Supporting Information for:

\(\gamma\)-Selective Directed Catalytic Asymmetric Hydroboration of 1,1-Disubstituted Alkenes.

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DFT calculations of possible octahedral intermediates (Figure S1)

The geometry optimizations of intermediates A–F were performed at the B3LYP density functional level\[1\] using Gaussian09.\[2\] The Hay-Wadt relativistic effective core potential (ECP) replaced the 28 core electrons of Rh.\[3\] The basis set for Rh was that associated with the ECP, with a double-\(\zeta\)valence basis set (LANL2DZ). All other atoms were represented by means of the 6-31+G(d,p) basis set.\[4\] Stationary points located at the potential energy hypersurface were characterized as true minima through vibrational analysis at the same level of theory.

Intermediates A (pro-gamma) and B (pro-beta) (0 kcal/mol and +1.9 kcal/mol, respectively) are discussed in the main text. Other possible intermediates C and D (+1.8 and +1.9 kcal/mol, respectively) have energies comparable to B. Intermediates E and F consist of (pin)B in the axial position and are considerably higher in energy (+11.2 and +7.0 kcal/mol, respectively) relative to A.


General procedures. Reactions were carried out in a dry nitrogen atmosphere. Dichloromethane (DCM) and tetrahydrofuran (THF) were freshly distilled under the following conditions: THF from sodium metal and benzophenone, and DCM from calcium hydride. HPLC solvents were filtered through Millipore filter paper. When indicated in the following procedures, solvents were degassed by freezing under reduced pressure followed by a dry nitrogen atmosphere thaw (3–4 times). 4,4,6-Trimethyl-1,3,2-dioxaborinane (tmdBH) was distilled immediately before use. All synthesized compounds were purified with flash chromatography using EMD Silica Gel 60 Geduran®, distilled via short path distillation, or triturated. Thin Layer Chromatography analyses were performed on Analtech Silica Gel HLF (0.25 mm) precoated analytical plates and visualized with use of handheld short wavelength UV light, Iodine stain (I₂ and EMD Silica Gel 60 Geduran®) and Vanillin stain (Ethanol, H₂SO₄, and vanillin). HPLC analyses were performed with use of an ISCO model 2360 HPLC and Chiral Technologies, Inc. chiral HPLC columns (Chiralcel OD; column: 250 x 4.6 mm, Chiralpak-AD; column: 250 x 4.6 mm, Chiralpak-IC; column: 4.6 x 250 mm). Data were recorded and analyzed with ChromPerfect chromatography.
software (version 5.1.0). NMR spectra were recorded on 400, and 300 MHz Bruker Advance NMR spectrometers using residue CHCl₃ (δ 7.27 ppm) or CDCl₃ (δ 77.0 ppm) for reference unless otherwise specified. Peaks are expressed as m (unresolved multiplet), q (quartet), t (triplet), d (doublet) or s (singlet). IR spectra were recorded using an Avatar 360 FT-IR. Optical rotations were measured as solutions, 1.0 g/100 mL in chloroform unless indicated otherwise, and recorded using an Autopol III automatic polarimeter. HRMS analyses were performed by the Nebraska Center for Mass Spectrometry.

**Assignment of Absolute Configuration.** The absolute stereochemistry of the γ-hydroxy esters were assigned based on conversions to the known lactones, (S)-20, (R)-22a, (R)-22b and (S)-22c. [Literature for (S)-20: Reference 14 from the supporting information (T. Ok, A. Jeon, J. Lee, J. H. Lim, C. S. Hong, H. –S. Lee, J. Org. Chem. 2007, 72, 7390–7393); for (R)-22a: Reference 16 from the supporting information (G. Hughes, M. Kimura, S. L. Buchwald, J. Am. Chem. Soc. 2003, 125, 11253–11258); for (R)-22b and (S)-22c: Reference 17 from the supporting information (J. W. Bode, M. P. Doyle, M. N. Protopopova, Q. –L. Zhou, J. Org. Chem. 1996, 61, 9146–9155)]. Other γ-hydroxyesters were assigned in analogy. The AlMe₃-mediated amidation of (S)-20 proved a sample of (S)-17 permitting the unambiguous assignment of γ-hydroxyamide (R)-17; other γ-hydroxyamides were assigned in analogy.

![Chemical structure](image)

**Procedure for the preparation of (E)-6-methyl-3-heptenoic acid phenyl amide (I):**[5] To a cooled (0 °C) degassed solution of (E)-6-Methylhept-3-enoic acid (2.49 g, 17.5 mmol) in N,N-dimethylformamide (DMF, 50 mL) was slowly added aniline (1.63 g, 17.5 mmol). The resulting solution was stirred (0.5 h, 0 °C) and then N-(3-dimethylaminopropyl)-N'-ethylcarbodiimide hydrochloride (3.35 g, 17.5 mmol) and 4-(dimethylamino)pyridine (DMAP, 1.07 g, 17.5 mmol) were added. The resulting mixture was allowed to slowly warm to room temperature and stirred overnight. The reaction mixture was quenched by the addition of satd. aq. sodium bicarbonate (50 mL) and extracted with diethyl ether (2 x 50 mL). The combined ether extracts were dried (anhyd. MgSO₄) and concentrated under reduced pressure. Flash chromatography on silica gel (90:10 hexanes:ethyl acetate) affords the title compound (2.66 g, 70%) as a light brown solid: mp 87–88.5 °C; TLC analysis R₅ 0.5 (75:25 hexanes:ethyl acetate); ¹H NMR (400 MHz, CDCl₃) δ 7.52 (2H, d, J = 8.3 Hz, c,c’) 7.44 (1H, br s, NH), 7.34 (2H, t, J = 7.7 Hz, b,b’), 7.13 (1H, t, J = 7.4 Hz, a), 5.80-5.55 (2H, m, g,h), 3.15 (2H, d, J = 6.9 Hz, f), 2.04 (2H, t, J = 6.8 Hz, i), 1.80-1.60 (1H, m, j), 0.96 (6H, d, J = 6.6 Hz, k,k’); ¹³C NMR (100 MHz, CDCl₃) δ 169.39 (e), 137.79 (d), 136.53 (g), 129.02 (b,b’), 124.31 (a), 123.41 (h), 119.61 (c,c’), 41.93 (f), 41.73 (i), 28.25 (j), 22.35 (k,k’); IR (neat) 3244 (N-H stretch), 2952, 1654 (C=O stretch), 1595, 1544 (N-H bend), 1443, 1247 (C-N stretch), 1187, 967, 843, 756 cm⁻¹; HRMS (FAB) calcd. for C₁₄H₂₅NO (M+H): 218.1545, found 218.1541 m/z.

General procedure for the preparation of $\beta,\gamma$-unsaturated phenyl amides via DCC-mediated condensation.

![Diagram]

Preparation of 3-methyl-3-butenolic acid phenyl amide (7a):[6] To a cooled (0 °C) solution of 3-methyl-3-butenolic acid (501 mg, 5.0 mmol) in dichloromethane (DCM, 10 mL) was added aniline (560 mg, 6.0 mmol) and $N,N$-dimethylamino pyridine (DMAP, 61 mg, 0.50 mmol). After the resulting mixture was allowed to stir for 0.5 h at the same temperature, $N,N$-dicyclohexylcarbodiimide (DCC, 1.14 g, 5.5 mmol) was added in one portion and allowed to warm to room temperature. After an overnight stir, the reaction mixture was filtered and the filtrate was washed with dilute HCl (2 x 15 mL, 1M). The organic layer was dried (anhyd. Na$_2$SO$_4$) and concentrated under reduced pressure. Flash chromatography on silica gel (85–75:15–25 hexanes:ethyl acetate) afforded the title compound (570 mg, 65%) as a white solid: mp 97.5–99.5 °C; TLC analysis $R_f$ 0.3 (75:25 hexanes:ethyl acetate); $^1$H NMR (400 MHz, CDCl$_3$) δ 7.65 (1H, br s, NH), 7.53 (2H, d, $J$ = 8.0 Hz, c,c'), 7.33 (2H, t, $J$ = 7.6 Hz, b,b'), 7.13 (1H, t, $J$ = 7.2 Hz, a), 5.09 and 5.02 (2H, s's, h), 3.15 (2H, s, f), 1.88 (3H, s, i); $^{13}$C NMR (100 MHz, CDCl$_3$) δ 168.58 (e), 140.35 (d), 137.80 (g), 128.98 (b,b'), 124.36 (a), 119.79 (c,c'), 116.09 (h), 47.41 (f), 22.46 (i); IR (neat) 3291 (N-H stretch), 3060, 2953, 2921, 2865, 1657 (C=O stretch), 1638, 1595, 1525 (N-H bend), 1440, 1307, 1251 (C-N stretch), 1162, 869, 738, 688, 617 cm$^{-1}$.

General procedure for the preparation of $\beta,\gamma$-unsaturated amides via carboxylation$^7$-hydrolysis sequence followed by DCC-mediated condensation.

![Diagram]

Preparation of 3-Cyclohexyl-3-butenolic acid phenyl amide (7e): A mixture of 2-cyclohexylallyl ethyl carbonate (1.06 mg, 5.0 mmol) and palladium tetrakis (116 mg, 0.10 mmol) was placed under a pressurized (70 psi) atmosphere of carbon monoxide. The mixture was heated (50 °C) for 16 h and then allowed to cool to room temperature and ambient pressure. The resultant black mixture was run over a silica plug to afford the crude $\beta,\gamma$-unsaturated ethyl ester. The crude residue was taken up in a mixture of ethanol (5 mL) and aqueous 2 M sodium hydroxide (50 mL) and stirred overnight at room temperature. The resultant basic solution was extracted with dichloromethane (2 x 15 mL) and then acidified. The acidic aqueous layer was extracted with dichloromethane (3 x 30 mL) and the combined organic extracts were dried (anhyd. Na$_2$SO$_4$) and concentrated under reduced pressure. The crude $\beta,\gamma$-unsaturated acid (537 mg, 3.2 mmol) was used in the next step without further purification.

Following the general condensation procedure with DCC, the crude $\beta,\gamma$-unsaturated acid affords, after flash chromatography on silica gel (85–75:15–25 hexanes:ethyl acetate), the title compound (469 mg, 39%, 3 steps) as a white solid: mp 81–83 °C; TLC analysis $R_f$ 0.5 (75:25 hexanes:ethyl acetate); $^1$H NMR (300 MHz, CDCl$_3$) $\delta$ 7.62 (1H, br s, NH), 7.51 (2H, d, $J = 7.8$ Hz, c,c’), 7.34 (2H, t, $J = 8.1$ Hz, b,b’), 7.12 (1H, t, $J = 7.5$ Hz, a), 5.15 and 5.06 (2H, s’s, h), 3.19 (2H, s, f), 2.05–1.95 (1H, m, i), 1.90–1.75 (4H, m, k,k’,l,j), 1.75–1.65 (1H, m, j’), 1.30–1.10 (5H, m, j,j’,k,k’,l);

3-Phenyl-3-butenedioic acid phenyl amide (7f): Following the general procedure, 2-phenylallyl ethyl carbonate (1.03 g, 5.0 mmol) affords, after flash chromatography on silica gel (85–75:15–25 hexanes:ethyl acetate), the title compound (215 mg, 18%, 3 steps) as a white solid: mp 90.5–93.5 °C; TLC analysis $R_f$ 0.4 (75:25 hexanes:ethyl acetate); $^1$H NMR (300 MHz, CDCl$_3$) $\delta$ 7.60–7.50 (3H, m, j,j’,NH), 7.45–7.35 (5H, m, c,c’,k,k’,l), 7.35–7.25 (2H, m, b,b’), 7.10 (1H, t, $J = 7.5$ Hz, a), 5.78 and 5.41 (2H, s’s, h), 3.65 (2H, s, f); $^{13}$C NMR (75 MHz, CDCl$_3$) $\delta$ 168.35 (e), 142.08 (d), 138.76 (i), 137.61 (g), 128.94 (b,b’), 128.82 (j,j’), 128.47 (l), 125.78 (k,k’), 124.43 (a), 119.84 (c,c’), 117.44 (h), 45.14 (f); IR (neat) 3368 (N–H stretch), 3192, 3135, 3085, 2929, 1804, 1656 (C=O stretch), 1597, 1554 (N–H bend), 1484, 1441, 1338, 1232 (C-N stretch), 1162, 896, 770, 752, 688 cm$^{-1}$; HRMS (ESI) calcd. for C$_{16}$H$_{21}$NaNO (M+Na): 266.1521, found 266.1526 m/z.

General procedure for the preparation of $\beta,\gamma$-unsaturated phenyl amides via hydrolysis followed by DCC-mediated condensation.

Preparation of 5-methyl-3-methylidenehexanoic acid phenyl amide (3): To tert-butyl ester 7i (595 mg, 3.0 mmol) was added trifluoroacetic acid (CF$_3$CO$_2$H, 6 mL) followed by a 1 h stir at room temperature. The mixture was concentrated under reduced pressure, taken up in ethyl acetate (15 mL), and washed with dilute sodium hydroxide (3 x 10 mL, 2 M). The basic aqueous layer was acidified and extracted with dichloromethane (3 x 15 mL). The combined organic extracts were dried (anhyd. Na$_2$SO$_4$) and concentrated under reduced pressure to afford the crude $\beta,\gamma$-unsaturated acid (326 mg, 2.3 mmol) which was used in the next step without further purification.

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Following the general DCC-mediated condensation procedure, the crude β,γ-unsaturated acid affords, after flash chromatography on silica gel (85–75:15–25 hexanes:ethyl acetate), the title compound (411 mg, 63%, 2 steps) as a white solid: mp 91–92.5 °C; TLC analysis Rf 0.4 (75:25 hexanes:ethyl acetate); 1H NMR (300 MHz, CDCl3) δ 7.87 (1H, br s, NH), 7.53 (2H, d, J = 8.1 Hz, c,c'), 7.32 (2H, t, J = 8.1 Hz, b,b'), 7.11 (1H, t, J = 7.5 Hz, a), 5.09 and 5.06 (2H, s's, h), 3.13 (2H, s, f), 2.02 (2H, d, J = 6.9 Hz, i), 1.90–1.75 (1H, m, j), 0.91 (6H, d, J = 6.6 Hz, k,k'); 13C NMR (75 MHz, CDCl3) δ 168.92 (e), 144.20 (d), 141.92 (k), 137.66 (g), 128.94 (b,b'), 124.30 (a), 119.84 (c,c'), 116.17 (h), 45.67 (f), 45.63 (j), 25.96 (i), 22.41 (k,k').

3-Methylidene-5-phenylpentanoic acid phenyl amide (7c): Following the general procedure, 3-methylidene-5-phenylpentanoic acid tert-butyl ester (739 mg, 3.0 mmol) affords, after flash chromatography on silica gel (85–75:15–25 hexanes:ethyl acetate), the title compound (484 mg, 61%, 2 steps) as a white solid: mp 79–80 °C; TLC analysis Rf 0.4 (75:25 hexanes:ethyl acetate); 1H NMR (400 MHz, CDCl3) δ 7.48 (2H, d, J = 8.0 Hz, l,l'), 7.40–7.30 (3H, m, c,c', NH), 7.30–7.25 (2H, m, b,b'), 7.25–7.20 (3H, m, m,m',n), 7.14 (1H, t, J = 6.8 Hz, a), 5.16 and 5.12 (2H, s's, h), 3.19 (2H, s, f), 2.86 (2H, t, J = 8.0 Hz, j), 2.50 (2H, t, J = 8.4 Hz, i); 13C NMR (100 MHz, CDCl3) δ 168.31 (e), 143.69 (d), 141.21 (k), 137.66 (g), 128.99 (b,b'), 128.44 (l,l'), 128.35 (m,m'), 126.06 (n), 124.38 (a), 119.69 (c,c'), 115.75 (h), 46.25 (f), 37.44 (i), 33.91 (j); IR (neat) 3237 (N-H stretch), 3185, 3061, 3028, 1638, 1596, 1541, 1469, 1443, 1398, 1346, 1247 (C-N stretch), 1193, 961, 897, 747, 694, 616 cm⁻¹; HRMS (EI) calcd. for C18H16NO: 265.1467, found 265.1475 m/z.

3-Methylidene-6-phenylhexanoic acid phenyl amide (7d): Following the general procedure, 3-methylidene-6-phenylhexanoic acid tert-butyl ester (781 mg, 3.0 mmol) affords, after flash chromatography on silica gel (90–80:10–20 hexanes:ethyl acetate), the title compound (476 mg, 57%, 2 steps) as a white solid: mp 51–52.5 °C; TLC analysis Rf 0.5 (75:25 hexanes:ethyl acetate); 1H NMR (400 MHz, CDCl3) δ 7.60 (1H, br s, NH), 7.52 (2H, d, J = 7.9 Hz, m,m'), 7.40–7.35 (2H, m, c,c'), 7.35–7.25 (2H, m, b,b'), 7.25–7.20 (3H, m, n,n',o), 7.15 (1H, t, J = 7.3 Hz, a), 5.13 and 5.11 (2H, s's, h), 3.18 (2H, s, f), 2.66 (2H, t, J = 7.7 Hz, k), 2.22 (2H, t, J = 7.4 Hz, i), 1.90–1.80 (2H, m, j); 13C NMR (100 MHz, CDCl3) δ 168.71 (e), 144.20 (d), 141.98 (l), 137.71 (g), 129.02 (b,b'), 128.44 (m,m'), 128.37 (n,n'), 125.87 (o), 124.43 (a), 119.83 (c,c'), 115.20 (h), 46.06 (f), 35.52 (i), 35.42 (k), 29.24 (j); IR (neat) 3303 (N-H stretch), 3061, 3028,
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2935, 1659 (C=O stretch), 1497, 1441, 1334, 1245 (C-N stretch), 1155, 899, 749, 690 cm⁻¹; HRMS (EI) calcd. for C₁₉H₂₁NO: 279.1623, found 279.1618 m/z.

**3-Methylidenepentanoic acid phenyl amide (7b):** Following the general procedure, tert-butyl ester 7h (511 mg, 3.0 mmol) affords, after flash chromatography on silica gel (85–75:15–25, hexanes:ethyl acetate), the title compound (362 mg, 64%, 2 steps) as a white solid: mp 101–102 °C; TLC analysis Rₙ 0.3 (75:25 hexanes:ethyl acetate); ¹H NMR (400 MHz, CDCl₃) δ 7.62 (1H, br s, NH), 7.52 (2H, d, J = 8.0 Hz, c,c’), 7.33 (2H, t, J = 7.6 Hz, b,b’), 7.12 (1H, t, J = 7.6 Hz, a), 5.11 and 5.06 (2H, s’s, h), 3.17 (2H, s, f), 2.18 (2H, q, J = 7.2 Hz, i), 1.11 (3H, t, J = 7.2 Hz, j); ¹³C NMR (100 MHz, CDCl₃) δ 168.72 (e), 146.09(d), 137.79 (g), 128.98 (b,b’), 124.33 (a), 119.74 (c,c’), 113.92 (h), 46.23 (f), 28.89 (i), 12.12 (j); IR (neat) 3240 (N-H stretch), 3187, 2955, 2839, 1658 (C=O stretch), 1595, 1544 (N-H bend), 1488, 1444, 1400, 1352, 1297, 1252 (C-N stretch), 1187, 969, 759, 693 cm⁻¹; HRMS (Cl) calcd. for C₁₂H₁₆NO (M+H): 190.1232, found 190.1237 m/z.

**General procedure for the preparation of β,γ-unsaturated tert-butyl esters via nickel-catalyzed substitution.**

Preparation of 3-methyl-3-butenoic acid tert-butyl ester (7g): To a cooled (-78 °C) solution of N,N-disopropylamine (4.2 mL, 30 mmol) in THF (5 mL) was slowly added n-butyllithium (12 mL of a 2.5 M soln. in hexanes, 30 mmol). The resultant mixture was allowed to stir for 0.5 h at the same temperature before the dropwise addition of tert-butyl acetate (4.0 mL, 30 mmol). The reaction mixture was allowed to stir for an additional 0.5 h and the generated tert-butyl lithioacetate solution was used in the next step.

To a cooled (-78 °C) suspension of nickel bromide (2.76 g, 12.6 mmol) in THF (15 mL) was added n-butyllithium (2 mL of a 2.5 M soln. in hexanes, 5 mmol). After the resultant black mixture was allowed to stir for 15 min, 2-bromopropene (2.66 mL, 30 mmol) was added followed by the tert-butyl lithioacetate solution prepared in the previous step. The reaction was allowed to slowly rise to room temperature and stirred for an additional 1 h. The reaction mixture was quenched by the addition of dilute HCl (15 mL, 1 M) and then extracted with diethylether (2 x 20 mL). The combined organic extracts were dried (anhyd. Na₂SO₄) and concentrated under reduced pressure. Flash chromatography over silica gel (80–70:20–30, hexanes:dichloromethane) affords the title compound (2.7 g, 59%) as a light yellow oil: TLC analysis Rₙ 0.5 (50:50)

hexanes:dichloromethane; \(^1\)H NMR (300 MHz, CDCl\(_3\)) \(\delta 4.88\) and 4.82 (2H, s’s, f), 2.93 (2H, s, d), 1.80 (3H, g), 1.45 (9H, a,a’,a’’); \(^{13}\)C NMR (75 MHz, CDCl\(_3\)) \(\delta 170.72\) (c), 139.13 (e), 114.09 (f), 80.42 (b), 44.79 (d), 27.99 (a,a’,a’’), 22.38 (g); IR (neat) 3075, 2976, 2934, 1728 (C=O stretch), 1647, 1546, 1455, 1366, 1258 (C-O stretch), 1139, 690, 843 cm\(^{-1}\).

![Diagram](7h)

**3-Methylidenepentanoic acid tert-butyl ester (7h):**\(^8\) Following the general procedure, 2-bromobutene (4.1 g, 30 mmol) affords, after flash chromatography on silica gel (80–70:20–30 hexanes:dichloromethane), the title compound (3.1 g, 62%) as a light yellow oil: TLC analysis \(R_f\) 0.6 (50:50 hexanes:dichloromethane); \(^1\)H NMR (400 MHz, CDCl\(_3\)) \(\delta 4.91\) and 4.88 (2H, s’s, f), 2.97 (2H, s, d), 2.12 (2H, q, \(J = 7.6\) Hz, g), 1.46 (9H, s, a,a’,a’’), 1.06 (3H, t, \(J = 7.6\) Hz, h); \(^{13}\)C NMR (100 MHz, CDCl\(_3\)) \(\delta 170.99\) (c), 144.65 (e), 111.83 (f), 80.40 (b), 43.47 (d), 28.78 (g), 28.01 (a,a’,a’’), 12.02 (h); IR (neat) 2935, 2848, 1731 (C=O stretch), 1653, 1391, 1252 (C-O stretch), 1145, 1122, 1040, 948, 761, 576 cm\(^{-1}\).

![Diagram](12)

**5-(2-Chlorophenyl)-3-methylidenepentanoic acid tert-butyl ester (12):** Following the general procedure, 2-bromo-4-(2-chlorophenyl)butene (3.68 g, 15 mmol) affords, after flash chromatography on silica gel (75–65:25–35 hexanes:dichloromethane), the title compound (1.72 g, 41%) as a light yellow oil: TLC analysis \(R_f\) 0.5 (50:50 hexanes:dichloromethane); \(^1\)H NMR (300 MHz, CDCl\(_3\)) \(\delta 7.40\)–7.30 (1H, m, k), 7.30–7.10 (3H, m, n,m,l), 4.98 and 4.97 (2H, s’s, f), 3.04 (2H, s, d), 2.91 (2H, t, \(J = 7.8\) Hz, h), 2.43 (2H, t, \(J = 8.4\) Hz, g), 1.48 (9H, s, a,a’,a’’); \(^{13}\)C NMR (75 MHz, CDCl\(_3\)) \(\delta 170.76\) (c), 142.22 (i), 139.34 (e), 133.91 (j), 130.28 (k), 129.45 (l), 127.38 (m), 126.77 (n), 113.79 (f), 80.61 (b), 43.39 (d), 35.89 (g), 31.91 (h), 28.05 (a,a’,a’’); IR (neat) 2935, 2848, 1731 (C=O stretch), 1647, 1474, 1443, 1366, 1254 (C-O stretch), 1145, 1052, 1038, 954, 900, 824, 749, 736, 671, 575 cm\(^{-1}\); HRMS (ESI) calcd. for C\(_{16}\)H\(_{21}\)ClNaO\(_2\) (M+Na): 303.1128, found 303.1120 m/z.

![Diagram](3)

**3-Methylidene-5-phenylpentanoic acid tert-butyl ester:**\(^9\) Following the general procedure, 2-bromo-4-phenylbutene (3.16 g, 15 mmol) affords, after flash chromatography on silica gel (75–60:35–25 hexanes:dichloromethane), the title compound (2.5 g, 70%) as a light yellow oil: TLC analysis \(R_f\) 0.4 (50:50 hexanes:dichloromethane); \(^1\)H NMR (300 MHz, CDCl\(_3\)) \(\delta 7.50\)–7.40 (2H, m, m’, n), 7.40–7.30 (2H, m, k), 7.30–7.10 (3H, m, n,m,l), 4.98 and 4.89 (2H, s’s, f), 3.04 (2H, s, d), 2.91 (2H, t, \(J = 7.8\) Hz, h), 2.43 (2H, t, \(J = 8.4\) Hz, g), 1.48 (9H, s, a,a’,a’’); \(^{13}\)C NMR (75 MHz, CDCl\(_3\)) \(\delta 170.76\) (c), 142.22 (i), 139.34 (e), 133.91 (j), 130.28 (k), 129.45 (l), 127.38 (m), 126.77 (n), 113.79 (f), 80.61 (b), 43.39 (d), 35.89 (g), 31.91 (h), 28.05 (a,a’,a’’); IR (neat) 2935, 2848, 1731 (C=O stretch), 1647, 1474, 1443, 1366, 1254 (C-O stretch), 1145, 1052, 1038, 954, 900, 824, 749, 736, 671, 575 cm\(^{-1}\); HRMS (ESI) calcd. for C\(_{16}\)H\(_{21}\)ClNaO\(_2\) (M+Na): 303.1128, found 303.1120 m/z.

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70:25–30 hexanes:dichloromethane, the title compound (1.96 g, 53%) as a light yellow oil: TLC analysis $R_f$ 0.6 (50:50 hexanes:dichloromethane); $^1$H NMR (300 MHz, CDCl$_3$) $\delta$ 7.40–7.30 (2H, m, j,k,k’), 7.30–7.20 (3H, m, j,j’,l), 4.99 and 4.97 (2H, s’s, f), 3.03 (2H, s, d), 2.83 (2H, t, $J$ = 7.5 Hz, h), 2.46 (2H, t, $J$ = 8.4 Hz, g), 1.51 (9H, s, a,a’,a”); $^{13}$C NMR (75 MHz, CDCl$_3$) $\delta$ 170.80 (c), 142.47 (i), 141.85 (e), 128.35 (j,j’,k,k’), 125.88 (l), 113.64 (f), 80.58 (b), 43.49 (d), 37.72 (g), 34.05 (h), 28.08 (a,a’,a”); IR (neat) 3028, 2978, 2931, 1726 (C=O stretch), 1647, 1496, 1454, 1366, 1255 (C–O stretch), 1139, 1030, 956, 896, 841, 744, 697 cm$^{-1}$.

**General procedure for the preparation of tert-butyl esters via the synthesis of vinyl bromides followed by nickel-catalyzed substitution.**

![Diagram](image)

**Preparation of 3-methylidene-5-methylhexanoic acid tert-butyl ester (7i):** To a mixture of 2,3-dibromopropene (7.01 g, 35 mmol) and copper chloride (173 mg, 1.8 mmol) in THF (30 mL) was slowly added isobutylmagnesium bromide (40 mmol, 13.8 mL of a 2.9 M solution in THF) at room temperature. After a 5 h stir, the reaction was quenched with satd. aq. ammonium chloride (30 mL) and then extracted with diethyl ether (3 x 30 mL). The combined organic extracts were dried (anhyd. Na$_2$SO$_4$) and concentrated under reduced pressure. The crude residue was taken up in hexanes, passed through a short silica plug, and concentrated under reduced pressure. The resultant crude 2-bromo-4-methylpentene (4.25 g, 26 mmol) was used in the next step without further purification.

Following the general procedure for the nickel-catalyzed substitution of vinyl bromides, crude vinyl bromide prepared in the previous step affords, after flash chromatography on silica gel (80–70:20–30, hexanes:dichloromethane), the title compound (3.12 g, 45%, 2 steps) as a light yellow oil: TLC analysis $R_f$ 0.6 (50:50 hexanes:dichloromethane); $^1$H NMR (400 MHz, CDCl$_3$) $\delta$ 4.91 and 4.87 (2H, s’s, f), 2.92 (2H, s, d), 1.98 (2H, d, $J$ = 7.2 Hz, g), 1.95–1.85 (1H, m, h.), 1.46 (9H, s, a,a’,a’’); 0.89 (6H, d, $J$ = 6.6 Hz, i,i’); $^{13}$C NMR (100 MHz, CDCl$_3$) $\delta$ 170.90 (c), 141.96 (e), 114.33 (f), 80.36 (b), 45.79 (d), 43.03 (g), 28.00 (a,a’,a’’), 25.75 (h), 22.38 (i,i’); IR (neat) 2969, 2912, 1722 (C=O stretch), 1431, 1376, 1177 (C-O stretch), 1117, 884, 826, 740, 521 cm$^{-1}$; HRMS (CI) calcd. for C$_{12}$H$_{23}$O$_2$ (M+H): 199.1698, found 199.1705 m/z.

**4-Phenyl-3-methylidenebutanoic acid tert-butyl ester (21a):** Following the general procedure, crude 2-bromo-3-phenylpropene prepared from 2,3-dibromopropene (7.01 g, 35 mmol) and phenylmagnesium bromide (40 mmol, 40 mL of a 1.0 M solution in THF) affords,

after flash chromatography on silica gel (85–70:15–30, hexanes:dichloromethane), the title compound (4.40 g, 54%, 2 steps) as a light yellow oil: TLC analysis Rf 0.6 (50:50 hexanes:dichloromethane); 1H NMR (300 MHz, CDCl3) δ 7.40–7.30 (2H, m, j,j’), 7.30–7.20 (3H, m, i,i’,k), 5.01 and 4.97 (2H, s’s, f), 3.48 (2H, s, g), 2.92 (2H, s, d), 1.49 (9H, s, a,a’,a”); 13C NMR (75 MHz, CDCl3) δ 170.75 (c), 142.43 (h), 138.97 (e), 129.17 (i,i’), 128.39 (j,j’), 126.30 (k), 115.26 (f), 80.59 (b), 42.68 (g), 42.40 (d), 28.06 (a,a’,a”); IR (neat) 2978, 1725 (C=O stretch), 1647, 1494, 1366, 1253 cm−1; HRMS (ESI) calcd. for C15H20NaO2 (M+Na): 255.1361, found 255.1371 m/z.

4-(3-methoxyphenyl)-3-methylidenebutanoic acid tert-butyl ester (21b): Following the general procedure, crude 2-bromo-3-(3-methoxyphenyl)propene prepared from 2,3-dibromopropene (7.01 g, 35 mmol) and 3-methoxyphenylmagnesium bromide (30 mmol) affords, after flash chromatography on silica gel (80–70:20–30 hexanes:dichloromethane), the title compound (3.31 g, 42%, 2 steps) as a colorless oil: TLC analysis Rf 0.3 (50:50 hexanes:dichloromethane); 1H NMR (400 MHz, CDCl3) δ 7.30–7.20 (1H, m, i), 6.85–6.75 (3H, m, m,l,k), 5.01 and 4.97 (2H, s’s, f), 3.82 (3H, s, n), 3.45 (2H, s, g), 2.92 (2H, s, d), 1.48 (9H, s, a,a’,a”); 13C NMR (100 MHz, CDCl3) δ 170.70 (c), 142.66 (h), 140.57 (e), 131.51 (l), 121.59 (m), 115.31 (i), 114.78 (f), 111.71 (k), 80.55 (b), 55.12 (n), 42.73 (d), 42.33 (g), 28.05 (a,a’,a”); IR (neat) 2977, 1725 (C=O stretch), 1600, 1584, 1488, 1435, 1366, 1257 (C-O stretch), 1140, 1050, 899, 779, 754, 695, 571 cm−1; HRMS (ESI) calcd. for C16H22NaO3 (M+Na): 285.1467, found 285.1479 m/z.

4-(3,4-dimethoxyphenyl)-3-methylidenebutanoic acid tert-butyl ester (21c): Following the general procedure, crude 2-bromo-3-(3,4-dimethoxyphenyl)propene prepared from 2,3-dibromopropene (7.01 g, 35 mmol) and 3,4-dimethoxyphenylmagnesium bromide (30 mmol) affords, after flash chromatography on silica gel (75–65:25–35 hexanes:dichloromethane), the title compound (3.16 g, 36%, 2 steps) as a colorless oil: TLC analysis Rf 0.3 (50:50 hexanes:dichloromethane); 1H NMR (400 MHz, CDCl3) δ 6.85–6.75 (1H, m, i), 6.75–6.65 (2H, m, l,m), 4.97 and 4.93 (2H, s’s, f), 3.87 (6H, s, n,o), 3.40 (2H, s, g), 2.90 (2H, s, d), 1.46 (9H, s, a,a’,a”); 13C NMR (100 MHz, CDCl3) δ 170.74 (c), 148.85 (k), 147.54 (j), 142.66 (e), 131.51 (h), 121.16 (m), 114.95 (i), 112.29 (l), 111.15 (f), 80.53 (b), 55.90 (o), 55.80 (n), 42.29 (g), 42.25 (d),
28.05 (a,a’,a’’); IR (neat) 2978, 1725 (C=O stretch), 1647, 1599, 1584, 1488, 1454, 1366, 1256 (C-O stretch), 1139, 1050, 899, 779, 738, 694, 572 cm⁻¹; HRMS (EI) calcd. for C₁₇H₂₄O₄: 292.1675, found 292.1684 m/z.

3-Methylidene-6-phenylhexanoic acid tert-butyl ester: Following the general procedure, crude 2-bromo-5-phenylpentene prepared from 2,3-dibromopropene (4.02 g, 20 mmol) and 2-phenylethylmagnesiumbromide (15 mmol) affords, after flash chromatography on silica gel (75–70:25–30 hexanes:dichloromethane), the title compound (2.23 g, 57%) as a light yellow oil: TLC analysis Rf 0.6 (50:50 hexanes:dichloromethane); ¹H NMR (300 MHz, CDCl₃) δ 7.35–7.25 (2H, m, l,l’), 7.25–7.15 (3H, m, k,k’,m), 4.94 and 4.93 (2H, s’s, f), 2.97 (2H, s, d), 2.65 (2H, t, J = 7.6 Hz, i), 2.17 (2H, t, J = 7.5 Hz, g), 1.90–1.75 (2H, m, h), 1.46 (9H, s, a,a’,a”); ¹³C NMR (75 MHz, CDCl₃) δ 170.93 (c), 142.74 (j), 142.33 (e), 128.45 (k,k’), 128.31 (l,l’), 125.74 (m), 113.30 (f), 80.54 (b), 43.35 (d), 35.50 (g), 35.47 (i), 29.14 (h), 28.03 (a,a’,a”); IR (neat) 3026, 2933, 2863, 1726 (C=O stretch), 1645, 1496, 1366, 1255 (C-O stretch), 1140, 897, 839, 744, 695 cm⁻¹; HRMS (ESI) calcd. for C₁₇H₂₄NaO₂(M+Na): 283.1674, found 283.1682 m/z.

General procedure for the preparation of vinyl bromides by the direct insertion of magnesium into benzylic chlorides in the presence of LiCl and ZnCl₂.¹¹¹

Preparation of 2-bromo-4-phenylbutene:¹² To a mixture of magnesium turnings (1.83 g, 75 mmol) in THF (5 mL) were added lithium chloride (37.5 mmol, 75 mL of a 0.5 M solution in THF) and zinc chloride (33 mmol, 33 mL of a 1.0 M solution in THF). To the resultant mixture was added benzyl chloride (3.80 g, 30 mmol) in one portion. The reaction mixture was allowed to stir for 1 h before transferring to a mixture of 2,3-dibromopropene (7.01 g, 35 mmol) and copper chloride (173 mg, 1.8 mmol) in THF (10 mL). After a 5 h stir, the reaction was quenched with satd. aq. ammonium chloride (30 mL) and then extracted with diethyl ether (3 x 30 mL). The combined organic extracts were dried (anhy. Na₂SO₄) and concentrated under reduced pressure. Flash chromatography on silica gel (hexanes) affords the title compound (3.48 g, 55%) as a light brown oil: TLC analysis Rf 0.7 (hexanes); ¹H NMR (300 MHz, CDCl₃) δ 7.30–7.20 (3H, m, f,f’,h), 5.58 (1H, s, a), 5.47 (1H, s, a), 2.97 (2H, t, J = 6.9 Hz, c), 2.80 (2H, t, J = 8.1 Hz, d); ¹³C NMR (75 MHz, CDCl₃) δ 140.42 (c), 133.62 (b), 128.56 (f,f’), 128.48 (g,g’), 126.26 (h), 117.20 (a), 43.36 (c), 34.44 (d); IR (neat) 3027, 2949, 2865, 1647, 1599, 1584, 1488, 1454, 1366, 1256 cm⁻¹; HRMS (EI) calcd. for C₁₇H₂₄O₄: 292.1675, found 292.1684 m/z.

2858, 1756, 1628, 1495, 1428, 1233, 1115, 1071 (C-Br stretch), 886, 766, 747, 696, 646, 559 cm⁻¹.

2-Bromo-4-(2-chlorophenyl)butene: Following the general procedure with 1-chloro-2-(chloromethyl)benzene (4.83 g, 30 mmol), flash chromatography on silica gel (hexanes) affords the title compound (4.33 g, 59%) as a colorless oil: TLC analysis Rf 0.7 (hexanes); ¹H NMR (300 MHz, CDCl₃) δ 7.40–7.35 (1H, m, i), 7.30–7.25 (1H, m, g), 7.25–7.15 (2H, m, f,h), 5.56 (1H, s, a), 5.44 (1H, s, a), 3.04 (2H, t, J = 7.2 Hz, c), 2.77 (2H, J = 8.0 Hz, d); ¹³C NMR (75 MHz, CDCl₃) δ 137.89 (e), 133.94 (j), 133.20 (b), 130.74 (i), 129.55 (h), 127.79 (g), 126.80 (f), 117.36 (a), 41.28 (c), 32.39 (d); IR (neat) 3027, 1628, 1474, 1282, 1189 (C-Cl stretch), 1052 (C-Br stretch), 1038, 890, 824, 751, 734, 684, 669, 550, 506 cm⁻¹; HRMS (EI) calcd. for C₁₀H₁₂BrCl: 243.9654, found 243.9660 m/z.

General procedure for the preparation of allylic alcohols.¹³

Preparation of 2-cyclohexyl-2-propenol: To a cooled (-78 °C) mixture of 3-propynol (1.68 g, 30 mmol) and copper iodide (2.86 g, 15 mmol) in toluene (40 mL) was added cyclohexylmagnesium chloride (45 mL of a 2.0 M solution in THF, 90 mmol) dropwise. The resultant reaction mixture was allowed to slowly warm to room temperature and stirred for 16 h. The reaction mixture was then cooled (0 °C) and quenched with satd. ammonium chloride (20 mL) and then extracted with diethyl ether (3 x 30 mL). The combined organic extracts were dried (anhyd. Na₂SO₄) and then concentrated under reduced pressure. Flash chromatography over silica gel (80:20 hexanes:ethyl acetate) affords the title compound (3.33 g, 79%) as a colorless oil: TLC analysis Rf 0.4 (75:25 hexanes:ethyl acetate); ¹H NMR (300 MHz, CDCl₃) δ 5.00 (1H, s, c), 4.86 (1H, s, c), 4.10 (2H, s, a), 2.00–1.85 (2H, m, a,OH), 1.85–1.70 (4H, m, e,e′,f,f′), 1.70–1.65 (1H, m, g), 1.30–1.10 (5H, m, e,e′,f,f′,g); ¹³C NMR (75 MHz, CDCl₃) δ 154.53 (b), 107.40 (c), 65.05 (a), 41.25 (d), 32.43 (e,e′), 26.70 (f,f′), 26.29 (g); IR (neat) 3306 (O-H stretch), 2850, 1649, 1060, 1019 (C-O stretch), 889, 625 cm⁻¹; HRMS (EI) calcd. for C₉H₁₆O: 140.1201, found 140.1204 m/z.

2-Phenyl-2-propenol: Using the general procedure, phenylmagnesium bromide (90 mL of a 1.0 M solution in THF, 90 mmol) affords, after flash chromatography on silica gel (80:20 hexanes:ethyl acetate), the title compound (3.08 g, 77%) as a light yellow oil: TLC analysis $R_f$ 0.3 (75:25 hexanes:ethyl acetate); $^1$H NMR (300 MHz, CDCl$_3$) δ 7.55–7.45 (2H, m, e,e’), 7.45–7.30 (3H, m, f,f’,g), 5.50 (1H, s, c), 5.39 (1H, s, c), 4.55 (2H, s, a), 2.28 (1H, br s, OH); $^{13}$C NMR (75 MHz, CDCl$_3$) δ 147.30 (b), 138.60 (d), 128.53 (f,f’), 127.94 (g), 126.10 (e,e’), 112.55 (c), 64.87 (a); IR (neat) 3370 (O–H stretch), 2945, 2883, 1735, 1632, 1495, 1444, 1372, 1239, 1043 (C–O stretch), 1024, 902, 778, 706, 609 cm$^{-1}$.

**General procedure for the preparation of allylic carbonates.**

**Preparation of 2-cyclohexylallyl ethyl carbonate**: To a cooled (0 °C) mixture of 2-cyclohexyl-2-propenol (2.80 g, 20 mmol) and pyridine (3.16 g, 40 mmol) in THF (30 mL) was slowly added ethyl chloroformate (2.17 g, 20 mmol) over a period of 10 min. The resultant reaction mixture was allowed to stir for 3 h and then diluted with a solution of dilute HCl (15 mL). The mixture was extracted with diethyl ether (3 x 3 mL) and the combined organic extracts were dried (anhyd. Na$_2$SO$_4$) and concentrated under reduced pressure. Flash chromatography on silica gel (98–95:2–5 hexanes:ethyl acetate) affords the title compound (3.69 g, 87%) as a colorless oil: TLC analysis $R_f$ 0.8 (95:5 hexanes:ethyl acetate); $^1$H NMR (300 MHz, CDCl$_3$) δ 5.04 (1H, s, f), 4.96 (1H, s, f), 4.60 (2H, s, d), 4.20 (2H, q, $J = 7.1$ Hz, b), 2.00–1.90 (1H, m, g), 1.90–1.75 (4H, m, h,h’,i,i’), 1.75–1.65 (1H, m, j), 1.31 (3H, t, $J = 7.1$ Hz, a), 1.30–1.10 (5H, m, h,h’,i,i’,j); $^{13}$C NMR (75 MHz, CDCl$_3$) δ 155.07 (c), 148.66 (e), 111.07 (f), 69.35 (d), 63.92 (b), 41.19 (g), 32.09 (h,h’), 26.56 (i,i’), 26.21 (j), 14.25 (a); IR (neat) 2926, 2853, 1742 (C=O stretch), 1649, 1448, 1374, 1241 (C–O stretch), 1004, 908, 790, 630 cm$^{-1}$; HRMS (CI) calcd. for C$_{12}$H$_{21}$O$_3$ (M+H): 213.1491, found 213.1493 m/z.

2-Phenylallyl ethyl carbonate: Using the general procedure, 2-phenyl-2-propenol (2.68 g, 20 mmol) affords, after flash chromatography on silica gel (98–95:2–5 hexanes:ethyl acetate), the title compound (3.46 g, 84%) as a colorless oil: TLC analysis $R_f$ 0.8 (95:5 hexanes:ethyl acetate); $^1$H NMR (300 MHz, CDCl$_3$) δ 7.50–7.45 (2H, m, h,h’), 7.45–7.30 (3H, m, i,i’,j), 5.60 (1H, s, f), 5.45 (1H, s, f), 5.06 (2H, s, d), 4.23 (2H, q, $J = 7.1$ Hz, b), 1.33 (3H, t, $J = 7.1$ Hz, a); $^{13}$C NMR (75 MHz, CDCl$_3$) δ 155.06 (c), 142.15 (e), 137.86 (g), 128.54 (i,i’), 128.14 (j), 126.04 (h,h’), 115.62 (f), 68.87 (d), 64.15 (b), 14.25 (a); IR (neat) 2984, 1740 (C=O stretch), 1634, 1375, 1242 (C–O stretch), 1006, 910, 872, 789, 705, 547 cm$^{-1}$.
General procedure for the directed catalytic asymmetric hydroboration (CAHB).

Preparation of \((R)-5\)-methyl-3-(4,4,6-trimethyl-1,3,2-dioxaboratomethyl)hexanoic acid phenyl amide (\((R)-4\)): A stock solution containing Rh(nbd)\(_2\)BF\(_4\) (2.6 mM) and (3,5-dimethylphenyl-TADDOL)POPh (\((R,R)-6\), 5.5 mM) in THF (2.0 mL) was prepared. To the resulting yellow solution [Rh(nbd)\(_2\)BF\(_4\) (2.0 mg, 0.0053 mmol) and \((R,R)-6\) (7.8 mg, 0.011 mmol)] was added \(\beta,\gamma\)-unsaturated amide 3 (115 mg, 0.53 mmol) as a solution in THF (2.0 mL). To the resulting solution was slowly added (i.e., dropwise over the course of 0.5 h) a solution of 4,4,6-trimethyl-1,3,2-dioxaborinane (tmdBH, 5, 135 mg, 1.1 mmol) in THF (1 mL). The mixture was then stirred at 40 °C for 24 h. Afterwards, the reaction was concentrated under reduced pressure and purified via flash chromatography on silica gel (80:20 hexanes:ethyl acetate) to afford the title compound (131 mg, 72%) as a yellow oil: TLC analysis \(R_f 0.7\) (60:40 hexanes:ethyl acetate); \([\alpha]_{D}^{20} = -17.9^\circ\) (c 0.5, CHCl\(_3\)); \(^1\)H NMR (400 MHz, CDCl\(_3\)) \(\delta 8.13\) (1H, br s, NH), 7.56 (2H, d, \(J = 8.3\) Hz, c,c’), 7.33 (2H, t, \(J = 7.9\) Hz, b,b’), 7.10 (1H, t, \(J = 7.4\) Hz, a), 4.30–4.20 (1H, m, l), 2.40–2.25 (2H, m, f), 2.25–2.15 (1H, m, g), 1.84 (1H, dd, \(J = 13.9\) Hz, 2.9 Hz, k), 1.80–1.70 (1H, m, o), 1.53 (1H, dd, \(J = 13.7\) Hz, 11.8 Hz, k), 1.35 (6H, s, j,j’), 1.31 (3H, dd, \(J = 6.2\) Hz, 2.0 Hz, m), 1.20 (2H, t, \(J = 6.8\) Hz, n), 0.95–0.85 (6H, t, \(J = 7.1\) Hz, p), 0.90–0.70 (2H, m, h); \(^{13}\)C NMR (100 MHz, CDCl\(_3\)) \(\delta 171.62\) (e), 138.45 (d), 128.91 (b,b’), 119.61 (c,c’), 71.21 and 71.16 (i), 64.90 (l), 46.75 (n), 44.99 (k), 45.88 (f), 31.40 (h), 30.96 (g), 28.26 and 28.20 (j,j’), 25.14 and 25.11 (o), 23.30 and 23.28 (m), 23.08, 23.06 and 23.34 (p,p’); IR (neat) 3304 (N-H stretch), 2954, 1659 (C=O stretch), 1600, 1544 (N-H bend), 1499, 1442, 1389, 1302 (C-O stretch), 1208 (C-N stretch), 1161, 755 cm\(^{-1}\); HRMS (El) calcd. for \(C_{20}H_{32}BNO_3\): 345.2475, found 345.2486 m/z.

Preparation of \((S)-3\)-methyl-4-(4,4,6-trimethyl-1,3,2-dioxaborato)butanoic acid phenyl amide (\((S)-8a\)): Using the representative procedure at room temperature, CAHB of \(\beta,\gamma\)-unsaturated amide 7a (93 mg, 0.53 mmol) affords, after flash chromatography on silica gel (80:20 hexanes:ethyl acetate), the title compound (85 mg, 53%) as a yellow oil: TLC analysis \(R_f 0.7\) (60:40 hexanes:ethyl acetate); \([\alpha]_{D}^{20} = -18.8^\circ\) (c 0.5, CHCl\(_3\)); \(^1\)H NMR (300 MHz, CDCl\(_3\)) \(\delta 7.82\) (1H, br s, NH), 7.56 (2H, d, \(J = 7.9\) Hz, c,c’), 7.33 (2H, t, \(J = 7.8\) Hz, b,b’), 7.11 (1H, t, \(J = 7.4\) Hz, a), 4.30–4.20 (1H, m, l), 2.40–2.20 (3H, m, g,f), 1.82 (1H, dd, \(J = 14.0\) Hz, 2.9 Hz, k), 1.80–1.70 (1H, m, o), 1.53 (1H, dd, \(J = 13.7\) Hz, 11.8 Hz, k), 1.35 (6H, s, j,j’), 1.31 (3H, dd, \(J = 6.2\) Hz, 2.0 Hz, m), 1.20 (2H, t, \(J = 6.8\) Hz, n), 0.95–0.85 (6H, t, \(J = 7.1\) Hz, p), 0.90–0.70 (2H, m, h); \(^{13}\)C NMR (100 MHz, CDCl\(_3\)) \(\delta 171.62\) (e), 138.45 (d), 128.91 (b,b’), 119.61 (c,c’), 71.21 and 71.16 (i), 64.90 (l), 46.75 (n), 44.99 (k), 45.88 (f), 31.40 (h), 30.96 (g), 28.26 and 28.20 (j,j’), 25.14 and 25.11 (o), 23.30 and 23.28 (m), 23.08, 23.06 and 23.34 (p,p’); IR (neat) 3304 (N-H stretch), 2954, 1659 (C=O stretch), 1600, 1544 (N-H bend), 1499, 1442, 1389, 1302 (C-O stretch), 1208 (C-N stretch), 1161, 755 cm\(^{-1}\); HRMS (El) calcd. for \(C_{20}H_{32}BNO_3\): 345.2475, found 345.2486 m/z.
1.51 (1H, dd, $J = 13.6$ Hz, 11.8 Hz, k), 1.33 (6H, s, j,j'), 1.29 (3H, d, $J = 6.2$ Hz, m), 1.05 (3H, d, $J = 6.2$ Hz, n), 0.81 (2H, d, $J = 5.7$ Hz, h); $^{13}$C NMR (75 MHz, CDCl$_3$) $\delta$ 171.38 (e), 138.33 (d), 128.92 (b,b'), 123.85 (a), 119.62 (c,c'), 71.02 (i), 64.79 (l), 46.97 (k), 45.89 (f), 31.35 (h), 28.38 (j,j'), 28.20 (m), 23.24 (n), 22.85 (g); IR (neat) 3301 (N-H stretch), 2972, 1660 (C=O stretch), 1600, 1554 (N-H bend), 1499, 1442, 1390, 1302 (C-O stretch), 1209 (C-N stretch), 1161, 755, 692 cm$^{-1}$; HRMS (EI) calcd. for C$_{17}$H$_{26}$BNO$_3$: 303.006, found 303.1996 m/z.

(R)-3-(4,4,6-Trimethyl-1,3,2-dioxaboratometethyl)pentanoic acid phenyl amide ((R)-8b): Using the representative procedure at room temperature, CAHB of $\beta,\gamma$-unsaturated amide 7b (100 mg, 0.53 mmol) affords, after flash chromatography on silica gel (80:20 hexanes:ethyl acetate), the title compound (100 mg, 60% as a yellow oil: TLC analysis R$_f$ 0.7 (60:40 hexanes:ethyl acetate); $[\alpha]_D^{20} = -22.4^\circ$ (c 0.5, CHCl$_3$); $^1$H NMR (400 MHz, CDCl$_3$) $\delta$ 8.04 (1H, br s, NH), 7.56 (2H, d, $J = 8.0$ Hz, c,c'), 7.33 (2H, t, $J = 7.9$ Hz, b,b'), 7.10 (1H, t, $J = 7.4$ Hz, a), 4.30–4.20 (1H, m, l), 2.40–2.30 (2H, m, f), 2.15–2.00 (1H, m, g), 1.83 (1H, dd, $J = 14.0$ Hz, 2.9 Hz, k), 1.52 (1H, dd, $J = 13.8$ Hz, 11.9 Hz, k), 1.50–1.35 (2H, m, n), 1.35 (6H, s, j,j'), 1.30 (3H, dd, $J = 6.2$ Hz, 1.5 Hz, m), 0.95 (3H, t, $J = 7.4$ Hz, o), 0.95–0.85 (1H, m, h), 0.85–0.75 (1H, m, h); $^{13}$C NMR (100 MHz, CDCl$_3$) $\delta$ 171.73 (e), 138.46 (d), 128.89 (b,b'), 123.77 (a), 119.63 (c,c'), 71.13 and 71.09 (i), 64.86 (l), 45.84 (k), 44.34 (f), 34.88 (g), 31.37 (h), 29.92 (n), 28.22 and 28.18 (j,j'), 23.26 (m), 11.66 (o); IR (neat) 3296 (N-H stretch), 2971, 2926, 1660 (C=O stretch), 1600, 1543 (N-H bend), 1499, 1441, 1389, 1302 (C-O stretch), 1209 (C-N stretch), 755 cm$^{-1}$; HRMS (EI) calcd. for C$_{18}$H$_{28}$BNO$_3$: 317.2162, found 317.2172 m/z.

(S)-3-Cyclohexyl-4-(4,4,6-trimethyl-1,3,2-dioxaboratometethyl)butanoic acid phenyl amide ((S)-8e): Using the representative procedure, CAHB of $\beta,\gamma$-unsaturated amide 7e (128 mg, 0.53 mmol) affords, after flash chromatography on silica gel (80:20 hexanes:ethyl acetate), the title compound (141 mg, 72%) as a yellow oil: TLC analysis R$_f$ 0.7 (60:40 hexanes:ethyl acetate); $[\alpha]_D^{20} = -16.4^\circ$ (c 0.5, CHCl$_3$); $^1$H NMR (400 MHz, CDCl$_3$) $\delta$ 8.03 (1H, br s, NH), 7.56 (2H, d, $J = 7.9$ Hz, c,c'), 7.32 (2H, t, $J = 7.9$ Hz, b,b'), 7.09 (1H, t, $J = 7.4$ Hz, a), 4.30–4.15 (1H, m, l), 2.50–2.30 (2H, m, f), 2.10–2.00 (1H, m, g), 1.80 (1H, dd, $J = 14.1$ Hz, 2.6 Hz, k), 1.80–1.65 (5H, m, n,p,p'), 1.51 (1H, t, $J = 12.8$ Hz, k), 1.32 (6H, s, j,j'), 1.28 (3H, d, $J = 6.0$ Hz, m), 1.25–0.95 (6H, m, o,o',q), 0.87 (1H, dd, $J = 15.3$ Hz, 5.2 Hz, h), 0.80–0.70 (1H, m, h); $^{13}$C NMR (100

S15
MH, CDCl 3) δ 172.35 (e), 138.48 (d), 128.90 (b,b’), 123.76 (a), 119.64 (c,c’), 71.09 and 71.00 (i), 64.86 and 64.80 (I), 45.78 (k), 43.29 and 43.26 (n), 42.25 and 42.21 (f), 38.48 (g), 31.36 (h), 30.49 (o,o’), 29.81, 29.70, 28.16, and 28.08 (j,j’), 26.73 (p,p’), 26.68 (q), 23.25 (m); IR (neat) 3298 (N-H stretch), 3255, 2928, 1656 (C=O stretch), 1595 (N-H stretch), 1414, 1418 (C-O stretch), 1246, 1206 (C-N stretch), 1141, 755 cm -1; HRMS (EI) calcd. for C 32 H 32 BNO 3: 371.2632, found 371.2627 m/z.

(S)-4-(4,4,6-trimethyl-1,3,2-dioxaborato)-3-phenylbutanoic acid phenyl amide ((S)-8f): Using the representative procedure, CAHB of β,γ-unsaturated amide 7f (125 mg, 0.53 mmol) affords, after flash chromatography on silica gel (80:20 hexanes:ethyl acetate), the title compound (137 mg, 73% yield). 1 H NMR (400 MHz, CDCl 3 ) δ 7.36 (2H, d, J = 7.8 Hz, c,c’), 7.35–7.25 (6H, m, b,b’,o,o’,p,p’), 7.25–7.15 (1H, m, q), 7.07 (1H, t, J = 7.2 Hz, a), 4.15–4.00 (1H, m, l), 3.50–3.40 (1H, m, g), 2.80–2.70 (1H, m, f), 2.62 (1H, dd, J = 13.6 Hz, 2.8 Hz, f), 1.69 (1H, dd, J = 13.9 Hz, 2.8 Hz, k), 1.35–1.25 (1H, m, k), 1.25–1.05 (1H, m, h,j,j’,m); 13 C NMR (100 MHz, CDCl 3 ) δ 170.56 (e), 146.23 (n), 137.95 (d), 128.84 (b,b’), 128.41 (p,p’), 127.32 and 127.30 (o,o’), 126.29 (q), 123.99 (a), 119.80 (c,c’), 70.80 (i), 64.71 and 64.68 (l), 47.15 and 47.11 (f), 45.70 (k), 39.05 (g), 31.15 and 31.11 (h), 27.97 and 27.90 (j,j’), 23.08 and 23.07 (m); IR (neat) 3299 (N-H stretch), 2973, 1657 (C=O stretching), 1600, 1544 (N-H bend), 1499, 1442, 1392, 1302 (C-O stretch), 1208 (C-N stretch), 1187, 909, 755, 731 cm -1; HRMS (EI) calcd. for C 22 H 28 BNO 3: 365.2162, found 365.2169 m/z.

(R)-3-((4,4,6-trimethyl-1,3,2-dioxaborato)methyl)-5-phenylpentanoic acid phenyl amide ((R)-8c): Using the representative procedure, CAHB of β,γ-unsaturated amide 7c (140 mg, 0.53 mmol) affords, after flash chromatography on silica gel (80:20 hexanes:ethyl acetate), the title compound (152 mg, 73%) as a yellow oil: TLC analysis R f 0.7 (60:40 hexanes:ethyl acetate); [α] D 20 = -12.6° (c 0.5, CHCl 3 ); 1 H NMR (300 MHz, CDCl 3 ) δ 8.05 (1H, br s, NH), 7.56 (2H, d, J = 8.0 Hz, c,c’), 7.40–7.15 (7H, m, b,b’,o,o’,p,p’,q), 7.11 (1H, t, J = 7.3 Hz, a), 4.35–4.15 (1H, m, l), 2.85–2.60 (2H, m, o), 2.45–2.35 (2H, m, f), 2.30–2.15 (1H, m, g), 1.85 (1H, dd, J = 14.0 Hz, 2.8 Hz, k), 1.80–1.60 (2H, m, n), 1.60–1.45 (1H, m, k), 1.36 (6H, s, j,j’), 1.32 (3H, d, J = 6.2 Hz, m), 1.00–0.90 (2H, m, h); 13 C NMR (75 MHz, CDCl 3 ) δ 171.35 (e), 142.74 (p), 138.36 (d),
(R)-3-((4,4,6-Trimethyl-1,3,2-dioxaborato)methyl)-6-phenylhexanoic acid phenyl amide ((R)-8d): Using the representative procedure, CAHB of $\beta,\gamma$-unsaturated amide 7d (148 mg, 0.53 mmol) affords, after flash chromatography on silica gel (80:20 hexanes:ethyl acetate), the title compound (151 mg, 70%) as a yellow oil: TLC analysis $R_f$ 0.7 (60:40 hexanes:ethyl acetate); $[\alpha]_D^{20} = -14.5^\circ$ (c 0.5, CHCl$_3$); $^1$H NMR (400 MHz, CDCl$_3$) $\delta$ 7.99 (1H, br s, NH), 7.55 (2H, d, $J = 7.8$ Hz, c,c’), 7.33 (2H, t, $J = 7.7$ Hz, b,b’), 7.30–7.25 (2H, m, s,s’), 7.25–7.15 (3H, m, r,r’,t), 7.11 (1H, t, $J = 7.3$ Hz, a), 4.25–4.15 (1H, m, l), 2.70–2.50 (2H, m, p), 2.40–2.30 (2H, m, f), 2.25–2.10 (1H, m, g), 1.81 (1H, dd, $J = 14.0$ Hz, 2.6 Hz, k), 1.80–1.65 (2H, m, o), 1.55–1.40 (2H, m, k,n), 1.35–1.25 (10H, m, n,j,j’,m), 0.95–0.85 (2H, m, h); $^{13}$C NMR (100 MHz, CDCl$_3$) $\delta$ 171.51 (e), 142.71 (q), 138.36 (d), 128.92 (b,b’), 128.42 (s,s’), 128.20 (r,r’), 125.57 (t), 123.84 (a), 119.63 (c,c’), 71.13 (i), 64.84 (l), 45.81 (k), 44.77 (f), 36.82 (n), 36.04 (p), 33.20 (g), 31.35 (h), 29.71 and 29.04 (j,j’), 28.15 (o), and 23.23 (m); IR (neat) 2973 (N-H stretch), 1595, 1495 (N-H bend), 1386, 1328, 1307, 1239 (C-N stretch), 1143 (C-O stretch), 1119 (C-O stretch), 966, 868, 772, 749, 698 cm$^{-1}$; HRMS (ESI) calcd. for C$_{25}$H$_{35}$BNaNO$_3$ (M+Na): 408.2710, found 408.2711 m/z.

(S)-3-Methyl-4-(4,4,6-trimethyl-1,3,2-dioxaborato)butanoic acid tert-butyl ester ((S)-8g): Using the representative procedure at room temperature, CAHB of $\beta,\gamma$-unsaturated ester 7g (83 mg, 0.53 mmol) affords, after flash chromatography on silica gel (95:5 hexanes:ethyl acetate), the title compound (93 mg, 62%) as a yellow oil: TLC analysis $R_f$ 0.5 (80:20 hexanes:ethyl acetate); $[\alpha]_D^{20} = -4.0^\circ$ (c 0.5, CHCl$_3$); $^1$H NMR (400 MHz, CDCl$_3$) $\delta$ 4.20–4.05 (1H, m, j), 2.25–2.15 (1H, m, d), 2.15–2.05 (1H, m, e), 2.05–1.95 (1H, m, d), 1.75 (1H, dd, $J = 13.8$ Hz, 2.7 Hz, i), 1.50–1.40 (1H, m, i), 1.43 (9H, s, a,a’,a”), 1.26 (6H, s, h,h’), 1.22 (3H, d, $J = 5.8$ Hz, k), 0.93 (3H, d, $J = 6.3$ Hz, l), 0.80–0.70 (1H, m, f), 0.65–0.50 (1H, m, f); $^{13}$C NMR (100 MHz, CDCl$_3$) $\delta$ 172.96 (c), 79.50 (b), 70.39 (g), 64.44 (j), 45.95 (i), 45.19 (e), 45.15 (d), 31.25 (f), 28.13
(R)-3-((4,4,6-Trimethyl-1,3,2-dioxaborato)methyl)pentanoic acid tert-butyl ester ((R)-8h): Using the representative procedure at room temperature, CAHB of \( \beta,\gamma \)-unsaturated ester 7h (90 mg, 0.53 mmol) affords, after flash chromatography on silica gel (95:5 hexanes:ethyl acetate), the title compound (102 mg, 65%) as a yellow oil: TLC analysis \( R_f \) 0.5 (80:20 hexanes:ethyl acetate); [\( \alpha \)]\(_D\)^{20} = -3.8° (c 0.5, CHCl\(_3\)); \(^1\)H NMR (300 MHz, CDCl\(_3\)) \( \delta \) 4.25–4.10 (1H, m, j), 2.19 (2H, dd, \( J = 6.9 \) Hz, d, cH), 2.05–1.95 (1H, m, e), 1.77 (1H, dd, \( J = 13.8 \) Hz, 3.0 Hz, i), 1.50–1.40 (1H, m, i), 1.46 (9H, s, a,a’,a’’), 1.40–1.30 (2H, m, l), 1.28 (6H, s, h,h’), 1.24 (3H, d, \( J = 6.2 \) Hz, k), 0.88 (3H, t, \( J = 7.4 \) Hz, m), 0.69 (2H, d, \( J = 6.8 \) Hz, f); \(^{13}\)C NMR (75 MHz, CDCl\(_3\)) \( \delta \) 173.24 (c), 79.51 (b), 70.39 (g), 64.41 (j), 43.17 (d), 43.17 (d), 31.30 (f), 29.62 (e), 28.16 (aa’,a’’), 28.06 (h,h’), 25.32 (m), 23.21 (k), 11.19 (m); IR (neat) 2976, 2926, 1725 (C=O stretch), 1456, 1379, 1315, 1248, 1141 (C-O stretch), 1051, 968, 917, 846, 750, 733, 681, 667 cm\(^{-1}\); HRMS (CI) calcd. for C\(_{15}\)H\(_{30}\)BO\(_4\) (M+H): 285.2237, found 285.2243 m/z.

(R)-5-Methyl-3-((4,4,6-trimethyl-1,3,2-dioxaborato)methyl)hexanoic acid tert-butyl ester ((R)-8i): Using the representative procedure at room temperature, CAHB of \( \beta,\gamma \)-unsaturated ester 7i (105 mg, 0.53 mmol) affords, after flash chromatography on silica gel (95:5 hexanes:ethyl acetate), the title compound (134 mg, 78%) as a yellow oil: TLC analysis \( R_f \) 0.5 (80:20 hexanes:ethyl acetate); [\( \alpha \)]\(_D\)^{20} = -2.7° (c 0.5, CHCl\(_3\)); \(^1\)H NMR (300 MHz, CDCl\(_3\)) \( \delta \) 4.20–4.10 (1H, m, j), 2.20–2.05 (3H, m, d,e), 1.77 (1H, dd, \( J = 13.8 \) Hz, 2.8 Hz, i), 1.70–1.55 (1H, m, m), 1.50–1.40 (1H, m, i), 1.46 (9H, s, a,a’,a’’), 1.28 (6H, s, h,h’), 1.24 (3H, d, \( J = 6.2 \) Hz, k), 1.13 (2H, t, \( J = 5.9 \) Hz, l), 0.90–0.85 (6H, m, n,n’), 0.69 (2H, d, \( J = 5.9 \) Hz, f); \(^{13}\)C NMR (75 MHz, CDCl\(_3\)) \( \delta \) 173.16 (c), 79.51 (b), 70.39 (g), 64.43 (j), 46.21 (l), 45.97 (i), 43.17 (d), 31.30 (f), 29.62 (e), 28.16 (aa’,a’’), 28.06 (h,h’), 25.32 (m), 23.21 (k), 23.15, 23.04, 22.83, 22.64 (n,n’); IR (neat) 2971, 2931, 2870, 1725 (C=O stretch), 1456, 1389, 1366, 1300, 1206, 1156 (C-O stretch), 1134 (C-O stretch), 956, 846, 739 cm\(^{-1}\); HRMS (ESI) calcd. for C\(_{18}\)H\(_{35}\)NaBO\(_4\) (M+Na): 349.2526, found 349.2515 m/z.
(R)-5-(2-Chlorophenyl)-3-(4,4,6-trimethyl-1,3,2-dioxaboratomethyl)pentanoic acid tert-butyl ester ((R)-13): Using the representative procedure, CAHB of 12 (148 mg, 0.53 mmol) with Rh(nbd)2BF4 (3.9 mg, 0.011 mmol) and (R,R)-6 (15.2 mg, 0.022 mmol) affords, after flash chromatography on silica gel (95:5 hexanes:ethyl acetate), the title compound (144 mg, 79 %) as a yellow oil: TLC analysis Rf 0.5 (80:20 hexanes:ethyl acetate); [o]D20 = -4.5º (c 0.5, CHCl3); 1H NMR (300 MHz, CDCl3) δ 7.32 (1H, dd, J = 7.6 Hz, 1.2 Hz, r), 7.23 (1H, dd, J = 7.5 Hz, 1.9 Hz, p), 7.18 (1H, dd, J = 7.2 Hz, 1.5 Hz, o), 7.12 (1H, dd, J = 7.6 Hz, 2.1 Hz, q), 4.25–4.10 (1H, m, j), 2.80–2.70 (2H, m, m), 2.35–2.25 (2H, m, d), 2.25–2.10 (1H, m, e), 1.77 (1H, dd, J = 13.8 Hz, 2.9 Hz, i), 1.70–1.55 (2H, m, l), 1.55–1.40 (1H, m, i), 1.46 (9H, s, a,a’,a”), 1.28 (6H, s, h,h’), 1.24 (3H, d, J = 6.2 Hz, k), 0.82 (2H, d, J = 6.2 Hz, f); 13C NMR (75 MHz, CDCl3) δ 172.90 (c), 140.65 (n), 133.84 (s), 130.29 (r), 129.33 (q), 126.99 (o), 126.77 (p), 79.71 and 79.70 (b), 70.51 (g), 64.52 (j), 45.94 (i), 42.56 (d), 36.45 (l), 31.82 (o), 31.08 (e), 28.16 (a,a’,a”), 28.11 (h,h’), 23.20 (k); IR (neat) 2978, 2930, 1724 (C=O stretch), 1475, 1443, 1366, 1320, 1240, 1142, 1050, 968, 917, 846, 750, 732, 680, 647 cm⁻¹; HRMS (ESI) calcd. for C22H34NaClO4 (M+Na): 431.2136, found 431.2145 m/z.

(S)-6-Methyl-3-(4,4,6-trimethyl-1,3,2-dioxaborato)heptanoic acid phenyl amide ((S)-2): Using the representative procedure, CAHB of βγ-unsaturated amide 1 (115 mg, 0.53 mmol) affords, after flash chromatography on silica gel (80:20 hexanes:ethyl acetate), the title compound (144 mg, 79%) as a yellow oil: TLC analysis Rf 0.7 (80:20 hexanes:ethyl acetate); [o]D20 = -7.9º (c 0.5, CHCl3); 1H NMR (400 MHz, CDCl3) δ 7.59 (1H, br s, NH), 7.52 (2H, d, J = 7.1 Hz, c,c’), 7.32 (2H, t, J = 7.4 Hz, b,b’), 7.09 (1H, t, J = 7.2 Hz, a), 4.30–4.15 (1H, m, k), 4.30–4.10 (1H, m, k), 2.55–2.40 (1H, m, f), 2.40–2.20 (4H, m, f,g,m), 1.85–1.65 (2H, m, j,o), 1.60–1.45 (3H, m, j,n), 1.29 (6H, s, j,j’), 1.26 (3H, dd, J = 6.2 Hz, 2.1 Hz, l), 0.89 (6H, d, J = 6.4 Hz, p,p’); 13C NMR (100 MHz, CDCl3) δ 172.34 (e), 138.39 (d), 128.90 (b,b’), 123.72 (a), 119.60 (c,c’), 70.80 (h), 64.80 and 64.76 (k), 45.93 and 45.89 (j), 39.79 (f), 38.67 (n), 38.11 and 38.05 (g), 31.28 and 27.99 (i,i’), 29.08 (o), 28.20 (m), 23.22 (l), 22.59 (p,p’); IR (neat) 3304 (N-H stretch), 2973, 1660 (C=O stretch), 1600, 1541 (N-H stretch), 1442, 1391, 1369, 1302 (C-O stretch), 1209 (C-N stretch), 1161, 898, 756 cm⁻¹; HRMS (ESI) calcd. for C20H32NaBNO3 (M+Na): 368.2373, found 368.2364 m/z.

General procedure for CAHB-oxidation sequence with H2O2.
(R)-3-Hydroxymethyl-5-methylhexanoic acid phenyl amide ((R)-17): After the CAHB of 3, the resultant mixture was diluted with THF (10 mL). Addition of sodium hydroxide (6 mL of a 3 M soln.) and slow addition of H_2O_2 (0.6 mL of a 30% soln.) afforded a mixture which was allowed to stir for 2 h. After extraction with dichloromethane (3 x 15 mL), the combined organic extracts were dried (anhyd. Na_2SO_4) and concentrated under reduced pressure. Flash chromatography on silica gel (80–40:20–60 hexanes:ethyl acetate) affords the title compound (88 mg, 71%) as a white solid: mp 92.5–94 °C; TLC analysis R_f 0.4 (30:70 hexanes:ethyl acetate); [α]_D^{20} = +5.1° (c 0.5, CHCl_3); Chiral HPLC analysis (Chiralpak-IC, 90:10 hexanes:isopropanol) showed peaks at 27 minutes (2.5% (S)) and 30 minutes (97.5% (R)); ^1^H NMR (300 MHz, CDCl_3) δ 7.98 (1H, br s, NH), 7.51 (2H, d, J = 7.8 Hz, c,c'), 7.32 (2H, t, J = 7.6 Hz, b,b'), 7.11 (1H, t, J = 7.4 Hz, a), 3.75 (1H, dd, J = 10.9 and 3.8 Hz, h), 3.52 (1H, dd, J = 10.9 and 6.8 Hz, h), 3.14 (1H, br s, OH), 2.45–2.40 (2H, m, f), 2.30–2.15 (1H, m, g), 1.75–1.60 (1H, m, j), 1.30–1.10 (2H, m, i), 0.92 and 0.91 (6H, overlapping d's, J = 6.5 Hz, k,k'); ^1^C NMR (75 MHz, CDCl_3) δ 171.71 (e), 137.85 (d), 128.97 (b,b'), 124.36 (a), 120.06 (c,c'), 65.73 (h), 40.89 (i), 40.72 (f), 35.80 (g), 25.27 (j), 22.78 (k), 22.65 (k'); IR (neat) 3307 (O-H stretch), 3150 (C=O stretch), 1548 (N-H bend), 1452, 1355 (C-O stretch), 1205 (C-N stretch), 1143, 1077, 1032, 973, 873, 735, 695 cm^{-1}; HRMS (CI) calcd. for C_{14}H_{22}NO_2 (M+H): 236.1651, found 236.1651 m/z.

(β;γ-unsaturated amide 7e (140 mg, 0.53 mmol) affords, after flash chromatography on silica gel (80–40:20–60 hexanes:ethyl acetate), the title compound (106 mg, 71%) as a white solid: mp 92–94 °C; TLC analysis R_f 0.4 (30:70 hexanes:ethyl acetate); [α]_D^{20} = +4.3° (c 0.5, CHCl_3); Chiral HPLC analysis (Chiralpak-IC, 85:15 hexanes:isopropanol) showed peaks at 23 minutes (3.0% (S)) and 26 minutes (97.0% (R)); ^1^H NMR (400 MHz, CDCl_3) δ 7.75 (1H, br s, NH), 7.50 (2H, d, J = 7.8 Hz, c,c'), 7.35–7.25 (4H, m, b,b',l,l'), 7.25–7.15 (3H, m, m,m',n), 7.13 (1H, t, J = 7.4 Hz, a), 3.85–3.75 (1H, m, h), 3.70–3.60 (1H, m, h), 2.92 (1H, br s, OH), 2.80–2.65 (2H, m, j), 2.55–2.45 (2H, m, f), 2.20–2.10 (1H, m, g), 1.80–1.65 (2H, m, i); ^1^C NMR (100 MHz, CDCl_3) δ 171.32 (e), 141.89 (k), 137.75 (d), 129.01 (l,l'), 128.48 (b,b'), 128.37 (m,m'), 125.98 (n), 124.44 (a), 120.02 (c,c'), 65.36 (h), 40.60 (f), 37.77 (j), 33.41 (g), 33.11 (i); IR (neat) 3679 (O-H stretch), 3150 (N-H stretch), 2993, 2950, 1678 (C=O stretch), 1598, 1498 (N-H bend), 1443, 1322 (C-O stretch), 1304, 1197 (C-N stretch), 1174, 1095, 957, 762 cm^{-1}; HRMS (CI) calcd. for C_{18}H_{22}NO_2 (M+H): 284.1651, found 284.1656 m/z.
General procedure for small scale oxidation of purified organoboronates with H₂O₂ for chiral HPLC analysis.

Preparation of (R)-4-hydroxy-3-methylbutanoic acid phenyl amide: To a solution of γ-dioxaboroamide (S)-8a (30 mg, 0.10 mmol) in THF (0.5 mL) was added sodium hydroxide (0.6 mL of a 3 M soln.) and H₂O₂ (0.15 mL of a 30% soln.). After allowing a 2 h stir, the resultant mixture was extracted with dichloromethane (2 x 2 mL) and the combined organic extracts were dried (anhyd. Na₂SO₄) and then concentrated under reduced pressure. Flash chromatography on silica gel (80–40:20–60 hexanes:ethyl acetate) affords the title compound (19 mg, 97%) as a white solid: mp 115–117 ºC; TLC analysis Rₛ 0.3 (30:70 hexanes:ethyl acetate); [α]D₂₀ = +2.5º (c 0.5, CHCl₃); Chiral HPLC analysis (Chiralpak-IC, 75:25 hexanes:isopropanol, flow rate = 1.0 mL/min) showed peaks at 16 minutes (3.2% (S)) and 19 minutes (96.8% (R), (see traces for racemate and enriched product below); ^1H NMR (300 MHz, CDCl₃) δ 8.21 (1H, br s, OH), 7.51 (2H, d, J = 7.8 Hz, c,c’), 7.30 (2H, t, J = 7.6 Hz, b,b’), 7.10 (1H, t, J = 7.4 Hz, a), 3.70–3.55 (1H, m, h), 3.55–3.40 (2H, m, h,OH), 2.52 and 2.29 (2H, overlapping dd’s, J₁ = 14.0 Hz, 6.8 Hz, J₂ = 14.0 Hz, 6.00 Hz, f), 2.30–2.20 (1H, m, g), 1.00 (3H, d, J = 6.7 Hz, i); ^13C NMR (75 MHz, CDCl₃) δ 171.71 (e), 137.88 (d), 128.94 (b,b’), 124.40 (a), 120.19 (c,c’), 67.46 (h), 42.16 (f), 33.36 (g), 17.03 (i); IR (neat) 3286 (O-H stretch), 3195 (N-H stretch), 3139, 2957, 2928, 1667 (C=O stretch), 1599, 1549 (N-H bend), 1487, 1444, 1376, 1319 (C-O stretch), 1257, 1231 (C-N stretch), 1132, 1047, 754 cm⁻¹; HRMS (CI) calcd. for C₁₁H₁₆NO₂ (M+H): 194.1181, found 194.1180 m/z.
(R)-3-(Hydroxymethyl)pentanoic acid phenyl amide: Using the general procedure, γ-dioxaborato amide (R)-8b (32 mg, 0.10 mmol) affords, after flash chromatography on silica gel (80–40:20–60 hexanes:ethyl acetate), the title compound (20 mg, 98%) as a white solid: mp 118–119.5 °C; TLC analysis Rf 0.3 (30:70 hexanes:ethyl acetate); [α]D^20 = +2.1° (c 0.5, CHCl3); Chiral HPLC analysis (Chiralpak-IC, 90:10 hexanes:isopropanol) showed peaks at 40 minutes (4.0% (S)) and 46 minutes (96.0% (R)); 1H NMR (400 MHz, CDCl3) δ 7.83 (1H, br s, NH), 7.52 (2H, d, J = 7.9 Hz, c,c’), 7.33 (2H, t, J = 7.8 Hz, b,b’), 7.12 (1H, t, J = 7.3 Hz, a), 3.78 (1H, dd, J1 = 10.5 Hz, J2 = 3.0 Hz, h), 3.59 (1H, dd, J1 = 10.5 Hz, J2 = 6.8 Hz, h), 2.87 (1H, br s, OH); 13C NMR (100 MHz, CDCl3) δ 171.63 (e), 137.83 (d), 128.99 (c,c’), 124.38 (a), 119.99 (b,b’), 65.32 (h), 40.46 (f), 39.75 (g), 24.36 (i), 11.59 (j); IR (neat) 3349 (O-H stretch), 3253 (N-H stretch), 2959, 1670 (C=O stretch), 1599, 1551 (N-H bend), 1443, 1319 (C-O stretch), 1255 (C-N stretch), 1143, 1074, 758 cm⁻¹; HRMS (CI) calcd. for C12H18NO2 (M+H): 208.1338, found 208.1333 m/z.

(S)-3-Cyclohexyl-4-hydroxybutanoic acid phenyl amide: Using the general procedure, γ-dioxaborato amide (S)-8e (37 mg, 0.10 mmol) affords, after flash chromatography on silica gel (80–40:20–60 hexanes:ethyl acetate), the title compound (25 mg, 96%) as a white solid: mp 88–89 °C; TLC analysis Rf 0.4 (30:70 hexanes:ethyl acetate); [α]D^20 = +3.1° (c 0.5, CHCl3); Chiral HPLC analysis (Chiralpak-IC, 90:10 hexanes:isopropanol) showed peaks at 48 minutes (5.0% (S)) and 52 minutes (95.0% (R)); 1H NMR (300 MHz, CDCl3) δ 7.90 (1H, br s, NH), 7.52 (2H, d, J = 7.9 Hz, c,c’), 7.33 (2H, t, J = 7.9 Hz, b,b’), 7.12 (1H, t, J = 7.2 Hz, a), 3.82 (1H, dd, J = 10.8 and 4.0 Hz, h), 3.67 (1H, dd, J = 10.8 and 7.1 Hz, h), 2.51 (2H, d, J = 6.2 Hz, f), 2.00–1.80 (1H, m, g), 1.80–1.60 (5H, m, j,j’,k,k’,OH), 1.35–1.00 (7H, m, i,j,j’,k,k’,l); 13C NMR (75 MHz, CDCl3) δ 172.23 (e), 137.94 (d), 128.97 (c,c’), 124.27 (a), 119.92 (b,b’), 64.38 (h), 49.20 (g), 43.41 (f), 39.54 (i), 38.64 (j), 33.93 (j’), 30.36 (l), 26.55 (k), 26.48 (k’); IR (neat) 3292 (O-H stretch), 3100 (N-H stretch), 2957, 2893, 1655 (C=O stretch), 1599, 1540 (N-H stretch), 1444, 1327 (C-O stretch), 1268 (C-N stretch), 1121, 1053, 881, 753 cm⁻¹; HRMS (CI) calcd. for C16H24NO2 (M+H): 262.1807, found 262.1808 m/z.
(S)-4-Hydroxy-3-phenylbutanoic acid phenyl amide: Using the general procedure, \(\gamma\)-dioxaborato amide (S)-8f (37 mg, 0.10 mmol) affords, after flash chromatography on silica gel (80:40:20–60 hexanes:ethyl acetate), the title compound (25 mg, 98\%) as a white solid: mp 95.5–97 °C; TLC analysis \(R_f\) 0.4 (30:70 hexanes:ethyl acetate); \([\alpha]_D^{20} = +3.8^\circ\) (c 0.5, CHCl\(_3\)); Chiral HPLC analysis (Chiralpak-IC, 90:10 hexanes:isopropanol) showed peaks at 56 minutes (3.5\% (S)) and 85 minutes (96.5\% (R)); \(^1\)H NMR (300 MHz, DMSO-\(d_6\)) \(\delta\) 9.86 (1H, br s, NH), 7.51 (2H, d, \(J = 8.0\) Hz, c,c'), 7.30–7.10 (7H, m, b,b', j,j', k,k',l), 6.98 (1H, t, \(J = 7.3\) Hz, a), 4.79 (1H, t, \(J = 5.2\) Hz, OH), 3.65–3.50 (2H, m, h), 3.35–3.20 (1H, m, g), 2.82 and 2.60 (2H, overlapping dd's, \(J_1 = 14.8\) Hz, 5.9 Hz, \(J_2 = 14.8\) Hz, 8.9 Hz, f); \(^{13}\)C NMR (75 MHz, DMSO-\(d_6\)) \(\delta\) 170.55 (e), 143.16 (d), 139.67 (i), 129.06 (j,j'), 128.55 (b,b'), 128.32 (k,k'), 126.64 (l), 123.40 (a), 119.45 (c,c'), 65.84 (h), 44.92 (f); IR (neat) 3365 (O–H stretch), 3254, 3191 (N–H stretch), 3000; H NMR (300 MHz, CDCl\(_3\)) \(\delta\) 7.51 (1H, br s, NH), 7.50 (2H, d, \(J = 7.9\) Hz, m,m'), 7.40–7.30 (2H, m, c,c'), 7.30–7.25 (2H, m, b,b'), 7.25–7.15 (3H, m, n,n',o), 7.13 (1H, t, \(J = 7.5\) Hz, a), 3.77 (1H, dd, \(J = 10.9\) and 4.0 Hz, h), 3.58 (1H, dd, \(J = 10.9\) and 6.7 Hz, h), 2.64 (2H, t, \(J = 7.3\) Hz, k), 2.50–2.40 (2H, m, f), 2.20–2.10 (1H, m, g), 1.80–1.60 (2H, m, i), 1.60–1.40 (2H, m, j); \(^{13}\)C NMR (75 MHz, CDCl\(_3\)) \(\delta\) 171.29 (e), 142.18 (d), 137.73 (l), 129.00 (b,b'), 128.39 (m,m'), 128.34 (n,n'), 125.81 (o), 124.41 (a), 119.96 (c,c'), 65.53 (h), 40.65 (f), 38.02 (g), 35.96 (k), 31.06 (i), 28.95 (j); IR (neat) 3714 (O–H stretch), 3040 (N–H stretch), 2890, 1680 (C=O stretch), 1601, 1590, 1545 (N-H bend), 1499, 1451, 1369, 1308 (C=O stretch), 1204 (C–N stretch), 1186, 1100, 1020, 990, 756 cm\(^{-1}\); HRMS (CI) calcd. for C\(_{18}\)H\(_{18}\)NO\(_2\) (M+H): 256.1338, found 256.1337 m/z.

(R)-3-(Hydroxymethyl)-6-phenylhexanoic acid phenyl amide: Using the general procedure, \(\gamma\)-dioxaborato amide (R)-8d (41 mg, 0.10 mmol) affords, after flash chromatography on silica gel (80:40:20–60 hexanes:ethyl acetate), the title compound (29 mg, 98\%) as a white solid: mp 78.5–80 °C; TLC analysis \(R_f\) 0.5 (30:70 hexanes:ethyl acetate); \([\alpha]_D^{20} = +4.1^\circ\) (c 0.5, CHCl\(_3\)); Chiral HPLC analysis (Chiralpak-IC, 90:10 hexanes:isopropanol) showed peaks at 35 minutes (4.0\% (S)) and 37 minutes (96.0\% (R)); \(^1\)H NMR (300 MHz, DMSO-\(d_6\)) \(\delta\) 7.58 (1H, br s, NH), 170.48 (1), 132.74 (24, 22, d), 131.18 (l), 130.84 (n,n'), 129.06 (j,j'), 128.55 (b,b'), 128.32 (k,k'), 126.64 (l), 123.40 (a), 119.45 (c,c'), 65.84 (h), 44.92 (f); IR (neat) 3382 (O–H stretch), 3032, 2924 (C–H stretch), 2914, 2857 (C–H stretch), 1714 (C=O stretch), 1601, 1590, 1545 (N-H bend), 1499, 1451, 1369, 1308 (C=O stretch), 1204 (C–N stretch), 1186, 1100, 1020, 990, 756 cm\(^{-1}\); HRMS (CI) calcd. for C\(_{19}\)H\(_{24}\)NO\(_2\) (M+H): 298.1807, found 298.1800 m/z.

(S)-3-Hydroxy-6-methylheptanoic acid phenyl amide: Using the general procedure, \(\gamma\)-dioxaborato amide (S)-2 (35 mg, 0.10 mmol) affords, after flash chromatography on silica (80:20 hexanes:ethyl acetate), the title compound (23 mg, 98\%) as a white solid: mp 130.2–131.7 °C; TLC analysis \(R_f\) 0.4 (50:50 hexanes:ethyl acetate); \([\alpha]_D^{20} = +6.8^\circ\) (c 0.5, ethanol); chiral HPLC analysis (Chiralcel-ASH, 90:10 hexanes:isopropanol) showed peaks at 41.1 minutes (2.5\% (R))
and 48.3 minutes (97.5% (S)); \(^1\)H NMR (400 MHz, CDCl\(_3\)) \(\delta 7.89\) (1H, br s, NH), 7.52 (2H, d, \(J = 7.7\) Hz, c,c’), 7.35 (2H, t, \(J = 7.6\) Hz, b,b’), 7.14 (1H, t, \(J = 7.4\) Hz, a), 4.15-4.00 (1H, m, g), 3.20 (1H, br s, OH), 2.58 and 2.49 (2H, overlapping dd’s, \(J_1 = 15.5\) Hz, 2.7 Hz, \(J_2 = 15.5\) Hz, 8.8 Hz, f) 1.70-1.50 (3H, m, h,i), 1.40-1.30 (1H, m, i), 1.30-1.15 (1H, m, j), 0.92 (3H, d, \(J = 6.6\) Hz, k), 0.91 (3H, d, \(J = 6.6\) Hz, k’);

\(^13\)C NMR (100 MHz, CDCl\(_3\)) \(\delta 170.56\) (e), 137.59 (d), 129.04 (b,b’), 124.46 (a), 120.02 (c,c’), 69.15 (g), 43.78 (f), 34.85 (h), 34.59 (i), 28.00 (j), 22.61 (k), 22.52 (k’); IR (neat) 3286 (N-H stretch), 2953, 2869, 1663 (C=O stretch), 1598, 1548, 1442, 1314, 1256, 1079, 716, 692 cm\(^{-1}\); HRMS (FAB) calcd. for C\(_{14}\)H\(_{22}\)NO\(_2\) (M+H): 236.1651, found 236.1645 m/z.

General procedure for lactonization via one pot CAHB-oxidation with H\(_2\)O\(_2\).

(S)-4-isobutylbutyrolactone ((S)-20).\(^{[14]}\) After the CAHB of 7i using the general procedure with (S,S)-6, the resultant mixture was diluted with THF (10 mL). Addition of sodium hydroxide (6 mL of a 3 M soln.) and H\(_2\)O\(_2\) (0.6 mL of a 30% soln.) afforded a mixture which was allowed to stir for 2 h. Sodium metabisulfite (Na\(_2\)SO\(_5\), 4 mL of a 10% soln.) was added and the resultant mixture was acidified (6 M HCl) and extracted with dichloromethane (3 x 15 mL). The combined organic extracts were dried (anhyd. Na\(_2\)SO\(_4\)) and concentrated under reduced pressure. Flash chromatography on silica gel (75:25 hexanes:ethyl acetate) affords the title compound (58.6 mg, 78%) as a light yellow oil: TLC analysis \(R_f\) 0.5 (75:25 hexanes:ethyl acetate); [\(\alpha\)]\(_D\)\(^{20}\) = –1.5\(^{\circ}\) (c 0.5, CHCl\(_3\)); subsequent amidation\(^{[15]}\) with Al(Me)\(_3\) and aniline affords (S)-17 which was used to determine the enantiomeric purity (91% ee) by chiral HPLC analysis; \(^1\)H NMR (400 MHz, CDCl\(_3\)) \(\delta 4.41\) (1H, dd, \(J_1 = 8.8\) Hz, \(J_2 = 8.1\) Hz, d), 3.88 (1H, dd, \(J_1 = 8.9\) Hz, \(J_2 = 8.6\) Hz, d), 2.70–2.55 (2H, m, b), 2.25–2.10 (1H, m, c), 1.65–1.50 (1H, m, f), 1.36 (2H, t, \(J = 7.1\) Hz, e), 0.93 (3H, t, \(J = 6.6\) Hz, g), 0.90 (3H, t, \(J = 6.6\) Hz, g’);

\(^13\)C NMR (100 MHz, CDCl\(_3\)) \(\delta 177.22\) (a), 73.56 (d), 42.21 (e), 34.76 (b), 33.83 (c), 26.28 (f), 22.64 (g), 22.40 (g’); IR (neat) 2956, 2903, 1773 (C=O stretch), 1469, 1420, 1367, 1216, 1168 (C-O stretch), 1011, 913, 838, 730, 646, 557 cm\(^{-1}\).


\(^{[15]}\) For the amidation of esters, see reference 1.
(R)-4-benzylbutyrolactone ((R)-22a): Following the general procedure, β,γ-unsaturated ester 21a (123 mg, 0.528 mmol) affords, after flash chromatography on silica gel (75:25 hexanes:ethyl acetate), the title compound (74.7 mg, 80%) as a light yellow oil: TLC analysis Rf 0.4 (75:25 hexanes:ethyl acetate); [α]D = +5.3° (c 0.5, CHCl3); Chiral HPLC analysis (Chiralpak-AD, 95:5 hexanes:isopropanol) shows peaks at 36 minutes (97.5% (R)) and 40 minutes (2.5% (S)); 1H NMR (400 MHz, CDCl3) δ 7.34 (2H, t, J = 7.2 Hz, h,h'), 7.27 (1H, d, J = 6.9 Hz, i), 7.17 (2H, d, J = 7.3 Hz, g,g'), 4.35 (1H, dd, J1 = 8.9 Hz, J2 = 8.9 Hz, d), 4.05 (1H, dd, J1 = 6.2 Hz, J2 = 6.1 Hz, d), 2.95–2.85 (1H, m, c), 2.85–2.75 (2H, m, e), 2.62 (1H, dd, J1 = 17.4 Hz, J2 = 7.9 Hz, b), 2.31 (1H, dd, J1 = 17.4 Hz, J2 = 6.9 Hz, b); 13C NMR (100 MHz, CDCl3) δ 176.84 (a), 138.25 (f), 128.81 (g,g'), 128.67 (h,h'), 126.83 (i), 72.66 (d), 38.95 (e), 37.18 (b), 34.25 (c);

![Image](R)-22b

IR (neat) 2963, 2909, 1773 (C=O stretch), 1496, 1417, 1257, 1166 cm–1.

(S)-22c

(R)-4-(3-Methoxyphenyl)methylbutyrolactone ((R)-22b): Following the general procedure, β,γ-unsaturated ester 21b (139 mg, 0.528 mmol) affords, after flash chromatography on silica gel (75:25 hexanes:ethyl acetate), the title compound (86.2 mg, 79%) as a light yellow oil: TLC analysis Rf 0.3 (75:25 hexanes:ethyl acetate); [α]D = +5.5° (c 0.5, CHCl3); Chiral HPLC analysis (Chiralpak-AD, 90:10 hexanes:isopropanol) showed peaks at 31 minutes (97.5% (R)) and 34 minutes (2.5% (S)); 1H NMR (300 MHz, CDCl3) δ 7.25 (1H, t, J = 8.1 Hz, h), 6.85–6.80 (1H, m, i), 6.75 (1H, d, J = 7.5 Hz, g), 7.71 (1H, s, k), 4.35 (1H, dd, J1 = 9.1 Hz, J2 = 6.0 Hz, d), 4.05 (1H, dd, J1 = 9.1 Hz, J2 = 6.9 Hz, d), 3.82 (3H, s, l), 2.95–2.80 (1H, m, c), 2.80–2.75 (2H, m, e), 2.62 (1H, dd, J1 = 17.4 Hz, J2 = 7.9 Hz, b), 2.30 (1H, dd, J1 = 17.4 Hz, J2 = 6.9 Hz, b); 13C NMR (75 MHz, CDCl3) δ 176.80 (a), 159.91 (j), 139.81 (f), 129.82 (h), 120.97 (g), 114.64 (k), 111.86 (i), 72.64 (d), 55.20 (l), 38.97 (e), 37.07 (b), 34.26 (c); IR (neat) 2913, 1774 (C=O stretch), 1601, 1584, 1481, 1454, 1261, 1165 (C-O stretch), 1152 (C-O stretch), 1039, 1013, 909, 784, 727, 698, 647 cm–1.

(S)-4-(3,4-Dimethoxyphenyl)methylbutyrolactone ((S)-22c): Following the general procedure with (S,S)-6, β,γ-unsaturated ester 21c (154 mg, 0.528 mmol) affords, after flash chromatography on silica gel (75:25 hexanes:ethyl acetate), the title compound (94.6 mg, 75%) as a light yellow oil: TLC analysis \( R_f 0.3 \) (75:25 hexanes:ethyl acetate); \([\alpha]_D^{20} = -5.8^\circ\ (c 0.5, \text{CHCl}_3)\); Chiral HPLC analysis (Chiralpak-AD, 90:10 hexanes:isopropanol) shows peaks at 30 minutes (4.0% (R)) and 34 minutes (96.0% (S)); \(^1\)H NMR (400 MHz, CDC\(_3\)) \( \delta 6.81 \) (1H, d, \( J = 8.1 \) Hz, h), 6.75–6.70 (1H, m, g), 6.67 (1H, s, k), 4.33 (1H, dd, \( J_I = 9.0 \) Hz, \( J_2 = 7.0 \) Hz, d), 4.04 (1H, dd, \( J_I = 9.0 \) Hz, \( J_2 = 6.1 \) Hz, d), 3.88 (3H, s, m), 3.87 (3H, s, l), 2.90–2.80 (1H, m, c), 2.80–2.65 (2H, m, e), 2.61 (1H, dd, \( J_I = 17.5 \) Hz, \( J_2 = 8.1 \) Hz, b), 2.30 (1H, dd, \( J_I = 17.5 \) Hz, \( J_2 = 6.8 \) Hz, e); \(^13\)C NMR (100 MHz, CDC\(_3\)) \( \delta 176.95 \) (a), 149.10 (j), 147.88 (i), 130.77 (f), 120.65 (g), 111.79 (k), 111.41 (h), 72.66 (d), 55.92 (l), 55.90 (m), 38.57 (e), 37.29 (b), 34.24 (c); IR (neat) 2908, 2836, 2253, 1771 (C=O stretch), 1474, 1464, 1418, 1262, 1234, 1158 (C–O stretch), 1139 (C–O stretch), 1014 (C–O stretch), 912, 805, 725, 646 cm\(^{-1}\).

\[(R)\]-4-(2-(2-Chlorophenyl)ethyl)butyrolactone: Following the general procedure, beta, gamma-unsaturated ester 12 (148 mg, 0.53 mmol) affords, after flash chromatography on silica gel (75:25 hexanes:ethyl acetate), the title compound (87 mg, 73%) as a light yellow oil: TLC analysis \( R_f 0.5 \) (75:25 hexanes:ethyl acetate); \([\alpha]_D^{20} = +4.4^\circ\ (c 0.5, \text{CHCl}_3)\); Chiral HPLC analysis (Chiralpak-AD, 90:10 hexanes:isopropanol) shows peaks at 25 minutes (95.0% (R)) and 28 minutes (5.0% (S)); \(^1\)H NMR (300 MHz, CDC\(_3\)) \( \delta 7.40 \) (1H, m, j), 7.25–7.15 (3H, m, i,k,l), 4.45 (1H, dd, \( J_I = 9.0 \) Hz, \( J_2 = 7.5 \) Hz, d), 3.99 (1H, dd, \( J_I = 9.0 \) Hz, \( J_2 = 7.0 \) Hz, d), 2.85–2.75 (2H, m, f), 2.75–2.50 (2H, m, b), 2.30–2.20 (1H, m, c), 1.90–1.75 (2H, m, e); \(^13\)C NMR (75 MHz, CDC\(_3\)) \( \delta 177.06 \) (a), 138.44 (g), 133.77 (h), 130.30 (i), 129.71 (j), 127.89 (k), 127.07 (l), 73.22 (d), 35.26 (c), 34.46 (b), 33.25 (f), 31.46 (e), 30.57 (d); IR (neat) 2923, 1771 (C=O stretch), 1474, 1170 (C–O stretch), 1050, 1020, 991, 908, 840, 752, 727, 680 cm\(^{-1}\); HRMS (ESI) calcd. for C\(_{12}\)H\(_{13}\)ClO\(_2\): 224.0604, found 224.0600 m/z.

**General procedure for one pot CAHB-oxidation of esters with NaBO\(_3\).**

![Diagram](image)

**Preparation of (R)-3-Hydroxymethyl-5-methylhexanoic acid tert-butyl ester ((R)-19):** Following the general procedure for the CAHB of β,γ-unsaturated ester 7i, the resultant reaction mixture was concentrated under reduced pressure and then taken up in THF (1.5 mL).

and H₂O (1.5 mL). NaBO₃-tetrahydrate (231 mg, 1.5 mmol) was added to the resulting mixture. After a 2 h vigorous stir, the reaction was diluted with H₂O (3 mL) and diethyl ether (5 mL). After separation of the organic and aqueous layers, the aqueous layer was extracted with diethyl ether (2 x 3 mL) and the combined organic extracts were dried (anhyd. Na₂SO₄) and concentrated under reduced pressure. The crude residue was purified via flash chromatography on silica gel (80–70:20–30 hexanes:dichloromethane) to afford the title compound (88 mg, 77%) as a light yellow oil: TLC analysis R_f 0.6 (50:50 hexanes:dichloromethane); [α]_D²⁰ = +2.3⁰ (c 0.5, CHCl₃). Subsequent amidation with Al(Me)₃ and aniline affords (R)-17 which was used to determine the enantiomeric purity (91% ee) by chiral HPLC analysis; ¹H NMR (300 MHz, CDCl₃) δ 3.70–3.60 (1H, m, f), 3.60–3.40 (1H, m, f), 2.28 (2H, dd, J₁ = 4.4 Hz, J₂ = 2.5 Hz, d), 2.16 (1H, br s, OH), 2.10–2.00 (1H, m, e), 1.70–1.60 (1H, m, h), 1.47 (9H, s, a,a’,a”), 1.30–1.20 (2H, m, g), 0.92 (3H, d, J = 4.7 Hz, i), 0.90 (3H, d, J = 4.7 Hz, i’); ¹³C NMR (75 MHz, CDCl₃) δ 173.32 (c), 80.62 (b), 66.07 (f), 40.43 (d), 35.71 (e), 28.08 (a,a’,a”), 25.19 (h), 22.80 (i), 22.67 (i’); IR (neat) 3404 (O–H stretch), 2956, 2930, 1728 (C=O stretch), 1468, 1367, 1311 (C–O stretch), 1254, 1154, 1062, 959, 733 cm⁻¹.

(R)-5-(2-Chlorophenyl)-3-hydroxymethylpentanoic acid tert-butyl ester ((R)-15): Using the general procedure, β,γ-unsaturated ester 12 (148 mg, 0.53 mmol) affords, after flash chromatography on silica gel (80–70:20–30 hexanes:dichloromethane), the title compound (115 mg, 73%) as a light yellow oil: TLC analysis R_f 0.6 (50:50 hexanes:dichloromethane); [α]_D²⁰ = +4.5⁰ (c 0.5, CHCl₃); ¹H NMR (300 MHz, CDCl₃) δ 7.40–7.30 (1H, m, k), 7.25–7.10 (3H, m, l,m,n), 3.80–3.65 (1H, m, f), 3.65–3.55 (1H, m, f), 2.78 (2H, t, J = 8.2 Hz, h), 2.45–2.35 (2H, m, d), 2.29 (1H, br s, OH), 2.15–2.00 (1H, m, e), 1.80–1.60 (2H, m, g), 1.47 (9H, s, a,a’,a”); ¹³C NMR (75 MHz, CDCl₃) δ 173.04 (c), 139.69 (i), 133.79 (j), 130.27 (k), 129.49 (l), 127.38 (m), 126.85 (n), 80.76 (b), 65.49 (f), 38.03 (d), 37.78 (e), 31.30 (h), 31.03 (g), 28.09 (a,a’,a”); IR (neat) 3437 (O–H stretch), 2930, 1720 (C=O stretch), 1468, 1367, 1311 (C–O stretch), 1254, 1154, 1062, 959, 733 cm⁻¹; HRMS (EI) calcd. for C₁₆H₂₅ClNaO₃ (M+Na): 321.1233, found 321.1237 m/z.

General procedure for the preparation of trifluoroborate salts.¹¹⁹

Preparation of (S)-4-trifluoroborato-3-methylbutanoic acid phenyl amide potassium salt ((S)-10a): To a solution of γ-dioxaborato amide (S)-8a (152 mg, 0.50 mmol, 1.0 equiv) in acetonitrile (MeCN, 1.0 mL) was slowly added a solution of KHF$_2$ (117 mg, 1.5 mmol, 3.0 equiv) in H$_2$O (0.3 mL). After a 20 min stir, the reaction mixture was concentrated under reduced pressure and allowed to dry under vacuum overnight. The resultant crude solid was extracted with acetone (2 x 2 mL) and the combined organic extracts were concentrated under reduced pressure. Diethyl ether (3.0 mL) was added to precipitate the product. Filtration affords the title compound (92 mg, 65%) as a white solid: mp 176.5–177.5 °C; [α]$_D^{20} = +5.7$° (c 0.5, MeOH); $^1$H NMR (300 MHz, MeOD) δ 7.55 (2H, d, $J = 7.8$ Hz, c,c’),7.29 (2H, t, $J = 7.6$ Hz, b,b’),7.07 (1H, t, $J = 7.3$ Hz, a), 2.55–2.40 (1H, m, f), 2.20–2.00 (2H, m, f,g), 1.01 (3H, d, $J = 5.7$ Hz, i), 0.45–0.20 (2H, m, h); $^{13}$C NMR (75 MHz, MeOD) δ 174.97 (c), 79.46 (b), 45.73 (d), 27.88 (e), 27.05 (a,a’,a’’), 21.84 (g); IR (neat) 2983, 2898, 1728 cm$^{-1}$; HRMS (CI) calcd. for C$_{11}$H$_{15}$NO (M+H-BF$_3$K): 177.1153, found 177.1148 m/z.

(S)-4-Trifluoroborato-3-methylbutanoic acid tert-butyl ester potassium salt ((S)-10g): Using the general procedure, γ-dioxaborato ester (S)-8g (142 mg, 0.50 mmol) affords the title compound (82 mg, 62%) as a white solid: mp 176.0–178.0 °C; [α]$_D^{20} = +6.4$° (c 0.5, MeOH); $^1$H NMR (400 MHz, MeOD) δ 2.35 (1H, dd, $J = 13.7$ Hz, 5.2 Hz, d), 2.05–1.95 (1H, m, e), 1.91 (1H, dd, $J = 13.7$ Hz, 8.9 Hz, d), 1.46 (9H, s, a,a’,a’’), 0.94 (3H, d, $J = 6.5$ Hz, g), 0.35–0.15 (2H, m, f); $^{13}$C NMR (100 MHz, MeOD) δ 174.97 (c), 79.46 (b), 45.73 (d), 27.88 (e), 27.05 (a,a’,a’’), 21.84 (g); IR (neat) 2983, 1727 (C=O stretch), 1457, 1368 (C-O stretch), 1274, 1152, 1099, 956, 918, 842, 769 cm$^{-1}$; HRMS (CI) calcd. for C$_9$H$_{17}$O$_2$ (M+H-BF$_3$K): 147.1214, found 147.1215 m/z.

(R)-5-Methyl-3-trifluoroboratomethylhexanoic acid tert-butyl ester potassium salt ((R)-10i): Using the general procedure, γ-dioxaboromethyl ester (R)-8i (163 mg, 0.50 mmol) affords the title compound (146 mg, 75%) as a white solid: mp 179.0–179.5 °C; [α]$_D^{20} = +9.7$° (c 0.5, MeOH); $^1$H NMR (400 MHz, MeOD) δ 2.50–2.40 (1H, m, d), 2.05–1.95 (2H, m, d,e), 1.75–1.65 (1H, m, h), 1.46 (9H, s, a,a’,a’’), 1.25–1.15 (1H, m, g), 1.15–1.00 (1H, m, g), 0.88 (6H, t, $J = 6.1$ Hz, i,i’), 0.40–0.35 (1H, m, f), 0.15–0.05 (1H, m, f); $^{13}$C NMR (100 MHz, MeOD) δ 175.30 (c), 79.38 (b), 46.83 (g), 43.06 (d), 30.23 (e), 27.07 (a,a’,a’’), 24.99 (h), 22.41 and 21.64 (i,i’); IR (neat) 2953, 2906, 1728 (C=O stretch), 1392, 1367 (C-O stretch), 1256, 1125, 1069, 974, 908, 759 cm$^{-1}$; HRMS (CI) calcd. for C$_{12}$H$_{23}$O$_2$ (M-BF$_3$K): 199.1698, found 199.1510 m/z.
Supporting Information for γ-Selective Directed Catalytic Asymmetric Hydroboration (CAHB) of 1,1-Disubstituted Alkenes

(3R)-4-Trifluoroboratopentanoic acid tert-butyl ester potassium salt ((R)-10h): Using the general procedure, γ-dioxaborato ester (R)-8h (149 mg, 0.50 mmol) affords the title compound (86 mg, 62%) as a white solid: mp 174.5–176.0 °C; [α]D20 = +6.3° (c 0.5, MeOH); 1H NMR (300 MHz, MeOD) δ 2.37 (1H, dd, J = 14.2 Hz, 5.6 Hz, d), 2.03 (1H, dd, J = 14.2 Hz, 8.6 Hz, d), 1.95–1.80 (1H, m, e), 1.45 (9H, s, a,a′,a′′), 1.34 (2H, t, J = 6.9 Hz, g), 0.87 (3H, t, J = 7.4 Hz, h), 0.40–0.25 (1H, m, f), 0.20–0.10 (1H, m, f); 13C NMR (75 MHz, MeOD) δ 175.31 (c), 79.39 (b), 42.23 (d), 33.95 (e), 28.79 (g), 27.05 (a,a′,a′′), 22.69 (f), 9.96 (h); IR (neat) 2983, 1728 (C=O stretch), 1499, 1329 (C-O stretch), 1080, 1029, 966, 915, 751 cm⁻¹; HRMS (CI) calcd. for C10H19O2 (M-BF3K): 171.1386, found 171.1185 m/z.

(R)-5-(2-Chlorophenyl)-3-(trifluoroboratomethyl)pentanoic acid tert-butyl ester potassium salt: Using the general procedure, γ-dioxaborato ester (R)-13 (204 mg, 0.50 mmol) affords the title compound (148 mg, 76%) as a white solid: mp 174.6–175.6 °C; [α]D20 = +6.9° (c 0.5, MeOH); 1H NMR (300 MHz, MeOD) δ 7.35–7.25 (2H, m, l,m), 7.25–7.05 (2H, m, j,k), 2.85–2.60 (2H, m, h), 2.50 (1H, dd, J = 13.4 Hz, 4.3 Hz, d), 2.20–1.95 (2H, m, d,e), 1.70–1.50 (2H, m, g), 1.43 (9H, s, a,a′,a′′), 0.55–0.40 (1H, m, f), 0.35–0.15 (1H, m, f); 13C NMR (75 MHz, MeOD) δ 174.97 (c), 141.01 (i), 133.35 (n), 130.27 (m), 128.81 (l), 126.63 (j), 126.46 (k), 79.48 (b), 42.68 (d), 36.78 (g), 32.50 and 32.47 (e), 30.41 (h), 27.02 (a,a′,a′′); IR (neat) 2978, 2922, 1703 (C=O stretch), 1474, 1391, 1310 (C-O stretch), 1260, 1030, 967, 953, 841, 777 cm⁻¹; HRMS (CI) calcd. for C16H22ClO2 (M-BF3K): 281.1308, found 281.1312 m/z.

General procedure for palladium-catalyzed C-C cross coupling of aryl- and heteroaryl halides with trifluoroborate salts.[19]

Preparation of (S)-3-methyl-4-phenylbutanoic acid phenyl amide (Entry 1, Table 2): An 8 mL vial was charged with Pd(OAc)2 (1.2 mg, 0.0050 mmol, 0.050 equiv), RuPhos (4.7 mg, 0.010 mmol, 0.10 equiv), K2CO3 (48.4 mg, 0.35 mmol, 3.5 equiv), γ-trifluorobororate amide (S)-10a (28.3 mg, 0.10 mmol, 1.0 equiv), toluene (0.4 mL), and H2O (0.1 mL). To the resultant
mixture was added chlorobenzene (13.5 mg, 0.12 mmol, 1.2 equiv) and the reaction mixture was raised to 85 °C. After allowing a 24 h stir, H2O (1 mL) was added to the resultant mixture and extracted with ethyl acetate (2 x 1 mL). The combined organic extracts were dried (anhyd. Na2SO4) and concentrated under reduced pressure. Flash chromatography on silica gel (75:25 hexane:ethyl acetate) affords the title compound (20.5 mg, 81%) as a white solid: mp 59–60.5 °C; TLC analysis Rf 0.4 (80:20 hexanes:ethyl acetate); [α]D20 = +6.5° (c 0.5, CHCl3); 1H NMR (300 MHz, CDCl3) δ 7.52 (2H, d, J = 8.0 Hz, c,c’), 7.40–7.25 (4H, m, J,j’,k,k’), 7.25–7.15 (3H, m, b,b’,l), 7.12 (1H, t, J = 6.9 Hz, a), 2.72 (1H, dd, J = 13.2 Hz, 6.4 Hz, h), 2.58 (1H, dd, J = 13.2 Hz, 6.8 Hz, h), 2.50–2.35 (2H, m, f,g), 2.20–2.05 (1H, m, f), 1.04 (3H, d, J = 6.2 Hz, m); 13C NMR (75 MHz, CDCl3) δ 170.58 (m), 141.83 (i), 137.85 (d), 129.29 (b,b’), 129.00 (j,j’), 128.33 (k,k’), 126.11 (l), 119.78 (c,c’), 44.50 (h), 32.67 (g), 19.69 (m); IR (neat) 3292 (N-H bend), 1658 (C=O stretch), 1600, 1544 (N-H stretch), 1153, 1069, 1043, 755 cm⁻¹; HRMS (EI) calcd. for C17H19NO: 253.1467, found 253.1474 m/z.

(S)-4-(3-Methoxyphenyl)-3-methylbutanoic acid phenyl amide (Entry 2, Table 2): Using the general procedure with SPhos (4.1 mg, 0.010 mmol, 0.10 equiv) and 3-bromoanisole (22.4 mg, 0.12 mmol, 1.2 equiv), γ-trifluoroborato amide (S)-10a (28.3 mg, 0.10 mmol, 1.0 equiv) affords, after flash chromatography on silica gel (75:25 hexanes:ethyl acetate), the title compound (21.8 mg, 71%) as a white solid: mp 65–66 °C; TLC analysis Rf 0.4 (80:20 hexanes:ethyl acetate); [α]D20 = +2.9° (c 0.5, CHCl3); 1H NMR (300 MHz, CDCl3) δ 7.52 (2H, d, J = 7.9 Hz, e,e’), 7.33 (2H, t, J = 7.8 Hz, b,b’), 7.30–7.15 (2H, m, NH,k), 7.12 (1H, t, J = 7.5 Hz, a), 6.85–6.70 (3H, m, j,l,n), 3.81 (3H, s, o), 2.67 (1H, dd, J = 13.2 Hz, 6.5 Hz, h), 2.56 (1H, dd, J = 13.2 Hz, 6.9 Hz, h), 2.50–2.35 (2H, m, f,g), 2.20–2.05 (1H, m, f), 1.04 (3H, d, J = 6.2 Hz, m); 13C NMR (75 MHz, CDCl3) δ 170.59 (e), 140.18 (i), 137.83 (d), 129.27 (b,b’), 128.31 (k,k’), 126.11 (l), 119.78 (c,c’), 44.48 (h), 43.14 (f), 32.58 (g), 19.69 (m); IR (neat) 3292 (N-H stretch), 2924, 1658 (C=O stretch), 1600, 1544 (N-H bend), 1498, 1441, 1322 (C-O stretch), 1260 (C-N stretch), 1153, 1069, 1043, 755 cm⁻¹; HRMS (EI) calcd. for C18H21NO2: 283.1572, found 283.1573 m/z.

(S)-3-Methyl-4-(4-methylcarboxyphenyl)butanoic acid phenyl amide (Entry 3, Table 2): Using the general procedure with methyl-4-bromobenzoate (25.8 mg, 0.12 mmol, 1.2 equiv), γ-trifluoroborato amide (S)-10a (28.3 mg, 0.10 mmol, 1.0 equiv) affords, after flash chromatography on silica gel (75:25 hexanes:ethyl acetate), the title compound (21.8 mg, 70%)
as a white solid: mp 68.5–69.5 °C; TLC analysis Rf 0.4 (80:20 hexanes:ethyl acetate); [α]D20 = +8.0° (c 0.5, CHCl3); 1H NMR (300 MHz, CDCl3) δ 7.98 (2H, d, J = 7.9 Hz, k,k’), 7.52 (2H, d, J = 7.8 Hz, c,c’), 7.40–7.25 (4H, m, b,b’,j’,j”), 7.12 (1H, t, J = 7.3 Hz, a), 3.92 (3H, s, n), 2.81 (1H, dd, J = 13.1 Hz, 5.9 Hz, h), 2.60 (1H, dd, J = 13.1 Hz, 7.6 Hz, h), 2.55–2.40 (1H, m, g), 2.37 (1H, dd, J = 14.2 Hz, 5.9 Hz, f), 2.18 (1H, dd, J = 14.1 Hz, 7.7 Hz, f), 1.01 (3H, d, J = 6.4 Hz, o); 13C NMR (75 MHz, CDCl3) δ 170.13 (e), 167.13 (m), 145.80 (i), 137.74 (d), 129.70 (k,k’), 129.30 (b,b’), 129.03 (j,j’), 128.12 (l), 124.31 (a), 119.80 (c,c’), 52.02 (n), 44.38 (h), 42.95 (f), 32.43 (g), 19.57 (o); IR (neat) 3311 (N-H stretch), 2929, 1725 (C=O stretch), 1655, 1600, 1530 (N-H stretch), 1424, 1403 (C-O stretch), 1273, 1175 (C-N stretch), 1020, 868, 767 cm⁻¹; HRMS (ESI) calcd. for C19H21NaNO3 (M+Na): 334.1419, found 334.1426 m/z.

(S)-3-Methyl-4-phenylbutanoic acid tert-butyl ester (Entry 4, Table 2): Using the general procedure with chlorobenzene (13.5 mg, 0.12 mmol, 1.2 equiv), γ-trifluoroborato ester (S)-10g (26.4 mg, 0.10 mmol, 1.0 equiv) affords, after flash chromatography on silica gel (98:2 hexanes:ethyl acetate), the title compound (19.2 mg, 82%) as a colorless oil: TLC analysis Rf 0.7 (90:10 hexanes:ethyl acetate); [α]D20 = +3.0° (c 0.5, CHCl3); 1H NMR (300 MHz, CDCl3) δ 7.35–7.25 (2H, m, i,i’), 7.25–7.15 (3H, m, h,h’j), 2.67 (1H, dd, J = 13.4 Hz, 6.1 Hz, f), 2.49 (1H, dd, J = 13.4 Hz, 7.4 Hz, f), 2.30–2.20 (2H, m, d,e), 2.15–2.00 (1H, m, d), 1.48 (9H, s, a,a’,a’’), 0.95 (3H, d, J = 6.4 Hz, k); 13C NMR (75 MHz, CDCl3) δ 172.45 (c), 159.54 (i), 151.80 (d), 137.74 (k,k’), 129.24 (i,i’), 128.22 (h,h’), 125.94 (j), 80.10 (b), 42.96 (f), 42.47 (d), 32.44 (e), 28.15 (a,a’,a’’), 19.41 (k); IR (neat) 2977, 1725 (C=O stretch), 1454, 1392, 1367 (C=O stretch), 1146, 1051, 755 cm⁻¹; HRMS (ESI) calcd. for C19H22O3: 257.1518, found 257.1520 m/z.

(S)-3-Methyl-4-(3-methoxyphenyl)butanoic acid tert-butyl ester (Entry 5, Table 2): Using the general procedure with 3-bromoanisole (22.4 mg, 0.12 mmol, 1.2 equiv), γ-trifluoroborato ester (S)-10g (26.4 mg, 0.10 mmol, 1.0 equiv) affords, after flash chromatography on silica gel (98:2 hexanes:ethyl acetate), the title compound (21.6 mg, 82%) as a colorless oil: TLC analysis Rf 0.6 (90:10 hexanes:ethyl acetate); [α]D20 = +3.2° (c 0.5, CHCl3); 1H NMR (400 MHz, CDCl3) δ 7.22 (1H, t, J = 7.8 Hz, i), 6.80–6.70 (3H, m, h,j,l), 3.82 (3H, s, m), 2.64 (1H, dd, J = 13.3 Hz, 6.1 Hz, f), 2.46 (1H, dd, J = 13.3, 7.4 Hz, f), 2.30–2.20 (2H, m, d,e), 2.15–2.00 (1H, m, d), 1.48 (9H, s, a,a’,a’’), 0.96 (3H, d, J = 6.3 Hz, n); 13C NMR (100 MHz, CDCl3) δ 172.45 (c), 159.54 (k), 142.10 (g), 129.15 (i), 121.70 (h), 114.94 (l), 111.25 (j), 80.11 (b), 55.13 (m), 43.01 (f), 42.48 (d), 32.36 (e), 28.15 (a,a’,a’’), 19.46 (n); IR (neat) 2929, 1725 (C=O stretch), 1601, 1584, 1455, 1366, 1316 (C=O stretch), 1260, 1044, 779 cm⁻¹; HRMS (EI) calcd. for C18H24O3: 264.1725, found 264.1729 m/z.
(S)-3-Methyl-4-(4-methylcarboxyphenyl)butanoic acid tert-butyl ester (Entry 6, Table 2): Using the general procedure with methyl-4-bromobenzoate (25.8 mg, 0.12 mmol, 1.2 equiv), γ-trifluoroborato ester (S)-10g (26.4 mg, 0.10 mmol, 1.0 equiv) affords, after flash chromatography on silica gel (98:2 hexanes:ethyl acetate), the title compound (25.7 mg, 88%) as a colorless oil: TLC analysis Rf 0.7 (90:10 hexanes:ethyl acetate); [α]D²⁰ = +2.6° (c 0.5, CHCl₃); ¹H NMR (400 MHz, CDCl₃) δ 7.98 (2H, d, J = 8.2 Hz, i,i’), 7.26 (2H, d, J = 8.2 Hz, h,h’), 3.92 (3H, s, l), 2.73 (1H, dd, J = 13.3 Hz, 6.0 Hz, f), 2.53 (1H, dd, J = 13.3 Hz, 7.7 Hz, f), 2.35–2.20 (2H, m, d,e), 2.15–2.05 (1H, m, d), 1.47 (9H, s, a,a’,a’’), 0.94 (3H, d, J = 6.6 Hz, m); ¹³C NMR (100 MHz, CDCl₃) δ 172.19 (c), 167.13 (k), 146.04 (g), 129.60 (i,i’), 129.25 (h,h’), 128.03 (j), 80.28 (b), 52.00 (l), 42.84 (f), 42.34 (d), 32.26 (e), 28.13 (a,a’,a’’), 19.36 (m); IR (neat) 2931, 1722 (C=O stretch), 1610, 1457, 1415, 1367 (C–O stretch), 1278, 1178, 1148, 1108, 667, 759 cm⁻¹; HRMS (ESI) calcd. for C₁₇H₂₄NaO₄ (M+Na): 315.1572, found 315.1566 m/z.

(S)-5-Methyl-3-phenylmethylhexanoic acid tert-butyl ester (Entry 7, Table 2): Using the general procedure with chlorobenzene (13.5 mg, 0.12 mmol, 1.2 equiv), γ-trifluoroborato ester (R)-10i (30.6 mg, 0.10 mmol, 1.0 equiv) affords, after flash chromatography on silica gel (98:2 hexanes:ethyl acetate), the title compound (22.1 mg, 80%) as a colorless oil: TLC analysis Rf 0.6 (90:10 hexanes:ethyl acetate); [α]D²⁰ = +5.6° (c 0.5, CHCl₃); ¹H NMR (400 MHz, CDCl₃) δ 7.35–7.25 (2H, m, i,i’), 7.25–7.15 (3H, m, h,h’,j), 2.67 (1H, dd, J = 13.5 Hz, 6.1 Hz, f), 2.56 (1H, dd, J = 13.5 Hz, 7.2 Hz, f), 2.30–2.15 (1H, m, e), 1.85–2.10 (2H, m, d), 1.80–1.65 (1H, m, l), 1.47 (9H, s, a,a’,a’’), 1.86 (2H, t, J = 6.9 Hz, k), 0.90 (6H, dd, J = 19.1 Hz, 6.6 Hz, m,m’); ¹³C NMR (100 MHz, CDCl₃) δ 172.62 (c), 140.46 (g), 129.37 (i,i’), 128.20 (h,h’), 125.87 (j), 80.05 (b), 43.26 (k), 40.52 (f), 39.93 (d), 34.92 (e), 28.15 (a,a’,a’’), 25.17 (l), 22.79 and 22.65 (m,m’); IR (neat) 2955, 1727 (C=O stretch), 1454, 1391, 1366 (C–O stretch), 1299, 1256, 1146, 747 cm⁻¹; HRMS (ESI) calcd. for C₁₈H₃₈NaO₂ (M+Na): 299.1987, found 299.1974 m/z.
(S)-5-Methyl-3-(3-methoxyphenyl)methylhexanoic acid tert-butyl ester (Entry 8, Table 2): Using the general procedure with 3-bromoanisole (22.4 mg, 0.12 mmol, 1.2 equiv), γ-trifluoroborato ester (R)-10i (30.6 mg, 0.10 mmol, 1.0 equiv) affords, after flash chromatography on silica gel (98:2 hexanes:ethyl acetate), the title compound (28.2 mg, 92%) as a colorless oil: TLC analysis $R_f$ 0.6 (90:10 hexanes:ethyl acetate); $[\alpha]_{D}^{20} = +2.3^\circ$ (c 0.5, CHCl$_3$); $^1$H NMR (300 MHz, CDCl$_3$) $\delta$ 7.22 (1H, t, $J = 7.5$ Hz, i), 6.85–6.70 (3H, m, h,j,l), 3.82 (3H, s, m), 2.65 (1H, dd, $J = 13.5$ Hz, 5.8 Hz, f), 2.53 (1H, dd, $J = 13.5$ Hz, 7.0 Hz, f), 2.30–2.05 (3H, m, d,e), 1.80–1.65 (1H, m, o), 1.47 (9H, s, a,a',a'''), 1.19 (2H, t, $J = 6.8$ Hz, n), 0.90 (6H, dd, $J = 12.7$ Hz, 6.5 Hz, p,p'); $^{13}$C NMR (75 MHz, CDCl$_3$) $\delta$ 172.60 (c), 159.52 (k), 142.11 (g), 129.12 (i), 121.83 (h), 115.11 (l), 111.17 (j), 80.05 (b), 43.28 (m), 39.94 (d), 34.81 (e), 28.14 (a,a',a'''), 25.15 (n); IR (neat) 2955, 1726 (C=O stretch), 1600, 1488, 1455, 1366 (C-O stretch), 1260, 1150, 1047, 777 cm$^{-1}$; HRMS (EI) calcd. for C$_{19}$H$_{30}$O$_4$: 306.2195, found 306.2207 m/z.

(S)-3-(4-Methylcarboxyphenyl)methyl-5-methylhexanoic acid tert-butyl ester (Entry 9, Table 2): Using the general procedure with methyl-4-bromobenzoate (25.8 mg, 0.12 mmol, 1.2 equiv), γ-trifluoroborato ester (R)-10i (30.6 mg, 0.10 mmol, 1.0 equiv) affords, after flash chromatography on silica gel (98:2 hexanes:ethyl acetate), the title compound (31.4 mg, 94%) as a colorless oil: TLC analysis $R_f$ 0.7 (90:10 hexanes:ethyl acetate); $[\alpha]_{D}^{20} = +4.1^\circ$ (c 0.5, CHCl$_3$); $^1$H NMR (400 MHz, CDCl$_3$) $\delta$ 7.97 (2H, d, $J = 7.5$ Hz, i), 7.26 (2H, d, $J = 8.1$ Hz, h,h'), 3.92 (3H, s, l), 2.75–2.60 (2H, m, f), 2.30–2.15 (1H, m, e), 2.15–2.10 (2H, m, d), 1.75–1.60 (1H, m, n), 1.46 (9H, s, a,a',a'''), 1.20–1.10 (2H, m, m), 0.88 (6H, dd, $J = 21.3$ Hz, 6.5 Hz, o,o'); $^{13}$C NMR (100 MHz, CDCl$_3$) $\delta$ 172.35 (c), 167.16 (k), 146.17 (g), 129.57 (i,i'), 129.37 (h,h'), 127.96 (j), 80.24 (b), 51.98 (l), 43.19 (m), 40.58 (f), 39.78 (d), 34.80 (e), 28.13 (a,a',a'''), 25.15 (n), 22.82 and 22.51 (o,o'); IR (neat) 2955, 1726 (C=O stretch), 1600, 1584, 1488, 1455, 1366 (C-O stretch), 1260, 1150, 1047, 851, 777 cm$^{-1}$; HRMS (ESI) calcd. for C$_{20}$H$_{30}$NaO$_4$ (M+Na): 357.2024, found 357.2028 m/z.

(S)-5-Methyl-3-(thiophen-3-yl)methylhexanoic acid tert-butyl ester (Entry 10, Table 2): Using the general procedure with 3-chlorothiophene (14.2 mg, 0.12 mmol, 1.2 equiv), γ-trifluoroborato ester (R)-10i (30.6 mg, 0.10 mmol, 1.0 equiv) affords, after flash chromatography on silica gel (98:2 hexanes:ethyl acetate), the title compound (27.7 mg, 98%) as a yellow oil: TLC analysis $R_f$ 0.6 (90:10 hexanes:ethyl acetate); $[\alpha]_{D}^{20} = +1.9^\circ$ (c 0.5, CHCl$_3$); $^1$H NMR (400 MHz, CDCl$_3$) $\delta$ 7.97 (2H, d, $J = 7.5$ Hz, i), 7.22 (1H, t, $J = 7.5$ Hz, i), 6.85–6.70 (3H, m, h,j,l), 3.82 (3H, s, m), 2.65 (1H, dd, $J = 13.5$ Hz, 5.8 Hz, f), 2.53 (1H, dd, $J = 13.5$ Hz, 7.0 Hz, f), 2.30–2.05 (3H, m, d,e), 1.80–1.65 (1H, m, o), 1.47 (9H, s, a,a',a'''), 1.19 (2H, t, $J = 6.8$ Hz, n), 0.90 (6H, dd, $J = 12.7$ Hz, 6.5 Hz, p,p'); IR (neat) 2955, 1726 (C=O stretch), 1600, 1584, 1488, 1455, 1366 (C-O stretch), 1260, 1150, 1047, 851, 777 cm$^{-1}$; HRMS (ESI) calcd. for C$_{19}$H$_{29}$O$_4$: 310.2082, found 310.2080 m/z.
(S)-3-(5-Acetylfuran-2-yl)methyl-5-methylhexanoic acid tert-butyl ester (Entry 11, Table 2): Using the general procedure with 5-chloro-2-furaldehyde (15.7 mg, 0.12 mmol, 1.2 equiv), γ-trifluoroborato ester (R)-10i (30.6 mg, 0.10 mmol, 1.0 equiv) affords, after flash chromatography on silica gel (94:6 hexanes:ethyl acetate), the title compound (24.7 mg, 84%) as a yellow oil: TLC analysis Rf 0.4 (90:10 hexanes:ethyl acetate); [α]D20  = +4.3° (c 0.5, CHCl3); 1H NMR (400 MHz, CDCl3) δ 9.55 (1H, s, l), 7.21 (1H, d, J = 3.3 Hz, i), 6.31 (1H, d, J = 3.3 Hz, j), 2.80–2.70 (2H, m, f), 2.40–2.25 (1H, m, e), 2.25–2.15 (2H, m, d), 1.75–1.60 (1H, m, n), 1.46 (9H, s, a,a’,a”), 1.25–1.10 (2H, m, m), 0.90 (6H, dd, J = 8.3 Hz, 6.9 Hz, o,o’); 13C NMR (100 MHz, CDCl3) δ 177.17 (k), 172.61 (c), 140.49 (g), 128.87 (j), 125.09 (i), 110.32 (j), 80.56 (b), 43.28 (m), 39.78 (d), 32.86 (f), 32.43 (e), 28.12 (a,a’,a’’), 25.17 (l), 22.77 and 22.72 (m,m’); IR (neat) 2956, 2929, 1723 (C=O stretch), 1593, 1484, 1451, 1366 (C=C stretch), 1298, 1255, 1146, 851, 772 cm⁻¹; HRMS (EI) calcd. for C16H26OS: 282.1653, found 282.1652 m/z.

(S)-3-(6-Fluoropyridin-3-yl)methyl-5-methylhexanoic acid tert-butyl ester (Entry 12, Table 2): Using the general procedure with 5-chloro-2-fluoropyridine (15.8 mg, 0.12 mmol, 1.2 equiv), γ-trifluoroborato ester (R)-10i (30.6 mg, 0.10 mmol, 1.0 equiv) affords, after flash chromatography on silica gel (92:8 hexanes:ethyl acetate), the title compound (15.1 mg, 51%) as a colorless oil: TLC analysis Rf 0.6 (90:10 hexanes:ethyl acetate); [α]D20  = +3.8° (c 0.5, CHCl3); 1H NMR (300 MHz, CDCl3) δ 8.02 (1H, s, k), 7.63 (1H, td, J = 8.1 Hz, 2.5 Hz, h), 6.88 (1H, dd, J = 8.3 Hz, 2.9 Hz, i), 2.61 (2H, d, J = 6.0 Hz, f), 2.20–2.05 (3H, m, d,e), 1.80–1.55 (1H, m, m), 1.46 (9H, s, a,a’,a”), 1.20–1.10 (2H, m, l), 0.88 (6H, dd, J = 15.9 Hz, 6.5 Hz, n,n’); 13C NMR (75 MHz, CDCl3) δ 172.12 (c), 163.99 (j), 147.88 and 147.69 (k), 141.88 and 141.78 (h), 139.46 (g), 109.27 and 108.78 (i), 80.43 (b), 43.98 (l), 39.42 (d), 36.55 (f), 34.65 (e), 28.12 (a,a’,a”), 25.13 (m), 22.88 and 22.38 (n,n’); IR (neat) 2958, 2929, 1724 (C=O stretch), 1593, 1484, 1451,
(S)-3-(Thiophen-3-yl)methylpentanoic acid tert-butyl ester (Entry 13, Table 2): Using the general procedure with 3-chlorothiophene (14.2 mg, 0.12 mmol, 1.2 equiv), γ-trifluoroborato ester (R)-10h (27.8 mg, 0.10 mmol, 1.0 equiv) affords, after flash chromatography on silica gel (98:2 hexanes:ethyl acetate), the title compound (20.4 mg, 80%) as a colorless oil: TLC analysis Rf 0.6 (90:10 hexanes:ethyl acetate); [α]D 20 = +1.8° (c 0.5, CHCl3); 1H NMR (300 MHz, CDCl3) δ 7.26 (1H, dd, J = 4.7 Hz, 3.2 Hz, i), 7.00–6.90 (2H, m, h,j), 2.75–2.55 (2H, m, f), 2.20–2.15 (2H, m, d), 2.15–2.00 (1H, m, e), 1.47 (9H, s, a,a’,a”), 1.45–1.25 (2H, m, k), 0.94 (3H, t, J = 7.4 Hz, l); 13C NMR (75 MHz, CDCl3) δ 172.71 (c), 140.64 (g), 128.80 (j), 125.11 (i), 121.31 (h), 80.10 (b), 39.40 (d), 37.95 (e), 34.02 (f), 28.15 (a,a’,a’’), 26.13 (k), 11.01 (l); IR (neat) 2964, 2929, 1726 (C=O stretch), 1459, 1366 (C–O stretch), 1255, 1144, 1090, 949, 850, 766, 693 cm−1; HRMS (ESI) calcd. for C14H22NaSO2 (M+Na): 277.1238, found 277.1245 m/z.

(S)-2-(1,2,3,4-Tetrahydronaphthalen-2-yl)acetic acid tert-butyl ester ((S)-14): Using the general procedure with (R)-5-(2-chlorophenyl)-3-(trifluoroboratomethyl)pentanoic acid tert-butyl ester potassium salt (38.9 mg, 0.10 mmol, 1.0 equiv) affords, after flash chromatography on silica gel (97:3 hexanes:ethyl acetate), the title compound (22.4 mg, 91%) as a colorless oil: TLC analysis Rf 0.6 (90:10 hexanes:ethyl acetate); [α]D 20 = -1.7° (c 0.5, CHCl3); 1H NMR (400 MHz, CDCl3) δ 7.20–7.00 (4H, m, h,i,j,k), 2.95–2.80 (3H, m, f,m), 2.53 (1H, dd, J = 16.4 Hz, 9.9 Hz, f), 2.35–2.20 (3H, m, d,c), 2.05–1.95 (1H, m, n), 1.55–1.45 (1H, m, n), 1.50 (9H, s, a,a’,a”); 13C NMR (100 MHz, CDCl3) δ 172.19 (c), 136.34 (l), 135.99 (g), 129.14 (h), 128.88 (k), 125.66 (i), 125.57 (j), 80.26 (b), 42.41 (d), 35.62 (f), 31.60 (e), 29.16 (n), 28.83 (m), 28.18 (a,a’,a’’); IR (neat) 2977, 2925, 1728 (C=O stretch), 1495, 1453, 1366 (C=O stretch), 1289, 1255, 1146, 1064, 1039, 744 cm−1; HRMS (CI) calcd. for C16H22O2 (M+H): 247.1698, found 247.1693 m/z.
(R)-2-(2,3,4,5-Tetrahydrobenzo[b]oxepin-3-yl)acetic acid tert-butyl ester ((R)-16);[20] Using the general procedure with γ-hydroxy ester (R)-15 (29.9 mg, 0.10 mmol) and no aryl halide, flash chromatography on silica gel (95:5 hexanes:ethyl acetate) affords the title compound (20 mg, 75%) as a colorless oil: TLC analysis Rf 0.6 (90:10 hexanes:ethyl acetate); [α]D20 = +3.3° (c 0.5, CHCl3); 1H NMR (400 MHz, CDCl3) δ 7.40–7.25 (3H, m, m,k,j), 7.05–6.95 (1H, m, l), 4.50–4.40 (1H, m, f), 4.05–3.95 (1H, m, f), 2.85–2.75 (2H, m, h), 2.55–2.45 (1H, m, e), 2.20–2.30 (2H, m, d), 1.90–1.80 (2H, m, g), 1.47 (9H, s, a,a’,a”); 13C NMR (75 MHz, CDCl3) δ 173.04 (c), 139.69 (i), 133.79 (j), 130.27 (k), 129.49 (l), 127.38 (m), 126.85 (n), 80.76 (b), 65.49 (f), 38.03 (d), 37.78 (e), 31.30 (h), 31.03 (g, 29.9 mg, 0.10 mmol) and triethylamine (TEA, 0.30 mL, 2.16 mmol) in dry, oxygen-free THF (35 mL) was added PCl5 (0.07 mL, 0.86 mmol) in one portion. The resulting mixture was allowed to slowly warm to room temperature and stir over a total of ca. 12 h. Afterwards, the reaction mixture was filtered and the volatiles were removed on a vacuum line. The residue was dissolved in THF (5 mL) and the resulting solution added (rapid addition) to a mixture of phenol (105.7 mg, 1.123 mmol) and triethylamine (TEA, 0.30 mL, 2.16 mmol) in dry, oxygen-free THF (35 mL) was added PCl5 (0.07 mL, 0.86 mmol) in one portion. The resulting mixture was allowed to slowly warm to room temperature and stir over a total of ca. 12 h. Afterwards, the reaction mixture was filtered and the volatiles were removed on a vacuum line. Flash chromatography on silica gel (97:3 hexanes:ethyl acetate) affords the title compound (412.0 mg, 68%) as a white foamy solid: mp 97.0–98.2 °C; TLC analysis Rf 0.8 (95:5 hexanes: ethyl acetate); [α]D20 = -120.0° (c 0.5, CHCl3); 1H NMR (400 MHz, CDCl3) δ 7.35–7.05 (6H, m), 6.92 (2H, d, J = 9.5 Hz), 4.40 (1H, d, J = 9.2 Hz), 2.50 (6H, s), 2.85 (2H, m, g), 2.30 (2H, m, f), 1.85 (9H, s, a,a’,a”). 13C NMR (100 MHz, CDCl3) δ 152.16 (m/z), 141.23 (3.0 Hz), 141.02, 137.37, 136.99, 136.50, 136.29, 129.45, 129.07, 128.94, 128.78, 126.89, 126.84, 125.10, 125.08, 123.33, 120.89, 120.81, 112.65, 85.51 (JCP = 8.1 Hz), 84.64 (JCP = 8.2 Hz), 72.00–71.78 (C–O stretch), 68.05–67.84 (C=O stretch), 52.20–52.00 ppm; IR (neat) 3450, 3180, 2950, 2872 (C–H stretch), 1730, 1610 (C=O stretch), 1550, 1450, 1415, 1367 (C=C stretch), 1300, 1277, 1187, 1148, 1110, 1020, 760 cm–1; HRMS (Cl) calcd. for C16H23O3 (M+H): 263.1647, found 263.1652 m/z.

**General procedures for the preparation of TADDOL-derived phosphite (R,R)-6 and dioxaborinane tmdBH (5).**

![Diagram](image)

**Preparation of 3,5-dimethylphenyl-(TADDOL)POPh ((R,R)-6).** 3,5-Dimethylphenyl-(TADDOL) was prepared as previously described.[21] To a cooled solution (dry ice-acetone bath, -78 °C) of 3,5-imethyl-TADDOL (500 mg, 0.864 mmol) and triethylamine (TEA, 0.30 mL, 2.16 mmol) in dry, oxygen-free THF (35 mL) was added PCl5 (0.07 mL, 0.86 mmol) in one portion. The resulting mixture was allowed to slowly warm to room temperature and stir over a total of ca. 12 h. Afterwards, the reaction mixture was filtered and the volatiles were removed on a vacuum line. The residue was dissolved in THF (5 mL) and the resulting solution added (rapid addition) to a mixture of phenol (105.7 mg, 1.123 mmol) and TEA (0.18 mL, 1.3 mmol) in THF (35 mL). The resulting mixture was allowed to stir at room temperature for ca. 12 h. The resulting mixture was filtered and the volatiles were removed on a vacuum line. Flash chromatography on silica gel (97:3 hexanes:ethyl acetate) affords the title compound (412.0 mg, 68%) as a white foamy solid: mp 97.0–98.2 °C; TLC analysis Rf 0.8 (95:5 hexanes: ethyl acetate); [α]D20 = -120.0° (c 0.5, CHCl3); 1H NMR (400 MHz, CDCl3) δ 7.35–7.05 (6H, m), 6.92 (2H, d, J = 9.5 Hz), 4.40 (1H, d, J = 9.2 Hz), 2.50 (6H, s), 2.85 (2H, m, g), 2.30 (2H, m, f), 1.85 (9H, s, a,a’,a”). 13C NMR (100 MHz, CDCl3) δ 152.16 (m/z), 141.23 (3.0 Hz), 141.02, 137.37, 136.99, 136.50, 136.29, 129.45, 129.07, 128.94, 128.78, 126.89, 126.84, 125.10, 125.08, 123.33, 120.89, 120.81, 112.65, 85.51 (JCP = 8.1 Hz), 84.64 (JCP = 8.2 Hz).

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Smith, Hoang, Pal, Khaled, Pelter, Zeng, and Takacs: Supporting Information for γ-Selective Directed Catalytic Asymmetric Hydroboration (CAHB) of 1,1-Disubstituted Alkenes

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\begin{align*}
\text{\text{31P NMR (162 MHz, CDCl}_3\text{) } & \delta 129.36; \text{IR (neat) 2916, 2863 (P-O stretching), 1595, 1489, 1455, 1370, 1213 (C-O-C stretch), 1159, 1035, 939, 853, 800, 761, 689 cm}^{-1}; \text{HRMS (FAB) calcd. for C}_{45}\text{H}_{49}\text{O}_5\text{P (M+H): 701.3396, found 701.3409 m/z.}
\end{align*}
\]

Preparation of 4,4,6-trimethyl-1,3,2-dioxaborinane (tmdBH, 5). To a cooled (0 °C) solution of 2-methyl-2,4-pentanediol (1.54 g, 12 mmol) in dichloromethane (6 mL) was slowly added borane (BH$_3$, 1 mL of a 10 M solution in dimethylsulfide, 10 mmol) dropwise. After the resulting mixture was stirred for 1.5 h at the same temperature, the ice bath was removed and the reaction was allowed to stir for an additional 0.5 h. Volatiles were carefully removed under reduced pressure (i.e., concentration via rotovap while the mixture was submerged in a room temperature water bath). After complete removal of dichloromethane and dimethylsulfide (SMe$_2$), the residue was purified via bulb-to-bulb distillation (160–165 °C) to afford the title compound (960 mg, 75%) as a colorless liquid: $^1$H NMR (300 MHz, CDCl$_3$) δ 4.30–4.15 (1H, m, d), 3.84 (1H, q, J = 155.6 Hz, BH), 1.90–1.75 (1H, m, c), 1.60–1.45 (1H, m, c), 1.31 (3H, s, a), 1.29 (3H, s, a'), 1.26 (3H, d, J = 6.2 Hz, e); $^{13}$C NMR (75 MHz, CDCl$_3$) δ 70.99 (b), 64.73 (d), 46.17 (c), 31.02 (a), 28.14 (a'), 22.93 (e); $^{11}$B NMR (193 MHz, THF with residual CDCl$_3$) δ 24.96 (d, J = 169.1 Hz); IR (neat) 2976 (CH sp$^3$ stretch), 2879, 2400, 1495, 1427, 1384, 1291, 1156 (C-O stretch), 1094, 1024, 889, 789, 666 cm$^{-1}$; HRMS (CI) calcd. for C$_6$H$_{14}$BO$_2$ (M+H): 129.1087, found 129.1082 m/z.