Supporting Information for *Synthesis of a New Chiral Nonracemic C₂-Symmetric 2,2'-Bipyridyl Ligand and Its Application in Copper(I)-Catalyzed Enantioselective Cyclopropanation Reactions*

Michael P. A. Lyle and Peter D. Wilson*

*Department of Chemistry, Simon Fraser University, 8888 University Drive,
Burnaby, British Columbia, Canada V5A 1S6*

1. General Experimental Details

All non-aqueous reactions were performed under an atmosphere of dry nitrogen in oven- or flame-dried glassware, unless indicated otherwise. The reaction temperatures stated were those of the external bath. Diethyl ether (ether) and tetrahydrofuran (THF) were dried over sodium/benzophenone ketyl and distilled under an atmosphere of dry nitrogen immediately prior to use. Benzene and dichloromethane were dried over calcium hydride and distilled under an atmosphere of dry nitrogen immediately prior to use. All other solvents and reagents were purified by standard techniques or used as supplied.¹ Brine refers to a saturated aqueous solution of sodium chloride. Silica gel column chromatography ("flash chromatography") was carried out using Merck silica gel 60 (230 to 400 mesh).² Melting points were measured on a Gallenkamp capillary melting point apparatus and are uncorrected. Optical rotations were recorded on a Perkin Elmer 341 polarimeter. All proton and carbon nuclear magnetic resonance spectra (¹H and ¹³C NMR, respectively) were recorded using a Bruker AMX 400 FT spectrometer (operating frequencies: ¹H, 400.13 MHz; ¹³C, 100.61 MHz) at ambient temperature unless stated otherwise. Chemical shifts (δ) for all compounds are listed in parts per million downfield from tetramethylsilane using the NMR solvent as an internal reference. The reference values used for deuterated chloroform (CDCl₃) were 7.26 and 77.16 ppm for ¹H and ¹³C NMR spectra, respectively. The reference values used for deuterated benzene (C₆D₆) were 7.15 and

(1) Armarego, W. L. F.; Perrin, D. D. *Purification of Laboratory Chemicals*, 4th ed.; Oxford: Butterworth-Heinemann, 1997.

(2) Still, W. C.; Kahn, M.; Mitra, A. *J. Org. Chem.* **1978**, *43*, 2923.

128.02 ppm, respectively. Infrared spectra (IR) were recorded as either KBr pellets (KBr), evaporated films (ef) or as films (neat) using a Perkin Elmer 599B IR spectrophotometer. Low-resolution mass spectra (MS) were recorded on a Hewlett Packard 5985 GC-mass spectrometer. The mode of ionization used was chemical ionization (CI) with isobutene. High-resolution mass spectra using fast atom bombardment (FAB HRMS) were recorded on a Kratos Concept IH mass spectrometer. Microanalyses were performed on a Carlo Erba Model 1106 CHN analyzer. Analytical chiral high performance liquid chromatography (HPLC) was performed on a Hewlett Packard Series 1050 instrument.

2. Experimental Procedures

4-Methyl-6,7-dihydro-5H-[1]pyrindine-2-ol (2).³ A mixture of cyclopentanone (25.2 g, 300 mmol), ethyl acetoacetate (39.0 g, 300 mmol) and ammonium acetate (23.1 g, 300 mmol) was heated at reflux for 8 h. The reaction mixture was then allowed to cool to room temperature and following dilution with ether (25 mL) was allowed to stand overnight during which time the product precipitated from the reaction mixture. The product was isolated by filtration, washed with ether (50 mL) and recrystallized from ethanol (100 mL) to afford the *title compound 2* (10.2 g, 23%) as a yellow crystalline solid. **M.p.** 243-244 °C, ethanol (lit.³ 243-244 °C, ethanol); **¹H NMR** (CDCl₃) δ 2.05-2.15 (5H, m, CH₂ and CH₃), 2.66 (2H, apparent t, J = 7.0 Hz, ArCH₂), 2.92 (2H, apparent t, J = 7.6 Hz, ArCH₂), 6.22 (1H, s, ArH); **¹³C NMR** (CDCl₃) δ 19.98, 22.70, 28.72, 31.45, 115.46, 121.19, 148.97, 151.40, 166.28; **IR** (KBr) 2912 (broad), 1653, 1621, 1578, 1447, 1425, 1371, 1327, 1221, 933, 901, 860 cm⁻¹; **MS** (CI) m/z (rel. intensity) 150 (M + H, 100).

(3) Sakurai, A.; Midorikawa, H. *Bull. Chem. Soc. Jpn.* **1968**, *41*, 165.

2-Chloro-4-methyl-6,7-dihydro-5H-[1]pyrindine (3).^{4,5} To phenylphosphonic dichloride (1.00 mL, 7.08 mmol) was added the pyridine-2-ol **2** (500 mg, 3.36 mmol) and the resultant mixture was heated in an oil bath at 160 °C for 16 h. The reaction mixture was then allowed to cool to room temperature and water (~5 mL) was added dropwise (*CAUTION*). The acidic reaction mixture was then diluted with an additional quantity of water (50 mL), neutralized by the careful addition of potassium carbonate (~1.0 g) and extracted with chloroform (3 x 30 mL). The combined organic extracts were washed with water (2 x 20 mL), dried over anhydrous magnesium sulfate and concentrated *in vacuo* to afford the crude product as a dark brown oil. Flash chromatography using chloroform as the eluant afforded the *title compound 3* (465 mg, 83%) as a white crystalline solid. **M.p.** 41-42 °C, chloroform; **¹H NMR** (CDCl₃) δ 2.12 (2H, m, CH₂), 2.22 (3H, s, CH₃), 2.81 (2H, apparent t, *J* = 7.9 Hz, ArCH₂), 2.98 (2H, apparent t, *J* = 8.3 Hz, ArCH₂), 6.90 (1H, s, ArH); **¹³C NMR** (CDCl₃) δ 20.09, 22.67, 28.69, 31.40, 115.26, 121.61, 149.03, 151.66, 166.05; **IR** (KBr) 1654, 1621, 1578, 1425, 1327 cm⁻¹; **MS** (CI) *m/z* (rel. intensity) 168 (M + H, 100); **Anal.** Calcd. for C₉H₁₀ClN: C, 64.48; H, 6.01; N, 8.36; Found: C, 64.29; H, 5.92; N, 8.30.

7(RS)-7-Acetoxy-2-chloro-4-methyl-6,7-dihydro-5H-[1]pyrindine (4).^{4,5} To a stirred solution of the chloropyridine **3** (3.00 g, 17.9 mmol) in glacial acetic acid (25 mL) was added an aqueous solution of hydrogen peroxide (30% w/w, 8.60 mL, 75.9 mmol) and the resultant mixture was heated at 80 °C for 16 h. The reaction mixture was then allowed to cool to room temperature and following concentration *in vacuo* was diluted with water (100 mL). The slightly acidic solution was neutralized by the careful addition of potassium carbonate (~1.0 g) and then extracted with chloroform (3 x 30 mL). The combined organic extracts were washed with water (3 x 15 mL),

(4) Rios, R.; Liang, J.; Lo, M. M.-C.; Fu, G. C. *Chem. Commun.* **2000**, 377.

(5) Robison, M. M. *J. Am. Chem. Soc.* **1958**, 80, 6254.

dried over anhydrous magnesium sulfate and concentrated *in vacuo* to afford the corresponding pyridine *N*-oxide (3.22 g, 98%) as a white crystalline solid. This material was taken up in acetic anhydride (25 mL) and the resultant suspension was stirred at room temperature for 1 h and then heated at 100 °C for 4 h. The reaction mixture was then allowed to cool to room temperature and was concentrated *in vacuo* to afford the crude product as a dark brown oil. Flash chromatography using hexanes:ether (1:1) as the eluant afforded the *title compound 4* (2.42 g, 60% over two-steps) as an orange oil. ¹H NMR (CDCl₃) δ 2.01-2.10 (4H, m, CH₃ and CHH), 2.27 (3H, s, OAc), 2.58-2.68 (1H, m, CHH), 2.76 (1H, ddd, *J* = 16.2, 8.9, 4.6 Hz, ArCHH), 2.94 (1H, ddd, *J* = 15.9, 8.9, 5.2 Hz, ArCHH), 6.00 (1H, dd, *J* = 7.6, 4.6 Hz, CHOAc), 7.06 (1H, s, ArH); ¹³C NMR (CDCl₃) δ 18.68, 21.11, 25.99, 28.17, 30.37, 124.40, 136.10, 147.06, 150.64, 159.94, 170.59; IR (neat) 2946, 1738, 1592, 1571, 1443, 1370, 1235, 1193, 1106, 1050, 890 cm⁻¹; MS (CI) *m/z* (rel. intensity) 226 (*M* + *H*, 100), 166 (38); Anal. Calcd. for C₁₁H₁₂ClNO₂: C, 58.54; H, 5.36; N, 6.21; Found: C, 58.79; H, 5.37; N, 6.11.

2-Chloro-4-methyl-5H-[1]pyrindine (5).^{4,5} A stirred solution of the acetate **4** (901 mg, 3.99 mmol) in concentrated sulfuric acid (1.5 mL) was heated at 120 °C for 10 min. The reaction mixture was then poured on to ice (~25 g), was neutralized with an aqueous solution of potassium hydroxide (40% w/v, 6 mL) and extracted with dichloromethane (3 x 25 mL). The combined organic extracts were washed with water (2 x 10 mL), dried over anhydrous magnesium sulfate and concentrated *in vacuo* to afford the crude product as a dark brown oil. Flash chromatography using hexanes:ether (1:1) as the eluant afforded the *title compound 5* (535 mg, 81%) as a colorless oil. ¹H NMR (CDCl₃) δ 2.36 (3H, s, CH₃), 3.29-3.32 (2H, m, ArCH₂), 6.91-6.98 (3H, m, 2 x vinylic-*H* and ArH); ¹³C NMR (CDCl₃) δ 35.50, 38.42, 120.14, 133.10, 134.55, 139.85, 144.05, 149.68, 163.88; IR (neat) 2919, 1595, 1576, 1550, 1430, 1375, 1333, 1261, 1179, 1116, 1032, 940, 892, 848 cm⁻¹; MS (CI) *m/z* (rel. intensity) 166 (*M* + *H*, 100). This material was used immediately in the subsequent dihydroxylation reactions.

(6*S*,7*R*)-2-Chloro-4-methyl-6,7-dihydro-5*H*-[1]pyrindine-6,7-diol 3-pentanone acetal [(+)-7].⁶

Method A: To a stirred solution of the chloropyridine **5** (101 mg, 0.604 mmol) in *t*-butanol:water (1:1, 6 mL) at 0 °C was added AD-mix- β^{TM} (840 mg) in one portion and the resultant orange suspension was stirred at 0 °C for 12 h. Sodium sulfite (300 mg) was then added to the reaction mixture. After an additional 30 min, brine (15 mL) was added and the reaction mixture was extracted with ethyl acetate (3 x 25 mL). The combined organic extracts were then washed with brine (10 mL), dried over anhydrous magnesium sulfate and concentrated *in vacuo* to afford the crude diol (+)-**6** as a light brown solid. This material was taken up in benzene (6 mL) and treated with 3-pentanone (0.078 mL, 0.752 mmol) and *p*-toluenesulfonic acid monohydrate (10.4 mg, 0.075 mmol). The resultant solution was then heated at reflux in a Dean-Stark trap for 16 h. The reaction mixture was then allowed to cool to room temperature and potassium carbonate (20 mg) was added. The reaction mixture was filtered, the filter-cake was washed with dichloromethane (10 mL) and the combined filtrates were concentrated *in vacuo* to afford the crude product as a dark brown oil. Flash chromatography using hexanes:ethyl acetate (2:1) as the eluant afforded the *title compound* (+)-**7** (92 mg, 57%, over two-steps) as a colorless oil which crystallized upon standing. The enantiomeric purity of this material was determined to be 90% ee by analytical chiral HPLC using a Daicel Chiracel OD column [hexanes:isopropanol (96:4), flow rate at 0.5 mL/min, detection at $\lambda = 220$ nm; $t_{\text{MAJOR}} = 18.99$ min, $t_{\text{MINOR}} = 23.10$ min]. The above procedure was also carried out using AD-mix- α^{TM} . The enantiomeric purity of the product of this reaction, following conversion to the acetal (-)-**7** (48% yield, over two-steps), was also determined by analytical chiral HPLC (82% ee). Acetal (+)-**7**: **M.p.** 43-44 °C; $[\alpha]_D^{20} + 80$ (c 0.5, chloroform); $^1\text{H NMR}$ (CDCl_3) δ 0.58 (3H, t, $J = 7.3$ Hz, CH_2CH_3), 0.94 (3H, t, $J = 7.6$ Hz, CH_2CH_3), 1.50 (2H, q, $J = 7.3$ Hz, CH_2CH_3), 1.68 (2H, q, $J = 7.6$ Hz, CH_2CH_3), 2.26 (3H, s, ArCH_3), 2.99-3.03 (2H, m, CH_2), 4.98-5.02 (1H, m, HCO), 5.41 (1H, d, $J = 5.8$ Hz, HCO), 7.06 (1H, s, ArH); $^{13}\text{C NMR}$ (CDCl_3) δ 7.72, 8.86, 18.96, 29.58,

(6) Kolb, H. C.; VanNieuwenhze, M. S.; Sharpless, K. B. *Chem. Rev.* **1994**, 94, 2483 and references therein.

30.21, 34.34, 77.67, 83.27, 115.85, 124.77, 132.98, 147.97, 151.58, 160.94; **IR** (KBr) 2973, 2939, 1748, 1717, 1589, 1570, 1463, 1442, 1377, 1314, 1286, 1267, 1191, 1169, 1131, 1104, 1084, 1011, 862 cm^{-1} ; **MS** (CI) m/z (rel. intensity) 269 ($M + H$, 100), 239 (48), 182 (97); **Anal.** Calcd. for $\text{C}_{14}\text{H}_{18}\text{ClNO}_2$: C, 62.80; H, 6.78; N, 5.23; Found: C, 62.65; H, 6.85; N, 5.35. **Method B:** To a suspension of potassium osmate dihydrate (2.8 mg, 0.0076 mmol, 1 mol %), $(\text{DHQD})_2\text{PHAL}$ (29.4 mg, 0.038 mmol, 5 mol %), potassium ferricyanide (746 mg, 2.27 mmol) and potassium carbonate (313 mg, 2.27 mmol) in *t*-butanol:water (1:1, 6 mL) at 0 °C was added the chloropyridine **5** (125 mg, 0.755 mmol). After 2 h, sodium sulfite (300 mg) was added to the reaction mixture and after an additional 30 min, brine (30 mL) was added. The reaction mixture was extracted with ethyl acetate (3 x 25 mL). The combined organic extracts were then washed with brine (10 mL), dried over anhydrous magnesium sulfate and concentrated *in vacuo* to afford the crude diol (+)-**6** as a light brown solid. This material was taken up in benzene (8 mL) and treated with 3-pentanone (0.100 mL, 0.94 mmol) and *p*-toluenesulfonic acid monohydrate (18 mg, 0.094 mmol). The resultant solution was then heated at reflux in a Dean-Stark trap for 16 h. The reaction mixture was then allowed to cool to room temperature and potassium carbonate (50 mg) was added. The reaction mixture was filtered, the filter-cake was washed with dichloromethane (10 mL) and the combined filtrates were concentrated *in vacuo* to afford the crude product as a dark brown oil. Flash chromatography using hexanes:ethyl acetate (2:1) as the eluant afforded the *title compound* (+)-**7** (164 mg, 81%) as a colorless oil which crystallized upon standing. $[\alpha]_D^{20} + 78$ (c 0.72, chloroform). The enantiomeric purity of this material was determined to be 90% ee by analytical chiral HPLC.

(6*S*,6'*S*,7*R*,7'*R*)-4,4'-Dimethyl-6,6',7,7'-tetrahydro-5*H*,5'*H*-(2,2')bi([1]pyrindinyl)-6,6',7,7'-tetraol 3-pentanone bis-acetal [(+)-1**].**⁷ To a stirred solution of nickel(II) chloride hexahydrate (135 mg, 0.570 mmol) and triphenylphosphine (597 mg, 2.27 mmol) in dry, degassed

(7) (a) Dehmlow, E. V.; Slegers, A. *Liebigs Ann. Chem.* **1992**, 953. (b) Iyoda, M.; Otsuka, H.; Sato, K.; Nisato, N.; Oda, M. *Bull. Chem. Soc. Jpn.* **1990**, 63, 80.

dimethylformamide (2 mL) was added zinc dust (<10 microns, 48.0 mg, 0.734 mmol) and the resultant suspension was heated at 60 °C for 1 h. A solution of the acetal (+)-**7** (150 mg, 0.560 mmol) in dry, degassed dimethylformamide (2 mL) was then added *via* cannula and resultant mixture was heated at 60 °C for 4 h. The reaction mixture was then allowed to cool to room temperature and was poured into an aqueous solution of ammonium hydroxide (10% w/w, 50 mL). The resultant mixture was extracted with dichloromethane (3 x 15 mL). The combined organic extracts were dried over anhydrous magnesium sulfate and concentrated *in vacuo* to afford the crude product. Flash chromatography using hexanes:ethyl acetate (2:1) afforded the *title compound* (+)-**1** (109 mg, 84%) as a white crystalline solid. The enantiomeric purity of this material was determined to be >99% ee by analytical chiral HPLC using a Daicel Chiracel OD column [hexanes:isopropanol (60:40), flow rate at 0.5 mL/min, detection at $\lambda = 220$ nm; $t = 23.59$ min]. The enantiomeric ligand (-)-**1** was also prepared from the acetal (-)-**7** (53% yield, unoptimized). The enantiomeric purity of this ligand was also determined to be >99% ee by analytical chiral HPLC using a Daicel Chiracel OD column [hexanes:isopropanol (60:40), flow rate at 0.5 mL/min, detection at $\lambda = 220$ nm; $t = 17.26$ min]. Ligand (+)-**1**: **M.p.** 220-221 °C, hexanes/ethyl acetate; $[\alpha]_D^{20} + 154$ (c 0.5, chloroform); $^1\text{H NMR}$ (CDCl_3) δ 0.58 (6H, t, $J = 7.6$ Hz, CH_2CH_3), 0.98 (6H, t, $J = 7.6$ Hz, CH_2CH_3), 1.47-1.55 (4H, m, CH_2CH_3), 1.73 (4H, q, $J = 7.6$ Hz, CH_2CH_3), 2.32 (6H, s, ArCH_3), 3.07-3.11 (4H, m, CH_2), 5.02-5.08 (2H, m, HCO), 5.53 (2H, d, $J = 5.8$ Hz, HCO), 8.30 (2H, s, ArH); $^{13}\text{C NMR}$ (CDCl_3) δ 7.76, 8.79, 18.97, 29.93, 30.45, 34.89, 77.98, 84.03, 115.71, 122.57, 134.13, 145.41, 157.06, 160.01; **IR** (KBr) 2971, 2937, 1746, 1591, 1463, 1434, 1376, 1307, 1202, 1168, 1135, 1080, 1060, 1009, 974, 932, 841, 730 cm^{-1} ; **MS** (CI) m/z (rel. intensity) 465 ($\text{M} + \text{H}$, 59) 123 (100); **FAB HRMS** Calcd. for $\text{C}_{28}\text{H}_{36}\text{N}_2\text{O}_4$: 464.2675; Found: 464.2675. **Anal.** Calcd. for $\text{C}_{28}\text{H}_{36}\text{N}_2\text{O}_4$: C, 72.39; H, 7.81; N, 6.03; Found: C, 72.28; H, 7.96; N, 5.77.

General Procedure for Copper(I)-Catalyzed Enantioselective Cyclopropanation of Alkenes.⁸

To a stirred solution of copper(II) triflate (9.00 mg, 0.025 mmol) in anhydrous dichloromethane (3 mL) was added ligand (+)-1 [or (-)-1] (13.9 mg, 0.030 mmol) and the resultant solution was stirred at room temperature for 30 min. Phenylhydrazine (3.0 μ L, 0.030 mmol) and the alkene **8a-e** (styrene, *p*-methoxystyrene, *p*-fluorostyrene, 4-phenyl-1-butene or 1,1-diphenylethene, 4.37 mmol) were then added. A solution of the diazoester **9a-c** (ethyl, benzyl or *t*-butyl diazoacetate, 2.00 mmol) in anhydrous dichloromethane (3 mL) was then added over the course of ~3 h *via* a syringe pump. After the addition was complete, the reaction was stirred for an additional 12 h. The reaction mixture was then concentrated *in vacuo* to afford the crude product. The ratios of the *trans*- and *cis*-isomers of the cyclopropane reaction products **10a-g** were then determined by ¹H NMR spectroscopy. Flash chromatography using petroleum ether:ethyl acetate (96:4) as the eluant afforded the pure *trans*-cyclopropanes **10a-g** and the corresponding *cis*-cyclopropanes. The enantiomeric purities of the major *trans*-isomers of the cyclopropane reaction products **10a-g** were determined following reduction with lithium aluminum hydride.

(1*R*,2*R*)-trans-2-Phenyl-cyclopropane-1-carboxylic acid ethyl ester (10a).⁹ Combined yield of *trans*- and *cis*-isomers (282 mg, 74%, 82:18) as colorless oils. [α]_D²⁰ - 231 (c 0.94, chloroform); ¹H NMR (CDCl₃) δ 1.25-1.34 (4H, m, CH₃ and CHH), 1.56-1.63 (1H, m, CHH), 1.87-1.93 (1H, m, CHCO₂Et), 2.52 (1H, ddd, *J* = 10.2, 6.4, 4.1 Hz, CHPh), 4.17 (2H, q, *J* = 7.2 Hz, CH₂CH₃), 7.07-7.14 (2H, m, ArH), 7.17-7.23 (1H, m, ArH), 7.24-7.32 (2H, m, ArH); ¹³C NMR (CDCl₃) δ 14.40, 17.18, 24.31, 26.29, 60.83, 126.30, 126.60, 128.61, 140.27, 173.54; IR (neat) 2988, 1721, 1603, 1496, 1411, 1189, 1040, 1019, 847, 761, 722, 701 cm⁻¹; MS (CI) *m/z* (rel. intensity) 191

(8) For example, see: Malkov, A. V.; Pernazza, D.; Bell, M.; Bella, M.; Massa, A.; Teplý, F.; Meghani, P.; Kočovský, P. *J. Org. Chem.* **2003**, *68*, 4727.

(9) Niimi, T.; Uchida, T.; Irie, R.; Katsuki, T. *Adv. Synth. Catal.* **2001**, *343*, 79.

(M + H, 100). Analytical chiral HPLC analysis of the corresponding primary alcohol using a Daicel Chiracel OD column [hexanes:isopropanol (90:10), flow rate at 0.5 mL/min, detection at $\lambda = 220$ nm, $t_{\text{MINOR}} = 15.4$ min, $t_{\text{MAJOR}} = 25.2$ min, ee = 82%].

(*R,R*)-trans-2-Phenyl-cyclopropane-1-carboxylic acid benzyl ester (10b).⁹⁻¹⁰ Combined yield of *trans*- and *cis*-isomers (247 mg, 49%, 92:8) as colorless oils. $[\alpha]_D^{20} - 264$ (c 0.65, chloroform); ¹H NMR (CDCl₃) δ 1.36 (1H, m, CHH), 1.67 (1H, m, CHH), 2.00 (1H, m, CHCO₂Bn), 2.59 (1H, m, CHPh), 5.18 (1H, s, OCHH), 5.19 (1H, s, OCHH), 7.08-7.14 (2H, m, ArH), 7.18-7.32 (3H, m, ArH), 7.33-7.43 (5H, m, ArH); ¹³C NMR (CDCl₃) δ 17.35, 24.22, 26.49, 66.68, 126.28, 126.63, 128.33, 128.59, 128.70, 136.05, 140.06, 173.35; IR (neat) 1720, 1603, 1498, 1457, 1407, 1338, 1325, 1168, 1030, 973, 934, 851, 752, 699 cm⁻¹; MS (CI) m/z (rel. intensity) 253 (M + H, 77), 91 (100). Analytical chiral HPLC analysis of the corresponding primary alcohol using a Daicel Chiracel OD column [hexanes:isopropanol (90:10), flow rate at 0.5 mL/min, detection at $\lambda = 220$ nm, $t_{\text{MINOR}} = 15.4$ min, $t_{\text{MAJOR}} = 25.2$ min, ee = 84%].

(*1R,2R*)-trans-2-Phenyl-cyclopropane-1-carboxylic acid *t*-butyl ester (10c).⁹ Combined yield of *trans*- and *cis*-isomers (293 mg, 67%, 92:8) as colorless oils. $[\alpha]_D^{20} - 237$ (c 0.92, chloroform); ¹H NMR (CDCl₃) δ 1.23 (1H, m, CHH), 1.47 (9H, s, *t*-Bu), 1.50-1.56 (1H, m, CHH), 1.84 (1H, m, CHCO₂*t*-Bu), 2.44 (1H, m, CHPh), 7.06-7.12 (2H, m, ArH), 7.16-7.22 (1H, m, ArH), 7.24-7.31 (2H, m, ArH); ¹³C NMR (CDCl₃) δ 17.36, 25.61, 26.05, 28.49, 80.86, 126.41, 126.65, 128.74, 140.86, 172.89; IR (neat) 2977, 1715, 1606, 1498, 1403, 1367, 1343, 1222, 1152, 936, 844, 783, 761, 744 cm⁻¹; MS (CI) m/z (rel. intensity) 219 (M + H, 18), 163 (100). Analytical chiral HPLC analysis of the corresponding primary alcohol using a Daicel Chiracel OD column [hexanes:isopropanol (90:10), flow rate at 0.5 mL/min, detection at $\lambda = 220$ nm, $t_{\text{MINOR}} = 15.4$ min, $t_{\text{MAJOR}} = 25.2$ min, ee = 92%]. The above procedure was also carried out,

(10) Vallgård, J.; Hacksell, U. *Tetrahedron Lett.* **1991**, 32, 5625.

on a smaller scale, using ligand (-)-**1** to afford the cyclopropanes **ent-10c** (181 mg, 68%, 96:4) as colorless oils. The enantiomeric purity of the product of this reaction, following reduction to the corresponding primary alcohol, was also determined by analytical chiral HPLC (93% ee).

(1R,2R)-trans-2-(4-Methoxyphenyl)-cyclopropane-1-carboxylic acid t-butyl ester (10d).¹¹

Combined yield of *trans*- and *cis*-isomers (343 mg, 69%, 96:4) as colorless oils. $[\alpha]_D^{20}$ - 189 (c 0.75, chloroform); $^1\text{H NMR}$ (CDCl_3) δ 1.18 (1H, m, CHH), 1.45-1.52 (10H, m, *t*-Bu and CHH), 1.75 (1H, m, $\text{CHCO}_2t\text{-Bu}$), 2.40 (1H, m, CHPh), 3.78 (3H, s, OCH_3), 6.80-6.84 (2H, m, ArH), 7.01-7.04 (2H, m, ArH); $^{13}\text{C NMR}$ (CDCl_3) δ 17.09, 25.32, 25.52, 28.51, 55.66, 80.81, 114.18, 127.55, 132.79, 158.53, 173.09; **IR** (neat) 2978, 2934, 1717, 1612, 1518, 1457, 1403, 1370, 1342, 1293, 1252, 1153, 1025, 845, 825, 813, 748 cm^{-1} ; **MS** (CI) m/z (rel. intensity) 249 (M + H, 6), 193 (100). Analytical chiral HPLC analysis of the corresponding primary alcohol using a Daicel Chiracel OD column [hexanes:isopropanol (90:10), flow rate at 0.5 mL/min, detection at $\lambda = 220$ nm, $t_{\text{MINOR}} = 21.2$ min, $t_{\text{MAJOR}} = 24.0$ min, ee = 71 %].

(1R,2R)-trans-2-(4-Fluorophenyl)-cyclopropane-1-carboxylic acid t-butyl ester (10e).

Combined yield of *trans*- and *cis*-isomers (345 mg, 73%, 91:9) as colorless oils. $[\alpha]_D^{20}$ - 182 (c 0.64, chloroform); $^1\text{H NMR}$ (CDCl_3) δ 1.18 (1H, m, CHH), 1.47 (9H, s, *t*-Bu), 1.48-1.53 (1H, m, CHH), 1.75-1.80 (1H, m, $\text{CHCO}_2t\text{-Bu}$), 2.42 (1H, m, CHPh), 6.93-6.99 (2H, m, ArH), 7.02-7.08 (2H, m, ArH); $^{13}\text{C NMR}$ (CDCl_3) δ 17.25, 25.33, 25.44, 28.49, 81.02, 115.46, 115.63, 127.94, 128.00, 134.92, 136.43, 162.81, 164.78, 172.78; **IR** (neat) 2980, 1719, 16708, 1515, 1457, 1398, 1368, 1334, 1312, 1218, 1152, 980, 846, 826, 767, 745 cm^{-1} ; **MS** (CI) m/z (rel. intensity) 237 (M + H, 19), 181 (100); **Anal.** Calcd. for $\text{C}_{14}\text{H}_{17}\text{FO}_2$: C, 71.16; H, 7.25; Found: C, 70.97; H, 7.07. Analytical chiral HPLC analysis of the corresponding primary alcohol using a Daicel Chiracel

(11) Ito, K.; Katsuki, T. *Tetrahedron Lett.* **1993**, 34, 2661.

OD column [hexanes:isopropanol (90:10), flow rate at 0.5 mL/min, detection at $\lambda = 220$ nm, $t_{\text{MINOR}} = 14.4$ min, $t_{\text{MAJOR}} = 16.2$ min, ee = 99%].

(1R,2R)-trans-2-(2'-Phenylethyl)-cyclopropane-1-carboxylic acid t-butyl ester (10f).

Combined yield of *trans*- and *cis*-isomers (404 mg, 82%, 95:5) as colorless oils. $[\alpha]_D^{20} - 41$ (c 0.50, chloroform); $^1\text{H NMR}$ (CDCl_3) δ 0.56 (1H, ddd, $J = 10.3, 6.3, 3.9$ Hz, CHH), 1.00-1.04 (1H, m, CHH), 1.18-1.28 (2H, m, $\text{PhCH}_2\text{CHHCH}$), 1.38 (9H, s, *t*-Bu), 1.50-1.57 (2H, m, PhCH_2CHH and $\text{CHCO}_2t\text{-Bu}$), 2.63-2.68 (2H, m, PhCH_2), 7.09-7.15 (3H, m, ArH), 7.18-7.24 (2H, m, ArH); $^{13}\text{C NMR}$ (CDCl_3) δ 15.45, 21.64, 22.31, 28.50, 35.33, 35.86, 80.31, 126.15, 128.66, 128.79, 142.14, 173.95; **IR** (neat) 2979, 2931, 2858, 1724, 1603, 1497, 1455, 1404, 1368, 1258, 1214, 1146, 1079, 978, 848, 748, 699 cm^{-1} ; **MS** (CI) m/z (rel. intensity) 247 ($\text{M} + \text{H}$, 49), 192 (14), 191 (100); **Anal.** Calcd. for $\text{C}_{16}\text{H}_{22}\text{O}_2$: C, 78.01; H, 9.00; Found: C, 77.78; H, 9.30. Analytical chiral HPLC analysis of the corresponding primary alcohol using a Daicel Chiracel OD column [hexanes:isopropanol (90:10), flow rate at 0.5 mL/min, detection at $\lambda = 220$ nm, $t_{\text{MINOR}} = 16.2$ min, $t_{\text{MAJOR}} = 19.8$ min, ee = 83%].

(1R)-2,2-Diphenyl-cyclopropane-1-carboxylic acid t-butyl ester (10g).¹² Yield (477 mg, 81%) as a colorless oil. $[\alpha]_D^{20} - 165$ (c 0.25, chloroform); $^1\text{H NMR}$ (CDCl_3) δ 1.21 (9H, s, *t*-Bu), 1.49-1.53 (1H, m, CHH), 2.09-2.13 (1H, m, CHH), 2.46 (1H, dd, $J = 7.8, 5.9$ Hz, $\text{CHCO}_2t\text{-Bu}$), 7.14-7.22 (2H, m, ArH), 7.23-7.29 (6H, m, ArH), 7.35-7.38 (2H, m, ArH); $^{13}\text{C NMR}$ (CDCl_3) δ 20.19, 27.96, 30.21, 39.60, 80.46, 126.51, 126.98, 127.70, 128.32, 128.52, 130.18, 140.39, 145.33, 169.84; **IR** (neat) 2977, 2934, 1719, 1662, 1601, 1496, 1448, 1390, 1367, 1293, 1250, 1150, 1028, 972, 847, 781, 747, 703 cm^{-1} ; **MS** (CI) m/z (rel. intensity) 295 ($\text{M} + \text{H}$, 6), 239 (100), 183 (16). Analytical chiral HPLC analysis of the corresponding primary alcohol using a

(12) Bedekar, A. V.; Koroleva, E. B.; Andersson, P. G. *J. Org. Chem.* **1997**, 62, 2518.

Daicel Chiracel OD column [hexanes:isopropanol (90:10), flow rate at 0.5 mL/min, detection at $\lambda = 220$ nm, $t_{\text{MINOR}} = 22.6$ min, $t_{\text{MAJOR}} = 18.8$ min, ee = 72%].

3. ^1H and ^{13}C NMR Spectra

^1H NMR spectrum (CDCl_3) of 4-methyl-6,7-dihydro-5H-[1]pyrindine-2-ol **2**

^{13}C NMR spectrum (CDCl_3) of 4-methyl-6,7-dihydro-5H-[1]pyrindine-2-ol **2**

^1H NMR spectrum (CDCl₃) of 2-chloro-4-methyl-6,7-dihydro-5H-[1]pyrindine **3**

^{13}C NMR spectrum (CDCl₃) of 2-chloro-4-methyl-6,7-dihydro-5H-[1]pyrindine **3**

¹H NMR spectrum (CDCl₃) of 7(*RS*)-7-acetoxy-2-chloro-4-methyl-6,7-dihydro-5H-[1]pyrindine **4**

^{13}C NMR spectrum (CDCl₃) of *7(RS)*-7-acetoxy-2-chloro-4-methyl-6,7-dihydro-5H-[1]pyrindine **4**

¹H NMR spectrum (CDCl₃) of 2-chloro-4-methyl-5H-[1]pyrindine **5**

^{13}C NMR spectrum (CDCl_3) of 2-chloro-4-methyl-5H-[1]pyrindine **5**

¹H NMR spectrum (CDCl₃) of *(6S,7R)*-2-chloro-4-methyl-6,7-dihydro-5H-[1]pyrindine-6,7-diol 3-pentanone acetal **(+)-7**

^{13}C NMR spectrum (CDCl_3) of *(6S,7R)*-2-chloro-4-methyl-6,7-dihydro-5H-[1]pyrindine-6,7-diol 3-pentanone acetal (+)-7

^1H NMR spectrum (CDCl_3) of *(6S,6'S,7R,7'R)*-4,4'-dimethyl-6,6',7,7'-tetrahydro-5*H*,5'*H*-(2,2')*bi*([1]pyrindinyl)-6,6',7,7'-tetraol 3-pentanone bis-acetal (+)-1

¹³C NMR spectrum (CDCl₃) of *(6S,6'S,7R,7'R)*-4,4'-dimethyl-6,6',7,7'-tetrahydro-5*H*,5'*H*-(2,2')bi([1]pyrindinyl)-6,6',7,7'-tetraol 3-pentanone bis-acetal (+)-1