz, 1H), 6.80 (d, *J* = 7.9 Hz, 1H), 5.00 (d, *J* = 15.6 Hz, 1H), 4.90 (d, *J* = 15.6 Hz, 1H), 4.81 (s, 1H), 3.87 (s, 3H). ^{13}C NMR (126 MHz, $CDCl_3$): δ 176.3, 157.7, 143.5, 135.9, 133.9, 131.7, 129.2, 129.0, 128.9, 128.7, 128.3, 127.6, 127.3, 126.5, 125.1, 122.8, 119.0, 109.2, 105.6, 55.2, 52.0, 43.9. HRMS (ESI+) Calc'd for $C_{26}H_{21}NO_2$ $[M + Na]^+$: 402.1470, found: 402.1474.

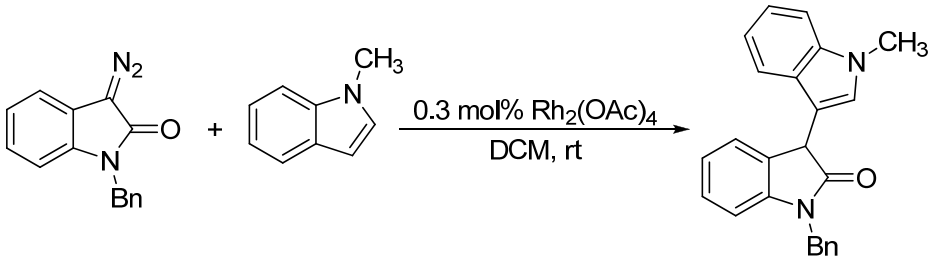
1-Benzyl-3-(5-methylthiophen-2-yl)indolin-2-one (12o):



Step 2: The alcohol was prepared according to the general procedure using *N*-benzylisatin (949 mg, 4.00 mmol), 2-bromo-5-methylthiophene (850 g, 4.80 mmol), and Mg turnings (136 mg, 5.60 mmol). The reaction was conducted in THF (25 ml) for 1 h. Purification by flash chromatography (25% EtOAc in petroleum ether, silica gel) afforded 1.28g (95%) of the alcohol intermediate. R_f = 0.32 (25% EtOAc/pet. ether). FTIR (neat): 3318, 2916, 1694, 1610, 1468, 1373, 1169, 998, 800, 760, 696, 664 cm^{-1}. ^1H NMR (500 MHz, $CDCl_3$): δ 7.52 (ddd, *J* = 7.5 Hz, *J* = 1.2 Hz, *J* = 0.5 Hz, 1H),7.32 – 7.24 (m, 5H), 7.21 (dt, *J* = 7.7 Hz, *J* = 1.5 Hz, 1H), 7.08 (dt, *J* = 7.6 Hz, *J* = 1.0 Hz, 1H), 6.79 (d, *J* = 3.5 Hz, 1H), 6.71 (d, *J* = 7.6 Hz, 1H), 6.58 – 5.57 (m, 1H), 4.99 (d, *J* = 15.7 Hz, 1H), 4.79 (d, *J* = 15.7 Hz, 1H), 3.78 (b, 1H), 2.44 (d, *J* = 1.1 Hz, 3H). ^{13}C NMR (126 MHz, $CDCl_3$): δ 176.3, 142.1, 141.6, 140.6, 135.2, 130.4, 129.9, 128.8, 127.7, 127.1, 125.9, 124.9, 124.8, 123.3, 109.8, 75.5, 43.9, 15.4.

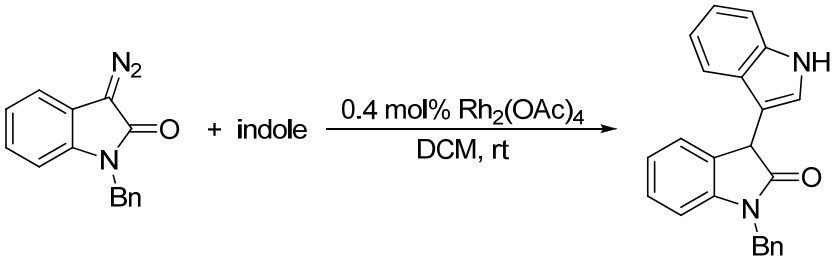
Step 3: Oxindole **12o** was prepared according to the general procedure using the alcohol (1.01 g, 3.00 mmol) and $SnCl_2$ (1.12 g, 6.00 mmol). The reaction was conducted in acetic acid (25 ml) at 80 °C for 1 h. Purification by flash chromatography (10% EtOAc in petroleum ether, silica gel) afforded 890 mg (93%) of oxindole **12o**. R_f = 0.85 (25% EtOAc/pet. ether). FTIR (neat): 3061, 2918, 2859, 1715, 1612, 1488, 1466, 1356, 1179, 1098, 1030, 797, 752, 730, 697 cm^{-1}. ^1H NMR (500 MHz, $CDCl_3$): δ 7.25 – 7.14 (m, 6H), 7.10 (dd, *J* = 7.8 Hz, *J* = 7.8 Hz, 1H), 6.94 (dd, *J* = 7.3 Hz, *J* = 7.3 Hz, 1H), 6.78 (d, *J* = 3.4 Hz, 1H), 6.69 (d, *J* = 7.8 Hz, 1H), 6.56 (dd, *J* = 3.4 Hz, *J* = 1.1 Hz, 1H), 4.88 (d, *J* = 15.8 Hz, 1H), 4.78 (d, *J* = 15.8 Hz, 1H), 4.77 (s, 1H), 2.33 (s, 3H). ^{13}C NMR (126 MHz, $CDCl_3$): δ 174.3, 142.7, 139.3, 135.3, 128.3, 128.1, 127.7, 127.2, 126.8, 125.7, 124.7, 124.6, 122.3, 108.9, 46.8, 43.4, 14.9. HRMS (ESI+) Calc'd for $C_{20}H_{17}NOS$ $[M + H]^+$: 320.1109, found: 320.1095.

1-benzyl-1'-methyl-3,3'-biindolin-2-one (12p)



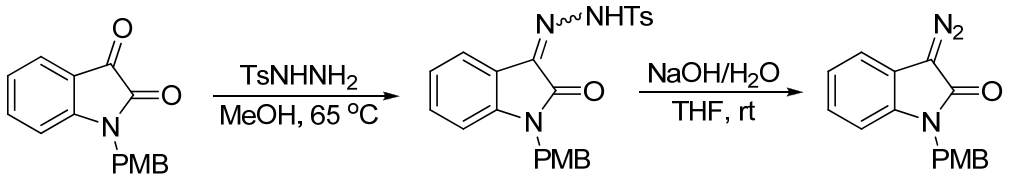
Oxindole **12p** was prepared according to the literature procedure shown above.[10] A catalytic amount of $Rh_2(OAc)_4$ (15.6 mg, 0.03543 mmol) was added to a stirred solution of the cyclic diazo compound[11] (2.94 g, 11.8 mmol) and *N*-methylindole (1.70 g, 13.0 mmol) in anhydrous CH_2Cl_2 (10 ml) at room temperature under an argon atmosphere. After stirring for 2 h, the solvent was evaporated *in vacuo*, and the residue was purified by flash chromatography (20% EtOAc in petroleum ether, silica gel) to afford 4.16 g (>99%) of oxindole **12p** as a solid. mp 93–95 °C (Lit.[10] mp 95–97 C). R_f = 0.36 (25% EtOAc/pet. ether). ^{1}H NMR (500 MHz, $CDCl_3$): δ 7.34 – 7.33 (m, 2H), 7.29 – 7.22 (m, 4H), 7.18 – 7.14 (m, 4H), 6.97 – 6.92 (m, 3H), 6.80 (d, *J* = 7.8 Hz, 1H), 5.03 (d, *J* = 15.6 Hz, 1H), 4.93 (s, 1H), 4.87 (d, *J* = 15.5 Hz, 1H), 3.66 (s, 3H); ^{13}C NMR (126 MHz, $CDCl_3$): δ 176.4, 143.2, 137.2, 135.9, 129.1, 128.6, 127.9, 127.7, 127.5(2), 126.6, 124.7, 122.5, 121.8, 119.4, 119.1, 109.3, 109.1, 108.9, 44.3, 43.9, 32.6. Spectral data was in agreement with that reported in the literature.[10]

1-benzyl-3,3'-biindolin-2-one (12q):



A 25 mL RBF flask with magnetic stir-bar was charged with 1.22 g (4.89 mmol) of the diazo compound, 0.596 g (5.09 mmol) of indole, and 8.7 mg (0.020 mmol) of $Rh_2(OAc)_4$, and the flask was put under Ar using vacuum/purge cycles. This solid material was then dissolved in 4.9 mL of CH_2Cl_2, and the homogenous mixture was allowed to stir at room temperature for 3 h. Removal of volatile material under reduced pressure, followed by purification of the crude material using silica gel chromatography (gradient, 1:0 to 10:1 CH_2Cl_2:Et_2O) afforded 1.46 g (88%) of oxindole **12q** as a tan solid. mp 144-150 °C. R_f = 0.18 (20:1 CH_2Cl_2:Et_2O). Spectral data was in agreement with that reported in the literature.[10]

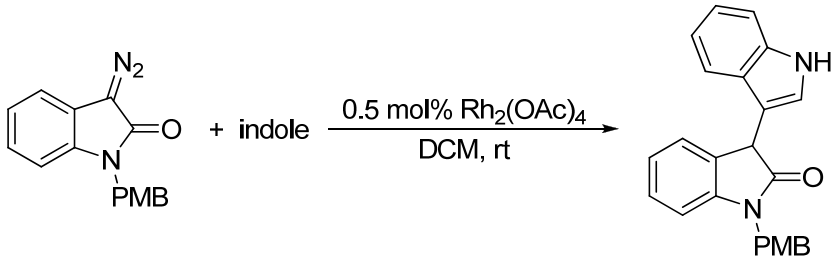
[10] Muthusamy, S.; Gunanathan, C.; Babu, S. A.; Suresh, E.; Dastidar, P. *Chem. Commun.* **2002**, 824.
[11] Prepared according to: Marti, C.; Carreira, E. M. *J. Am. Chem. Soc.* **2005**, *127*, 11505.



The procedure was adapted from the literature.[11] A 200 mL RBF flask with magnetic stir-bar was charged with 4.98 g (18.6 mmol) of the PMB-protected isatin derivative[12] and 129 mL of anhydrous MeOH. This mixture was heated at 65 °C for 20 min followed by the addition of 3.50 g (18.8 mmol) of $TsNHNH_2$. The mixture turned from orange to yellow, and heating was continued for 20 h. The yellow solid was collected by filtration and washed with petroleum ether to afford 7.40 g (91%) of the tosyl hydrazone intermediate as an ~1.5:1 mixture of *E*- and *Z*-isomers (the configuration of the major isomer was not determined). ^{1}H NMR (400 MHz, $CDCl_3$) data for the crude tosyl hydrazone intermediate: δ 8.60 (s, 1H), 7.96 (d, *J* = 8.0 Hz, 1H), 7.88 (d, *J* = 8.4 Hz, 1H), 7.57 (t, *J* = 7.6 Hz, 1H), 7.21-7.39 (m, 3H), 7.20 (d, *J* = 8.4 Hz, 2H), 7.04 (t, *J* = 7.6 Hz, 1H), 6.80 (d, *J* = 8.8 Hz, 2H), 6.71-6.80 (m, 1H), 4.81 (s, 1.2H, major isomer), 4.80 (s, 0.8H, minor isomer), 3.75 (s, 1.2H, minor isomer), 3.74 (s, 1.8H, major isomer), 2.41 (s, 1.8H, major isomer), 2.40 (s, 1.2H, minor isomer).

This crude material was taken up in 68 mL of THF and a solution of 1.36 g (34 mmol) of NaOH in 170 mL of H_2O was added. After stirring for 3 h, 135 mL of EtOAc was added, and the layers were separated after shaking in a separatory funnel. The aqueous layer was neutralized with dry ice and extracted with EtOAc (2 x 150 mL). The combined organics were washed with brine, dried with anhydrous Na_2SO_4, and volatile material removed under reduced pressure. Purification of the crude mixture by silica gel chromatography (gradient, 10:1 to 7:1 pet. ether:EtOAc) afforded 2.23 g (43% overall) of the diazo compound as a red solid. mp 91-94 °C. R_f = 0.24 (4:1 pet. ether:EtOAc)**.** ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.23 (dd, *J* = 6.8 Hz, *J* = 2.0 Hz, 2H), 7.16 (d, *J* = 7.6 Hz, 1H), 7.08 (td, *J* = 7.6 Hz, *J* = 1.6 Hz 1H), 7.02 (td, *J* = 7.6 Hz, *J* = 1.2 Hz, 1H), 6.79-6.86 (m, 3H), 4.93 (s, 2H), 3.74 (s, 3H). ^{13}CNMR (100 MHz, $CDCl_3$): δ 166.7, 159.0, 133.5, 128.6, 128.0, 125.3, 122.0, 118.2, 116.6, 114.0, 109.4, 55.11, 43.65. FTIR (thin film): 2932 (w), 2091 (s), 1681 (s), 1609 (s), 1512 (s), 1467 (s), 1437 (m), 1399 (s), 1379 (m), 1340 (s), 1273 (m), 1246 (s), 1174 (s) cm^{-1}.

1-(4-methoxybenzyl)-3,3'-biindolin-2-one (12r):

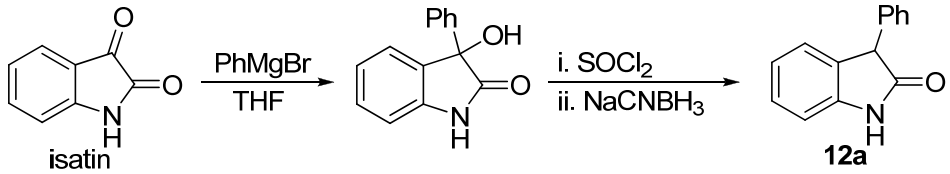


A 25 mL RBF flask with magnetic stir-bar was charged with 2.01 g (7.20 mmol) of the diazo compound, 0.886 g (7.56 mmol) of indole, and 15.9 mg (0.0360 mmol) of $Rh_2(OAc)_4$ and the flask was put under Ar using vacuum/purge cycles. This solid material was then dissolved in 7.2 mL of CH_2Cl_2, and the homogenous mixture was allowed to stir at room temperature for 6 h. Removal of volatile material under reduced pressure, followed by purification of the crude material using silica gel chromatography (gradient, 1:0 to 10:1 CH_2Cl_2:Et_2O) afforded 2.43 g (92%) of oxindole **12r** as a tan solid. mp 144-150 °C. R_f = 0.18 (20:1

[12] Itoh, T.; Ishikawa, H.; Hayashi, Y. *Org. Lett.* **2009**, *11*, 3854.

CH_2Cl_2:Et_2O). ^{1}H NMR (400 MHz, $CDCl_3$): δ 8.47 (s, 1H), 7.31 (d, *J* = 8.8 Hz, 2H), 7.28 (d, *J* = 8.0 Hz, 1H), 7.21 (t, *J* = 8.0 Hz, 1H), 7.16 (d, *J* = 7.4 Hz, 1H), 7.11 (t, *J* = 7.4 Hz, 1H), 7.07 (d, *J* = 8.0 Hz, 1H), 6.90-7.00 (m, 3H), 6.87 (d, *J* = 8.0 Hz, 1H), 6.84 (d, *J* = 8.8 Hz, 2H), 5.04 (d, *J* = 15 Hz, 1H), 4.92 (s, 1H), 4.86 (d, *J* = 15 Hz, 1H), 3.77 (s, 3H). ^{13}CNMR (100 MHz, $CDCl_3$): δ 176.7, 159.0, 143.2, 136.6, 129.2, 129.0, 128.03, 128.00, 126.1, 124.9, 123.7, 122.6, 122.1, 119.5, 119.2, 114.1, 111.4, 110.4, 109.0, 55.23, 44.65, 43.50. FTIR (thin film): 3405 (m), 3322 (m), 3053 (w), 2931 (w), 1697 (s), 1611 (s), 1512 (s), 1486 (m), 1464 (s), 1437 (m), 1351 (s), 1302 (m), 1248 (s), 1178 (s) cm^{-1}.

3-phenylindolin-2-one (12a):

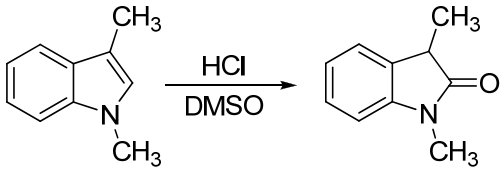


Isatin (1.47 g, 10.0 mmol) was dissolved in anhydrous THF (25 ml) and cooled to 0 °C followed by dropwise addition of a 2.0 M solution of PhMgBr in THF (11.0 ml, 22.0 mmol). The ice-bath was removed, and the reaction was stirred under N_2 for 30 min at which point tlc analysis indicated complete consumption of the starting material. The reaction mixture was quenched with saturated aqueous NH_4Cl (10 ml), and extracted with EtOAc (3 × 10 ml). The combined organic layers were washed with saturated aqueous $NaHCO_3$ (10 ml), brine (10 ml), dried over anhydrous $MgSO_4$, filtered, and concentrated *in vacuo*. The residue was evacuated under high vacuum to give the crude alcohol (2.25 g, 100%). R_f = 0.35 (25% EtOAc in pet. ether). ^{1}H NMR (500 MHz, $CDCl_3$): δ 7.40 – 7.36 (m, 2H), 7.34 – 7.24 (m, 4H), 7.19 (d, *J* = 7.3 Hz, 1H), 7.05 (dt, *J* = 7.6 Hz, *J* = 0.96 Hz, 1H), 6.98 (d, *J* = 7.8 Hz, 1H). Spectral data was in agreement with that reported in the literature.[5]

The alcohol (901 mg, 4.0 mmol) was dissolved in CH_2Cl_2 (5 ml), and then $SOCl_2$ (2.90 ml, 40.0 mmol) was added. The reaction mixture was stirred at room temperature overnight and concentrated to give the crude tertiary chloride, which was then dissolved in CH_3CN (20 ml) and treated with $NaCNBH_3$ (698 mg, 11.1 mmol) at 0 °C. The reaction flask contents were slowly warmed to room temperature and stirred overnight. After being quenched with saturated aqueous $NaHCO_3$ (15 ml), it was poured into water (15 ml), and extracted with EtOAc (3 × 15 ml). The combined organic layers were then washed with brine (15 ml), dried over anhydrous $MgSO_4$, filtered, and concentrated *in vacuo*. The resulting solid was purified by flash column chromatography (25% EtOAc in petroleum ether, silica gel) to afford 540 mg (70% over two steps) of oxindole **12a** as a white solid. mp 181 – 183 °C (Lit.[13] mp 183-185 °C). R_f =0.31 (25% EtOAc / pet. ether). IR (neat): 3180, 3063, 1706, 1616, 1469, 1322, 1224, 1180, 751, 704 cm^{-1}. ^{1}H NMR (500 MHz, $CDCl_3$): δ 9.36 (broad, 1H), 7.36 – 7.28 (m, 3H), 7.24 – 7.20 (m, 3H), 7.11 (d, *J* = 7.3 Hz, 1H), 7.01 (t, *J* = 7.4 Hz, 1H), , 6.92 (d, *J* = 7.8Hz, 1H), 4.63 (s, 1H). ^{13}C NMR (126 MHz, $CDCl_3$): δ 179.1, 141.7, 136.4, 129.6, 128.9, 128.5, 128.4, 127.6, 125.1, 122.6, 110.1, 52.7. Spectral data was in agreement with that reported in the literature.[5]

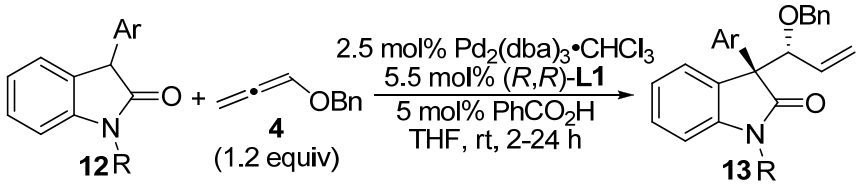
[13] Fleming, I.; Loreto, M. A.; Wallace, I. H. M.; Michael, J. P. *J. Chem. Soc. Perkin Trans. 1* **1986**, *2*, 349.

1,3-dimethylindolin-2-one:

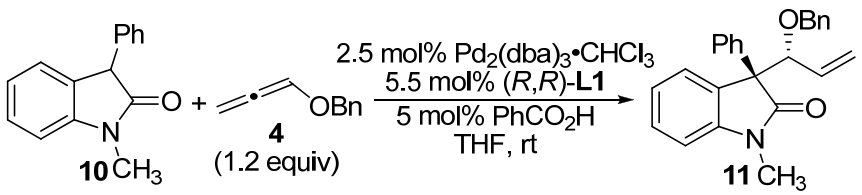


The oxindole was prepared according to the literature procedure.[14] To a solution of the *N*-methyl-3-methylindole (1.45 g, 10.0 mmol) in DMSO (17 ml) was added slowly concentrated HCl (34 ml) at room temperature. After stirring for 1 h, the solution was diluted with water (50 ml) and extracted with EtOAc (3 × 30 ml). The combined organic layers were washed with water (2 × 10 ml), saturated $NaHCO_3$ (15 ml), brine (15 ml), dried over anhydrous $MgSO_4$, filtered, and concentrated *in vacuo*. The residue was purified by flash chromatography (20% EtOAc in petroleum ether, silica gel) to afford 1.31 g (>99%) of the desired oxindole. R_f = 0.40 (25% EtOAc/pet. ether). ^{1}H NMR (500 MHz, $CDCl_3$): δ 7.29 – 7.25 (m, 1H), 7.24 – 7.22 (m, 1H), 7.05 (dt, *J* = 7.6 Hz, *J* = 0.9 Hz, 1H), 6.82 (d, *J* = 7.7 Hz, 1H), 3.42 (q, *J* = 7.7 Hz, 1H), 3.20 (s, 3H), 1.47 (d, *J* = 7.6 Hz, 3H). ^{13}C NMR (126 MHz, $CDCl_3$): δ 178.5, 143.8, 130.4, 127.7, 123.3, 122.2, 107.8, 40.4, 26.0, 15.2. Spectral data was in agreement with that reported in the literature.[14]

Representative procedure for the Pd-catalyzed hydrocarbonation reaction (Table 7):



(*R*)-3-((*R*)-1-(benzyloxy)allyl)-1-methyl-3-phenylindolin-2-one (11):

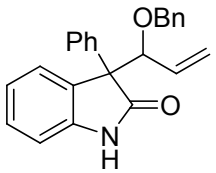


A microwave vial was charged with of $Pd_2(dba)_3$•$CHCl_3$ (5.2 mg, 5.0 μmol), (*R*,*R*)-**L1** ligand (7.6 mg, 11 μmol), oxindole **10** (41.8 mg, 0.200 mmol), and benzoic acid (1.2 mg, 10 μmol), and the flask was put under an Ar atmosphere using vacuum-purge cycles (3x). The reaction was diluted with 2.0 mL of anhydrous THF (taken from a N_2 pressurized alumina-column purification system), and the mixture was stirred under argon at room temperature for 15 min. Next, benzoxylallene **4** (35.6 μl, 0.24 mmol) was added *via* syringe. After stirring at room temperature for 6 h, the mixture was concentrated to give the crude product in 14:1 d.r. and >99% yield (The yield was determined by ^{1}H NMR using mesitylene as the internal standard. Diastereomeric ratio was

[14] Szabopusztay, K.; Szabo, L. *Synthesis* **1979**, *4*, 276.

determined by ^{1}H NMR by comparison of the diastereotopic –CH_2– group of the –OBn group). The crude material was purified by flash chromatography (20% EtOAc in petroleum ether, silica gel) to give oxindole **11** (d.r. = 14:1, 87% ee). A single recrystallization in hexanes/EtOAc from 500 mg of material (82% ee) gave 430 mg of white crystals (86%yield, >99% ee). The relative stereochemistry was confirmed by Xray crystallography of a single crystal obtained from this recrystallization. Absolute stereochemistry was assigned by analogy to that determined for the allene hydrocarbonation product **17**. mp 135 – 137 ^{o}C. R_f = 0.55 (50% ether / pet. ether). IR (neat): 3059, 2930, 2871, 1715, 1611, 1493, 1470, 1372, 1348, 1253, 1078, 934, 758, 734, 696 cm^{-1}. ^{1}H NMR (500 MHz, $CDCl_3$): δ 7.65 (d, *J* = 7.4 Hz, *J* = 0.9 Hz, 1H), 7.47 – 7.45 (m, 2H), 7.36 (dt, *J* = 7.8 Hz, *J* = 1.2 Hz, 1H), 7.29 – 7.22 (m, 6H), 7.13 (ddd, *J* = 7.6 Hz, *J* = 7.6 Hz, *J* = 1.0 Hz, 1H), 7.00 – 6.98 (m, 2H), 6.86 (d, *J* = 7.7Hz, 1H), 5.30 – 5.27 (m, 2H), 5.15 – 5.13 (m, 1H), 4.72 (m, 1H), 4.54 (d, *J* = 12.0, 1H), 4.26 (d, *J* = 12.0, 1H), 3.13 (s, 3H). ^{13}C NMR (126 MHz, $CDCl_3$): δ 175.9, 144.2, 138.0, 137.6, 133.9, 128.8, 128.4, 128.2, 128.1, 127.8, 127.6, 127.62, 127.4, 127.2, 122.3, 120.8, 107.9, 84.0, 70.6, 61.1, 26.3. HRMS (ESI+) Calc'd for $C_{25}H_{23}NO_2$ $[M]^+$: 369.1729, found: 369.1724. $[\alpha]_D^{23}$ = 261.0 (c = 2.20, CH_2Cl_2, >99%ee), Enantiomeric excess was determined to be 87% ee by chiral HPLC analysis (Chiralpak AD, 254 nm, heptane:*i*-PrOH = 98:2, 1.0 ml/min, t_1 = 14.20 min (major), t_2 = 18.38 min).

3-(1-Benzyloxy-allyl)-3-phenylindolin-2-one (13a):



13a

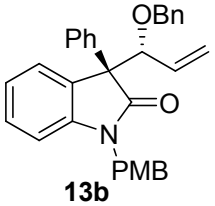
Oxindole **13a** was prepared according to the general procedure of the Pd-catalyzed hydrocarbonation of allenes, using $Pd_2(dba)_3$•$CHCl_3$ (5.2 mg, 5.0 μmol), (*R*,*R*)-**L1** ligand (7.6 mg, 11 μmol), $PhCO_2H$ (1.2 mg, 10 μ mol), oxindole **12a** (41.8 mg, 0.20 mmol), and benzyloxyallene **4** (35.6 μl, 0.24 mmol). Reaction was conducted in THF (2.0 ml) for 6 h at room temperature, giving **13a** (49.7 mg, 70%) with a 1.5:1 d.r. (Yield was determined by ^{1}H NMR using mesitylene as the internal standard. Diastereomeric ratio was determined by ^{1}H NMR by comparison of the diastereotopic –CH_2– group of the –OBn group). Purification by flash chromatography (15% Et_2O in petroleum ether, silica gel) afforded two diastereomers of **13a**.

Major diastereomer: R_f = 0.26 (50% ether / pet. ether). IR (neat): 3239, 3030, 2923, 1708, 1618, 1472, 1328, 1207, 1071, 936, 739, 696 cm^{-1}. ^{1}H NMR (500 MHz, $CDCl_3$): δ 8.28 (broad, 1H), 7.59 (dd, *J* = 7.0 Hz, *J* = 0.6 Hz, 1H), 7.44 – 7.41 (m, 2H), 7.29 – 7.22 (m, 7H), 7.09 (ddd, *J* = 7.6 Hz, *J* = 7.6 Hz, *J* = 1.0 Hz, 1H), 7.02 – 7.00 (m, 2H), 6.89 (d, *J* = 7.8Hz, 1H), 5.36 – 5.32 (m, 2H), 5.18 – 5.15 (m, 1H), 4.72 – 4.71 (m, 1H), 4.55 (d, *J* = 12 Hz, 1H), 4.28 (d, *J* = 12 Hz, 1H). ^{13}C NMR (126 MHz, $CDCl_3$): δ 178.1, 141.2, 137.9, 137.5, 133.7, 129.5, 128.3, 128.2, 128.1, 128.0, 127.7, 127.6, 127.4, 127.3, 122.3, 121.1, 109.6, 83.6, 70.6, 61.5. Elemental Analysis Calc'd for $C_{24}H_{22}NO_2$: C, 81.10; H, 5.96; N, 3.94; found: C, 81.21; H, 6.07; N, 3.72.

Minor diastereomer: R_f = 0.38 (50% ether / pet. ether). IR (neat): 3240, 3030, 2923, 1712, 1619, 1472, 1330, 1212, 1060, 932, 736, 697cm^{-1}. ^{1}H NMR (500 MHz, $CDCl_3$): δ 7.78 (d, *J* = 12.8 Hz, 1H), 7.51 – 7.48 (m, 2H), 7.38 (dd, *J* = 7.6 Hz, *J* = 0.5 Hz, 1H), 7.32 – 7.18 (m, 7H), 7.16 – 7.14 (m, 2H), 7.09 (ddd, *J* = 7.6 Hz, *J* = 7.6 Hz, *J* = 1.0 Hz, 1H), 6.91 (d, *J* = 7.8Hz, 1H), 5.83 (ddd, *J* = 17.0 Hz, *J* = 10.6 Hz, *J* = 6.3 Hz, 1H), 5.25 (ddd, *J*

= 10.6 Hz, *J* = 1.4 Hz, *J* = 1.4 Hz, 1H), 5.18 (ddd, *J* = 17.2 Hz, *J* = 1.5 Hz, *J* = 1.5 Hz, 1H), 4.96 (ddd, *J* = 6.3 Hz, *J* = 1.3 Hz, *J* = 1.0 Hz, 1H), 4.56 (d, *J* = 12.0, 1H), 4.47 (d, *J* = 12.0, 1H). ^{13}C NMR (126 MHz, $CDCl_3$): δ 178.7, 141.8, 138.1, 136.4, 132.9, 128.4, 128.3, 128.1, 127.7, 127.6, 127.3, 127.3, 121.6, 119.8, 109.7, 84.4, 71.4, 60.9. HRMS (ESI+) Calc'd for $C_{24}H_{21}NO_2$ $[M + H]^+$: 356.1651, found: 356.1638.

3-(*R*)-(1-(*R*)-Benzyloxy-allyl)-1-(4-methoxy-benzyl)-3-phenylindolin-2-one (13b):

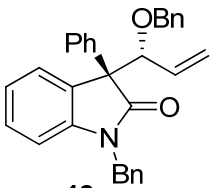


13b

Oxindole **13b** was prepared according to the general procedure of the Pd-catalyzed hydrocarbonation of allenes, using $Pd_2(dba)_3$ •$CHCl_3$ (5.2 mg, 5.0 μmol), (*R*,*R*)-**L1** ligand (7.6 mg, 11 μmol), $PhCO_2H$ (1.2 mg, 10 μ mol), oxindole **12b** (65.9 mg, 0.20 mmol), and benzyloxyallene **4** (35.6 μl, 0.24 mmol). Reaction was conducted in THF (2.0 ml) for 8 h at room temperature, giving **13b** (87.5 mg, 92%) in 13:1 d.r. (Yield was determined by ^{1}H NMR using mesitylene as the internal standard. Diastereomeric ratio was determined by ^{1}H NMR by comparison of the diastereotopic $–CH_2–$ group of the –OBn group). Purification by flash chromatography (10% ether in petroleum ether, silica gel) afforded **13b** as a diastereomeric mixture (d.r. = 13:1) so that the following data was obtained from the diastereomeric mixture. The relative stereochemistry was assigned by analogy to that determined for the allene hydrocarbonation product **11**. The absolute stereochemistry was assigned by analogy to that determined for the allene hydrocarbonation product **17**.

R_f = 0.65 (25% ether in pet. ether). FTIR (neat): 3059, 2931, 1712, 1611, 1514, 1466, 1353, 1248, 1177, 1069, 1034, 750, 736, 697 cm^{-1}. ^{1}H NMR (500 MHz, $CDCl_3$): δ 7.62 (d, *J* = 7.4 Hz, *J* = 0.9 Hz, 1H), 7.47 – 7.45 (m, 2H), 7.30 – 7.25 (m, 3H), 7.24 – 7.20 (m, 4H), 7.14 (dd, *J* = 6.7 Hz, *J* = 2.0 Hz, 1H), 7.06 (dt, *J* = 7.6 Hz, *J* = 1.0 Hz, 1H), 7.00 – 6.98 (m, 2H), 6.76 – 6.63 (m, 3H), 5.36 – 5.34 (m, 2H), 5.17 – 5.14 (m, 1H), 4.92 (d, *J* = 15.5, 1H), 4.79 – 4.77 (m, 1H), 4.61 (d, *J* = 15.5Hz, 1H), 4.55 (d, *J* = 12.0, 1H), 4.28 (d, *J* = 12.0, 1H), 2.73 (s, 3H). ^{13}C NMR (126 MHz, $CDCl_3$): δ 175.9, 158.8, 143.3, 137.9, 137.8, 134.0, 129.1, 128.6, 128.2, 128.1, 127.7, 127.68, 127.6, 127.5, 127.3, 127.2, 121.1, 113.8, 109.0, 84.0, 70.6, 60.9, 55.2, 43.2. HRMS (ESI+) Calc'd for $C_{32}H_{29}NO_3$ $[M + H]^+$: 476.2226, found: 476.2223. $[\alpha]_D^{23}$ = 105.4 (*c* = 5.80, CH_2Cl_2). Enantiomeric excess was determined to be 90% ee by chiral HPLC (Chiralpak ODH, 254 nm, heptane:*i*-PrOH = 98:2, 0.8 ml/min, t_1 = 22.63 min (major), t_2 = 27.54 min).

1-Benzyl-3-(*R*)-(1-(*R*)-benzyloxy-allyl)-3-phenylindolin-2-one (13c):

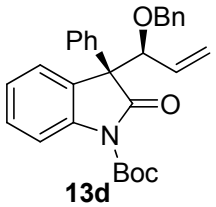


13c

Oxindole **13c** was prepared according to the general procedure of the Pd-catalyzed hydrocarbonation of allenes, using $Pd_2(dba)_3$•$CHCl_3$ (5.2 mg, 5.0 μmol), (*R*,*R*)-**L1** ligand (7.6 mg, 11 μmol), $PhCO_2H$ (1.2 mg, 10 μ mol), oxindole **12c** (59.9 mg, 0.20 mmol), and benzyloxyallene **4** (35.6 μl, 0.24 mmol). Reaction was conducted in THF (2.0 ml) for 8 h at room temperature, giving **13c** (84.7 mg, 95%) in 16:1 d.r. (Yield was determined by ^{1}H NMR using mesitylene as the internal standard. Diastereomeric ratio was determined by ^{1}H NMR by comparison of the diastereotopic –CH_2– group of the –OBn group). Purification by flash chromatography (15% ether in petroleum ether, silica gel) afforded **13c** as a diastereomeric mixture (d.r. = 16:1) so that the following data were obtained from the diastereomeric mixture. The relative stereochemistry was assigned by analogy to that determined for the allene hydrocarbonation product **11**. The absolute stereochemistry was assigned by analogy to that determined for the allene hydrocarbonation product **17**.

R_f = 0.49 (25% ether in pet. ether): 0.49. IR (neat): 3061, 2923, 2868, 1714, 1610, 1487, 1466, 1348, 1189, 1072, 933, 735, 697 cm^{-1}. ^{1}H NMR (500 MHz, $CDCl_3$): δ 7.63 (dd, *J* = 7.4 Hz, *J* = 0.9 Hz,1H), 7.46 (m, 2H), 7.31 – 7.25 (m, 3H), 7.24 – 7.21 (m, 9H), 7.07 (dt, *J* = 7.4 Hz, *J* = 1.0 Hz, 1H), 7.01 – 6.99 (m, 2H), 6.71 (d, *J* = 7.7 Hz, 1H), 5.37 – 5.35 (m, 2H), 5.18 – 5.15 (m, 1H), 4.97 (d, *J* = 15.7Hz, 1H), 4.79 (m, 1H), 4.68 (d, *J* = 15.7 Hz, 1H), 4.66 (d, *J* = 12.0 Hz, 1H), 4.28 (d, *J* = 12.0Hz, 1H). ^{13}C NMR (126 MHz, $CDCl_3$): δ 176.0, 143.3, 137.9, 137.8, 135.7, 134.0, 129.0, 128.5, 128.2, 128.1, 127.7, 127.6, 127.4, 127.3, 127.27, 127.23, 122.3, 121.3, 109.0, 84.0, 70.6, 60.9, 43.8. HRMS (ESI) Calc'd for $C_{31}H_{28}NO_2$ $[M + H]^+$: 446.2120, found: 446.2110. $[\alpha]^{23}$ = 118.90 (*c* 2.40, CH_2Cl_2). Enantiomeric excess was determined to be 93% ee by chiral HPLC (Chiralpak ODH, 254 nm, heptane : *i*-PrOH = 98 : 2, 0.8 ml/min, t = 13.21 min, t = 15.13 min (major).

***tert*-Butyl 3-(1-(benzyloxy)allyl)-2-oxo-3-phenylindoline-1-carboxylate (13d):**



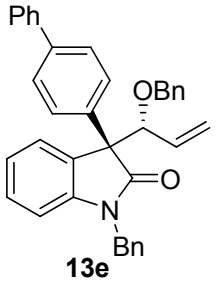
13d

Oxindole **13d** was prepared according to the general procedure of the Pd-catalyzed hydrocarbonation of allenes, using $Pd_2(dba)_3$•$CHCl_3$ (5.2 mg, 5.0 μmol), (*R*,*R*)-**L4** ligand (8.9 mg, 11 μmol), $PhCO_2H$ (1.2 mg, 10 μ mol), oxindole **12d** (61.9 mg, 0.20 mmol), and benzyloxyallene **4** (35.6 μl, 0.24 mmol). Reaction was conducted in THF (2.0 ml) for 8 h at room temperature, giving **13d** (90.2 mg, 99%) in 8.0:1 d.r. (Yield was determined by ^{1}H NMR using mesitylene as the internal standard. Diastereomeric ratio was determined by ^{1}H NMR by comparison of the diastereotopic –CH_2– group of the –OBn group). Purification by flash chromatography (15% ether in petroleum ether, silica gel) afforded 83.8 mg (92%) of **13d** as a diastereomeric mixture (d.r. = 8.0:1). This material can be crystallized from CH_2Cl_2 to afford a single diastereomer and was determined to be racemic by HPLC. The relative stereochemistry was determined by Xray crystallography.

R_f = 0.59 (25% Ether in pet. ether). IR (neat): 3062, 2982, 2931, 1764, 1729, 1606, 1480, 1465, 1347, 1287, 1253, 1149, 1060, 736, 728, 697 cm^{-1}. ^{1}H NMR (500 MHz, $CDCl_3$): δ 7.96 – 7.94 (m, 1H), 7.40 – 7.42 (m, 2H), 7.40 – 7.35 (m, 2H), 7.32 – 7.19 (m, 7H), 7.15 – 7.13 (m, 2H), 5.81 (ddd, *J* = 17.2 Hz, *J* = 10.6 Hz, *J* = 6.2 Hz, 1H), 5.27 (dd, *J* = 10.6 Hz, *J* = 1.4 Hz,1H), 5.21 (dt, *J* = 17.3 Hz, *J* = 1.5 Hz,1H), 5.27 (dd, *J* = 6.2 Hz, *J* = 1.3 Hz,1H), 4.54 (d, *J* = 12.6 Hz, 1H), 4.45 (d, *J* = 12.6 Hz, 1H), 1.60 (s, 9H). ^{13}C NMR (126 MHz, $CDCl_3$): δ

175.7 149.3, 141.1, 137.9, 136.1, 132.5, 128.6, 128.5, 128.1, 127.9, 127.8, 127.3, 127.2, 126.8, 123.4, 120.1, 115.0, 85.1, 84.0, 71.7, 60.9, 28.1. Elemental Analysis Calc'd for $C_{29}H_{29}NO4$: C, 76.46; H, 6.42; N, 3.07; found: C, 76.70; H, 6.26; N, 2.98. Enantiomeric excess was determined to be 0% ee by chiral HPLC (Chiralpak AD, 254 nm, heptane : *i*-PrOH = 99.7 : 0.3, 1.0 ml/min, t_1 = 13.22 min, t_2 = 23.14 min).

(*R*)-1-benzyl-3-((*R*)-1-(benzyloxy)allyl)-3-(biphenyl-4-yl)indolin-2-one (13e):

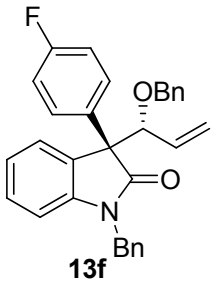


13e

Oxindole **13e** was prepared according to the general procedure of the Pd-catalyzed hydrocarbonation of allenes, using $Pd_2(dba)_3$•$CHCl_3$ (5.2 mg, 5.0 μmol), (*R*,*R*)-**L1** ligand (7.6 mg, 11 μmol), $PhCO_2H$ (1.2 mg, 10 μ mol), oxindole **12e** (75.1 mg, 0.20 mmol), and benzyloxyallene **4** (35.6 μl, 0.24 mmol). Reaction was conducted in THF (2.0 ml) for 6 h at room temperature, giving **13e** (99.8 mg, 96%) in 13:1 d.r. (Yield was determined by ^{1}H NMR using mesitylene as the internal standard. Diastereomeric ratio was determined by ^{1}H NMR by comparison of the diastereotopic $-CH_2-$ group of the –OBn group). Purification by flash chromatography (15% ether in petroleum ether, silica gel) afforded 99.1 mg (95%) of **13e** as a diastereomeric mixture (d.r. = 13:1) so that the following data were obtained from the diastereomeric mixture. The relative stereochemistry was assigned by analogy to that determined for the allene hydrocarbonation product **11**. The absolute stereochemistry was assigned by analogy to that determined for the allene hydrocarbonation product **17**.

A white solid. mp 164–166 ^{o}C. R_f = 0.43 (25% ether in pet. ether). IR (neat): 3030, 2923, 2867, 1712, 1610, 1487, 1360, 1190, 1067, 1008, 909, 734, 697 cm^{-1}. ^{1}H NMR (500 MHz, $CDCl_3$): δ 7.67 (d, *J* = 7.0 Hz, 1H), 7.58 (dd, *J* = 8.1 Hz, *J* = 1.0 Hz, 2H), 7.55 – 7.50 (m, 4H), 7.41 (dd, *J* = 7.6 Hz *J* =7.6Hz, 2H), 7.32 (dd, *J* = 7.3 Hz, *J* = 7.3Hz, 2H), 7.23 – 7.19 (m, 9H), 7.09 (dd, *J* = 7.5 Hz, *J* = 7.5 Hz, 1H), 7.04 – 7.02 (m, 2H), 6.72 (d, *J* = 7.8 Hz, 1H), 5.39 – 5.36 (m, 2H), 5.20 – 5.17 (m, 1H), 4.98 (d, *J* = 15.7Hz, 1H), 4.83 – 4.81 (m, 1H), 4.69 (d, *J* = 15.7Hz, 1H), 4.59 (d, *J* = 12.0 Hz, 1H), 4.31 (d, *J* = 12.0 Hz, 1H). ^{13}C NMR (126 MHz, $CDCl_3$): δ 175.9, 143.3, 140.9, 140.0, 137.8, 136.9, 135.6, 134.0, 129.0, 128.7, 128.5, 128.3, 128.1, 128.0, 127.8, 127.6, 127.4, 127.3, 127.2, 127.0, 126.9, 122.4, 121.4, 109.1, 83.8, 70.5, 60.8, 43.8. Elemental Analysis Calc'd. for $C_{37}H_{31}NO_2$: C, 85.19, H, 5.99, N, 2.69; found: C, 84.94, H, 5.85, N 2.51. $[\alpha]_D^{23}$ = 134.55 (*c* 0.60, CH_2Cl_2). Enantiomeric excess was determined to be 93% ee by chiral HPLC (Chiralpak ODH, 254 nm, heptane : *i*-PrOH = 98 : 2, 0.8 ml/min, t_1 = 9.06 min, t_2 = 10.67 min (major).

(*R*)-1-benzyl-3-((*R*)-1-(benzyloxy)allyl)-3-(4-fluorophenyl)indolin-2-one (13f):

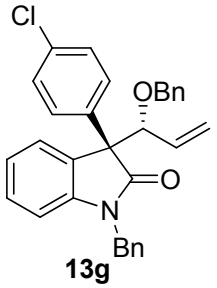


13f

Oxindole **13f** was prepared according to the general procedure of the Pd-catalyzed hydrocarbonation of allenes, using $Pd_2(dba)_3$•$CHCl_3$ (5.2 mg, 5.0 μmol), (*R*,*R*)-**L1** ligand (7.6 mg, 11 μmol), $PhCO_2H$ (1.2 mg, 10 μ mol), oxindole **12f** (63.5 mg, 0.20 mmol), and benzyloxyallene **4** (35.6 μl, 0.24 mmol). Reaction was conducted in THF (2.0 ml) for 2 h at room temperature, giving **13f** (88.1 mg, 95%) in 13.4:1 d.r. (Yield was determined by ^{1}H NMR using mesitylene as the internal standard. Diastereomeric ratio was determined by ^{1}H NMR by comparison of the diastereotopic $–CH_2–$ group of the –OBn group). Purification by flash chromatography (15% ether in petroleum ether, silica gel) afforded **13f** as a diastereomeric mixture (d.r. = 13.4:1) so that the following data was obtained from the diastereomeric mixture. The relative stereochemistry was assigned by analogy to that determined for the allene hydrocarbonation product **11**. The absolute stereochemistry was assigned by analogy to that determined for the allene hydrocarbonation product **17**.

R_f = 0.48 (25% ether in pet. ether). IR (neat): 3062, 2869, 1712, 1611, 1508, 1467, 1361, 1232, 1164, 1069, 740, 697 cm^{-1}. ^{1}H NMR (500 MHz, $CDCl_3$): δ 7.62 (d, *J* = 7.5 Hz, 1H), 7.43 (d, *J* = 8.8 Hz, 1H), 7.42 (d, *J* = 8.8 Hz, 1H), 7.25 – 7.18 (m, 9H), 7.10 – 7.07 (m, 1H), 7.02 – 6.99 (m, 2H), 6.96 (d, *J* = 8.7 Hz, 2H), 6.72 (d, *J* = 7.8 Hz, 1H), 5.34 – 5.30 (m, 2H), 5.18 – 5.16 (m, 1H), 4.95 (d, *J* = 15.9 Hz, 1H), 4.71 (s, 1H), 4.68 (d, *J* = 15.9 Hz, 1H), 4.56 (d, *J* = 12.0 Hz, 1H), 4.26 (d, *J* = 12.0Hz, 1H). ^{13}C NMR (126 MHz, $CDCl_3$): δ 175.8, 163.0, 161.1, 143.2, 137.7, 135.6, 133.8, 129.3, 129.2, 128.5, 128.4, 128.1, 127.8, 127.6, 127.5, 127.4, 127.2, 126.7, 122.4, 121.5, 115.0, 114.9, 109.1, 83.9, 70.4, 60.3, 43.8. HRMS (ESI+) Calc'd for $C_{31}H_{26}NO_2F$ $[M + H]^+$: 464.2026, found: 464.2021. $[\alpha]_D^{23}$ = 154.3 (*c* 1.45, CH_2Cl_2). Enantiomeric excess was determined to be 90% ee by chiral HPLC (Chiralpak ODH, 254 nm, heptane : *i*-PrOH = 98 : 2, 0.8 ml/min, t_1 = 13.48 min, t_2 = 15.68 min (major).

1-Benzyl-3-(*R*)-(1-(*R*)-benzyloxy-allyl)-3-(4-chloro-phenyl)indolin-2-one (13g):

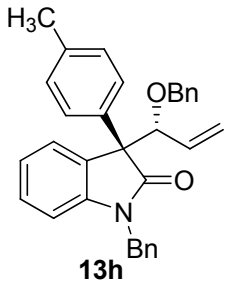


13g

Oxindole **13g** was prepared according to the general procedure of the Pd-catalyzed hydrocarbonation of allenes, using $Pd_2(dba)_3$•$CHCl_3$ (5.2 mg, 5.0 μmol), (*R*,*R*)-**L1** ligand (7.6 mg, 11 μmol), $PhCO_2H$ (1.2 mg, 10 μ mol), oxindole **12g** (66.0 mg, 0.20 mmol), and benzyloxyallene **4** (35.6 μl, 0.24 mmol). Reaction was conducted in THF (2.0 ml) for 8 h at room temperature, giving **13g** (96.0 mg, 100%) in 11.0:1 d.r. (Yield was determined by ^{1}H NMR using mesitylene as the internal standard. Diastereomeric ratio was determined by ^{1}H NMR by comparison of the diastereotopic –CH_2– group of the –OBn group). Purification by flash chromatography (10% ether in petroleum ether, silica gel) afforded **13g** as a diastereomeric mixture (d.r. = 11.0:1) so that the following data were obtained from the diastereomeric mixture. The relative stereochemistry was assigned by analogy to that determined for the allene hydrocarbonation product **11**. The absolute stereochemistry was assigned by analogy to that determined for the allene hydrocarbonation product **17**.

R_f = 0.59 (25% ether in pet. ether). IR (neat): 3062, 3031, 2923, 2869, 1712, 1610, 1491, 1467, 1362, 1094, 1066, 1014, 734, 697 cm^{-1}. ^{1}H NMR (500 MHz, $CDCl_3$): δ 7.62 (dd, *J* = 7.4 Hz, *J* = 0.9 Hz, 1H), 7.39 – 7.37 (m, 2H), 7.27 – 7.18 (m, 11H), 7.09 (dt, *J* = 7.6 Hz, *J* = 1.0 Hz, 1H), 7.02 – 7.00 (m, 2H), 6.73 (d, *J* = 7.6 Hz, 1H), 5.38 – 5.26 (m, 2H), 5.17 (m, 1H), 4.94 (d, *J* = 15.7 Hz, 1H), 4.70 (d, *J* = 7.3 Hz, 1H), 4.68 (d, *J* = 15.7 Hz, 1H), 4.56 (d, *J* = 12.1 Hz, 1H), 4.26 (d, *J* = 12.1 Hz, 1H). ^{13}C NMR (126 MHz, $CDCl_3$): δ 175.6, 143.2, 137.6, 136,3, 135.5, 133.7, 133.2, 129.1, 128.5, 128.4, 128.3, 128.2, 127.8, 127.6, 127.5, 127.4, 127.2, 122.4, 121.6, 109.2, 83.7, 70.4, 60.4, 43.8. HRMS (ESI+) Calc'd for $C_{31}H_{26}NO_2Cl$ $[M + Na]^+$: 502.1550, found: 502.1532. $[\alpha]^{23}$ = 107.0 (*c* 3.7, CH_2Cl_2). Enantiomeric excess was determined to be 84% ee by chiral HPLC (Chiralpak ODH, 254 nm, heptane : *i*-PrOH = 90 : 10, 0.8 ml/min, t_1 = 9.60 min, t_2 = 10.97 min(major).

1-Benzyl-3-(*R*)-(1-(*R*)-benzyloxy-allyl)-3-*p*-tolylindolin-2-one (13h):

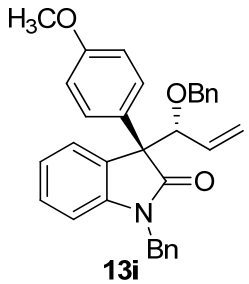


13h

Oxindole **13h** was prepared according to the general procedure of the Pd-catalyzed hydrocarbonation of allenes, using $Pd_2(dba)_3$•$CHCl_3$ (5.2 mg, 5.0 μmol), (*R*,*R*)-**L1** ligand (7.6 mg, 11 μmol), $PhCO_2H$ (1.2 mg, 10 μ mol), oxindole **12h** (62.7 mg, 0.20 mmol), and benzyloxyallene **4** (35.6 μl, 0.24 mmol). Reaction was conducted in THF (2.0 ml) for 6 h at room temperature, giving **13h** (92.0 mg, 100%) in 18.1:1 d.r. (Yield was determined by ^{1}H NMR using mesitylene as the internal standard. Diastereomeric ratio was determined by ^{1}H NMR by comparison of the diastereotopic –CH_2– group of the –OBn group). Purification by flash chromatography (15% ether in petroleum ether, silica gel) afforded 85.6 mg (93%) of **13h** as a diastereomeric mixture (d.r. = 18.1:1) so that the following data were obtained from the diastereomeric mixture. The relative stereochemistry was assigned by analogy to that determined for the allene hydrocarbonation product **11**. The absolute stereochemistry was assigned by analogy to that determined for the allene hydrocarbonation product **17**.

R_f = 0.50 (25% ether in pet. ether). IR (neat): 3030, 2922, 2868, 1712, 1609, 1488, 1466, 1359, 1188, 1062, 741, 697 cm^{-1}. ^1H NMR (500 MHz, $CDCl_3$): δ 7.61 (d, *J* = 7.4 Hz,1H), 7.33 (d, *J* = 8.2 Hz, 2H), 7.24 – 7.18 (m, 9H), 7.10 – 7.02 (m, 5H), 6.70 (d, *J* = 7.8Hz, 1H), 5.38 – 5.35 (m, 2H), 5.17 – 5.15 (m, 1H), 4.98 (d, *J* = 15.7Hz, 1H), 4.77 (d, *J* = 6.7Hz, 1H), 4.67 (d, *J* = 15.7Hz, 1H), 4.56 (d, *J* = 12.0Hz, 1H), 4.29 (d, *J* = 12.0 Hz, 1H), 3.32 (s, 3H). ^{13}C NMR (126 MHz, $CDCl_3$): δ 176.1, 143.3, 138.0, 136.8, 135.7, 134.8, 134.1, 129.4, 129.0, 128.5, 128.1, 128.0, 127.7, 127.5, 127.4, 127.3, 127.2, 122.3, 121.2, 109.0, 83.8, 70.5, 60.7, 43.7, 21.0. HRMS (ESI+) Calc'd for $C_{32}H_{29}NO_2$ $[M + H]^+$: 460.2277, found: 460.2277. $[\alpha]_D^{23}$ = 105.1 (*c* 2.80, CH_2Cl_2). Enantiomeric excess was determined to be 86% ee by chiral HPLC (Chiralpak ODH, 254 nm, heptane : *i*-PrOH = 90 : 10, 0.8 ml/min, t_1 = 7.79 min, t_2 = 8.20 min (major).

1-Benzyl-3-(*R*)-(1-(*R*)-benzyloxy-allyl)-3-(4-methoxy-phenyl)indolin-2-one (13i):

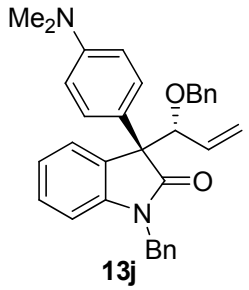


13i

Oxindole **13i** was prepared according to the general procedure of the Pd-catalyzed hydrocarbonation of allenes, using $Pd_2(dba)_3$•$CHCl_3$ (5.2 mg, 5.0 μmol), (*R*,*R*)-**L1** ligand (7.6 mg, 11 μmol), $PhCO_2H$ (1.2 mg, 10 μ mol), oxindole **12i** (65.9 mg, 0.20 mmol), and benzyloxyallene **4** (35.6 μl, 0.24 mmol). Reaction was conducted in THF (2.0 ml) for 6 h at room temperature, giving **13i** (87.4 mg, 92%) with a 17.4:1 d.r. (Yield was determined by ^1H NMR using mesitylene as the internal standard. Diastereomeric ratio was determined by ^1H NMR by comparison of the diastereotopic $–CH_2–$ group of the –OBn group). Purification by flash chromatography (15% ether in petroleum ether, silica gel) afforded 79.8 mg (84%) of **13i** as a diastereomeric mixture (d.r. = 17.4:1) so that the following data were obtained from the diastereomeric mixture. The relative stereochemistry was assigned by analogy to that determined for the allene hydrocarbonation product **11**. The absolute stereochemistry was assigned by analogy to that determined for the allene hydrocarbonation product **17**.

R_f = 0.41 (25% ether in pet. ether). IR (neat): 3062, 2930, 2836, 1712, 1609, 1511, 1466, 1360, 1252, 1183, 1067, 742, 697 cm^{-1}. ^1H NMR (500 MHz, $CDCl_3$): δ 7.62 (dd, *J* = 7.4 Hz, *J* = 1.0 Hz, 1H), 7.38 (td, *J* = 8.9 Hz, *J* = 2.1 Hz, 2H), 7.25 – 7.18 (m, 9H), 7.06 (dt, *J* = 7.5 Hz, *J* = 0.9 Hz, 1H), 7.04 – 7.02 (m, 2H), 6.82 (td, *J* = 8.9 Hz, *J* = 2.2 Hz, 2H), 6.70 (d, *J* = 7.8 Hz, 1H), 5.37 – 5.34 (m, 2H), 5.17 – 5.14 (m, 1H), 4.97 (d, *J* = 15.8 Hz, 1H), 4.74 – 4.72 (m, 1), 4.67 (d, *J* = 15.8 Hz, 1H), 4.56 (d, *J* = 12.0 Hz, 1H), 4.29 (d, *J* = 12.0Hz, 1H), 3.77 (s, 3H). ^{13}C NMR (126 MHz, $CDCl_3$): δ 176.2, 158.7, 143.2, 137.9, 135.7, 134.1, 129.7, 129.3, 128.7, 128.5, 128.1, 128.0, 127.7, 127.5, 127.4, 127.2, 122.3, 121.2, 113.6, 109.0, 83.9, 70.5, 60.3, 66.2, 43.7. HRMS (ESI+) Calc'd for $C_{32}H_{29}NO_3$ $[M + H]^+$: 476.2226, found: 476.2228. $[\alpha]_D^{23}$ = 102.2 (*c* 2.0, CH_2Cl_2). Enantiomeric excess was determined to be 90% ee by chiral HPLC (Chiralpak ODH, 254 nm, heptane : *i*-PrOH = 95 : 5, 0.8 ml/min, t_1 = 15.72 min, t_2 = 17.24 min (major).

1-(*R*)-Benzyl-3-(1-(*R*)-benzyloxy-allyl)-3-(4-dimethylamino-phenyl)-1,3-di-hy-droindol-2-one (13j):

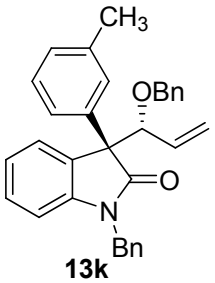


13j

Oxindole **13j** was prepared according to the general procedure of the Pd-catalyzed hydrocarbonation of allenes, using $Pd_2(dba)_3$•$CHCl_3$ (5.2 mg, 5.0 μmol), (*R*,*R*)-**L1** ligand (7.6 mg, 11 μmol), $PhCO_2H$ (1.2 mg, 10 μ mol), oxindole **12j** (68.4 mg, 0.20 mmol), and benzyloxyallene **4** (35.6 μl, 0.24 mmol). Reaction was conducted in THF (2.0 ml) for 20 h at room temperature, giving **13j** (84.0 mg, 86%, 100% based on recovered 9.6 mg **3.7i**) in 12.0:1 d.r. (Yield was determined by ^{1}H NMR using mesitylene as the internal standard. Diastereomeric ratio was determined by ^{1}H NMR by comparison of the diastereotopic $–CH_2–$ group of the –OBn group). Purification by flash chromatography (10% ether in petroleum ether, silica gel) afforded **13j** as a diastereomeric mixture (d.r. = 12.0:1) so that the following data were obtained from the diastereomeric mixture. The relative stereochemistry was assigned by analogy to that determined for the allene hydrocarbonation product **11**. The absolute stereochemistry was assigned by analogy to that determined for the allene hydrocarbonation product **17**.

R_f = 0.50 (25% ether in pet. ether). IR (neat): 3030, 2920, 1710, 1610, 1520, 1466, 1349, 1066, 734, 697 cm^{-1}. ^{1}H NMR (500 MHz, $CDCl_3$): δ 7.61 (dd, *J* = 7.4 Hz, *J* = 0.8 Hz, 1H), 7.31 (dd, *J* = 6.9 Hz, *J* = 2.2 Hz, 2H), 7.25 – 7.16 (m, 9H), 7.06 – 7.03 (m, 3H), 6.68 – 6.65 (m, 3H), 5.41 (ddd, *J* = 17.3 Hz, *J* = 10.9 Hz, *J* = 7.8 Hz, 1H), 5.32 (dd, *J* = 17.4 Hz, *J* = 2.1 Hz, 1H), 5.15 (dd, *J* = 10.9 Hz, *J* = 2.1 Hz, 1H), 4.98 (d, *J* = 15.7 Hz, 1H), 4.73 (d, *J* = 7.7 Hz, 1H), 4.65 (d, *J* = 15.7 Hz, 1H), 4.56 (d, *J* = 12.1 Hz, 1H), 4.31 (d, *J* = 12.1 Hz, 1H), 2.90 (s, 6H). ^{13}C NMR (126 MHz, $CDCl_3$): δ 176.5, 149.7, 143.2, 138.1, 135.8, 134.3, 129.8, 128.5, 128.2, 128.0, 127.9, 127.7, 127.4, 127.2, 125.3, 122.1, 120.8, 112.4, 108.8, 83.9, 70.6, 60.2, 43.7, 40.5. HRMS (ESI+) Calc'd for $C_{33}H_{32}N_2O_2$ $[M + H]^+$: 488.2464, found: 488.2451. $[\alpha]_D^{23}$ = 133.6 (*c* 1.0, CH_2Cl_2). Enantiomeric excess was determined to be 85% ee by chiral HPLC (Chiralpak ODH, 254 nm, heptane : *i*-PrOH = 90 : 10, 0.8 ml/min, t_1 = 10.97 min, t_2 = 12.72 min (major).

1-Benzyl-3-(*R*)-(1-(*R*)-benzyloxy-allyl)-3-m-tolylindolin-2-one (13k):

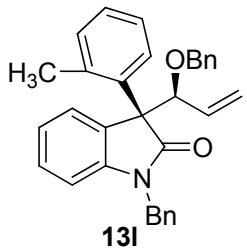


13k

Oxindole **13k** was prepared according to the general procedure of the Pd-catalyzed hydrocarbonation of allenes, using $Pd_2(dba)_3$•$CHCl_3$ (5.2 mg, 5.0 μmol), (*R*,*R*)-**L1** ligand (7.6 mg, 11 μmol), $PhCO_2H$ (1.2 mg, 10 μ mol), oxindole **12k** (62.7 mg, 0.20 mmol), and benzyloxyallene **4** (35.6 μl, 0.24 mmol). Reaction was conducted in THF (2.0 ml) for 2 h at room temperature, giving **13k** (84.6 mg, 92%) with a 16.7:1 d.r. (Yield was determined by H NMR using mesitylene as the internal standard. Diastereomeric ratio was determined by ^{1}H NMR by comparison of the diastereotopic –CH_2– group of the –OBn group). Purification by flash chromatography (10% ether in petroleum ether, silica gel) afforded **13k** as a diastereomeric mixture (d.r. = 16.7:1) so that the following data were obtained from the diastereomeric mixture. The relative stereochemistry was assigned by analogy to that determined for the allene hydrocarbonation product **11**. The absolute stereochemistry was assigned by analogy to that determined for the allene hydrocarbonation product **17**.

R_f = 0.63 (25% ether in pet. ether). IR (neat): 3030, 2922, 2859, 1714, 1609, 1488, 1359, 1180, 1069, 740, 697 cm^{-1}. ^{1}H NMR (500 MHz, $CDCl_3$): δ 7.62 (dd, *J* = 7.6 Hz, *J* = 1.0 Hz, 1H), 7.27 (m, 1H),7.25 – 7.16 (m, 11H), 7.09 – 7.05 (m, 2H), 7.03 – 7.01 (m, 2H), 6.71 (d, *J* = 7.7 Hz, 1H), 5.36 – 5.33 (m, 2H), 5.17 – 5.15 (m, 1H), 4.97 (d, *J* = 15.7 Hz, 1H), 4.77 (dd, *J* = 4.8 Hz, *J* = 3.0 Hz, 1H), 4.67 (d, *J* = 15.7 Hz, 1H), 4.57 (d, *J* = 12.1 Hz, 1H), 4.29 (d, *J* = 12.1 Hz, 1H), 2.29 (s, 3H). ^{13}C NMR (126 MHz, $CDCl_3$): δ 176.0, 143.2, 137.8, 137.7, 137.6, 135.7, 134.0, 129.3, 128.5, 128.4, 128.2, 128.14, 128.10, 128.0, 127.8, 127.6, 127.4, 127.3, 124.7, 122.3, 121.3, 108.9, 83.6, 70.4, 60.9, 43.8, 21.6. HRMS (ESI+) Calc'd for $C_{32}H_{29}NO_2$ $[M + Na]^+$: 482.2096, found: 482.2092. $[\alpha]_D^{23}$= 111.83 (*c* 2.60, CH_2Cl_2). Enantiomeric excess was determined to be 93% ee by chiral HPLC (Chiralpak AD, 254 nm, heptane : *i*-PrOH = 90 : 10, 1.0 ml/min, t_1 = 9.54 min (major), t_2 = 14.29 min).

1-Benzyl-3-(1-benzyloxy-allyl)-3-o-tolylindolin-2-one (13l):



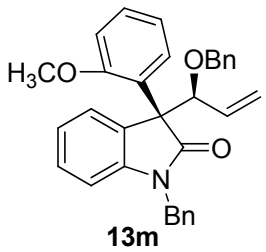
13l

Oxindole **13l** was prepared according to the general procedure of the Pd-catalyzed hydrocarbonation of allenes, using $Pd_2(dba)_3$•$CHCl_3$ (5.2 mg, 5.0 μmol), (*R*,*R*)-**L1** ligand (7.6 mg, 11 μmol), $PhCO_2H$ (1.2 mg, 10 μ mol), oxindole **12l** (62.7 mg, 0.20 mmol), and benzyloxyallene **4** (35.6 μl, 0.24 mmol). Reaction was conducted in CH_3CN (2.0 ml) for 4 h at room temperature, giving **13l** (92.1 mg, 100%) in 12.5:1 d.r. (Yield was determined by ^{1}H NMR using mesitylene as the internal standard. Diastereomeric ratio was determined by ^{1}H NMR by comparison of the diastereotopic –CH_2– group of the –OBn group). Purification by flash chromatography (15% ether in petroleum ether, silica gel) afforded 85.6 mg (93%) of **13l** as a diastereomeric mixture (d.r. = 12.5:1) so that the following data were obtained from the diastereomeric mixture. The relative stereochemistry was assigned to be the opposite of that observed for other *N*-benzyl substituted oxindoles without *orhto*-substitution (*i.e.* **13b** – **12k** and **12n** – **12r**) by ^{1}H NMR spectroscopy (the chemical shift for the methine vinyl C-H proton was ≤ 5.4 ppm for all other *N*-benzyl substituted oxindoles without *ortho*-substitution, while this proton resonated at > 6.0 ppm for **13l** and **13m**). The absolute stereochemistry was not determined.

R_f = 0.65 (25% ether in pet. ether). IR (neat): 3061, 3030, 2926, 2866, 1716, 1610, 1487, 1466, 1346, 1184, 1059, 928, 739, 697 cm^{-1}. ^{1}H NMR (500 MHz, $CDCl_3$): δ 7.62 (d, *J* = 7.7 Hz, 1H), 7.32 – 7.30 (m, 2H), 7.28 –

7.23 (m, 3H), 7.20 – 7.12 (m, 8H), 7.02 – 6.92 (m, 3H), 6.72 (d, J = 7.8 Hz, 1H), 6.05 (ddd, J = 17.6 Hz, J = 10.6 Hz, J = 7.2 Hz, 1H), 5.48 (dd, J = 10.5 Hz, J = 1.4 Hz, 1H), 5.33 (dd, J = 17.2 Hz, J = 1.4 Hz, 1H), 5.11 (d, J = 15.6 Hz, 1H), 4.89 (d, J = 7.0 Hz, 1H), 4.74 (d, J = 15.6 Hz, 1H), 4.62 (d, J = 11.8 Hz, 1H), 4.41 (d, J = 11.9 Hz, 1H), 1.68 (s, 3H). ^{13}C NMR (126 MHz, $CDCl_3$): δ 176.9, 144.2, 137.8, 137.5, 133.0, 132.4, 130.3, 129.4, 128.5, 127.7, 127.3, 125.7, 125.6, 121.9, 120.7, 108.8, 82.4, 70.8, 60.9, 44.3, 20.5. HRMS (ESI+) Calc'd for $C_{32}H_{29}NO_2$ $[M]^+$: 459.2198, found: 459.2214. $[\alpha]_D^{23}$ = -35.1 (*c* 2.40, CH_2Cl_2). Enantiomeric excess was determined to be 94% ee by chiral HPLC (Chiralpak ODH, 254 nm, heptane : *i*-PrOH = 99 : 1, 0.9 ml/min, t_1 = 36.66 min, t_1 = 42.24 min (major)).

1-Benzyl-3-(1-benzyloxy-allyl)-3-(2-methoxy-phenyl)-indolin-2-one (13m):

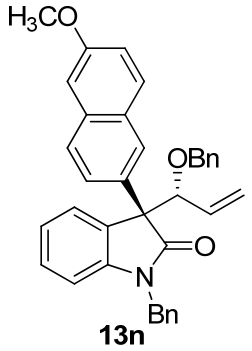


13m

Oxindole **13m** was prepared according to the general procedure of the Pd-catalyzed hydrocarbonation of allenes, using $Pd_2(dba)_3$•$CHCl_3$ (5.2 mg, 5.0 μmol), (*R*,*R*)-**L1** ligand (7.6 mg, 11 μmol), $PhCO_2H$ (1.2 mg, 10 μ mol), oxindole **12m** (65.9 mg, 0.20 mmol), and benzyloxyallene **4** (35.6 μl, 0.24 mmol). Reaction was conducted in CH_3CN (2.0 ml) for 4 h at room temperature, giving **13m** (90.4 mg, 95%) in 10.0:1 d.r. (Yield was determined by ^{1}H NMR using mesitylene as the internal standard. Diastereomeric ratio was determined by ^{1}H NMR by comparison of the diastereotopic $-CH_2-$ group of the –OBn group). Purification by flash chromatography (15% ether in petroleum ether, silica gel) afforded 79.9 mg (84%) of **13m** as a diastereomeric mixture (d.r. = 10.0:1) so that the following data were obtained from the diastereomeric mixture. The relative stereochemistry was assigned to be the opposite of that observed for other *N*-benzyl substituted oxindoles without *orhto*-substitution (*i.e.* **13b** – **12k** and **12n** – **12r**) by ^{1}H NMR spectroscopy (the chemical shift for the methine vinyl C-H proton was ≤ 5.4 ppm for all other *N*-benzyl substituted oxindoles without *ortho*-substitution, while this proton resonated at > 6.0 ppm for **13l** and **13m**). The absolute stereochemistry was not determined.

R_f = 0.50 (25% ether in pet. ether). IR (neat): 3030, 2931, 1716, 1610, 1489, 1465, 1348, 1252, 1027, 749, 698 cm^{-1}. ^{1}H NMR (500 MHz, $CDCl_3$): δ 7.58 (d, J = 7.8 Hz, 1H), 7.38 – 7.34 (m, 3H), 7.28 – 7.18 (m, 8H), 7.11 (ddd, J = 7.6 Hz, J = 7.6 Hz, J = 1.1 Hz, 1H), 6.97 (d, J = 7.4 Hz, 1H), 6.91 (ddd, J = 7.6 Hz, J = 7.6 Hz, J = 1.1 Hz, 1H), 6.87 (ddd, J = 7.6 Hz, J = 7.6 Hz, J = 0.8 Hz, 1H), 6.76 (d, J = 7.8 Hz, 1H), 6.68 (d, J = 7.7 Hz, 1H), 6.05 (ddd, J = 17.1 Hz, J = 10.5 Hz, J = 7.4 Hz, 1H), 5.35 (d, J = 10.4 Hz, 1H), 5.31 (d, J = 17.3 Hz, 1H), 5.03 (d, J = 15.6 Hz, 1H), 4.85 (d, J = 15.7 Hz, 1H), 4.76 (d, J = 6.6 Hz, 1H), 4.62 (d, J = 12.8 Hz, 1H), 4.39 (d, J = 12.8 Hz, 1H), 3.28 (s, 3H). ^{13}C NMR (126 MHz, $CDCl_3$): δ 177.4, 157.6, 144.1, 137.9, 126.4, 133.5, 131.2, 129.7, 128.4, 128.1, 127.8, 127.6, 127.5, 127.3, 127.2, 124.7, 121.4, 120.5, 112.5, 108.1, 82.0, 70.8, 58.6, 55.5, 44.0. $[\alpha]_D^{23}$= 0.04 (*c* 5.85, CH_2Cl_2). HRMS (ESI+) Calc'd for $C_{32}H_{29}NO_3$ $[M]^+$: 475.2147, found: 475.2156. Enantiomeric excess was determined to be 95% ee by chiral HPLC (Chiralpak OD-H, 254 nm, heptane : *i*-PrOH = 99 : 1, 0.9 ml/min, t_1 = 31.51 min, t_2 = 47.72 min (major)).

1-Benzyl-3-(*R*)-(1-(*R*)-benzyloxy-allyl)-3-(6-methoxy-naphthalen-2-yl)-indolin-2-one (13n):

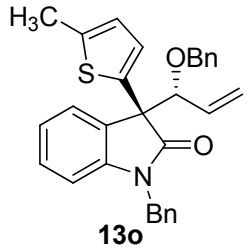


13n

Oxindole **13n** was prepared according to the general procedure of the Pd-catalyzed hydrocarbonation of allenes, using $Pd_2(dba)_3$•$CHCl_3$ (5.2 mg, 5.0 μmol), (*R*,*R*)-**L1** ligand (7.6 mg, 11 μmol), $PhCO_2H$ (1.2 mg, 10 μ mol), oxindole **12n** (76.0 mg, 0.20 mmol), and benzyloxyallene **4** (35.6 μl, 0.24 mmol). Reaction was conducted in THF (2.0 ml) for 6 h at room temperature, giving **13n** (99.9 mg, 95%) in 15.0:1 d.r. (Yield was determined by ^{1}H NMR using mesitylene as the internal standard. Diastereomeric ratio was determined by ^{1}H NMR by comparison of the diastereotopic $–CH_2–$ group of the –OBn group). Purification by flash chromatography (15% ether in petroleum ether, silica gel) afforded **13n** as a diastereomeric mixture (d.r. = 15.0:1) so that the following data were obtained from the diastereomeric mixture. The relative stereochemistry was assigned by analogy to that determined for the allene hydrocarbonation product **11**. The absolute stereochemistry was assigned by analogy to that determined for the allene hydrocarbonation product **17**.

R_f = 0.29 (25% ether in pet. ether). IR (neat): 3030, 2935, 1710, 1608, 1486, 1466, 1361, 1267, 1222, 1182, 1067, 1030, 732, 697 cm^{-1}. ^{1}H NMR (500 MHz, $CDCl_3$): δ 7.73 – 7.59 (m, 5H), 7.26 – 7.20 (m, 7H), 7.18 – 7.08 (m, 5H), 6.97 (d, *J* = 7.1, 2H), 6.74 (d, *J* = 7.8, 2H), 5.40 – 5.38 (m, 2H), 5.20 – 5.17 (m, 1H), 4.97 (d, *J* = 15.7 Hz, 1H), 4.88 (dd, *J* = 7.8 Hz, *J* = 3.9 Hz,1H), 4.71 (d, *J* = 15.7 Hz, 1H), 4.57 (d, *J* = 12.1 Hz, 1H), 4.30 (d, *J* = 12.1 Hz, 1H), 3.90 (s, 3H). ^{13}C NMR (126 MHz, $CDCl_3$): δ 176.1, 157.7, 143.3, 137.8, 135.7, 134.1, 133.7, 132.9, 129.8, 129.2, 128.7, 128.5, 128.3, 128.1, 127.8, 127.7, 127.4, 127.3, 126.7, 126.0, 122.4, 121.4, 118.6, 109.1, 105.2, 83.6, 70.4, 60.9, 55.2, 43.8. HRMS (EI) Calc'd for $C_{36}H_{31}NO_3$ $[M]^+$: 525.2304, found: 525.2288. $[\alpha]_D^{23}$ = 49.4 (*c* = 2.60, CH_2Cl_2). Enantiomeric excess was determined to be 93% ee by chiral HPLC (Chiralpak ODH, 254 nm, heptane : *i*-PrOH = 90 : 10, 0.8 ml/min, t_1 = 10.97 min, t_2 = 12.72 min (major)).

1-Benzyl-3-(*R*)-(1-(*R*)-benzyloxy-allyl)-3-(5-methyl-thiophen-2-yl)-indolin-2-one (13o):



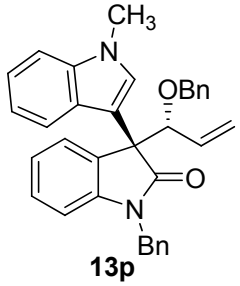
13o

Oxindole **13o** was prepared according to the general procedure of the Pd-catalyzed hydrocarbonation of allenes, using $Pd_2(dba)_3$•$CHCl_3$ (5.2 mg, 5.0 μmol), (*R*,*R*)-**L1** ligand (7.6 mg, 11 μmol), *p*-nitrobenzoic acid

(1.7 mg, 10 μ mol), oxindole **12o** (63.9 mg, 0.20 mmol), and benzyloxyallene **4** (35.6 μl, 0.24 mmol). Reaction was conducted in THF (2.0 ml) for 4 h at room temperature, giving **13o** (83.8 mg, 90%) in 7.8:1 d.r. (Yield was determined by ^{1}H NMR using mesitylene as the internal standard. Diastereomeric ratio was determined by ^{1}H NMR by comparison of the diastereotopic –CH_2– group of the –OBn group). Purification by flash chromatography (15% ether in petroleum ether, silica gel) afforded 85.1 mg (91%) of **13o** as a diastereomeric mixture (d.r. = 7.8:1) so that the following data were obtained from the diastereomeric mixture. The relative stereochemistry was assigned by analogy to that determined for the allene hydrocarbonation product **11**. The absolute stereochemistry was assigned by analogy to that determined for the allene hydrocarbonation product **17**.

R_f = 0.50 (25% ether in pet. ether). IR (neat): 3029, 2920, 2862, 1714, 1610, 1487, 1466, 1360, 1182, 1069, 994, 935, 746, 697 cm^{-1}. ^{1}H NMR (500 MHz, $CDCl_3$): δ 7.67 (dd, *J* = 7.5 Hz, *J* = 1.1 Hz, 1H), 7.26 – 7.19 (m, 7H), 7.16 (dd, *J* = 7.8 Hz, *J* = 1.2 Hz, 1H), 7.12 – 7.09 (m, 2H), 7.03 (ddd, *J* = 7.5 Hz, *J* = 7.5 Hz, *J* = 1.0 Hz, 1H), 6.81 (d, *J* = 3.5, 1H), 6.67 (d, *J* = 7.7 Hz, 1H), 6.57 (m, 1H), 5.39 (ddd, *J* = 17.2 Hz, *J* = 9.8 Hz, *J* = 7.6 Hz, 1H), 5.31 (dd, *J* = 17.2 Hz, *J* = 2.1 Hz, 1H), 5.15 (dd, *J* = 9.8 Hz, *J* = 2.1 Hz, 1H), 5.01 (d, *J* = 15.7 Hz, 1H), 4.68 (d, *J* = 15.9 Hz, 1H), 4.56 (d, *J* = 11.8 Hz, 1H), 4.55 (d, *J* = 7.6 Hz, 1H), 4.35 (d, *J* = 11.9 Hz, 1H), 2.41 (d, *J* = 1.1 Hz, 3H). ^{13}C NMR (126 MHz, $CDCl_3$): δ 175.1, 142.8, 139.4, 138.6, 128.1, 135.5, 133.5, 129.2, 128.9, 128.5, 128.4, 128.3, 128.1, 127.5, 127.4, 127.3, 127.2, 126.7, 125.7, 124.4, 122.3, 121.2, 108.9, 85.3, 77.3, 77.0, 76.7, 70.9, 58.8, 43.8, 15.2. HRMS (ESI) Calc'd for $C_{30}H_{27}NO_2S$ [M + H]: 466.1841, found: 466.1841. $[\alpha]_D^{23}$ = 96.1 (*c* 4.70, CH_2Cl_2). Enantiomeric excess was determined to be 83% ee by chiral HPLC (Chiralpak AD, 254 nm, hexane : *i*-PrOH = 90 : 10, 1.0 ml/min, t_1 = 13.42 min (major), t_2 = 14.89 min).

(*R*)-1-benzyl-3-((*R*)-1-(benzyloxy)allyl)-1'-methyl-3,3'-biindolin-2-one (13p):

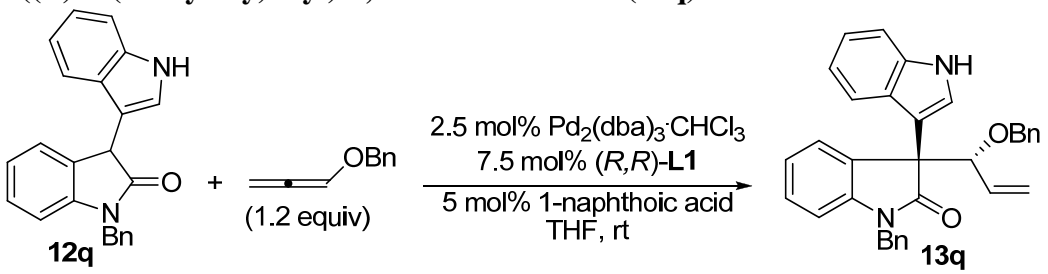


13p

Oxindole **13p** was prepared according to the general procedure of the Pd-catalyzed hydrocarbonation of allenes, using $Pd_2(dba)_3$•$CHCl_3$ (40.6 mg, 0.0392 mmol), (*R*,*R*)-**L1** ligand (59.3 mg, 0.0858 mmol), 1-naphthoic acid (13.4 mg, 0.0802 mmol), oxindole **12p** (0.550 g, 1.56 mmol), and benzyloxyallene **4** (0.28 mL, 280 mg, 1.9 mmol). Reaction was conducted in THF (15.6 ml) for 24 h at room temperature, giving **13p** in 7.0:1 d.r. (Diastereomeric ratio was determined by ^{1}H NMR by comparison of the diastereotopic –CH_2– group of the –OBn group). Purification by flash chromatography (25% ether in petroleum ether, silica gel) afforded 732 mg (94%) of **13p** as a diastereomeric mixture (d.r. = 7.0:1) so that the following data were obtained from the diastereomeric mixture. The relative stereochemistry was assigned by analogy to that determined for the allene hydrocarbonation product **11**. The absolute stereochemistry was assigned by analogy to that determined for the allene hydrocarbonation product **17**.

R_f = 0.45 (25% EtOAc in pet. ether). IR (neat): 3059, 2925, 1712, 1610, 1487, 1466, 1347, 1069, 738, 698 cm^{-1}. ^1H NMR (500 MHz, $CDCl_3$): δ 7.95 (ddd, *J* = 7.5 Hz, *J* = 0.9 Hz, *J* = 0.9 Hz, 1H), 7.83 (dd, *J* = 7.3 Hz, *J* = 0.9 Hz, 1H), 7.18 – 7.09 (m, 5H), 7.05 – 6.95 (m, 8H), 6.83 (ddd, *J* = 7.4 Hz, *J* = 7.4 Hz, *J* = 1.1 Hz, 1H), 6.81 – 6.80 (m, 1 H), 6.55 (d, *J* = 7.5 Hz, 1H), 5.76 (ddd, *J* = 17.3 Hz, *J* = 10.2 Hz, *J* = 8.0 Hz, 1H), 5.41 (ddd, *J* = 17.2 Hz, *J* = 1.7 Hz, *J* = 0.6 Hz,1H), 5.26 (d, *J* = 8.2 Hz, 1H), 5.07 (dd, *J* = 10.2 Hz, *J* = 1.7 Hz, 1H), 4.80 (d, *J* = 15.6 Hz, 1H), 4.56 (d, *J* = 15.6 Hz, 1H), 4.52 (d, *J* = 11.8 Hz, 1H), 4.23 (d, *J* = 11.8 Hz, 1H), 2.80 (s, 3H). ^{13}C NMR (125 MHz, C_6D_6): δ 176.3, 143.8, 138.6, 137.9, 136.5, 134.8, 130.9, 129.1, 128.7, 128.5, 127.7, 127.6, 127.5, 127.2, 127.0, 122.3, 121.9, 121.8, 120.9, 119.4, 112.0, 109.7, 109.0, 83.3, 71.1, 58.0, 43.7, 31.9. HRMS (ESI+) Calc'd for $C_{34}H_{30}N_2O_2$ $[M + Na]^+$: 521.2205, found: 521.2215. $[\alpha]_D^{23}$ = 113.3 (*c* 1.2, CH_2Cl_2). Enantiomeric excess was determined to be 88% ee by chiral HPLC (Chiralpak IA, 254 nm, heptane : *i*-PrOH = 90 : 10, 1.0 ml/min, t_1 = 15.70 min, t_2 = 24.75 min (major).

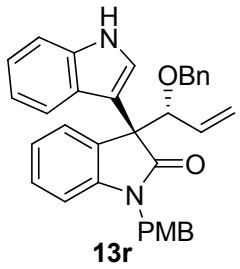
(*R*)-1-benzyl-3-((*R*)-1-(benzyloxy)allyl)-3,3'-biindolin-2-one (13q):



A 25 mL Schlenk flask with magnetic stir-bar was charged with 44.8 mg (0.0433 mmol) of $Pd_2(dba)_3$•$CHCl_3$, 89.8 mg (0.130 mmol) of (*R*,*R*)-**L1**, 14.9 mg (0.0865 mmol) of 1-naphthoic acid, and 584 mg (1.73 mmol) of oxindole **12q**. The flask was then put under a N_2 atmosphere by evacuating with reduced pressure (~1 torr) for 5 min followed by refilling with N_2. This process was performed a total of 3 times and finally an Ar balloon was fitted on the reaction vessel. The solids were then diluted with 17 mL of freeze-pump-thaw degassed THF. After allowing this mixture to stir for 15 min, an orange-red solution was obtained and 300 μL (304 mg, 2.08 mmol) of allene was then added by gas-tight syringe. The resultant mixture was allowed to stir at ambient temperature for 41 h, and then volatile material was removed under reduced pressure. Silica gel chromatography of the crude mixture (gradient, 3:1 to 3:2 pet. ether:Et_2O) afforded 591 mg (71%) of **13q** a slight-pinkish solid. The diastereomeric ratio was determined to be 7.7:1 by ^1H NMR analysis of the purified material. The enantiomeric ratio was determined to be 91% ee for the major diastereomer and 29% ee for the minor diastereomer by chiral HPLC analysis of the purified material. The relative stereochemistry was assigned by analogy to that determined for the allene hydrocarbonation product **11**. The absolute stereochemistry was assigned by analogy to that determined for the allene hydrocarbonation product **17**. mp 152-162 °C. R_f = 0.26 (1:1 pet. ether:Et_2O). ^1H NMR (400 MHz, $CDCl_3$): δ 8.04 (br s, 1H), 7.56 (d, *J* = 7.6 Hz, 1H), 7.14-7.38 (m, 13H), 7.10 (t, *J* = 6.8 Hz, 1H), 7.05 (m, 3H), 7.00 (t, *J* = 7.6 Hz, 1H), 6.90 (dd, *J* = 8.0 Hz, *J* = 7.2 Hz, 1H), 6.75 (d, *J* = 8.2 Hz, 1H), 5.39-5.55 (m, 1H), 5.38 (dd, *J* = 17 Hz, *J* = 2.4 Hz, 1H), 5.18 (dd, *J* = 10 Hz, *J* = 2.4 Hz, 1H), 5.02 (d, *J* = 12 Hz, 1H), 5.01 (d, *J* = 12 Hz, 1H), 4.76 (d, *J* = 15 Hz, 1H), 4.58 (d, *J* = 12 Hz, 1H), 4.33 (d, *J* = 12 Hz, 1H). ^{13}C NMR: δ 176.4, 143.2, 138.2, 136.7, 135.8, 133.9, 130.2, 128.5, 128.1, 127.54, 127.50, 127.4, 127.3, 126.8, 125.7, 124.1, 122.4, 121.9, 121.1, 120.9, 119.5, 113.0, 111.2, 108.8, 82.55, 70.56, 57.65, 43.89. FTIR (thin film): 3414 (m), 3329 (m), 3060 (m), 3030 (m), 2922 (m), 2866 (m), 1698 (s), 1610 (s), 1487 (s), 1465 (s), 1430 (m), 1350 (s), 1215 (m), 1176 (m) cm^{-1}. HRMS (ESI+) Calc'd for $C_{33}H_{28}N_2O_2$ $[M + Na]^+$: 507.2049, found: 507.2043. $[\alpha]_D^{24}$ = 154 (*c* = 0.56, $CHCl_3$). Chiral HPLC analysis (Chiralpak IA, 254 nm,

heptane:*i*-PrOH = 70:30, 0.9 ml/min): minor diastereomer: t_1 = 10.78 min, t_2 = 22.88 min, 29% ee; major diastereomer: t_1 = 16.66 min, t_2 = 26.60 min (major), 91% ee.

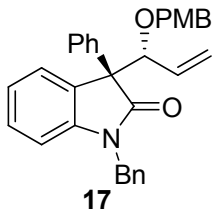
(*R*)-3-((*R*)-1-(benzyloxy)allyl)-1-(4-methoxybenzyl)-3,3'-biindolin-2-one (13r):



13r

Prepared according to the procedure for **13q** using 70.2 mg (0.0678 mmol) of $Pd_2(dba)_3$•$CHCl_3$, 0.140 g (0.203 mmol) of (*R*,*R*)-**L1**, 23.4 mg (0.136 mmol) of 1-naphthoic acid, 1.00 g (2.71 mmol) of oxindole **12r**, and 0.47 mL (470 mg, 3.2 mmol) of allene **4**. Purification of the crude material using silica gel chromatrography (gradient, 4:1 to 2:3 pet. ether:Et_2O) afforded 1.11 g (80%) of the desired product as a 7.4:1 mixture of diastereomers. The enantiomeric ratio was determined to be 91% ee for the major diastereomer and 28% ee for the minor diastereomer by chiral HPLC analysis of the purified material. The relative stereochemistry was assigned by analogy to that determined for the allene hydrocarbonation product **11**. The absolute stereochemistry was assigned by analogy to that determined for the allene hydrocarbonation product **17**. mp 64-80 °C. R_f = 0.25 (1:1 pet. ether:Et_2O). ^{1}H NMR: δ 8.13 (s, 1H), 7.54 (d, *J* = 7.2 Hz, 1H), 7.17-7.33 (m, 7H), 6.96-7.12 (m, 6H), 6.92 (t, *J* = 7.6 Hz, 1H), 6.78 (d, *J* = 7.6 Hz, 1H), 6.74 (d, *J* = 8.8 Hz, 2H), 5.45 (ddd, *J* = 17 Hz, *J* = 10 Hz, *J* = 8.0 Hz, 1H), 5.38 (dd, *J* = 17 Hz, *J* = 2.4 Hz, 1H), 5.17 (dd, *J* = 10 Hz, *J* = 2.4 Hz, 1H), 5.00 (d, *J* = 8.0 Hz, 1H), 4.96 (d, *J* = 16 Hz, 1H), 4.70 (d, *J* = 16 Hz, 1H), 4.58 (d, *J* = 12 Hz, 1H), 4.32 (d, *J* = 12 Hz, 1H), 3.75 (s, 3H). ^{13}C NMR: δ 176.4, 158.9, 138.2, 136.7, 133.9, 130.3, 128.9, 128.11, 128.08, 127.9, 127.5, 127.3, 126.7, 125.7, 124.1, 122.3, 121.9, 121.0, 120.9, 119.5, 113.9, 113.0, 111.2, 108.8, 82.60, 70.54, 57.59, 55.21, 43.33. FTIR (thin film): 3410 (br m), 3332 (br m), 3055 (m), 2931 (m), 2834 (m), 1697 (s), 1610 (s), 1512 (s), 1485 (m), 1464 (m), 1436 (m), 1350 (m), 1302 (m), 1247 (s), 1214 (m), 1176 (m) cm^{-1}. HRMS (ESI+) Calc'd for $C_{34}H_{30}N_2O_3$ $[M + Na]^+$: 537.2154, found: 537.2149. $[\alpha]_D^{26}$ = 130 (*c* = 0.57, $CHCl_3$). Chiral HPLC analysis (Chiralpak IA, 254 nm, heptane:EtOAc = 80:20, 0.7 ml/min): minor diastereomer: t_1 = 25.75 min, t_2 = 29.53 min, 28% ee; major diastereomer: t_1 = 31.56 min, t_2 = 35.24 min (major), 91% ee.

(*R*)-1-Benzyl-3-((*R*)-1-(4-methoxybenzyloxy)allyl)-3-phenylindolin-2-one (17):

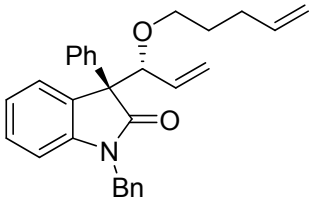


17

Oxindole **17** was prepared according to the general procedure of the Pd-catalyzed hydrocarbonation of allenes, using $Pd_2(dba)_3$•$CHCl_3$ (5.2 mg, 5.0 μmol), (*R*,*R*)-**L1** ligand (7.6 mg, 11 μmol), $PhCO_2H$ (1.2 mg, 10 μ mol), oxindole **12c** (59.9 mg, 0.20 mmol), and 4-methoxybenzyloxyallene (42.3 mg, 0.24 mmol). Reaction was conducted in THF (2.0 ml) for 6 h at room temperature, giving **17** (95.0 mg, 100%) in 17.0:1 d.r. (Yield was determined by ^{1}H NMR using mesitylene as the internal standard. Diastereomeric ratio was determined by ^{1}H NMR integration of the $–CH_2–$ of the –NBn group). Purification by flash chromatography (15% ether in petroleum ether, silica gel) afforded 91.2 mg (96%) of **17** as a diastereomeric mixture (d.r. = 17.0:1) so that the following data were obtained from the diastereomeric mixture. The relative stereochemistry was assigned by analogy to that determined for the allene hydrocarbonation product **11**. The absolute stereochemistry was determined as described below (pages S36-S38).

R_f = 0.66 (25% EtOAc / pet. ether). IR (neat): 3059, 3031, 2931, 1712, 1611, 1513, 1466, 1357, 1248, 1076, 1034, 754, 698 cm^{-1}. ^{1}H NMR (500 MHz, $CDCl_3$): δ 7.61 (dd, *J* = 7.4 Hz, *J* = 1.2 Hz, 1H), 7.45 – 7.43 (m, 2H), 7.30 – 7.25 (m, 3H), 7.24 – 7.18 (m, 6H), 7.06 (dt, *J* = 7.4 Hz, *J* = 0.9 Hz, 1H), 6.93 – 6.91 (m, 2H), 6.79 – 6.76 (m, 2H), 6.80 (d, *J* = 7.8 Hz, 1H), 5.37 – 5.33 (m, 2H), 5.17 – 5.14 (m, 1H), 4.96 (d, *J* = 15.9 Hz, 1H), 4.77 (d, *J* = 3.3 Hz, 1H), 4.67 (d, *J* = 15.7 Hz, 1H), 4.49 (dd, *J* = 11.6 Hz, *J* = 1.6 Hz, 1H), 4.21 (dd, *J* = 11.6 Hz, *J* = 1.7 Hz, 1H), 3.78 (s, 3H). ^{13}C NMR (126 MHz, $CDCl_3$): δ 176.0, 159.0, 143.2, 137.8, 135.7, 134.1, 129.9, 129.3, 129.1, 128.5, 128.4, 128.2, 127.6(2). 127.4, 127.3, 127.2, 122.3, 121.1, 113.5, 109.0, 83.4, 70.2, 60.9, 55.2, 43.7. HRMS (ESI+) Calc'd for $C_{32}H_{29}NO_3$ $[M + Na]^+$: 498.2045, found: 498.2047. $[\alpha]_D^{23}$ = 126.9 (*c* 2.30, CH_2Cl_2). Enantiomeric excess was determined to be 87% ee by chiral HPLC (Chiralpak OD, 254 nm, heptane : *i*-PrOH = 98 : 2, 0.9 ml/min, t_1 = 19.11 min, t_2 = 21.84 min (major).

(*R*)-1-Benzyl-3-((*R*)-1-(pent-4-enyloxy)allyl)-3-phenylindolin-2-one:

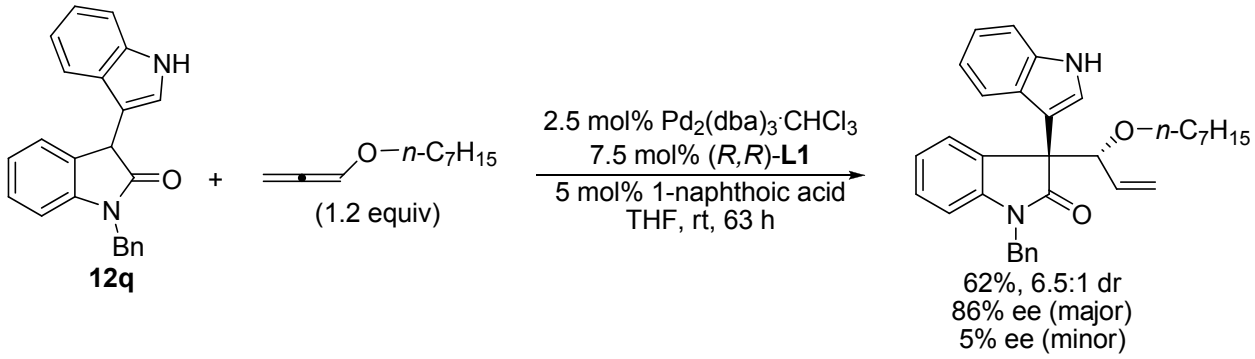


The oxindole was prepared according to the general procedure of the Pd-catalyzed hydrocarbonation of allenes, using $Pd_2(dba)_3$•$CHCl_3$ (5.2 mg, 5.0 μmol), (*R*,*R*)-**L1** ligand (7.6 mg, 11 μmol), $PhCO_2H$ (1.2 mg, 10 μ mol), oxindole **12c** (59.9 mg, 0.20 mmol), and 5-(propa-1,2-dienyloxy)pent-1-ene (29.8 mg, 0.24 mmol). Reaction was conducted in THF (2.0 ml) for 4 h at room temperature, giving the hydrocarbonation product (84.7 mg, 100%) with a 8.0:1 d.r. (Yield was determined by ^{1}H NMR using mesitylene as the internal standard. Diastereomeric ratio was determined by ^{1}H NMR integration of the $–CH_2–$ of the –NBn group). Purification by flash chromatography (15% Et_2O in petroleum ether, silica gel) afforded the desired product as a diastereomeric mixture (d.r. = 8.0:1) so that the following data were obtained from the diastereomeric mixture. The relative stereochemistry was assigned by analogy to that determined for the allene hydrocarbonation product **11**. The absolute stereochemistry was assigned by analogy to that determined for the allene hydrocarbonation product **17**.

R_f = 0.66 (25% Et_2O in pet. ether). FTIR (neat): 3062, 2932, 2866, 1714, 1611, 1487, 1467, 1359, 1189, 1100, 754, 698 cm^{-1}. ^{1}H NMR (500 MHz, $CDCl_3$): δ 7.61 (d, *J* = 7.5 Hz, 1H), 7.51 (d, *J* = 7.3 Hz, 2H), 7.31 (t, *J* = 7.1

Hz, 2H), 7.26 – 7.19 (m, 7H), 7.09 (t, *J* = 7.4 Hz, 1H), 6.71 (d, *J* = 7.8 Hz, 1H), 5.69 – 5.61 (m, 1H), 5.31 – 5.29 (m, 2H), 5.10 – 5.06 (m, 1H), 4.97 (d, *J* = 15.7 Hz, 1H), 4.90 – 4.83 (m, 2H), 4.71 – 4.67 (m, 2H), 3.51 – 3.47 (m, 1H), 3.19 – 3.15 (m, 1H), 1.87 – 1.82 (m, 2H), 1.52 – 1.46 (m, 2H). ^{13}C NMR (126 MHz, $CDCl_3$): δ 176.1, 143.3, 138.3, 135.7, 134.5, 129.3, 128.5, 128.4, 128.2(2), 127.5, 127.4, 127.3, 127.2, 122.2, 120.4, 114.5, 109.0, 84.8, 68.3, 61.0, 43.7, 30.1, 28.7. HRMS (ESI+) Calc'd for $C_{29}H_{29}NO_2$ $[M + H]^+$: 424.2277, found: 424.2267. $[\alpha]_D^{23}$ = 105.8 (*c* 1.70, CH_2Cl_2). Enantiomeric excess was determined to be 87% ee by chiral HPLC (Chiralpak OD, 254 nm, heptane:*i*-PrOH = 98:2, 0.9 ml/min, t_1 = 19.11 min, t_2 = 21.84 min(major)).

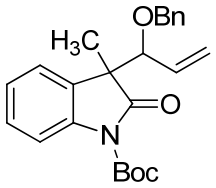
(*R*)-1-benzyl-3-((*R*)-1-(heptyloxy)allyl)-3,3'-biindolin-2-one:



A microwave vial with magnetic stir-bar was charged with 18.0 mg (0.0174 mmol) of $Pd_2(dba)_3$•$CHCl_3$, 36.1 mg (0.523 mmol) of (*R*,*R*)-**L1**, 6.0 mg (0.035 mmol) of 1-naphthoic acid, and 235 mg (0.697 mmol) of oxindole **12q**. The vial was sealed and put under an Ar atmosphere by evacuating with reduced pressure (~1 torr) for 5 min followed by refilling with Ar. This process was performed a total of 3 times, and finally, an Ar balloon was fitted on the reaction vessel. The solids were then diluted with 6.9 mL of freeze-pump-thaw degassed THF. After allowing this mixture to stir for 15 min, an orange-red solution was obtained, and 155 μL (129 mg, 0.836 mmol) of allene **4** was then added by gas-tight syringe. The resultant mixture was allowed to stir at ambient temperature for 63 h, and then volatile material was removed under reduced pressure. Silica gel chromatography of the crude mixture (gradient, 3:1 to 3:2 pet. ether:Et_2O) afforded 214 mg (62%) of the allene hydrocarbonation product as a slight-pinkish solid. The diastereomeric ratio was determined by ^{1}H NMR analysis of the purified material. The enantiomeric ratio was determined to be 86% ee for the major diastereomer and 5% ee for the minor diastereomer by chiral HPLC analysis of the purified material. The relative stereochemistry was assigned by analogy to that determined for the allene hydrocarbonation product **11**. The absolute stereochemistry was assigned by analogy to that determined for the allene hydrocarbonation product **17**. mp 39-60 °C. R_f = 0.17 (2:1 pet. ether:Et_2O). ^{1}H NMR (400 MHz, $CDCl_3$): δ 8.24 (br s, 1H), 7.55 (dd, *J* = 7.6 Hz, *J* = 0.8 Hz, 1H), 7.41 (d, *J* = 7.6 Hz, 1H), 6.90-7.35 (m, 11H), 6.76 (d, *J* = 7.6 Hz, 1H), 5.41 (ddd, *J* = 17 Hz, *J* = 10Hz, *J* = 2.0 Hz, 1H), 5.34 (dd, *J* = 17 Hz, *J* = 2.0 Hz, 1H), 5.12 (dd, *J* = 10 Hz, *J* = 2.0 Hz, 1H), 5.03 (d, *J* = 16 Hz, 1H), 4.88 (d, *J* = 7.6 Hz, 1H), 4.78 (d, *J* = 16 Hz, 1H), 3.49 (dt, *J* = 9.2 Hz, *J* =6.4 Hz, 1H), 3.20 (dt, *J* = 9.2 Hz, *J* = 6.4 Hz, 1H), 1.41 (p, *J* = 6.4 Hz, 2H), 1.00-1.30 (m, 8H), 0.85 (t, *J* = 7.2 Hz, 3H). ^{13}CNMR (100 MHz, $CDCl_3$): δ 176.7, 143.1, 136.7, 135.9, 134.4, 130.5, 128.5, 128.0, 127.6, 127.4, 126.7, 125.8, 124.1, 122.3, 121.8, 120.8, 120.2, 119.4, 113.2, 111.3, 108.7, 82.98, 68.99, 57.70, 43.88, 31.74, 29.63, 28.91, 25.97, 22.54, 14.08. FTIR (thin film): 3408 (m), 3326 (m), 3057 (m), 2927 (m), 2856 (m), 1698 (s), 1611 (s), 1487 (s), 1466 (s), 1430 (m), 1350 (s), 1215 (m), 1175 (m) cm^{-1}. HRMS (ESI+) Calc'd for $C_{33}H_{36}N_2O_2$ $[M + Na]^+$: 515.2675, found: 515.2670. $[\alpha]_D^{22}$ = 124 (*c* = 0.31, $CHCl_3$). Chiral HPLC analysis

(Chiralpak IC, 254 nm, heptane:EtOAc = 85:15, 0.8 ml/min): minor diastereomer: t_1 = 7.70 min, t_2 = 10.61 min, 5% ee; major diastereomer: t_1 = 8.94 min, t_2 = 19.49 min (major), 86% ee.

***tert*-Butyl 3-(1-(benzyloxy)allyl)-3-methyl-2-oxoindoline-1-carboxylate:**

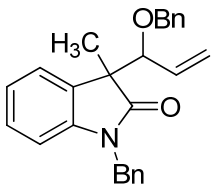


The oxindole was prepared according to the general procedure of the Pd-catalyzed hydrocarbonation of allenes, using $Pd_2(dba)_3$•$CHCl_3$ (5.2 mg, 5.0 μmol), (*R*,*R*)-**L1** ligand (7.6 mg, 11 μmol), $PhCO_2H$ (1.2 mg, 10 μ mol), *N*-Boc 3- methyloxindole (49.5 mg, 0.20 mmol), and allene **4** (35.6 μl, 0.24 mmol). Reaction was conducted in CH_3CN (2.0 ml) for 4 h at room temperature, giving hydrocarbonation product (72.4 mg, 92%) with a 1.5:1 d.r. (Yield was determined by ^{1}H NMR using mesitylene as the internal standard. Diastereomeric ratio was determined by ^{1}H NMR by comparison of the diastereotopic $–CH_2–$ group of the –OBn group). Purification by flash chromatography (15% ether in petroleum ether, silica gel) afforded two diastereomers of the hydrocarbonation product.

Major diastereomer: R_f = 0.71 (25% Et_2O/pet. ether). FTIR (neat): 2980, 2932, 2869, 1766, 1729, 1607, 1480, 1351, 1290, 1250, 1151, 1092, 1070, 753, 698 cm^{-1}. ^{1}H NMR (500 MHz, $CDCl_3$): δ 7.82 (dd, *J* = 8.2 Hz, *J* = 2.5 Hz, 1H), 7.35 – 7.25 (m, 5H), 7.17 (d, *J* = 7.3 Hz, 2H), 7.13 (dt, *J* = 7.5 Hz, *J* = 0.9 Hz, 1H), 5.55 – 5.48 (m, 1H), 5.26 – 5.22 (m, 2H), 4.57 (d, *J* = 12.1 Hz, 1H), 4.29 (d, *J* = 12.2 Hz, 1H), 3.99 (d, *J* = 8.5 Hz, 1H), 1.63 (s, 9H), 1.48 (s, 3H). ^{13}C NMR (126 MHz, $CDCl_3$): δ 177.1, 149.2, 139.4, 138.0, 133.7, 130.9, 128.2, 127.5, 127.4, 124.2, 121.0, 114.5, 84.7, 84.1, 70.3, 52.9, 28.1, 21.3. HRMS (ESI+) Calc'd for $C_{24}H_{27}NO_4$ $[M + H]^+$: 394.2018, found: 394.2011.

Minor diastereomer: R_f = 0.71 (25% Et_2O/pet. ether). FTIR (neat): 2980, 2932, 2871, 1767, 1729, 1608, 1480, 1351, 1289, 1251, 1152, 1072, 754, 698 cm^{-1}. ^{1}H NMR (500 MHz, $CDCl_3$): δ 7.824(d, *J* = 8.2 Hz, 1H), 7.32 – 7.27 (m, 2H), 7.25 – 7.16 (m, 4H), 7.13 – 7.10 (m, 2H), 5.92 (ddd, *J* = 17.3 Hz, *J* = 10.4 Hz, *J* = 8.2 Hz, 1H), 5.49 (dd, *J* = 10.4 Hz, *J* = 0.8 Hz, 1H), 5.38 (dd, *J* = 17.3 Hz, *J* = 0.9 Hz, 1H), 4.43 (d, *J* = 12.0 Hz, 1H), 4.27 (d, *J* = 12.0 Hz, 1H), 4.14 (d, *J* = 8.2 Hz, 1H), 1.64 (s, 9H), 1.33 (s, 3H). ^{13}C NMR (126 MHz, $CDCl_3$): δ 178.3, 149.3, 140.1, 137.9, 133.2, 129.9, 128.2, 128.0, 127.7, 127.2, 124.0, 123.7, 121.3, 114.8, 85.7, 83.9, 70.7, 52.4, 28.1, 20.3. HRMS (ESI+) Calc'd for $C_{24}H_{27}NO_4$ $[M + H]^+$: 394.2018, found: 394.2006.

1-Benzyl-3-(1-(benzyloxy)allyl)-3-methylindolin-2-one:

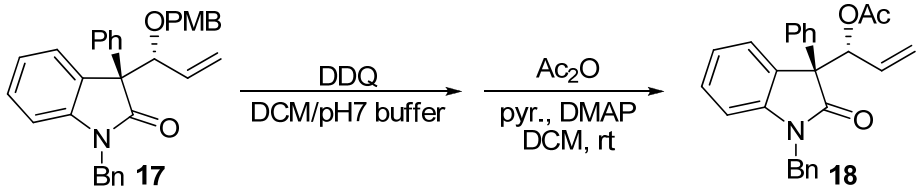


The oxindole was prepared from according to the general procedure of the Pd-catalyzed hydrocarbonation of allenes, using $Pd_2(dba)_3$•$CHCl_3$ (5.2 mg, 5.0 μmol), (*R*,*R*)-**L1** ligand (7.6 mg, 11 μmol), $PhCO_2H$ (1.2 mg, 10 μ mol), *N*-benzyl 3-methyloxindole (47.5 mg, 0.20 mmol), and allene **4** (35.6 μl, 0.24 mmol). Reaction was conducted in CH_3CN (2.0 ml) for 24 h at room temperature, giving the hydrocarbonation product (64.4 mg, 84%, 95% based on 5 mg of recovered oxindole starting material) in 4.4:1 d.r. (Yield was determined by ^1H NMR using mesitylene as the internal standard. Diastereomeric ratio was determined by ^1H NMR by comparison of the diastereotopic $–CH_2–$ group of the –OBn group). Purification by flash chromatography (10% Et_2O in petroleum ether, silica gel) afforded two diasteromers of the desired product.

Major diastereomer: R_f = 0.50 (25% Et_2O in pet. ether). FTIR (neat): 3030, 2926, 2866, 1711, 1611, 1489, 1433, 1357, 1183, 1071, 741, 696 cm^{-1}. ^1H NMR (500 MHz, $CDCl_3$): δ 7.38 Ð 7.36 (m, 1H), 7.30 Ð 7. 23 (m, 5H), 7.19 Ð 7. 17 (m, 5H), 7.12 (ddd, *J* = 7.7 Hz, *J* = 7.7 Hz, *J* = 1.0 Hz, 1H), 6.98 (dd, *J* = 7.6 Hz, *J* = 7.6 Hz, 1H), 6.64 (d, *J* = 7.4 Hz, 1H), 5.55 (ddd, *J* = 17.3 Hz, *J* = 10.1 Hz, *J* = 8.8 Hz, 1H), 5.28 (dd, *J* = 17.3 Hz, *J* = 1.7 Hz, 1H), 5.20 (dd, *J* = 10.1 Hz, *J* = 1.7 Hz, 1H), 5.06 (d, *J* = 15.9 Hz, 1H), 4.68 (d, *J* = 15.9 Hz, 1H), 4.60 (d, *J* = 12.0 Hz, 1H), 4.31 (d, *J* = 12.0 Hz, 1H), 4.09 (d, *J* = 8.5 Hz, 1H), 1.51 (s, 3H). ^{13}C NMR (126 MHz, $CDCl_3$): δ 178.3, 142.5, 138.2, 135.7, 134.2, 132.0, 128.4, 128.2, 127.6, 127.5, 127.3, 127.2, 127.1, 124.2, 122.2, 120.6, 108.6, 84.7, 70.4, 52.5, 43.4, 20.8. HRMS (ESI+) Calc'd for $C_{26}H_{25}NO_2$ $[M + H]^+$: 384.1964, found: 384.1953. Enantiomeric excess was determined to be 63% ee by chiral HPLC analysis (Chiralpak AD, 254 nm, heptane:*i*-PrOH = 90:10, 1.0 ml/min, t_1 = 8.68 min, t_2 = 9.32 min(major)).

Minor diastereomer R_f = 0.45 (25% Et_2O in pet. ether): 0.50. FTIR (neat): 3030, 2926, 2866, 1711, 1611, 1489, 1433, 1357, 1183, 1071, 741, 696 cm^{-1}. ^1H NMR (500 MHz, $CDCl_3$): δ 7.31 – 7.26 (m, 1H), 7.25 – 7. 20 (m, 6H), 7.14 – 7. 10 (m, 3H), 7.04 – 7.97 (m, 3H), 6.59 (d, *J* = 7.6 Hz, 1H), 6.03 (ddd, *J* = 17.2 Hz, *J* = 10.4 Hz, *J* = 8.3 Hz, 1H), 5.51 (ddd, *J* = 10.4 Hz, *J* = 1.6 Hz, *J* = 0.9 Hz, 1H), 5.42 (ddd, *J* = 17.2 Hz, *J* = 1.7 Hz, *J* = 1.0 Hz,1H), 5.22 (d, *J* = 16.0 Hz, 1H), 4.65 (d, *J* = 16.1 Hz, 1H), 4.50 (d, *J* = 11.9 Hz, 1H), 4.34 (d, *J* = 11.8 Hz, 1H), 4.26 (d, *J* = 8.3 Hz, 1H), 1.35 (s, 3H). ^{13}C NMR (126 MHz, $CDCl_3$): δ 179.6, 143.2, 138.0, 135.6, 133.8, 131.2, 128.5, 128.1, 127.8, 127.6, 127.2, 127.1, 126.8, 124.1, 121.9, 121.0, 109.0, 84.9, 70.6, 52.0, 43.5, 20.4. Elemental Analysis Calc'd for $C_{26}H_{25}NO_2$: C, 81.43; H, 6.57; N, 3.65; found: C, 81.27; H, 6.70; N, 3.80.

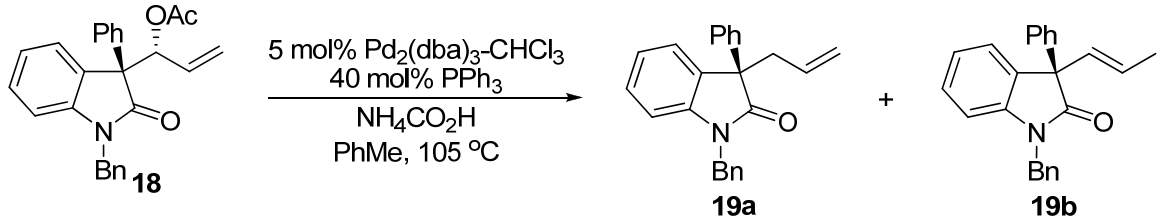
Determination of absolute stereochemistry (Scheme 5):



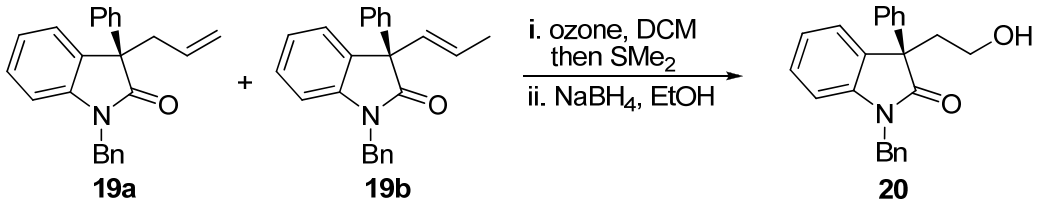
To a mixture of 36.0 mg (0.0757 mmol) of oxindole **17**, 0.84 mL of CH_2Cl_2, and 0.05 mL of pH7 buffer was added 27.5 mg (0.121 mmol) of DDQ, and the resultant mixture was rapidly stirred at room temperature for 1 h. Saturated $NaHCO_3$ was then added, followed by extraction with CH_2Cl_2 (3 x). The combined organics were washed with satd $NaHCO_3$ (1 x), dried with anhydrous Na_2SO_4, and volatile material removed under reduced pressure. Purification of the crude alcohol on silica gel led to loss of acrolein via retro-aldol, so the crude alcohol was used in the next step without purification.

The crude alcohol was dissolved in 0.70 mL of CH_2Cl_2 and cooled to 0 °C. To this solution was sequentially added 36.7 μL (35.9 mg, 0.454 mmol) of pyridine, 1.7 mg (0.014 mmol) of DMAP, and 24 μL (26 mg, 0.26

mmol) of Ac_2O. The mixture was allowed to warm to rt and stir for 16 h. To the reaction was then added 1 M $NaHSO_4$ followed by extraction with CH_2Cl_2 (3x). The combined organic layers were washed with satd $NaHCO_3$, dried with anhydrous Na_2SO_4, and volatile material removed under reduced pressure. Purification of the crude residue using preparatory TLC on silica gel (6:1 pet. ether:Et_2O) afforded 27.7 mg (92%) of allylic acetate **18** as a colorless oil. R_f = 0.11 (6:1 pet. ether:Et_2O). ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.55 (dd, *J* = 7.6 Hz, *J* = 1.2 Hz, 1H), 7.16-7.49 (m, 11H), 7.11 (td, *J* = 7.2 Hz, *J* = 1.2 Hz, 1H), 6.75 (d, *J* = 8.0 Hz, 1H), 6.35 (d, *J* = 6.0 Hz, 1H), 5.30-5.48 (m, 2H), 5.09 (m, 1H), 4.97 (d, *J* = 16 Hz, 1H), 4.72 (d, *J* = 16 Hz, 1H), 1.86 (s, 3H). ^{13}CNMR (100 MHz, $CDCl_3$): δ 175.2, 169.6, 143.3, 136.7, 135.6, 131.7, 128.7, 128.62, 128.56, 128.53, 127.7, 127.6, 127.4, 127.3, 126.8, 122.6, 121.1, 109.4, 77.66, 60.01, 43.93, 20.78. FTIR (thin film): 3060 (w), 3030 (w), 2926 (w), 1744 (s), 1713 (s), 1611 (m), 1488 (m), 1467 (m), 1365 (m), 1221 (s), 1190 (m) cm^{-1}. $[\alpha]_D^{22}$ = 158 (*c* = 1.4, $CHCl_3$).



A conical microwave vial was charged with 1.3 mg (0.0012 mmol) of $Pd_2(dba)_3$-$CHCl_3$, 2.6 mg (0.0099 mmol) of PPh_3, and 7.8 mg (0.12 mmol) of NH_4CO_2H (purified by recrystallization from MeOH), and the vial was sealed and put under an Ar atmosphere using vac-purge cycles (3x). Toluene was added (0.2 mL), and the mixture was allowed to stir for 10 min. To this yellow solution was added 9.8 mg (0.0247 mmol) of allylic acetate **18** as a solution in 0.3 mL of toluene using canula. The vial was immersed in an oil bath at 105 °C and monitored by TLC (5:1 pet. ether:Et_2O). After 6 h, the reaction became a gray color and black precipitate had formed. Volatile material was removed under reduced pressure, and the crude residue was purified by prepatory TLC (5:1 pet. ether:Et_2O, R_f = 0.31) to afford 7.6 mg of a 7:1 mixture of **19a**:**19b** contaminated with 16% dba (determined by ^{1}H NMR integration). Overall yield of **19a** and **19b** = 6.7 mg (80%). Spectral data was consistent with the literature,[15,16] and partial racemization did occur under the reaction conditions: $[\alpha]_D^{23}$ = 56 (*c* 0.67, $CHCl_3$). Lit.[15] $[\alpha]_D^{27}$ = 87 (*c* 0.5, $CHCl_3$, 81% ee) and Lit.[16] $[\alpha]_D^{20}$ = – 78 (*c* 2.0, $CHCl_3$, – 81% ee).

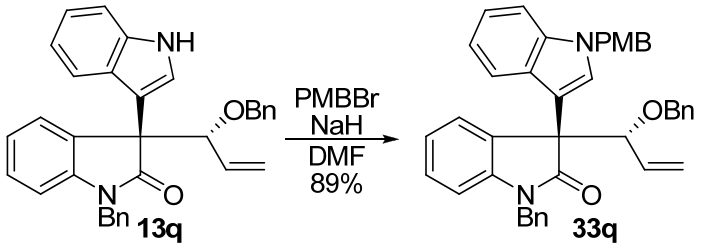


The procedure was adapted from the literature.[16] To 6.7 mg (0.020 mmol) of a 7:1 mixture of oxindoles **19a**:**19b** contaminated with 0.004 mmol of dba was added 2.0 mL of CH_2Cl_2, and the solution was cooled to -78 °C. This solution was then sparged with Ar for ~1 min, followed by ozone until the solution remained blue (~2 min). The reaction was then sparged with Ar until the blue color dissipated forming a white cloudy mixture. At this point, 10.0 μL (8.5 mg, 0.14 mmol) of SMe_2 was added, and the mixture was allowed to warm to ambient

[15] Luan, X.; Wu, L.; Drinkel, E.; Mariz, R.; Gatti, M.; Dorta, R. *Org. Lett.* **2010**, *12*, 1912.
[16] Duguet, N.; Slawin, A. M. Z.; Smith, A. D. *Org. Lett.* **2009**, *11*, 3858.

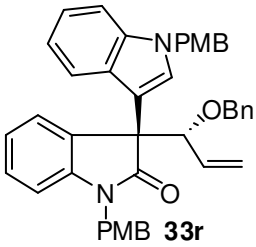
temperature. After stirring at rt for 5 min, volatile materials were removed under reduced pressure, and the crude residue was dissolved in 0.35 mL of EtOH and 13 mg (0.34 mmol) of $NaBH_4$ was added. This mixture was rapidly stirred for 40 min and subsequently quenched with 4 mL of 0.5 M NaOH. The mixture was extracted with EtOAc (3x), and the combined organic layers were dried with anhydrous Na_2SO_4, and volatile material was removed under reduced pressure. Purification of the crude residue using preparatory TLC (100% Et_2O, R_f = 0.43) afforded 3.8 mg (63% based off of the amount of **19a** present) of alcohol **20** (Note that the alcohol formed from ozonolysis/reduction of **19b** decomposes via retro-aldol during chromatography). Spectroscopic data was consistent with the literature, and the absolute configuration was verified by comparison of the optical rotation to that of the known compound in the literature.[16,17] ^{1}HNMR (500 MHz, $CDCl_3$): δ 7.16-7.38 (m, 12H), 7.06 (td, *J* = 7.5 Hz, *J* = 1.0 Hz, 1H), 6.77 (d, *J* = 8.0 Hz, 1H), 4.92 (s, 2H), 3.45-3.60 (m, 2H), 3.33 (s, 1H), 2.83 (dt, *J* = 14 Hz, *J* = 7.5 Hz, 1H), 2.44 (dt, *J* = 14 Hz, *J* = 6.0 Hz, 1H). FTIR (thin film): 3423 (br), 3060 (m), 3028 (m), 2919 (s), 2850 (s), 1711 (s), 1611 (s), 1555 (m), 1488 (s), 1467 (s), 1360 (s), 1265 (m), 1187 (m) cm^{-1}. $[\alpha]_D^{22}$ = 17 (*c* = 0.17, $CHCl_3$). Lit.[16, 17] $[\alpha]_D^{20}$ = – 45 (*c* 2.48, $CHCl_3$, – 81% ee) and $[\alpha]_D^{23}$ = – 41 (*c* 0.36, $CHCl_3$, – 84% ee) for the opposite enantiomer.

Studies towards the synthesis of the gliocladins:

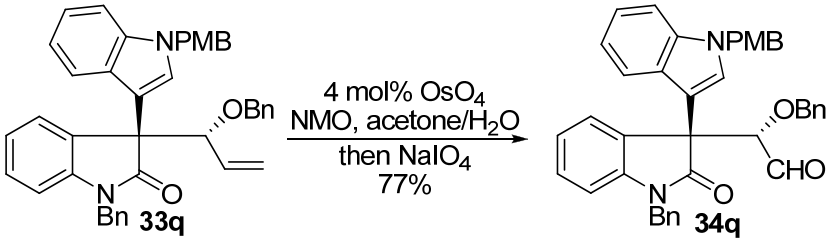


To a solution of 434 mg (0.896 mmol) of oxindole **13q** in 2.8 mL of DMF at 0 °C was added 43 mg (1.1 mmol) of 60% NaH in mineral oil under N_2. After allowing this mixture to stir for 5 min, 269 mg (1.34 mmol) of PMBBr was added by canula in 1.0 mL of DMF. The reaction was allowed to reach rt and allowed to stir for 2 h. Water was then added followed by extraction with EtOAc (3x). The combined organic layers were washed with H_2O (3x) and brine (1x) and dried with anhydrous Na_2SO_4. Silica gel chromatography of the crude mixture (gradient, 8:1 to 1:1 pet. ether:EtOAc) afforded 484 mg (89%) of the desired PMB-protected product (**33q**) as a cream solid. mp 52-64 °C. R_f = 0.33 (3:1 pet. ether:EtOAc)**.** ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.56 (d, *J* = 6.0 Hz, 1H), 6.94-7.34 (m, 18H), 6.88 (t, *J* = 7.6 Hz, 1H), 6.74 (t, *J* = 7.2 Hz, 2H), 6.73 (d, *J* = 8.4 Hz, 1H), 5.38-5.50 (m, 1H), 5.38 (dd, *J* = 18 Hz, *J* = 2.8 Hz, 1H), 5.16 (dd, *J* = 10 Hz, *J* = 2.8 Hz, 1H), 5.15 (s, 3H), 5.00 (d, *J* = 12 Hz, 1H), 4.99 (d, *J* = 12 Hz, 1H), 4.77 (d, *J* = 16 Hz, 1H), 4.56 (d, *J* = 12 Hz, 1H), 4.29 (d, *J* = 12 Hz, 1H), 3.73 (s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$): δ 176.6, 159.2, 143.5, 138.5, 137.2, 136.2, 134.2, 130.4, 129.7, 128.8, 128.5, 128.4, 128.2, 128.0, 127.81, 127.77, 127.66, 127.5, 127.3, 126.9, 122.6, 121.8, 121.4, 121.3, 119.5, 114.3, 112.2, 110.1, 109.0, 82.78, 70.87, 57.90, 55.49, 49.78, 44.16. FTIR (thin film): 3030 (m), 2930 (m), 1711 (s), 1611 (s), 1513 (s), 1487 (s), 1465 (s), 1350 (s), 1248 (s), 1176 (s) cm^{-1}. $[\alpha]_D^{22}$ = 120 (*c* = 0.47, $CHCl_3$).

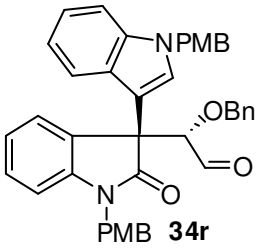
[17] Dounay, A. B.; Hatanaka, K.; Kodanko, J. J.; Oestreich, M.; Overman, L. E.; Pfeifer, L. A.; Weiss, M. W. *J. Am. Chem. Soc.* **2003**, *125*, 6261.



Prepared as above using 1.01 g (1.96 mmol) of the PMB-protected oxindole (**13r**). Purification of the crude material using silica gel chromatrography (gradient, 5:1 to 1:1 pet. ether:Et_2O) afforded 1.16 g (94%) of the desired product as a white solid. mp 42-52 ^oC. R_f = 0.32 (1:1 pet. ether:Et_2O). ^1H NMR (400 MHz, CDCl3): δ 7.56 (dd, *J* = 7.2 Hz, *J* = 0.8 Hz, 1H), 6.70-7.32 (m, 21H), 5.34-5.49 (m, 2H), 5.11-5.22 (m, 1H), 5.15 (s, 2H), 4.99 (d, *J* = 7.2 Hz, 1H), 4.94 (d, *J* = 16 Hz, 1H), 4.71 (d, *J* = 16 Hz, 1H), 4.57 (d, *J* = 12 Hz, 1H), 4.30 (d, *J* = 12 Hz, 1H), 3.75 (s, 3H), 3.74 (s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$): δ 176.3, 158.9, 143.2, 138.2, 136.9, 133.9, 130.1, 129.4, 128.9, 128.6, 128.2, 128.1, 127.94, 127.90, 127.5, 127.2, 126.9, 126.6, 122.3, 121.5, 121.1, 121.0, 119.2, 114.0, 113.9, 113.8, 111.9, 109.8, 108.8, 82.54, 70.57, 57.56, 55.21, 55.20, 49.50, 43.32. FTIR (thin film): 3027 (m), 3001 (m), 2930 (m), 2834 (m), 1709 (s), 1610 (s), 1512 (s), 1485 (m), 1464 (s), 1439 (m), 1352 (m), 1302 (m), 1247 (s), 1176 (s) cm^{-1}. $[\alpha]_D^{24}$ = 98.3 (*c* = 1.0, $CHCl_3$).

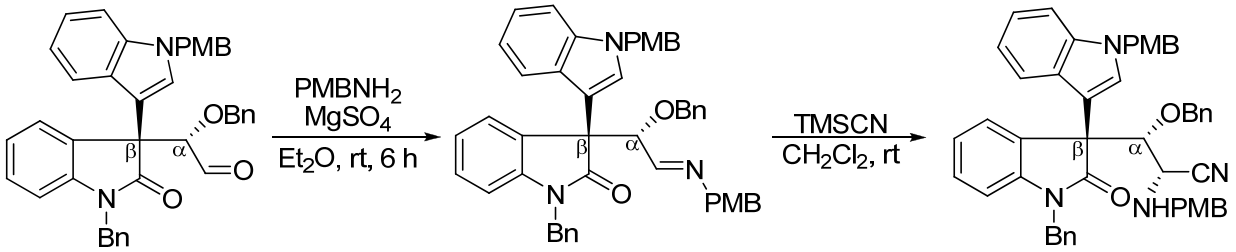


To a solution of 411 mg (0.680 mmol) of alkene **33q** in 3.4 mL of 8:1 acetone:H_2O was added 159 mg (1.36 mmol) of *N*-methylmorpholine-*N*-oxide followed by 173 μL (0.0272 mmol) of a 4% solution of OsO_4 in H_2O under N_2. The resultant mixture was allowed to stir at ambient temperature for 24 h. Saturated $NaHCO_3$ was then added followed by extraction with EtOAc (3x). The combined organic layers were washed with brine, dried with anhydrous Na_2SO_4, and concentrated under reduced pressure. The crude residue was then taken up in 6 mL of a 4:1 acetone:H_2O mixture and 291 mg (1.36 mmol) of $NaIO_4$ was added, and the resultant mixture was allowed to stir for 16 h. The reaction was quenched by the addition of 10 mL of 10 wt% Na_2SO_3 and extracted with EtOAc (3x). The combined organic layers were washed with brine, dried with anhydrous Na_2SO_4, and concentrated under reduced pressure. Silica gel chromatography of the crude mixture (gradient, 6:1 to 3:1 pet. ether:EtOAc) afforded 318 mg (77%) of aldehyde **34q** as a yellow solid. mp 74-85 ^oC. R_f = 0.28 (3:1 pet. ether:EtOAc)**.** ^1H NMR (400 MHz, $CDCl_3$): δ 9.67 (d, *J* = 2.2 Hz, 1H), 7.71 (d, *J* = 8.0 Hz, 1H), 7.49 (d, *J* = 7.2 Hz, 1H), 6.73-7.35 (m, 20H), 6.71 (d, *J* = 8.0 Hz, 1H), 5.16 (s, 2H), 5.07 (d, *J* = 16 Hz, 1H), 4.97 (d, *J* =2.2 Hz, 1H), 4.87 (d, *J* = 16 Hz, 1H), 4.57 (d, *J* = 11 Hz, 1H), 4.36 (d, *J* = 11 Hz, 1H), 3.74 (s, 3H). ^{13}CNMR (100 MHz, $CDCl_3$): δ 200.8, 197.6, 175.5, 159.0, 143.1, 137.2, 136.8, 135.5, 129.3, 129.1, 128.6, 128.3, 128.2, 128.0, 127.9, 127.8, 127.4, 127.3, 126.1, 125.4, 122.6, 122.2, 121.2, 119.8, 114.1, 110.3, 110.2, 109.4, 84.55, 73.97, 55.60, 55.23, 49.60, 44.08. FTIR (thin film): 3030 (m), 2934 (m), 1713 (s), 1611 (s), 1513 (s), 1487 (s), 1466 (s), 1357 (s), 1248 (s), 1176 (s) cm^{-1}. $[\alpha]_D^{26}$ = 33.2 (*c* = 0.47, $CHCl_3$).



34r

Prepared as above using 1.16 g (1.83 mmol) of the PMB-protected oxindole (**33r**). Purification of the crude material using silica gel chromatrography (gradient, 5:1 to 2:1 pet. ether:EtOAc) afforded 772 mg (64%) of aldehyde **34r** as a yellow solid. mp 65-100 °C. R_f = 0.15 (3:1 pet. ether:EtOAc). ^{1}H NMR (400 MHz, $CDCl_3$): δ 9.66 (d, *J* = 2.0 Hz, 1H), 7.68 (d, *J* = 8.0 Hz, 1H), 7.48 (dd, *J* = 7.2 Hz, *J* = 0.8 Hz, 1H), 6.64-7.30 (m, 20H), 5.16 (s, 2H), 5.06 (d, *J* = 16 Hz, 1H), 4.96 (d, *J* =2.0 Hz, 1H), 4.78 (d, *J* = 16 Hz, 1H), 4.56 (d, *J* = 12 Hz, 1H), 4.35 (d, *J* = 12 Hz, 1H), 3.74 (s, 3H), 3.72 (s, 3H). ^{13}CNMR (100 MHz, $CDCl_3$): δ 200.8, 175.4, 158.9, 143.1, 137.2, 136.8, 129.4, 129.1, 128.65, 128.60, 128.35, 128.29, 128.23, 128.18, 128.0, 127.8, 127.5, 126.1, 125.3, 122.6, 122.2, 121.2, 119.8, 114.1, 114.0, 110.3, 110.2, 109.4, 84.62, 77.21, 73.98, 55.23, 55.17, 49.60, 43.54. FTIR (thin film): 3004 (m), 2930 (m), 2834 (m), 1712 (s), 1610 (s), 1512 (s), 1486 (m), 1464 (s), 1439 (m), 1354 (s), 1301 (m), 1247 (s), 1176 (s) 1106 (m) cm^{-1}. $[\alpha]_D^{23}$ = 31.3 (*c* = 1.0, $CHCl_3$).

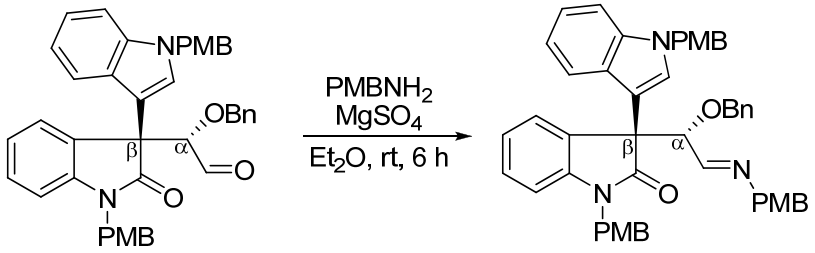


34q **35q** **32q**

To a mixture of 217 mg (0.356 mmol) of aldehyde **34q** and 550 mg of anhydrous $MgSO_4$ in 3.6 mL of Et_2O was added 46.5 μL (48.8 mg, 0.356 mmol) of $PMBNH_2$. The resultant mixture was allowed to stir at ambient temperature for 6 h. The reaction was then filtered, and volatile material was removed under reduced pressure to afford 258 mg (>99%) of aldimine **35q** as a 7:1 mixture of diastereomers relative to C_α and C_β (the diastereomers are a result of the initial allene-hydrocarbonation). The material was isolated as a yellow solid and was used in the next step without further purification. ^{1}H NMR (400 MHz, $CDCl_3$) data for the crude aldimine: δ 8.00 (d, *J* = 7.0 Hz, 1H), 7.35 (d, *J* = 8.0 Hz, 1H), 7.31 (d, *J* = 7.6 Hz, 1H), 6.65-7.28 (m, 25H), 5.08 (d, *J* = 16 Hz, 1H), 5.03 (d, *J* = 16 Hz, 1H), 5.00 (d, *J* = 7.0 Hz, 1H), 4.97 (d, *J* = 16 Hz, 1H), 4.80 (d, *J* = 16 Hz, 1H), 4.52 (d, *J* = 12 Hz, 1H), 4.51 (d, *J* = 13 Hz, 1H), 4.31 (d, *J* = 13 Hz, 1H), 4.29 (d, *J* = 12 Hz, 1H), 3.75 (s, 3H), 3.72 (s, 3H).

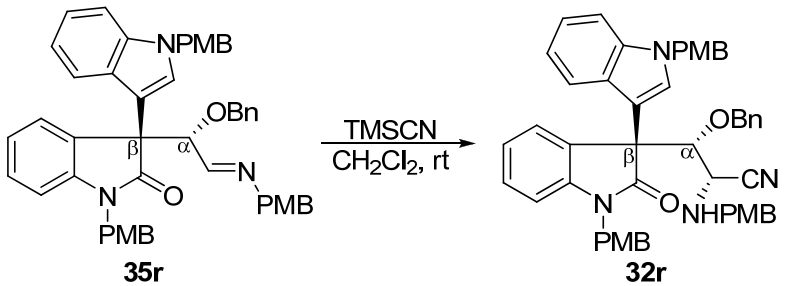
To a solution of 97.8 mg (0.135 mmol) of aldimine **35q** in 1.5 mL of CH_2Cl_2 at 0 °C was added 27.0 μL (20.1 mg, 0.203 mmol) of TMSCN dropwise. The mixture was allowed to warm to room temperature and stirred for 13 h. Then, 10 mL of satd $NaHCO_3$ solution was added, followed by extraction with EtOAc (3 x 30 mL). The combined organics were dried with anhydrous Na_2SO_4, and volatile material was removed under reduced pressure. Purification of the crude material using silica gel chromatrography (gradient, 6:1 to 3:1 pet. ether:EtOAc) afforded 88.1 mg (86%) of α-aminonitrile **32q** as a 8.9:1 mixture of diastereomers relative to C_α and C_β (The diastereomers are a result of the initial allene-hydrocarbonation. Other potential diastereomers that could form through attack of cyanide to the opposite π-face of the imine were not observed in the ^{1}H NMR spectrum.). The stereochemistry of the cyanide addition was assigned by analogy to the accepted model for the addition of TMSCN to α-chiral imines. A yellow solid. mp 58-67 °C. R_f = 0.18 (4:1 pet. ether:EtOAc). ^{1}H NMR (400 MHz, $CDCl_3$): δ 8.30 (m, 1H), 7.62 (d, *J* = 7.6 Hz, 1H), 6.68-7.36 (m, 21H), 6.63 (d, *J* = 8.8 Hz, 2H), 6.53 (d, *J* = 8.8 Hz, 2H), 5.43 (d, *J* = 2.0 Hz, 1H), 5.18 (d, *J* = 16 Hz, 1H), 5.10 (d, *J* = 16 Hz, 1H), 4.84 (d, *J* = 16 H, 1H), 4.76 (d, *J* = 16 Hz, 1H), 4.67 (d, *J* = 10 Hz, 1H), 4.16 (d, *J* =10, 1H), 4.04 (s, 1H), 3.70-3.85 (m,

1H), 3.75 (s, 3H), 3.72 (s, 3H), 3.66 (d, *J* = 13 Hz, 1H), 3.28 (d, *J* = 13 Hz, 1H). ^{13}CNMR (100 MHz, $CDCl_3$): δ 175.9, 159.0, 158.5, 142.7, 137.5, 137.2, 135.7, 130.9, 130.2, 129.2, 128.8, 128.6, 128.3, 128.2, 128.0, 127.8, 127.7, 127.4, 127.3, 127,0, 126.6, 126.0, 122.4, 122.35, 120.0, 118.7, 114.1, 113.3, 112.3, 110.3, 109.4, 81.67, 56.04, 55.20, 52.87, 50.77, 49.47, 43.60. $[\alpha]_D^{23}$ = 137 (*c* = 0.30, $CHCl_3$).



34r **35r**

To a mixture of 764 mg (1.20 mmol) of aldehyde **34r** and 1.85 g of anhydrous $MgSO_4$ in 12 mL of Et_2O was added 157 μL (165 mg, 1.20 mmol) of $PMBNH_2$. The resultant mixture was allowed to stir at ambient temperature for 6 h. The reaction was then filtered, and volatile material was removed under reduced pressure to afford 866 mg (95%) of aldimine **35r** as a 7:1 mixture of diastereomers relative to C_α and C_β (the diastereomers are a result of the initial allene-hydrocarbonation). The stereochemistry of the cyanide addition was assigned by analogy to the accepted model for the addition of TMSCN to α-chiral imines.[18] Isolated as a yellow solid. mp 50-70 °C. ^{1}H NMR (400 MHz, $CDCl_3$): δ 8.02 (d, *J* = 6.4 Hz, 1H), 7.31 (t, *J* = 7.2 Hz, 2H), 6.68-7.22 (m, 21H), 6.57 (d, *J* = 8.8 Hz, 2H), 5.09 (d, *J* = 16 Hz, 1H), 5.02 (d, *J* = 16 Hz, 1H), 4.98 (d, *J* = 6.4 Hz, 1H), 4.95 (d, *J* = 16 Hz, 1H), 4.72 (d, *J* = 16 Hz, 1H), 4.52 (d, *J* = 12 Hz, 1H), 4.51 (d, *J* = 13 Hz, 1H), 4.31 (d, *J* = 13 Hz, 1H), 4.28 (d, *J* = 12 Hz, 1H), 3.75 (s, 3H), 3.72 (s, 3H), 3.68 (s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$): δ 176.1, 162.7, 158.8, 158.7, 158.4, 143.1, 137.4, 136.7, 131.3, 130.7, 129.2, 129.0, 128.5, 128.4, 128.0, 127.9, 127.8, 127.7, 127.5, 127.3, 126.2, 124.5, 122.4, 121.8, 120.6, 119.5, 113.9, 113.8, 113.7, 110.6, 109.9, 108.9, 83.14, 77.21, 71.96, 64.11, 56.03, 55.11, 55.06, 49.41, 43.17. FTIR (thin film): 3029 (m), 3000 (m), 2931 (m), 2833 (m), 1712 (s), 1610 (s), 1585 (m), 1512 (s), 1486 (m), 1464 (s), 1440 (m), 1355 (m), 1301 (m), 1247 (s), 1176 (s), 1107 (m) cm^{-1}. $[\alpha]_D^{23}$ = - 25.4 (*c* = 0.42, $CHCl_3$).

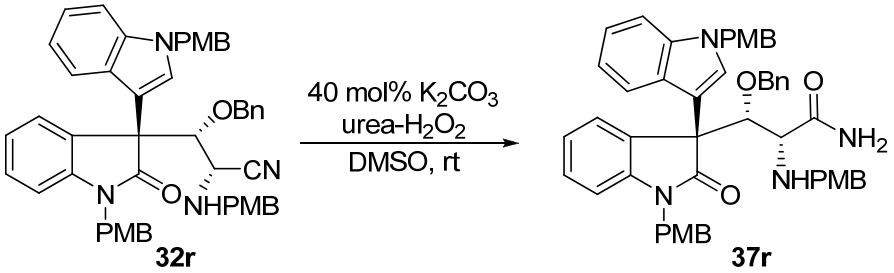


35r **32r**

To a solution of 685 mg (0.906 mmol) of aldimine **35r** in 10 mL of CH_2Cl_2 at 0 °C was added 242 μL (0.180 g, 1.81 mmol) of TMSCN dropwise. The mixture was allowed to warm to room temperature and stirred for 15 h. Then, 30 mL of satd $NaHCO_3$ solution was added, followed by extraction with EtOAc (3 x 30 mL).

[18] (a) Cativiela, C.; de Villegas, M. D.; Galvez, J. *Tetrahedron* **1996**, *52*, 9563. (b) Cainelli, G.; Giacomini, D.; Trere, A.; Galletti, P. *Tetrahedron Asymm.* **1995**, *6*, 1593.

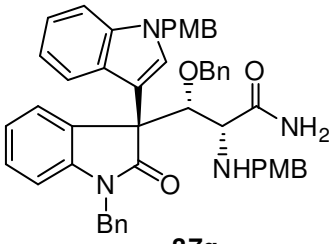
The combined organics were dried with anhydrous Na_2SO_4, and volatile material was removed under reduced pressure. Purification of the crude material by silica gel chromatography (gradient, 6:1 to 2:1 pet. ether:EtOAc) afforded 644 mg (91%) of α-aminonitrile **32r** as a 9:1 mixture of diastereomers relative to C_α and C_β (The diastereomers are a result of the initial allene-hydrocarbonation. Other potential diastereomers that could form through attack of cyanide to the opposite π-face of the imine were not observed in the ^{1}H NMR spectrum.). The stereochemistry of the cyanide addition was assigned by analogy to the accepted model for the addition of TMSCN to α-chiral imines.[18] Isolated as a yellow solid. mp 60-80 °C. R_f = 0.20 (3:1 pet. ether:EtOAc). ^{1}H NMR: δ 8.30 (m, 1H), 7.63 (d, *J* = 7.2 Hz, 1H), 6.45-7.36 (m, 24H), 5.43 (s, 1H), 5.17 (d, *J* = 16 Hz, 1H), 5.10 (d, *J* = 16 Hz, 1H), 4.80 (d, *J* = 16 H, 1H), 4.68 (d, *J* = 16 Hz, 1H), 4.67 (d, *J* = 10 Hz, 1H), 4.17 (d, *J* =10, 1H), 4.04 (s, 1H), 3.75 (s, 3H), 3.72 (s, 3H), 3.67 (d, *J* = 12 Hz, 1H), 3.60 (s, 3H), 3.25 (d, *J* = 12 Hz, 1H). ^{13}C NMR: δ 175.9, 159.0, 158.8, 158.5, 142.7, 137.5, 137.1, 131.0, 130.2, 129.2, 128.6, 128.5, 128.4, 128.2, 127.8, 127.7, 127.64, 127.57, 126.5, 126.0, 122.4, 122.3, 120.0, 118.8, 114.1, 113.9, 113.6, 113.2, 112.3, 110.3, 109.5, 81.69, 76.75, 56.00, 55.17, 55.05, 52.88, 50.72, 49.44, 43.06. FTIR (thin film): 3005 (m), 2928 (m), 2833 (m), 1702 (s), 1610 (s), 1512 (s), 1485 (m), 1463 (s), 1354 (m), 1301 (m), 1247 (s), 1176 (s) 1106 (m) cm^{-1}. $[\alpha]_D^{25}$ = 141 (*c* = 0.49, $CHCl_3$).



An oven dried 20 mL scintillation vial containing a magnetic stir bar was charged with 449 mg (0.573 mmol) of nitrile **32r**, 324 mg (3.44 mmol) of urea hydrogen peroxide complex, and 31.7 mg (0.229 mmol) of K_2CO_3. The vial was then put under a N_2 atmosphere using vacuum/purge cycles (3x). To this mixture was added 4.5 mL of DMSO, and the vial was quickly sealed with a cap and allowed to stir at room temperature for 19 h. The reaction was then quenched at 0 °C with 2 mL of satd $Na_2S_2O_3$ followed by the addition of 20 mL of satd $NaHCO_3$ solution. The resultant mixture was extracted with EtOAc (3 x 25 mL), and the combined organics were washed with water (2 x 25 mL), brine (1 x 15 mL), and dried with anhydrous Na_2SO_4. Removal of volatile material under reduced pressure, and silica gel chromatography (gradient, 1:0 to 2:1 CH_2Cl_2:acetone) of the crude mixture allowed for separation of the diastereomers (resulting from the initial allene-hydrocarbonation) giving 31.9 mg of the minor diastereomer [R_f = 0.33 (10:1 CH_2Cl_2:acetone)] and 354 mg of the major diastereomer (**37r**) [R_f = 0.20 (10:1 CH_2Cl_2:acetone)] as white solids (combined yield = 84%).

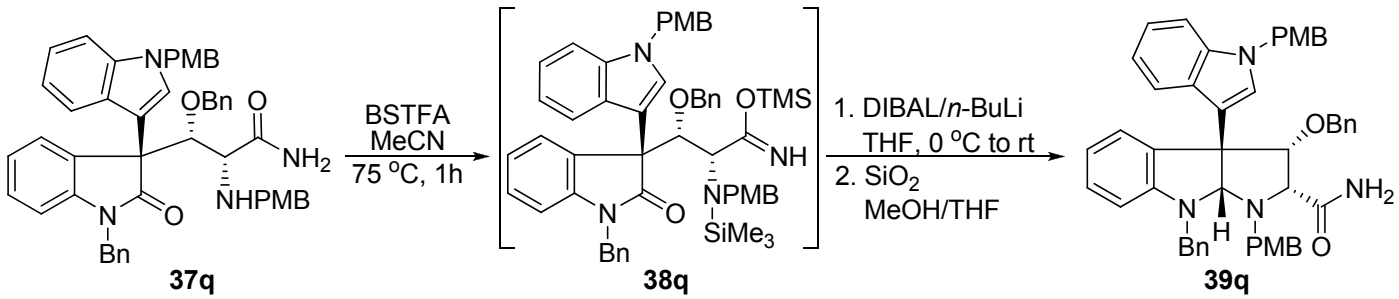
Data for major diastereomer (**37r**): mp 111-120 °C. ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.96 (d, *J* = 8.0 Hz, 1H), 7.77 (br d, *J* = 5.2 Hz, 1H), 7.60 (d, *J* = 7.6 Hz, 1H), 6.65-7.25 (m, 22H), 6.60 (d, *J* = 8.8 Hz, 2H), 5.53 (s, 1H), 5.44 (br d, *J* = 5.2 Hz, 1H), 5.15 (s, 2H), 5.03 (d, *J* = 16 Hz, 1H), 4.75 (d, *J* = 16 Hz, 1H), 4.46 (d, *J* = 11 Hz, 1H), 4.05 (d, *J* = 11 Hz, 1H), 3.73 (s, 3H), 3.69 (s, 3H), 3.67 (s, 3H), 3.38 (s, 1H), 3.00 (s, 2H). ^{13}C NMR (100 MHz, $CDCl_3$): δ 177.4, 176.4, 158.93, 158.88, 158.4, 142.8, 137.7, 137.2, 132.1, 129.3, 128.8, 128.1, 128.0, 127.9, 127.8, 127.6, 127.3, 126.2, 125.1, 122.7, 122.1, 121.8, 119.9, 114.04, 113.96, 113.5, 112.4, 110.0, 109.3, 82.98, 77.20, 75.18, 63.29, 57.99, 55.14, 52.80, 49.51, 43.38. FTIR (thin film): 3421 (br m), 3315 (br m), 3056 (m), 3003 (m), 2930 (m), 2834 (m), 1699 (s), 1680 (s), 1609 (s), 1512 (s), 1485 (m), 1464 (s), 1439 (m), 1354 (m), 1301 (m), 1247 (s), 1176 (s), 1105 (m) cm^{-1}. HRMS (ESI+) Calc'd for $C_{50}H_{48}N_4O_6$ $[M + H]^+$: 801.3647, found: 801.3641. $[\alpha]_D^{24}$ = -24.2 (*c* = 1.0, $CHCl_3$).

Data for minor diastereomer (all *syn*): mp 135-148 °C. ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.80 (s, 1H), 7.46 (d, *J* = 7.2 Hz, 1H), 7.42 (br d, *J* = 5.2 Hz, 1H), 6.62-7.25 (m, 22H), 6.54 (d, *J* = 8.8 Hz, 2H), 5.51 (br d, *J* = 5.2Hz, 1H), 5.22 (s, 2H), 5.13 (s, 1H), 4.85 (d, *J* = 15 Hz, 1H), 4.83 (d, *J* = 15 Hz, 1H), 4.69 (d, *J* = 11 Hz, 1H), 4.53 (d, *J* = 11 Hz, 1H), 3.92 (s, 1H), 3.75 (s, 3H), 3.72 (s, 3H), 3.67 (s, 3H), 3.50 (d, *J* = 12Hz, 1H), 3.44 (d, *J* = 12 Hz, 1H). ^{13}C NMR (100 MHz, $CDCl_3$): δ 177.9, 177.1, 159.0, 158.7, 158.6, 143.5, 137.8, 136.8, 131.6, 130.0, 129.6, 129.3, 129.1, 128.7, 128.4, 128.3, 128.2, 127.7, 127.5, 127.4, 126.6, 125.9, 121.9, 121.8, 121.1, 119.4, 114.0, 113.9, 113.7, 110.6, 110.1, 109.3, 82.48, 74.58, 61.31, 57.73, 55.20, 55.14, 52.54, 51.80, 49.95, 43.41. FTIR (thin film): 3427 (br m), 3045 (m), 2930 (m), 2836 (m), 1710 (s), 1683 (s), 1611 (s), 1513 (s), 1487 (m), 1465 (s), 1441 (m), 1353 (m), 1302 (m), 1248 (s), 1209 (m), 1177 (s), 1108 (m) cm^{-1}. $[\alpha]_D^{24}$ = - 10.0 (*c* = 0.67, $CHCl_3$, 28% ee).



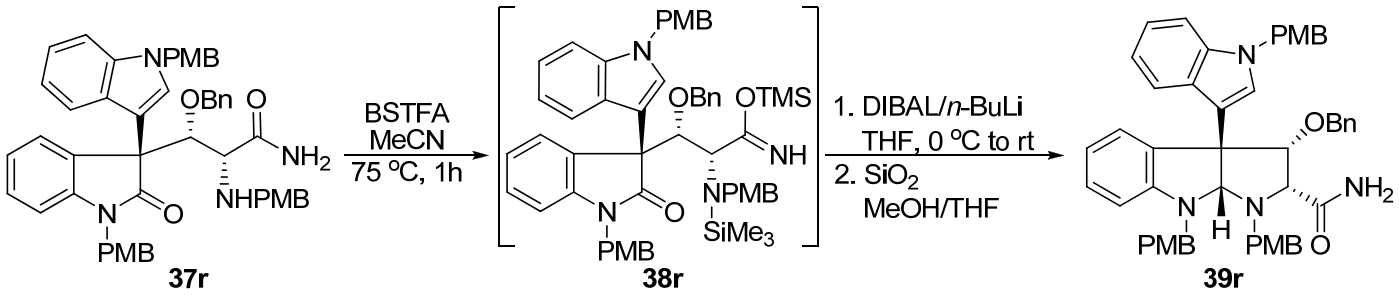
37q

Prepared as above using 67.3 mg (0.0894 mmol) of nitrile **32q**. Purification of the crude material using silica gel chromatrography (gradient, 1:0 to 2:1 CH_2Cl_2:acetone) afforded 6.8 mg of the minor diastereomer [R_f = 0.41 (9:1 CH_2Cl_2:acetone)] and 51.9 mg of the major diastereomer (**37q**) [R_f = 0.29 (9:1 CH_2Cl_2:acetone)] as white solids (combined yield = 85%). Data for major diastereomer (**37q**): mp 75-86 °C. ^{1}H NMR (400 MHz, $CDCl_3$): δ 8.00 (d, *J* = 8.8 Hz, 1H), 7.83 (br d, *J* = 4.4 Hz, 1H), 7.62 (d, *J* = 7.2 Hz, 1H), 6.64-7.32 (m, 25H), 5.83 (br d, *J* = 4.4 Hz, 1H), 5.57 (s, 1H), 5.16 (s, 2H), 5.08 (d, *J* = 16 H, 1H), 4.86 (d, *J* = 16 Hz, 1H), 4.49 (d, *J* = 11 Hz, 1H), 4.08 (d, *J* =11, 1H), 3.74 (s, 3H), 3.69 (s, 3H), 3.39 (s, 1H), 3.03 (d, *J* = 12 Hz, 1H), 2.95 (d, *J* = 12 Hz, 1H). ^{13}C NMR (100 MHz, $CDCl_3$): δ 177.4, 176.5, 158.9, 158.3, 142.7, 137.7, 137.1, 135.6, 132.0, 131.9, 129.2, 128.6, 128.1, 128.0, 127.9, 127.8, 127.6, 127.43, 127.40, 127.3, 126.1, 125.1, 122.8, 122.1, 121.8, 119.9, 114.0, 113.5, 112.4, 110.0, 109.3, 82.84, 77.20, 75.16, 63.26, 58.00, 55.13, 52.77, 49.50, 43.92. FTIR (thin film): 3412 (br m), 3307 (br m), 3029 (m), 2931 (m), 2833 (m), 1703 (s), 1675 (s), 1609 (s), 1512 (s), 1485 (m), 1464 (s), 1356 (m), 1301 (m), 1247 (s), 1174 (s) cm^{-1}. HRMS (ESI+) Calc'd for $C_{49}H_{46}N_4O_5$ $[M + H]^+$: 771.3541, found: 771.3536. $[\alpha]_D^{23}$ = -24.6 (*c* = 0.38, $CHCl_3$). Data for minor diastereomer: ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.78 (s, 1H), 7.50 (d, *J* = 7.6 Hz, 1H), 7.41 (br d, *J* = 4.8 Hz, 1H), 6.60-7.30 (m, 25H), 5.34 (br d, *J* = 4.8 Hz, 1H), 5.22(s, 2H), 5.11 (s, 1H), 4.92 (d, *J* = 16 H, 1H), 4.87 (d, *J* = 16 Hz, 1H), 4.67 (d, *J* = 11 Hz, 1H), 4.52 (d, *J* =11, 1H), 3.91 (s, 1H), 3.75 (s, 3H), 3.72 (s, 3H), 3.48 (d, *J* = 12 Hz, 1H), 3.42 (d, *J* = 12 Hz, 1H). ^{13}C NMR (100 MHz, $CDCl_3$): δ 177.8, 177.2, 159.0, 158.6, 143.4, 137.8, 136.9, 135.6, 131.6, 130.1, 129.7, 129.3, 129.1, 128.7, 128.6, 128.3, 128.2, 127.8, 127.5, 127.3, 127.1, 126.7, 126.0, 122.0, 121.8, 121.2, 119.5, 114.1, 113.8, 110.6, 110.1, 109.3, 82.54, 77.20, 74.67, 61.32, 57.76, 55.23, 52.58, 49.98, 44.00. FTIR (thin film): 3431 (br m), 3030 (m), 2929 (m), 2836 (m), 1712 (s), 1683 (s), 1611 (s), 1513 (s), 1488 (m), 1465 (s), 1353 (m), 1302 (m), 1248 (s) cm^{-1}. $[\alpha]_D^{22}$ = - 0.7 (*c* = 0.53, $CHCl_3$, 29% ee).



To a solution of 24.5 mg (0.0318 mmol) of amide **37q** in 1.06 mL of MeCN in a 20 mL scintillation vial containing a magnetic stir bar, under N_2, was added 0.0845 mL (81.9 mg, 0.318 mmol) of bis(trimethylsilyl)trifluoroacetamide. The vial was sealed, and immersed in an oil bath at 75 ^oC and heated for 1 h. Volatile material was then removed under reduced pressure. ^{1}HNMR (400 MHz, C_6D_6) data for crude **38q**: δ 8.48 (d, *J* = 8.0 Hz, 1H), 8.08 (s, 1H), 7.66 (d, *J* = 7.2 Hz, 1H), 7.42 (s, 1H), 7.28 (td, *J* = 8.4 Hz, *J* = 1.2 Hz, 1H), 6.90-7.20 (m, 12H), 7.05 (d, *J* = 8.8 Hz, 2H), 6.87 (d, *J* = 7.6 Hz, 1H), 6.82 (td, *J* = 8.0 Hz, *J* = 1.2 Hz, 1H), 6.74 (d, *J* = 8.8 Hz, 2H), 6.68 (d, *J* = 8.8 Hz, 2H), 6.53 (d, *J* = 8.8 Hz, 2H), 6.42 (d, *J* = 7.6 Hz, 1H), 6.02 (s, 1H), 4.98 (d, *J* = 16 Hz, 1H), 4.79 (d, *J* = 11 Hz, 1H), 4.64 (d, *J* = 16 Hz, 1H), 4.57 (d, *J* = 16 Hz, 1H), 4.52 (d, *J* = 16 Hz, 1H), 4.31 (d, *J* = 11 Hz, 1H), 3.88 (s, 1H), 3.47 (m, 1H), 3.26 (s, 3H), 3.18 (s, 3H), 3.08 (dd, *J* = 12 Hz, *J* = 9.2 Hz, 1H), 0.23 (s, 9H), -0.063 (s, 9H).

After subjecting this crude material to high vacuum (~1 torr) for at least 2 h, the material was dissolved in 0.55 mL of THF, under N_2, and cooled to 0 ^oC. To this mixture was then added 0.48 mL (0.19 mmol) of a 0.4 M solution of a 1:1 mixture of DIBAL and *n*-BuLi [This mixture was prepared as follows: To 0.23 mL (0.23 mmol) of a 1.0 M toluene solution of DIBAL in 0.25 mL of THF at -78 ^oC was added 0.10 mL (0.23 mmol) of a 2.3 M *n*-BuLi solution in hexane dropwise. The mixture was stirred for 5 min at -78 ^oC and then allowed to warm to 0 ^oC. The mixture was then stirred at this temperature for 20 min before use.] dropwise over a 1 min period (gas evolution observed). After addition, the reaction was allowed to warm to room temperature and allowed to stir for 18 h. The reduction was quenched with 0.6 mL of MeOH, and after stirring for 5 min, 1 mL of brine and 1 mL of water was added. The reaction mixture was extracted with EtOAc (3 x). Combined organics were dried with anhydrous Na_2SO_4, and volatile material was removed under reduced pressure. The resultant crude residue was then diluted with 1.58 mL of a 4:1 mixture of MeOH:THF and 402 mg of silica gel was added. This mixture was allowed to stir at room temperature for 16 h and was then filtered through celite using EtOAc. Removal of volatile material under reduced pressure, and purification of the residue by silica gel chromatography (gradient, 10:1 to 4:1 CH_2Cl_2:Et_2O) afforded 20.5 mg (85%) of the reductively cyclized product (**39q**) as a white solid. mp 84-94 ^oC. R_f = 0.36 (7:1 CH_2Cl_2:Et_2O). ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.29 (d, *J* = 8.0 Hz, 1H), 6.91-7.23 (m, 16H), 6.85 (d, *J* = 8.4 Hz, 2H), 6.79-6.84 (m, 2H), 6.70 (d, *J* = 8.8 Hz, 2H), 6.64 (br d, *J* = 3.8 Hz, 1H), 6.55 (d, *J* = 8.4 Hz, 2H), 6.53 (t, *J* = 8.0 Hz, 1H), 6.14 (d, *J* = 8.0 Hz, 1H), 5.56 (s, 1H), 5.23 (d, *J* = 15 Hz, 1H), 5.12 (d, *J* = 15 Hz, 1H), 5.10 (br d, *J* = 3.8 Hz, 1H), 4.91 (d, *J* = 5.2 Hz, 1H), 4.39 (d, *J* = 9.6 Hz, 1H), 4.22 (d, *J* = 17 Hz, 1H), 4.17 (d, *J* = 9.6 Hz, 1H), 4.14 (d, *J* = 5.2 Hz, 1H), 3.83 (d, *J* = 17 Hz, 1H), 3.77 (s, 3H), 3.74 (s, 3H), 3.65 (d, *J* = 13 Hz, 1H), 3.46 (d, *J* = 13 Hz, 1H). ^{13}CNMR (100 MHz, $CDCl_3$): δ 174.1, 159.4, 159.1, 151.3, 139.6, 137.9, 137.8, 130.9, 129.7, 129.42, 129.38, 128.6, 128.3, 128.2, 127.8, 127.3, 126.9, 126.5, 125.5, 124.6, 122.0, 121.1, 119.3, 116.7, 114.7, 114.4, 113.7, 110.0, 105.5, 96.04, 86.64, 77.19, 75.32, 73.87, 60.87, 58.76, 55.31, 55.19, 49.58, 49.25. FTIR (thin film): 3467 (br m), 3340 (br m), 3056 (m), 3024 (m), 2924 (m), 2833 (m), 1684 (s), 1609 (s), 1511 (s), 1491 (s), 1463 (m), 1452 (m), 1354 (m), 1301 (m), 1247 (s), 1176 (s), 1102 (s) cm^{-1}. HRMS (ESI+) Calc'd for $C_{49}H_{46}N_4O_4$ $[M + H]^+$: 755.3592, found: 755.390. $[\alpha]_D^{24}$ = -14.6 (*c* = 1.0, $CHCl_3$).



37r **38r** **39r**

To a solution of 188 mg (0.235 mmol) of amide **37r** in 6.4 mL of MeCN in a 20 mL scintillation vial containing a magnetic stir bar, under N_2, was added 0.62 mL (0.60 g, 2.3 mmol) of bis(trimethylsilyl)trifluoroacetamide. The vial was sealed, and immersed in an oil bath at 75 °C and heated for 1 h. Volatile material was then removed under reduced pressure. After subjecting the crude material to high vacuum (~1 torr) for at least 2 h, the material was dissolved in 3.9 mL of THF, under N_2, and cooled to 0 °C. To this mixture was then added 3.5 mL (1.4 mmol) of a 0.4 M solution of a 1:1 mixture of DIBAL and *n*-BuLi [This mixture was prepared as follows: To 1.6 mL (1.6 mmol) of a 1.0 M toluene solution of DIBAL in 1.73 mL of THF at -78 °C was added 0.67 mL (1.6 mmol) of a 2.4 M *n*-BuLi solution in hexane dropwise. The mixture was stirred for 5 min at -78 °C and then allowed to warm to 0 °C. The mixture was then stirred at this temperature for 20 min before use.] dropwise over a 1 min period (gas evolution observed). After addition, the reaction was allowed to warm to room temperature and allowed to stir for 14 h. The reduction was quenched with 2 mL of MeOH, and after stirring for 5 min, 10 mL of brine and 10 mL of water was added. The reaction mixture was extracted with EtOAc (3 x). Combined organics were dried with anhydrous Na_2SO_4, and volatile material was removed under reduced pressure. The resultant crude residue was then diluted with 10 mL of a 4:1 mixture of MeOH:THF and 2.99 g of silica gel was added. This mixture was allowed to stir at room temperature for 3 h and was then filtered through celite using EtOAc. Removal of volatile material under reduced pressure, and purification of the residue by silica gel chromatography (gradient, 10:1 to 2:1 CH_2Cl_2:Et_2O) afforded 130 mg (71%) of the reductively cyclized product (**39r**) as a white solid. mp 128-134 °C. R_f = 0.26 (4:1 CH_2Cl_2:Et_2O). ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.30 (d, *J* = 8.0 Hz, 1H), 7.13-7.21 (m, 5H), 7.02-7.12 (m, 5H), 6.94-7.00 (m, 3H), 6.86 (d, *J* = 9.2 Hz, 2H), 6.80-6.85 (m, 2H), 6.73 (d, *J* = 8.8 Hz, 2H), 6.69 (br d, *J* = 4.0 Hz, 1H), 6.58 (d, *J* = 8.4 Hz, 2H), 6.52 (td, *J* = 7.6 Hz, *J* = 0.8 Hz, 1H), 6.45 (d, *J* = 8.4 Hz, 2H), 6.14 (d, *J* = 8.0 Hz, 1H), 5.56 (s, 1H), 5.24 (d, *J* = 16 Hz, 1H), 5.14 (br d, *J* = 4.0 Hz, 1H), 5.12 (d, *J* = 16 Hz, 1H), 4.92 (d, *J* = 5.2 Hz, 1H), 4.40 (d, *J* = 9.2 Hz, 1H), 4.17 (d, *J* = 9.2 Hz, 1H), 4.15 (d, *J* = 5.2 Hz, 1H), 4.14 (d, *J* = 16 Hz, 1H), 3.80 (d, *J* = 16 Hz, 1H), 3.77 (s, 3H), 3.74 (s, 3H), 3.70 (s, 3H), 3.67 (d, *J* = 13 Hz, 1H), 3.48 (d, *J* = 13 Hz, 1H). ^{13}CNMR (100 MHz, $CDCl_3$): δ 174.2, 159.2, 158.9, 158.1, 151.0, 137.7, 137.5, 131.1, 130.8, 129.6, 129.2, 128.8, 128.5, 128.3, 127.83, 127.80, 127.3, 126.7, 125.3, 124.4, 121.9, 121.0, 119.1, 116.4, 114.4, 114.2, 113.5, 113.4, 109.9, 105.3, 95.72, 86.57, 77.20, 75.31, 73.85, 60.71, 58.72, 55.23, 55.12, 49.44, 48.02. FTIR (thin film): 3442 (br m), 3356 (br m), 3027 (m), 3001 (m), 2930 (m), 2834 (m), 1683 (s), 1609 (s), 1511 (s), 1489 (m), 1463 (s), 1440 (m), 1354 (m), 1301 (m), 1247 (s), 1175 (s), 1104 (m) cm^{-1}. HRMS (ESI+) Calcd for $C_{50}H_{48}N_4O_5$ $[M + H]^+$: 785.3703, found: 785.3699. $[\alpha]_D^{24}$ = -16.4 (*c* = 1.0, $CHCl_3$).