Electronic Supporting Information

Enantioselective Intramolecular Friedel-Crafts Type α -Arylation of Aldehydes

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- I. Experimental Procedures and Spectroscopic Data for Compounds**
- II. ¹H and ¹³C NMR Spectra of Compounds**
- III. References**
- IV. HPLC Spectra**

I. Experimental Procedures

General procedures. All reactions were carried out under an argon atmosphere with dry solvents under anhydrous conditions, unless otherwise noted. Dry dimethoxyethane (DME), toluene, diethyl ether (Et₂O), acetonitrile (CH₃CN), dimethylformamide (DMF), methanol, triethylamine (Et₃N), and dichloromethane (CH₂Cl₂), were obtained by passing commercially available pre-dried, oxygen-free formulations through activated alumina columns. Tetrahydrofuran (THF) was distilled immediately before use from sodium-benzophenone ketyl. Dimethylsulfoxide (DMSO) was purchased in anhydrous form and used without further purification. Reagents were purchased at the highest commercial quality and used without further purification, unless otherwise stated. Reactions were monitored by thinlayer chromatography (TLC) carried out on S-2 0.25 mm E. Merck silica gel plates (60F-254) using UV light as visualizing agent and ethanolic *p*-anisaldehyde, aqueous ammonium cerium nitrate/ammonium molybdate or basic aqueous potassium permanganate as developing agents. E. Merck silica gel (60, particle size 0.040–0.063 mm) was used for flash column chromatography.

Preparative thin-layer chromatography separations were carried out on 0.25 or 0.50 mm E. Merck silica gel plates (60F-254). NMR spectra were recorded on Bruker AV-400, DRX-500 or DRX-600 instruments and calibrated using residual undeuterated chloroform ($\delta = 7.26$ ppm) or CDCl₃ ($\delta = 77.0$ ppm) as an internal reference. The following abbreviations are used to designate multiplicities: s = singlet, d = doublet, t = triplet, q = quartet, m = multiplet, quint = quintet, br = broad. IR spectra were recorded on a Perkin–Elmer Spectrum 100 FT-IR spectrometer. High-resolution mass spectra (HRMS) were recorded on an Agilent ESI-TOF (time of flight) mass spectrometer at a 4000 V emitter voltage. Optical rotations were recorded on a Perkin–Elmer Model 343 polarimeter at 589 nm, and are reported in units of 10⁻¹ (deg cm² g⁻¹).

General procedure A (for the Sonogashira coupling of halobenzene-derivatives with 4-pentyn-1-ol):¹

To a solution of the halobenzene (1.0 equiv) in *n*-BuNH₂ (0.5 M) was added 4-pentyn-1-ol (1.10 equiv), CuI (0.10 equiv) and Pd(PPh₃)₂Cl₂ (0.05 equiv) and the solution was heated at reflux for 16 h. The mixture was cooled down to room temperature, diluted with water and extracted three times with diethyl ether. The combined organic extracts were washed with brine, dried over MgSO₄, filtered and concentrated *in vacuo*. The resulting residue was further purified by column chromatography to give the pure title compound.

General procedure B (for the hydrogenation of the coupling products):

A solution of the alkyne (1.0 equiv) in MeOH (0.1 M) was degassed and flushed with argon three times. After that 10% Pd/C (10 mol%) was added and the solution was degassed again with argon. A balloon of hydrogen was attached and the reaction mixture was stirred at room temperature for 16 h. The mixture was filtered through a pad of Celite[®] and the Celite[®] was washed with MeOH. The solution was concentrated to afford essentially pure product.

General procedure C (for the oxidation of the alcohols):

To a mixture of the alcohol (1.0 equiv), DMSO (14.0 equiv), and triethylamine (4.0 equiv) in dichloromethane (0.33 M) was added SO₃·pyridine (3.0 equiv) at 0 °C and the resulting mixture was stirred for 2 h at this temperature. After completion (TLC), the solution was diluted with diethyl ether and washed with sat. aq. NH₄Cl. The combined organic extracts were dried over Na₂SO₄, filtered and concentrated *in vacuo*. The resulting residue was further purified by column chromatography to give the pure title compound.

General procedure D (for the enantioselective synthesis of α -aryl aldehydes).

A solution of the trifluoromethanesulfonic acid salt of either (2*S*,5*S*)- or (2*R*,5*R*)-2-*tert*-butyl-5-benzyl-3-methylimidazolidin-4-one (20 mol%) in DME (4.0 mL, 0.0625 M) in an oven-dried 10 mL vial equipped with a magnetic stirring bar was cooled to –78 °C under argon. The aldehyde (0.25 mmol, 1.00 equiv), water (2.0 equiv) and CAN (2.0 equiv) were added to the mixture in that order. After vigorously stirring the mixture for 1 min under argon, the solution was warmed to –30 °C and held at a constant temperature for 24 h with stirring.

After completion, the mixture was quenched with sat. aq. NaHCO₃ (10 mL), extracted with diethyl ether (2×25 mL), dried over MgSO₄ and concentrated *in vacuo*. The resulting residue was further purified by column chromatography to give the pure title compounds.

The enantiomeric excess (*ee*) of each product was determined by chiral HPLC analysis (*vide infra*) after reduction of the aldehydes to the primary alcohols with sodium borohydride.

5-(3,5-dimethoxyphenyl)pent-4-yn-1-ol:

Following general procedure A, 1-bromo-3,5-dimethoxybenzene (10.0 g, 46.1 mmol) was reacted with 4-pentyn-1-ol (4.71 mL, 50.7 mmol) to yield 10.2 g (46.3 mmol, 76 %) of alkyne as an orange oil after flash column chromatography (silica, EtOAc/hexanes, 1:1). R_f = 0.62 (silica, EtOAc/hexanes, 1:1); ^1H NMR (400 MHz, CDCl_3): δ = 6.54 (d, J = 2.3 Hz, 2 H), 6.40 (t, J = 2.3 Hz, 1 H), 3.80 (q, J = 4.7 Hz, 2 H), 3.76 (s, 6 H), 2.52 (t, J = 6.9 Hz, 2 H), 1.85 (m, 2 H), 1.73 (s, 1 H) ppm; ^{13}C NMR (100 MHz, CDCl_3): δ = 160.4, 125.0, 109.3, 101.2, 89.0, 81.0, 61.7, 55.3, 31.3, 15.9 ppm; IR (film): ν_{max} = 3488, 2938, 2838, 1711, 1671, 1593, 1458, 1428, 1346, 1325, 1292, 1204, 1150, 1062, 988, 927, 835 cm^{-1} ; HRMS (ESI): calcd for $\text{C}_{13}\text{H}_{17}\text{O}_3^+$ [$\text{M} + \text{H}^+$]: 221.1172, found: 221.1171.

5-(3,5-Dimethoxyphenyl)pentan-1-ol:²

Following general procedure B, 5-(3,5-dimethoxyphenyl)pent-4-yn-1-ol (7.71 g, 35.0 mmol) was hydrogenated to yield 6.64 g (29.6 mmol, 85 %) of alcohol as a light yellow oil which was used in the next step without further purification. Its spectra properties were in agreement with those in the literature.²

5-(3,5-Dimethoxyphenyl)pentanal (**1a**, Table 2, Entry 1):

Following general procedure C, 5-(3,5-dimethoxyphenyl)pentan-1-ol (6.64 g, 29.6 mmol) was oxidized with $\text{SO}_3 \cdot \text{pyridine}$ (14.1 g, 88.8 mmol) to yield 5.04 g (22.7 mmol, 77 %) of **1a** as a yellow oil after flash column chromatography (silica, EtOAc/hexanes, 1:1). R_f = 0.50 (silica, EtOAc/hexanes, 1:1); ^1H NMR (400 MHz, CDCl_3): δ = 9.75 (t, J = 1.7 Hz, 1 H), 6.33 (d, J = 2.2 Hz, 2 H), 6.30 (t, J = 2.2 Hz, 1 H), 3.78 (s, 6 H), 2.58 (t, J = 7.1 Hz, 2 H), 2.45 (dt, J = 7.0, 1.7 Hz, 2 H), 1.73–1.59 (m, 4 H) ppm; ^{13}C NMR (100 MHz, CDCl_3): δ = 202.3, 160.6, 144.2, 106.3, 97.6, 55.1, 43.6, 35.8, 30.5, 21.5 ppm; IR (film): ν_{max} = 2936, 2721, 1721, 1593, 1459, 1428, 1345, 1292, 1203, 1147, 1055, 919, 829, 730, 692 cm^{-1} ; HRMS (ESI): calcd for $\text{C}_{13}\text{H}_{19}\text{O}_3^+$ [$\text{M} + \text{H}^+$]: 223.1329, found: 223.1328.

(*S*)-6,8-dimethoxy-1,2,3,4-tetrahydronaphthalene-1-carbaldehyde (**1b**, Table 2, Entry 1):

Following general procedure D, 5-(3,5-dimethoxyphenyl)pentanal (55.6 mg, 0.25 mmol) was reacted with (*2R,5R*)-2-*tert*-butyl-5-benzyl-3-methylimidazolidin-4-one (20 mol%) to yield 44.0 mg (0.20 mmol, 80%) of bicyclic aldehyde **1b** as a light yellow oil after flash column chromatography (silica, EtOAc/hexanes, 1:1). R_f = 0.55 (silica, EtOAc/hexanes, 1:1); *ee* (93%) was determined by HPLC analysis of the corresponding alcohol [Chiralcel OD-H, hexanes/*i*-PrOH, 95:5, 1 mL/min: (*R*) t_r = 12.38 min, (*S*) t_r = 13.32 min]; $[\alpha]_{\text{D}}^{20}$ = -28.2 (c = 0.35, CHCl_3); ^1H NMR (500 MHz, CDCl_3): δ = 9.57 (d, J = 2.0 Hz, 1 H), 6.33 (d, J = 2.3 Hz, 1 H), 6.30 (d, J = 2.3 Hz, 1 H), 3.79 (s, 3 H), 3.76 (s, 3 H), 3.67 (dt, J = 5.0, 2.0 Hz, 1 H), 2.72 (t, J = 5.8 Hz, 2 H), 2.15–2.09 (m, 1 H), 1.83–1.76 (m, 1 H), 1.75–1.64 (m, 2 H) ppm; ^{13}C NMR (125 MHz, CDCl_3): δ = 203.1, 159.5, 158.4, 140.1, 113.5, 105.0, 96.2, 55.3, 55.2, 46.0, 29.7, 23.2, 20.4 ppm; IR (film): ν_{max} = 2936, 2838, 1720, 1605, 1593, 1489, 1455, 1424, 1355,

1301, 1278, 1202, 1153, 1139, 1104, 1048, 945, 826 cm^{-1} ; HRMS (ESI): calcd for $\text{C}_{13}\text{H}_{17}\text{O}_3^+$ [$\text{M} + \text{H}^+$]: 221.1172, found: 221.1175.

5-(3-Methoxyphenyl)pent-4-yn-1-ol:

Following general procedure A, 3-iodoanisole (2.34 g, 10.0 mmol) was reacted with 4-pentyn-1-ol (1.02 mL, 11.0 mmol) to yield 1.51 g (7.96 mmol, 80%) of alkyne as an orange oil after flash column chromatography (silica, EtOAc/hexanes, 1:1). $R_f = 0.31$ (silica, EtOAc/hexanes, 1:1); ^1H NMR (500 MHz, CDCl_3): $\delta = 7.19$ (dd, $J = 8.3, 7.7$ Hz, 1 H), 6.99 (dd, $J = 7.7, 1.4$ Hz, 1 H), 6.92 (dd, $J = 2.6, 1.4$ Hz, 1 H), 6.83 (dd, $J = 8.3, 2.6$ Hz, 1 H), 3.83 (q, $J = 5.5$ Hz, 2 H), 3.79 (s, 3 H), 2.54 (t, $J = 6.9$ Hz, 2 H), 1.87 (quint, $J = 6.2$ Hz, 2 H), 1.45 (t, $J = 5.5$ Hz, 1 H) ppm; ^{13}C NMR (125 MHz, CDCl_3): $\delta = 159.1, 129.1, 124.6, 124.0, 116.3, 114.1, 89.2, 80.8, 61.4, 55.1, 31.2, 15.8$ ppm; IR (film): $\nu_{\text{max}} = 2941, 2253, 1702, 1598, 1489, 1465, 1286, 1263, 1164, 1043, 904, 728$ cm^{-1} ; HRMS (ESI): calcd for $\text{C}_{12}\text{H}_{15}\text{O}_2^+$ [$\text{M} + \text{H}^+$]: 191.1067, found: 191.1068.

5-(3-Methoxyphenyl)pentan-1-ol:³

Following general procedure B, 5-(3-methoxyphenyl)pent-4-yn-1-ol (1.51 g, 7.96 mmol) was hydrogenated to yield 1.07 g (5.51 mmol, 70%) of alcohol as a light yellow oil that was used in the next step without further purification. Its spectra properties were in agreement with those in the literature.³

5-(3-Methoxyphenyl)pentanal (Table 2, Entry 3):

Following general procedure C, 5-(3-methoxyphenyl)pentan-1-ol (480 mg, 2.47 mmol) was oxidized with $\text{SO}_3 \cdot \text{pyridine}$ (1.18 g, 7.42 mmol) to yield 426 mg (2.22 mmol, 90%) of aldehyde as a yellow oil after flash column chromatography (silica, EtOAc/hexanes, 1:1). $R_f = 0.64$ (silica, EtOAc/hexanes, 1:1); ^1H NMR (500 MHz, CDCl_3): $\delta = 9.74$ (t, $J = 1.7$ Hz, 1 H), 7.19 (dd, $J = 8.2, 7.7$ Hz, 1 H), 6.78 (d, $J = 7.7$ Hz, 1 H), 6.74 (d, $J = 8.2$ Hz, 1 H), 3.79 (s, 3 H), 2.63–2.60 (m, 2 H), 2.46–2.42 (m, 2 H), 1.71–1.62 (m, 4 H) ppm; ^{13}C NMR (125 MHz, CDCl_3): $\delta = 202.9, 157.4, 139.5, 127.1, 121.8, 121.1, 107.5, 55.3, 46.5, 29.3, 23.2, 20.3$ ppm; IR (film): $\nu_{\text{max}} = 2937, 2859, 2845, 2722, 1721, 1601, 1583, 1488, 1454, 1437, 1258, 1151, 1041, 874, 779, 695$ cm^{-1} ; HRMS (ESI): calcd for $\text{C}_{12}\text{H}_{17}\text{O}_2^+$ [$\text{M} + \text{H}^+$]: 193.1223, found: 193.1219.

(S)-8-Methoxy-1,2,3,4-tetrahydronaphthalene-1-carbaldehyde (Table 2, Entry 3):

Following general procedure D, 5-(3-methoxyphenyl)pentanal (48.1 mg, 0.25 mmol) was reacted with (2*R*,5*R*)-2-*tert*-butyl-5-benzyl-3-methylimidazolidin-4-one (20 mol%) to yield 36.6 mg (0.19 mmol, 77%) of bicyclic aldehyde as a colorless oil after flash column chromatography (silica, EtOAc/hexanes, 1:1). $R_f = 0.75$ (silica, EtOAc/hexanes, 1:1); *ee* (97%) was determined by HPLC analysis of the corresponding alcohol [Chiralcel OD-H, hexanes/*i*-PrOH, 95:5], 1 mL/min: (*R*) $t_r = 11.78$ min, (*S*) $t_r = 13.62$ min]; $[\alpha]_D^{20} = -17.4$ ($c = 0.31$, CHCl_3); ^1H NMR (400 MHz, CDCl_3): $\delta = 9.60$ (d, $J = 1.8$ Hz, 1 H), 7.19 (t, $J = 7.9$ Hz, 1 H), 6.78 (d, $J = 7.7$ Hz, 1 H), 6.74 (d, $J = 8.2$ Hz, 2 H), 3.80 (s, 3 H), 3.77 (t, $J = 5.3$ Hz, 1 H), 2.76 (t, $J = 5.7$ Hz, 2 H), 2.20–2.13 (m, 1 H), 1.87–1.78 (m, 1 H), 1.77–1.66 (m, 2 H) ppm; ^{13}C NMR (100 MHz, CDCl_3): $\delta = 202.9, 157.4, 139.5, 127.1, 121.8, 121.1, 107.5, 55.3, 46.5,$

29.3, 23.2, 20.3 ppm; IR (film): ν_{max} = 2937, 2838, 1722, 1585, 1468, 1439, 1318, 1256, 1097, 1058, 907, 772, 730 cm^{-1} ; HRMS (ESI): calcd for $\text{C}_{12}\text{H}_{15}\text{O}_2^+$ [$\text{M} + \text{H}^+$]: 191.1067, found: 191.1071.

5-(3,4-Dimethoxyphenyl)pent-4-yn-1-ol:

Following general procedure A, 4-bromoveratrole (1.09 g, 5.00 mmol) was reacted with 4-pentyn-1-ol (0.51 mL, 5.50 mmol) to yield 0.74 g (3.36 mmol, 67%) of alkyne as an orange oil after flash column chromatography (silica, EtOAc/hexanes, 1:1). R_f = 0.28 (silica, EtOAc/hexanes, 1:1); ^1H NMR (500 MHz, CDCl_3): δ = 6.99 (dd, J = 8.2, 1.8 Hz, 1 H), 6.90 (d, J = 1.8 Hz, 1 H), 6.78 (d, J = 8.2 Hz, 1 H), 3.88 (s, 3 H), 3.87 (s, 3 H), 3.83 (t, J = 6.1 Hz, 2 H), 2.53 (t, J = 6.9 Hz, 2 H), 1.87 (m, 2 H), 1.25 (s, 1 H) ppm; ^{13}C NMR (125 MHz, CDCl_3): δ = 149.0, 148.5, 124.6, 115.9, 114.3, 110.9, 81.2, 81.0, 61.9, 55.9, 55.8, 31.4, 16.0 ppm; IR (film): ν_{max} = 3381, 2935, 2836, 1600, 1578, 1510, 1463, 1409, 1317, 1263, 1240, 1207, 1168, 1135, 1022, 853, 808, 762 cm^{-1} ; HRMS (ESI): calcd for $\text{C}_{13}\text{H}_{17}\text{O}_3^+$ [$\text{M} + \text{H}^+$]: 221.1172, found: 221.1170.

5-(3,4-Dimethoxyphenyl)pentan-1-ol:⁴

Following general procedure B, 5-(3,4-dimethoxyphenyl)pent-4-yn-1-ol (741 mg, 3.36 mmol) was hydrogenated to yield 646 mg (2.88 mmol, 86%) of alcohol as a light yellow oil which was used in the next step without further purification. Its spectra properties were in agreement with those in the literature.⁴

5-(3,4-Dimethoxyphenyl)pentanal (Table 2, Entry 7):

Following general procedure C, 5-(3,4-dimethoxyphenyl)pentan-1-ol (645 mg, 2.88 mmol) was oxidized with $\text{SO}_3 \cdot \text{pyridine}$ (1.37 g, 8.64 mmol) to yield 441 mg (2.19 mmol, 69%) of aldehyde as a yellow oil after flash column chromatography (silica, EtOAc/hexanes, 1:1). $R_f = 0.53$ (silica, EtOAc/hexanes, 1:1); ^1H NMR (500 MHz, CDCl_3): $\delta = 9.74$ (t, $J = 1.7$ Hz, 1 H), 6.77 (d, $J = 7.9$ Hz, 1 H), 6.70–6.68 (m, 2 H), 3.85 (s, 3 H), 3.83 (s, 3 H), 2.57 (t, $J = 7.1$ Hz, 2 H), 2.44 (dt, $J = 6.9, 1.7$ Hz, 2 H), 1.69–1.59 (m, 4 H) ppm; ^{13}C NMR (125 MHz, CDCl_3): $\delta = 202.4, 148.7, 147.1, 134.5, 120.1, 111.6, 111.2, 55.8, 55.7, 43.6, 35.1, 30.9, 21.6$ ppm; IR (film): $\nu_{\text{max}} = 2935, 2834, 2723, 1720, 1590, 1514, 1463, 1417, 1259, 1234, 1154, 1139, 1027, 853, 807, 763$ cm^{-1} ; HRMS (ESI): calcd for $\text{C}_{13}\text{H}_{19}\text{O}_3^+$ [$\text{M} + \text{H}^+$]: 223.1329, found: 223.1336.

(S)-6,7-Dimethoxy-1,2,3,4-tetrahydronaphthalene-1-carbaldehyde (Table 2, Entry 7):

Following general procedure D, 5-(3,4-dimethoxyphenyl)pentanal (55.6 mg, 0.25 mmol) was reacted with (2*R*,5*R*)-2-*tert*-butyl-5-benzyl-3-methylimidazolidin-4-one (20 mol%) to yield 31.9 mg (0.15 mmol, 58%) of bicyclic aldehyde as a light yellow oil after flash column chromatography (silica, EtOAc/hexanes, 1:1). $R_f = 0.58$ (silica, EtOAc/hexanes, 1:1); *ee* (94%) was determined by HPLC analysis of the corresponding alcohol [Chiralcel OD-H, hexanes/*i*-PrOH, 95:5, 1 mL/min: (*R*) $t_r = 18.45$ min, (*S*) $t_r = 23.68$ min]; $[\alpha]_D^{20} = -13.1$ ($c = 0.48$, CHCl_3); ^1H NMR (400 MHz, CDCl_3): $\delta = 9.63$ (d, $J = 2.6$ Hz, 1 H), 6.64 (s, 1 H), 6.59 (s, 1 H), 3.86 (s, 3 H), 3.84 (s, 3 H), 3.50 (m, 1 H), 2.71 (t, $J = 6.2$ Hz, 2 H), 2.19–2.11 (m, 1 H), 1.96–1.88 (m, 1 H), 1.82–1.76 (m, 2 H) ppm; ^{13}C NMR (150 MHz, CDCl_3): $\delta = 202.2, 148.2,$

147.4, 130.2, 122.2, 112.2, 112.0, 56.0, 55.8, 51.3, 28.7, 23.2, 20.5 ppm; IR (film): $\nu_{\max}$ = 2359, 2344, 1758, 1604, 1513, 1242, 1061, 911, 775, 612 cm^{-1} ; HRMS (ESI): calcd for $\text{C}_{13}\text{H}_{17}\text{O}_3^+$ [$\text{M} + \text{H}^+$]: 221.1172, found: 221.1170.

5-(3,4-Methylenedioxyphenyl)pent-4-yn-1-ol:

Following general procedure A, 1-bromo-(3,4-methylene-dioxy)benzene (1.01 g, 5.00 mmol) was reacted with 4-pentyn-1-ol (0.51 mL, 5.50 mmol) to yield 0.62 g (3.04 mmol, 61%) of alkyne as an orange oil after flash column chromatography (silica, EtOAc/hexanes, 1:1). R_f = 0.41 (silica, EtOAc/hexanes, 1:1); ^1H NMR (500 MHz, CDCl_3): δ = 6.91 (dd, J = 8.0, 1.6 Hz, 1 H), 6.84 (d, J = 1.6 Hz, 1 H), 6.72 (d, J = 8.0 Hz, 1 H), 5.95 (s, 2 H), 3.81 (t, J = 5.8 Hz, 2 H), 2.51 (t, J = 6.9 Hz, 2 H), 1.85 (m, 2 H), 1.47 (bs, 1 H) ppm; ^{13}C NMR (125 MHz, CDCl_3): δ = 147.3, 147.2, 125.9, 117.0, 111.6, 108.3, 101.2, 87.5, 80.9, 61.9, 31.4, 16.0 ppm; IR (film): $\nu_{\max}$ = 3349, 2895, 1503, 1488, 1440, 1330, 1246, 1211, 1101, 1037, 934, 860, 811 cm^{-1} ; HRMS (ESI): calcd for $\text{C}_{12}\text{H}_{13}\text{O}_3^+$ [$\text{M} + \text{H}^+$]: 205.0859, found: 205.0856.

5-(3,4-Methylenedioxyphenyl)pentan-1-ol:⁵

Following general procedure B, 5-(3,4-methylenedioxyphenyl)pent-4-yn-1-ol (620 mg, 3.04 mmol) was hydrogenated to yield 555 mg (2.67 mmol, 88%) of alcohol as a light yellow oil which was used in the next step without further purification. Its spectra properties were in agreement with those in the literature.⁵

5-(3,4-Methylenedioxyphenyl)pentan-1-al (Table 2, Entry 8):

Following general procedure C, 5-(3,4-methylenedioxyphenyl)pentan-1-ol (555 mg, 2.67 mmol) was oxidized with $\text{SO}_3 \cdot \text{pyridine}$ (1.72 g, 7.99 mmol) to yield 451 mg (2.19 mmol, 82%) of aldehyde as a yellow oil after flash column chromatography (silica, EtOAc/hexanes, 1:1). $R_f = 0.60$ (silica, EtOAc/hexanes, 1:1); ^1H NMR (600 MHz, CDCl_3): $\delta = 9.73$ (t, $J = 1.7$ Hz, 1 H), 6.71 (d, $J = 7.9$ Hz, 1 H), 6.65 (d, $J = 1.7$ Hz, 1 H), 6.60 (dd, $J = 7.9$, 1.7 Hz, 1 H), 5.90 (s, 2 H), 2.54 (t, $J = 7.1$ Hz, 2 H), 2.42 (dt, $J = 7.1$, 1.7 Hz, 2 H), 1.67–1.57 (m, 4 H) ppm; ^{13}C NMR (150 MHz, CDCl_3): $\delta = 202.0$, 146.8, 146.0, 135.7, 123.4, 109.4, 109.1, 100.9, 51.6, 29.3, 23.0, 20.5 ppm; IR (film): $\nu_{\text{max}} = 2936$, 2360, 1720, 1503, 1488, 1442, 1243, 1187, 1123, 934, 809, 612 cm^{-1} ; HRMS (ESI): calcd for $\text{C}_{12}\text{H}_{15}\text{O}_3^+ [\text{M} + \text{H}^+]$: 207.1016, found: 207.1009.

(S)-5,6,7,8-Tetrahydronaphtho[2,3-d][1,3]dioxole-5-carbaldehyde (Table 2, Entry 8):

Following general procedure D, 5-(3,4-methylenedioxyphenyl)pentanal (51.6 mg, 0.25 mmol) was reacted with (2*R*,5*R*)-2-*tert*-butyl-5-benzyl-3-methylimidazolidin-4-one (20 mol%) to yield 27.6 mg (0.14 mmol, 54%) of bicyclic aldehyde as a light yellow oil after flash column chromatography (silica, EtOAc/hexanes, 1:1). $R_f = 0.65$ (silica, EtOAc/hexanes, 1:1); *ee* (84%) was determined by HPLC analysis of the corresponding Naproxen[®] ester [Chiralcel OD-H, hexanes/*i*-PrOH, 95:5, 1 mL/min: (*R*) $t_r = 11.85$ min, (*S*) $t_r = 13.80$ min]; $[\alpha]_D^{20} = -19.0$ ($c = 0.10$, CHCl_3); ^1H NMR (600 MHz, CDCl_3): $\delta = 9.63$ (d, $J = 2.2$ Hz, 1 H), 6.61 (s, 1 H), 6.60 (s, 1 H), 5.92 (d, $J = 1.3$ Hz, 1 H), 5.91 (d, $J = 1.3$ Hz, 1 H), 3.48 (m, 1 H), 2.68 (t, $J = 6.3$ Hz, 2 H), 2.19–2.15 (m, 1 H), 1.92–1.87 (m, 1 H), 1.81–1.70 (m, 2 H) ppm;

^{13}C NMR (150 MHz, CDCl_3): δ = 202.0, 146.8, 146.0, 131.4, 123.4, 109.4, 109.1, 100.9, 51.6, 29.3, 23.0, 20.5 ppm; IR (film): ν_{max} = 3733, 3632, 2360, 2341, 1772, 1670, 1482, 1245, 680, 668, 651 cm^{-1} ; HRMS (ESI): calcd for $\text{C}_{12}\text{H}_{13}\text{O}_3^+$ [$\text{M} + \text{H}^+$]: 205.0859, found: 205.0861.

5-(Naphthalen-2-yl)pent-4-yn-1-ol:⁶

Following general procedure A, 2-bromonaphthalene (1.29 g, 7.50 mmol) was reacted with 4-pentyn-1-ol (0.77 mL, 8.25 mmol) to yield 1.07 g (5.09 mmol, 68%) of alkyne as an orange oil after flash column chromatography (silica, EtOAc/hexanes, 1:1). R_f = 0.50 (silica, EtOAc/hexanes, 1:1). Its spectra properties were in agreement with those in the literature.⁶

5-(Naphthalen-2-yl)pentan-1-ol:⁵

Following general procedure B, 5-(naphthalen-2-yl)pent-4-yn-1-ol (1.07 g, 5.09 mmol) was hydrogenated to yield 1.08 g (5.04 mmol, 99%) of alcohol as a light yellow oil which was used in the next step without further purification. Its spectra properties were in agreement with those in the literature.⁵

5-(Naphthalen-2-yl)pentanal (Table 2, Entry 10):

Following general procedure C, 5-(naphthalen-2-yl)pentan-1-ol (1.07 g, 5.09 mmol) was oxidized with $\text{SO}_3 \cdot \text{pyridine}$ (2.58 g, 16.2 mmol) to yield 743 mg (3.50 mmol, 69%) of aldehyde as a yellow oil after flash column chromatography (silica, EtOAc/hexanes, 1:2). R_f = 0.47 (silica, EtOAc/hexanes, 1:2); ^1H NMR (500 MHz, CDCl_3): δ = 9.76 (s, 1 H), 7.83–7.75 (m, 3 H), 7.64 (s, 1 H), 7.50–7.44 (m, 2 H), 7.32 (d, J = 8.4 Hz, 1 H),

2.82 (t, $J = 7.5$ Hz, 2 H), 2.46 (t, $J = 7.0$ Hz, 2 H), 1.80–1.68 (m, 4 H) ppm; ^{13}C NMR (125 MHz, CDCl_3): $\delta = 202.3, 139.3, 133.5, 131.9, 127.8, 127.5, 127.3, 127.1, 126.3, 125.8, 125.1, 43.6, 35.7, 30.6, 21.6$ ppm; IR (film): $\nu_{\text{max}} = 3052, 2933, 2858, 2720, 1720, 1600, 1507, 1459, 1271, 1078, 1017, 962, 893, 856, 817, 748$ cm^{-1} ; HRMS (ESI): calcd for $\text{C}_{15}\text{H}_{16}\text{ONa}^+$ [$\text{M} + \text{Na}^+$]: 235.1093, found: 235.1100.

(*R*)-1,2,3,4-Tetrahydrophenanthrene-4-carbaldehyde (Table 2, Entry 10):

Following general procedure D, 5-(naphthalen-2-yl)pentanal (53.1 mg, 0.25 mmol) was reacted with (*2S,5S*)-2-*tert*-butyl-5-benzyl-3-methylimidazolidin-4-one (20 mol%) to yield 29.4 mg (0.14 mmol, 56%) of tricyclic aldehyde as a light yellow oil after column chromatography (silica, EtOAc/hexanes, 1:3). $R_f = 0.51$ (silica, EtOAc/hexanes, 1:3); *ee* (92%) was determined by HPLC analysis of the corresponding alcohol [Chiralcel OD-H, hexanes/*i*-PrOH, 95:5, 1 mL/min: (*R*) $t_r = 10.73$ min, (*S*) $t_r = 12.73$ min]; $[\alpha]_D^{20} = -44.8$ ($c = 0.39$, CHCl_3); ^1H NMR (400 MHz, CDCl_3): $\delta = 9.78$ (dd, $J = 2.1, 0.5$ Hz, 1 H), 7.86–7.81 (m, 2 H), 7.73 (d, $J = 8.4$ Hz, 1 H), 7.54–7.44 (m, 2 H), 7.28 (d, $J = 8.4$ Hz, 1 H), 4.27 (m, 1 H), 2.98 (dd, $J = 7.8, 4.8$ Hz, 2 H), 2.50–2.44 (m, 1 H), 2.06–1.78 (m, 3 H) ppm; ^{13}C NMR (100 MHz, CDCl_3): $\delta = 202.8, 136.3, 132.5, 132.4, 128.8, 128.2, 127.7, 126.6, 126.2, 125.1, 122.7, 47.9, 30.0, 24.0, 19.8$ ppm; IR (film): $\nu_{\text{max}} = 2359, 2344, 1720, 1606, 1505, 1451, 1242, 911, 739, 612$ cm^{-1} ; HRMS (ESI): calcd for $\text{C}_{15}\text{H}_{15}\text{O}^+$ [$\text{M} + \text{H}^+$]: 211.1117, found: 211.1117.

5-(Naphthalen-1-yl)pent-4-yn-1-ol:⁷

Following general procedure A, 1-bromonaphthalene (1.29 g, 7.50 mmol) was reacted with 4-pentyn-1-ol (0.77 mL, 8.25 mmol) to yield 1.27 g (6.03

mmol, 80%) of alkyne as an orange oil after flash column chromatography (silica, EtOAc/hexanes, 1:1). $R_f = 0.49$ (silica, EtOAc/hexanes, 1:1). Its spectra properties were in agreement with those in the literature.⁷

5-(Naphthalen-1-yl)pentan-1-ol:⁸

Following general procedure B, 5-(naphthalen-1-yl)pent-4-yn-1-ol (1.27 g, 6.03 mmol) was hydrogenated to yield 1.17 g (5.41 mmol, 90%) of alcohol as a light yellow oil which was used in the next step without further purification. Its spectra properties were in agreement with those in the literature.⁸

5-(naphthalen-1-yl)pentanal (Table 2, Entry 9):

Following general procedure C, 5-(naphthalen-1-yl)pentan-1-ol (1.16 g, 5.41 mmol) was oxidized with $\text{SO}_3 \cdot \text{pyridine}$ (2.58 g, 16.2 mmol) to yield 862 mg (4.06 mmol, 74%) of aldehyde as a yellow oil after flash column chromatography (silica, EtOAc/hexanes, 1:2). $R_f = 0.51$ (silica, EtOAc/hexanes, 1:2); ^1H NMR (500 MHz, CDCl_3): $\delta = 9.76$ (s, 1 H), 8.06 (d, $J = 8.3$ Hz, 1 H), 7.90 (d, $J = 8.1$ Hz, 1 H), 7.76 (d, $J = 8.2$ Hz, 1 H), 7.58–7.51 (m, 2 H), 7.44 (dd, $J = 8.2, 7.0$ Hz, 1 H), 7.35 (d, $J = 7.0$ Hz, 1 H), 3.12 (t, $J = 7.5$ Hz, 2 H), 2.45 (t, $J = 6.8$ Hz, 2 H), 1.84–1.74 (m, 4 H) ppm; ^{13}C NMR (125 MHz, CDCl_3): $\delta = 202.9, 138.5, 134.4, 132.3, 129.3, 127.2, 126.5, 126.3, 126.0, 125.9, 124.2, 44.2, 33.3, 30.7, 22.6$ ppm; IR (film): $\nu_{\text{max}} = 3045, 2936, 2865, 2720, 1720, 1596, 1509, 1462, 1395, 1166, 1014, 798, 790, 778, 735$ cm^{-1} ; HRMS (ESI): calcd for $\text{C}_{15}\text{H}_{16}\text{ONa}^+ [\text{M} + \text{Na}^+]$: 235.1093, found: 235.1092.

(R)-1,2,3,4-Tetrahydrophenanthrene-1-carbaldehyde (Table 2, Entry 10):

Following general procedure D, 5-(naphthalen-1-yl)pentanal (53.1 mg, 0.25 mmol) was reacted with (2*S*,5*S*)-2-*tert*-butyl-5-benzyl-3-methylimidazolidin-4-one (20 mol%) to yield 26.8 mg (0.13 mmol, 51%) of tricyclic aldehyde as a light yellow oil after flash column chromatography (silica, EtOAc/hexanes, 1:3). R_f = 0.51 (silica, EtOAc/hexanes, 1:3); *ee* (85%) was determined by HPLC analysis of the corresponding alcohol [Chiralcel OD-H, hexanes/*i*-PrOH, 95:5, 1 mL/min: (*R*) t_r = 11.03 min, (*S*) t_r = 12.48 min]; $[\alpha]_D^{20}$ = +44.5 (c = 0.20, CHCl₃); ¹H NMR (400 MHz, CDCl₃): δ = 9.78 (d, J = 2.1 Hz, 1 H), 8.03–8.00 (m, 1 H), 7.85–7.82 (m, 1 H), 7.73 (d, J = 8.4 Hz, 1 H), 7.56–7.47 (m, 2 H), 7.27–7.25 (m, 1 H), 3.75 (m, 1 H), 3.30–3.07 (m, 2 H), 2.36–2.28 (m, 1 H), 2.07–1.87 (m, 3 H) ppm; ¹³C NMR (100 MHz, CDCl₃): δ = 202.2, 133.5, 132.6, 132.5, 128.5, 128.1, 127.5, 126.6, 126.2, 125.7, 123.1, 52.5, 25.3, 22.8, 20.2 ppm; IR (film): $\nu_{\max}$ = 3729, 2360, 2342, 1242, 900, 682, 668, 647, 611 cm⁻¹; HRMS (ESI): calcd for C₁₅H₁₅O⁺ [$M + H^+$]: 211.1117, found: 211.1119.

4-(3,5-Dimethoxyphenoxy)butan-1-ol:

To a solution of 3,5-dimethoxyphenol (2.38 g, 15.4 mmol) in DMF (25 mL) were added K₂CO₃ (4.27 g, 30.9 mmol) and *tert*-butyl(4-iodo-butoxy)dimethylsilane (7.28 g, 23.2 mmol). The solution was heated to 65 °C and stirred for 16 h. After the reaction was complete, water (20 mL) was added and the mixture was extracted with Et₂O (2 × 30 mL). The combined organic layers were washed with brine, dried over MgSO₄, filtered and concentrated *in vacuo*. The residue was dissolved in dry THF (30 mL) and TBAF (1 M in THF, 30.8 mL, 30.8 mmol) was added at room temperature. After stirring for 4 h at that temperature, the reaction mixture was concentrated *in vacuo* and the residue was purified by flash column

chromatography (silica, pentane/Et₂O, 1:5) to give 2.44 g (10.8 mmol, 70%) of the pure title compound. R_f = 0.41 (silica, pentane/Et₂O, 1:5); ¹H NMR (500 MHz, CDCl₃): δ = 6.08 (s, 3 H), 3.97 (t, J = 6.2 Hz, 2 H), 3.76 (s, 6 H), 3.72 (t, J = 6.3 Hz, 2 H), 1.90–1.84 (m, 2 H), 1.78–1.72 (m, 2 H) ppm; ¹³C NMR (125 MHz, CDCl₃): δ = 161.5, 160.8, 94.4, 93.0, 67.8, 62.6, 55.3, 29.5, 25.7 ppm; IR (film): $\nu_{\max}$ = 3372, 2941, 1594, 1471, 1391, 1203, 1194, 1149, 1061, 945, 819, 682 cm⁻¹; HRMS (ESI): calcd for C₁₂H₁₉O₄⁺ [M + H⁺]: 227.1278, found: 227.1281.

4-(3,5-Dimethoxyphenoxy)butanal (Table 2, Entry 2):

Following general procedure C, 4-(3,5-dimethoxyphenoxy)butan-1-ol (2.44 g, 10.8 mmol) was oxidized with SO₃·pyridine (5.14 g, 32.3 mmol) to yield 2.00 g (8.92 mmol, 83%) of aldehyde as a yellow oil after flash column chromatography (silica, pentane/Et₂O, 1:1). R_f = 0.42 (silica, pentane/Et₂O, 1:1); ¹H NMR (500 MHz, CDCl₃): δ = 9.82 (s, 1 H), 6.07 (t, J = 2.2 Hz, 1 H), 6.05 (d, J = 2.2 Hz, 2 H), 3.95 (t, J = 5.9 Hz, 2 H), 3.75 (s, 6 H), 2.63 (t, J = 6.9 Hz, 2 H), 2.09 (m, 2 H) ppm; ¹³C NMR (125 MHz, CDCl₃): δ = 201.6, 161.5, 160.5, 93.3, 93.1, 66.6, 55.2, 40.5, 21.9 ppm; IR (film): $\nu_{\max}$ = 2939, 2840, 2726, 1722, 1594, 1459, 1426, 1200, 1146, 1102, 1065, 946, 820, 683 cm⁻¹; HRMS (ESI): calcd for C₁₂H₁₇O₄⁺ [M + H⁺]: 225.1121, found: 225.1120.

(*R*)-5,7-Dimethoxychroman-4-carbaldehyde (Table 2, Entry 2):

Following general procedure D, 4-(3,5-dimethoxyphenoxy)butanal (56.1 mg, 0.25 mmol) was reacted with (2*S*,5*S*)-2-*tert*-butyl-5-benzyl-3-methylimidazolidin-4-one (20 mol%) to yield 42.2 mg (0.19 mmol, 76%) of bicyclic aldehyde as a colorless oil after flash column chromatography (silica, EtOAc/hexanes, 1:1). R_f = 0.71 (silica,

EtOAc/hexanes, 1:1); *ee* (86%) was determined by HPLC analysis of the corresponding alcohol [Chiralcel OD-H, hexanes/*i*-PrOH, 98:2), 1 mL/min: (*R*) t_r = 65.67 min, (*S*) t_r = 74.03 min]; $[\alpha]_D^{20} = -100.9$ (c = 1.45, CHCl₃); ¹H NMR (500 MHz, CDCl₃): δ = 9.67 (d, J = 1.1 Hz, 1 H), 6.11 (d, J = 2.4 Hz, 1 H), 6.07 (d, J = 2.4 Hz, 1 H), 4.19–4.15 (m, 1 H), 3.92 (dt, J = 10.8, 2.5 Hz, 1 H), 3.80 (s, 3 H), 3.77 (s, 3 H), 3.72–3.69 (m, 1 H), 2.38–2.33 (m, 1 H), 1.97–1.89 (m, 1 H) ppm; ¹³C NMR (125 MHz, CDCl₃): δ = 201.5, 160.6, 158.7, 156.7, 98.9, 93.8, 91.6, 64.0, 55.5, 55.3, 42.1, 21.5 ppm; IR (film): $\nu_{\max}$ = 2938, 2838, 1723, 1606, 1460, 1378, 1319, 1275, 1214, 1201, 1146, 1103, 908, 823, 731 cm⁻¹; HRMS (ESI): calcd for C₁₂H₁₅O₄⁺ [$M + H^+$]: 223.0965, found: 223.0966.

***N*-(3,5-Dimethoxyphenyl)-*N*-(4-hydroxybutyl)-4-methylbenzenesulfonamide:**

To a stirred solution of aniline (2.30 g, 15.0 mmol) in CH₂Cl₂ (50 mL) were added pyridine (7.50 mL, 90 mmol) and TsCl (3.43 g, 18.0 mmol) at room temperature. The mixture was stirred for 1 h, washed with water (30 mL) and brine (30 mL), dried over MgSO₄, filtered and concentrated *in vacuo*. The resulting residue was subjected to flash column chromatography (silica, R_f = 0.50, EtOAc/hexanes, 1:1) to give 3.12 g (10.2 mmol, 68%) of the *N*-tosylaniline. This compound was mixed with K₂CO₃ (2.80 g, 20.3 mmol) and *tert*-butyl(4-iodo-butoxy)dimethylsilane (4.78 g, 15.2 mmol) in DMF (20 mL) and stirred at 65 °C for 16 h. After the reaction was complete, water (20 mL) was added and the mixture was extracted with Et₂O (2 × 30 mL). The combined organic layers were washed with brine, dried over MgSO₄, filtered and concentrated *in vacuo*. The residue was dissolved in dry THF (20 mL) and TBAF (1 M in THF, 20.4 mL, 20.4 mmol) was added at room temperature. After stirring for 4 h at that temperature, the reaction mixture was concentrated *in vacuo* and the residue was

purified by flash column chromatography (silica, hexanes/EtOAc, 1:1) to give 2.88 g (7.59 mmol, 75%) of the pure title alcohol. $R_f = 0.49$ (silica, hexanes/EtOAc, 1:1); ^1H NMR (500 MHz, CDCl_3): $\delta = 7.50$ (d, $J = 8.2$ Hz, 2 H), 7.23 (d, $J = 8.2$ Hz, 2 H), 6.37 (t, $J = 2.2$ Hz, 1 H), 6.17 (d, $J = 2.2$ Hz, 2 H), 3.68 (s, 6 H), 3.58 (t, $J = 6.4$ Hz, 2 H), 3.49 (t, $J = 6.8$ Hz, 2 H), 2.39 (s, 3 H), 1.80 (bs, 1 H), 1.61–1.55 (m, 2 H), 1.52–1.46 (m, 2 H) ppm; ^{13}C NMR (125 MHz, CDCl_3): $\delta = 160.5, 143.3, 140.7, 135.1, 129.3, 127.7, 106.9, 100.0, 62.1, 55.3, 50.2, 29.3, 24.5, 21.4$ ppm; IR (film): $\nu_{\text{max}} = 3512, 2933, 1593, 1459, 1427, 1339, 1204, 1154, 1047, 927, 835, 814, 779, 693, 662$ cm^{-1} ; HRMS (ESI): calcd for $\text{C}_{19}\text{H}_{26}\text{NO}_5\text{S}^+$ [$\text{M} + \text{H}^+$]: 380.1526, found: 380.1534.

***N*-(3,5-Dimethoxyphenyl)-4-methyl-*N*-(4-oxobutyl)benzenesulfonamide (Table 2, Entry 4):**

Following general procedure C, *N*-(3,5-dimethoxyphenyl)-*N*-(4-hydroxybutyl)-4-methylbenzenesulfonamide (1.44 g, 3.79 mmol) was oxidized with $\text{SO}_3 \cdot \text{pyridine}$ (1.81 g, 11.4 mmol) to yield 1.07 g (2.83 mmol, 75%) of aldehyde as a yellow solid after flash column chromatography (silica, EtOAc/hexanes, 1:1). $R_f = 0.39$ (silica, EtOAc/hexanes, 1:1); ^1H NMR (500 MHz, CDCl_3): $\delta = 9.74$ (t, $J = 1.1$ Hz, 1 H), 7.49 (d, $J = 8.3$ Hz, 2 H), 7.24 (d, $J = 8.3$ Hz, 2 H), 6.38 (t, $J = 2.3$ Hz, 1 H), 6.17 (d, $J = 2.3$ Hz, 2 H), 3.70 (s, 6 H), 3.50 (t, $J = 6.6$ Hz, 2 H), 2.57 (dt, $J = 7.1, 1.1$ Hz, 2 H), 2.39 (s, 3 H), 1.73 (m, 2 H) ppm; ^{13}C NMR (125 MHz, CDCl_3): $\delta = 201.3, 160.7, 143.5, 140.5, 135.0, 129.3, 127.7, 106.8, 100.1, 55.3, 49.6, 40.5, 21.4, 20.5$ ppm; IR (film): $\nu_{\text{max}} = 2939, 2840, 2728, 1720, 1593, 1459, 1428, 1342, 1204, 1154, 1120, 1088, 1063, 1047, 928, 816, 769, 694, 663$ cm^{-1} ; HRMS (ESI): calcd for $\text{C}_{19}\text{H}_{24}\text{NO}_5\text{S}^+$ [$\text{M} + \text{H}^+$]: 378.1370, found: 378.1374.

(S)-5,7-dimethoxy-1-tosyl-1,2,3,4-tetrahydroquinoline-4-carbaldehyde (Table 2, Entry 4):

Following general procedure D, *N*-(3,5-dimethoxyphenyl)-4-methyl-*N*-(4-oxobutyl)benzenesulfonamide (94.4 mg, 0.25 mmol) was reacted with (2*R*,5*R*)-2-*tert*-butyl-5-benzyl-3-methylimidazolidin-4-one (20 mol%) to yield 71.3 mg (0.19 mmol, 76%) of bicyclic aldehyde as a yellow solid after flash column chromatography (silica, EtOAc/hexanes, 1:1). R_f = 0.57 (silica, EtOAc/hexanes, 1:1); *ee* (87%) was determined by HPLC analysis of the corresponding alcohol [Chiralpak AD, hexanes/*i*-PrOH, 80:20, 5 mL/min: (*R*) t_r = 41.63 min, (*S*) t_r = 62.87 min]; $[\alpha]_D^{20}$ = +44.4 (c = 0.46, CHCl₃); ¹H NMR (400 MHz, CDCl₃): δ = 9.17 (t, J = 1.2 Hz, 1 H), 7.54 (d, J = 8.1 Hz, 2 H), 7.22 (d, J = 8.1 Hz, 2 H), 7.12 (d, J = 1.6 Hz, 1 H), 6.32 (d, J = 1.6 Hz, 1 H), 3.90–3.85 (m, 1 H), 3.83 (s, 3 H), 3.75 (s, 3 H), 3.69–3.63 (m, 1 H), 3.56–3.53 (m, 1 H), 2.38 (s, 3 H), 1.86–1.78 (m, 1 H), 1.56–1.50 ppm; ¹³C NMR (100 MHz, CDCl₃): δ = 201.1, 159.8, 158.3, 144.2, 139.2, 137.2, 129.9, 127.3, 105.0, 101.1, 96.0, 55.8, 55.7, 44.6, 43.9, 21.8, 20.4 ppm; IR (film): $\nu_{\max}$ = 2939, 2835, 1723, 1608, 1585, 1492, 1459, 1350, 1203, 1163, 1130, 1089, 1050, 940, 814, 751, 671 cm⁻¹; HRMS (ESI): calcd for C₁₉H₂₂NO₅S⁺ [*M* + H⁺]: 376.1213, found: 376.1228.

***tert*-Butyl 2-(5-hydroxypentyl)-1*H*-indole-1-carboxylate:**

2-Methylindole (307 mg, 2.34 mmol) was dissolved in degassed ether (10 mL) at room temperature under an argon atmosphere. To the resulting solution was added of *n*-BuLi (2.5 M in hexanes, 2.81 mL, 7.02 mmol) followed by potassium *tert*-butoxide (525 mg, 4.68 mmol) to give a bright yellow solution. After stirring for 30 min at room temperature, the reaction mixture was cooled down to –78 °C and *tert*-butyl(4-iodobutoxy)dimethylsilane (1.21 mL, 4.68 mmol) was added dropwise. The solution was

kept at $-78\text{ }^{\circ}\text{C}$ for 2 h, and then quenched with a few drops of water. The solution was warmed to room temperature and poured into water (75 mL). The mixture was neutralized with 1 M aq. HCl and extracted with diethyl ether ($2 \times 50\text{ mL}$). The combined organic extracts were washed with water ($2 \times 60\text{ mL}$), dried over Na_2SO_4 , filtered, concentrated *in vacuo* and filtered through a pad of silica with ether.⁹ After removal of solvent, the resulting residue was dissolved in 25 mL CH_2Cl_2 , and to the resulting solution di-*tert*-butyl dicarbonate (613 mg, 2.81 mmol), triethylamine (0.65 mL, 4.68 mmol) and DMAP (10 mol%) were added at $0\text{ }^{\circ}\text{C}$. The mixture was warmed to room temperature and stirred for 16 h. After completion of the reaction (TLC), the solvent was evaporated and the residue was further purified by flash column chromatography (silica, EtOAc/hexanes, 1:1) to give 547 mg (1.80 mmol, 77%) of the pure title alcohol. $R_f = 0.58$ (silica, EtOAc/hexanes, 1:1); ^1H NMR (600 MHz, CDCl_3): $\delta = 8.09$ (d, $J = 7.7\text{ Hz}$, 1 H), 7.45 (d, $J = 7.4\text{ Hz}$, 1 H), 7.24–7.21 (m, 1 H), 7.18 (dt, $J = 7.4, 1.2\text{ Hz}$, 1 H), 6.36 (s, 1 H), 3.66 (q, $J = 5.4\text{ Hz}$, 2 H), 3.02 (t, $J = 7.5\text{ Hz}$, 2 H), 1.76–1.71 (m, 4 H), 1.69 (s, 1 H), 1.66–1.62 (m, 2 H), 0.93 (s, 1 H) ppm; ^{13}C NMR (150 MHz, CDCl_3): $\delta = 150.5, 142.1, 136.5, 129.3, 123.1, 122.5, 119.6, 115.5, 107.0, 83.6, 62.8, 32.6, 30.0, 28.6, 28.2, 25.6\text{ ppm}$; IR (film): $\nu_{\text{max}} = 3350, 2983, 2936, 2359, 1770, 1758, 1730, 1455, 1370, 1327, 1247, 1158, 1116, 1058, 851, 770, 747, 612\text{ cm}^{-1}$; HRMS (ESI): calcd for $\text{C}_{18}\text{H}_{26}\text{NO}_3^+ [\text{M} + \text{H}^+]$: 304.1907, found: 304.1905.

***tert*-Butyl 2-(5-oxopentyl)-1*H*-indole-1-carboxylate (Table 2, Entry 5):**

Following general procedure C, *tert*-butyl 2-(5-hydroxypentyl)-1*H*-indole-1-carboxylate (547 mg, 1.80 mmol) was oxidized with $\text{SO}_3\cdot\text{pyridine}$ (860 mg, 5.40 mmol) to yield 430 mg (1.43 mmol, 79%) of aldehyde as a yellow solid after flash column chromatography (silica, EtOAc/hexanes, 1:1). $R_f = 0.71$ (silica, EtOAc/hexanes, 1:1); ^1H NMR

(400 MHz, CDCl₃): δ = 9.79 (t, J = 1.7 Hz, 1 H), 8.08 (d, J = 7.9 Hz, 1 H), 7.46–7.44 (m, 1 H), 7.25–7.16 (m, 2 H), 6.36 (d, J = 0.8 Hz, 1 H), 3.04 (t, J = 7.1 Hz, 1 H), 2.50 (dt, J = 7.0, 1.7 Hz, 2 H), 1.78–1.74 (m, 4 H), 1.69 (s, 9 H) ppm; ¹³C NMR (120 MHz, CDCl₃): δ = 202.3, 150.5, 141.6, 136.5, 129.2, 123.2, 122.6, 119.7, 115.5, 107.3, 83.7, 43.7, 29.8, 28.2, 25.6, 21.8 ppm; IR (film): ν_{max} = 2977, 1724, 1606, 1588, 1466, 1452, 1369, 1302, 1251, 1155, 841, 757 cm⁻¹; HRMS (ESI): calcd for C₁₈H₂₄NO₃⁺ [M + H⁺]: 302.1751, found: 302.1753.

(*R*)-*tert*-Butyl 4-formyl-1,2,3,4-tetrahydrocarbazole-9-carboxylate (Table 2, Entry 5):

Following general procedure D, *tert*-butyl 2-(5-oxopentyl)-1*H*-indole-1-carboxylate (75.3 mg, 0.25 mmol) was reacted with (2*S*,5*S*)-2-*tert*-butyl-5-benzyl-3-methylimidazolidin-4-one (20 mol%) to yield 47.9 mg (0.16 mmol, 64%) of tricyclic aldehyde as a yellow oil after flash column chromatography (silica, EtOAc/hexanes, 1:1). R_f = 0.76 (silica, EtOAc/hexanes, 1:1); *ee* (98%) was determined by HPLC analysis of the corresponding alcohol [Chiralcel OD-H, hexanes/*i*-PrOH, 95:5, 1 mL/min: (*R*) t_r = 7.87 min, (*S*) t_r = 8.80 min]; $[\alpha]_D^{20}$ = -6.7 (c = 0.28, CHCl₃); ¹H NMR (400 MHz, CDCl₃): δ = 9.73 (d, J = 2.6 Hz, 1 H), 8.15 (d, J = 8.2 Hz, 1 H), 7.38 (d, J = 7.4 Hz, 1 H), 7.32–7.12 (m, 2 H), 3.71 (bs, 1 H), 3.20–2.94 (m, 2 H), 2.24–2.16 (m, 1 H), 1.95–1.87 (m, 3 H), 1.68 (s, 9 H) ppm; ¹³C NMR (100 MHz, CDCl₃): δ = 201.3, 150.4, 150.1, 137.9, 135.8, 128.6, 123.8, 122.8, 117.7, 115.6, 111.3, 83.8, 45.9, 28.2, 25.5, 22.4, 20.8 ppm; IR (film): ν_{max} = 3354, 2970, 2934, 1728, 1610, 1457, 1364, 1318, 1256, 1219, 1157, 1138, 1115, 1034, 950, 840, 816, 744, 683 cm⁻¹; HRMS (ESI): calcd for C₁₈H₂₂NO₃⁺ [M + H⁺]: 300.1600, found: 300.1605.

***tert*-butyl 2-(5-hydroxypentyl)-5-methoxy-1*H*-indole-1-carboxylate:**

To a solution of 5-methoxy-2-(pent-4-enyl)-1*H*-indole (398 mg, 1.85 mmol), (prepared by a literature procedure)¹⁰ in CH₂Cl₂ (20 mL) were added di-*tert*-butyl dicarbonate (485 mg, 2.22 mmol), triethylamine (0.52 mL, 3.70 mmol) and DMAP (10 mol%) at 0 °C. The mixture was warmed to room temperature and stirred for 16 h. After completion, the solvent was evaporated and the residue was flushed through a short pad of silica with ether. After evaporation of the solvent, the resulting oil was dissolved in dry THF (20 mL) and BH₃·THF (1 M in THF, 2.22 mL, 2.22 mmol) were added dropwise at 0 °C. After the addition, the mixture was allowed to warm to room temperature and was left stirring for an additional 1.5 h. The excess of BH₃ was quenched with water (5 mL) and to the resulting mixture NaBO₃·4H₂O (285 mg, 1.85 mmol) was added at 0 °C. The mixture was allowed to warm to room temperature and stirred for additional 16 h. After completion of the reaction (TLC), the mixture was diluted with water (20 mL), extracted with ethyl acetate (2 × 50 mL), dried over Na₂SO₄, filtered and concentrated *in vacuo*. The residue was further purified by flash column chromatography (silica, Et₂O/hexanes, 2:1) to give 473 mg (1.42 mmol, 77%) of the pure title alcohol. *R*_f = 0.21 (silica, Et₂O/hexanes, 2:1); ¹H NMR (500 MHz, CDCl₃): δ = 7.96 (d, *J* = 9.0 Hz, 1 H), 6.92 (d, *J* = 2.6 Hz, 1 H), 6.83 (dd, *J* = 9.0, 2.6 Hz, 1 H), 6.28 (s, 1 H), 3.84 (s, 3 H), 3.67 (t, *J* = 6.5 Hz, 2 H), 3.00 (t, *J* = 7.6 Hz, 2 H), 1.76–1.61 (m, 4 H), 1.67 (s, 9 H), 1.56–1.43 (m, 3 H) ppm; ¹³C NMR (125 MHz, CDCl₃): δ = 155.8, 150.5, 143.0, 131.3, 130.2, 116.3, 111.5, 107.0, 102.5, 83.5, 62.9, 55.7, 32.6, 30.1, 28.7, 28.3, 25.6 ppm; IR (film): ν_{max} = 2938, 2360, 1728, 1478, 1369, 1206, 1163, 1122, 1082, 851, 768 cm⁻¹; HRMS (ESI): calcd for C₁₉H₂₈NO₄⁺ [M + H⁺]: 334.2013, found: 334.2015.

***tert*-Butyl 5-methoxy-2-(5-oxopentyl)-1*H*-indole-1-carboxylate (Table 2, Substrate 6):**

To a solution of *tert*-butyl 2-(5-hydroxypentyl)-5-methoxy-1*H*-indole-1-carboxylate (239 mg, 0.72 mmol) in CH₂Cl₂ (7.5 mL) were added NaHCO₃ (602 mg, 7.16 mmol) and DMP (608 mg, 1.44 mmol) at 0 °C. The solution was allowed to reach the room temperature and stirred for further 1.5 h. After completion the reaction was quenched by addition of sat. aq. NaHCO₃ (5 mL), sat. aq. Na₂S₂O₇ (5 mL), H₂O (5 mL) and ether (30 mL). After stirring this mixture for 0.5 h, the aqueous phase was separated and extracted with Et₂O (2 × 15 mL). The combined organic extracts were dried over MgSO₄, filtered and concentrated *in vacuo*. The resulting residue was further purified by flash column chromatography (silica, Et₂O/hexanes, 1:2) to give 237 mg (0.72 mmol, quant.) of the pure aldehyde. *R*_f = 0.28 (silica, Et₂O/hexanes, 1:2); ¹H NMR (500 MHz, CDCl₃): δ = 9.78 (t, *J* = 1.6 Hz, 1 H), 7.96 (d, *J* = 9.0 Hz, 1 H), 6.93 (d, *J* = 2.4 Hz, 1 H), 6.84 (dd, *J* = 9.0, 2.4 Hz, 1 H), 6.28 (s, 1 H), 3.83 (s, 3 H), 3.02 (t, *J* = 6.5 Hz, 2 H), 2.49 (dt, *J* = 6.8, 1.6 Hz, 2 H), 1.76–1.73 (m, 4 H), 1.68 (s, 9 H) ppm; ¹³C NMR (125 MHz, CDCl₃): δ = 202.2, 155.7, 150.4, 142.3, 131.2, 130.0, 116.3, 111.6, 107.1, 102.5, 83.5, 55.6, 43.6, 29.8, 28.3, 28.2, 21.7 ppm; IR (film): ν_{max} = 2936, 2833, 2720, 1721, 1614, 1593, 1476, 1593, 1476, 1449, 1368, 1313, 1253, 1205, 1160, 1118, 1087, 1034, 939, 848, 795, 767, 736, 681 cm⁻¹; HRMS (ESI): calcd for C₁₉H₂₆NO₄⁺ [M + H⁺]: 332.1856, found: 332.1865.

(*S*)-*tert*-butyl 5-formyl-3-methoxy-5,6,7,8-tetrahydrocarbazole-9-carboxylate (Table 2, Substrate 6):

Following general procedure D, *tert*-butyl 5-methoxy-2-(5-oxopentyl)-1*H*-indole-1-carboxylate (82.8 mg, 0.25 mmol) was reacted with (*2R,5R*)-2-*tert*-

butyl-5-benzyl-3-methylimidazolidin-4-one (20 mol%) to yield 45.3 mg (0.14 mmol, 55%) of tricyclic aldehyde as a yellow oil after flash column chromatography (silica, hexanes/Et₂O, 2:1). R_f = 0.39 (silica, hexanes/Et₂O, 2:1); *ee* (94%) was determined by HPLC analysis of the corresponding Naproxen[®] ester [Chiralcel OD-H, hexanes/*i*-PrOH, 98:2, 1 mL/min: (*R*) t_r = 12.67 min, (*S*) t_r = 14.25 min]; $[\alpha]_D^{20}$ = -40.7 (c = 0.13, CHCl₃); ¹H NMR (500 MHz, CDCl₃): δ = 9.71 (d, J = 2.8 Hz, 1 H), 8.02 (d, J = 9.0 Hz, 1 H), 6.87 (dd, J = 9.0, 2.5 Hz, 1 H), 6.83 (d, J = 2.5 Hz, 1 H), 3.83 (s, 3 H), 3.68–3.65 (m, 1 H), 3.25–2.95 (m, 2 H), 2.22–2.16 (m, 1 H), 1.95–1.88 (m, 3 H), 1.67 (s, 9 H), ppm; ¹³C NMR (125 MHz, CDCl₃): δ = 201.4, 156.0, 149.3, 138.7, 130.4, 129.5, 116.4, 112.1, 111.1, 100.8, 83.7, 55.7, 45.9, 28.3, 25.6, 22.5, 20.8 ppm; IR (film): $\nu_{\max}$ = 3468, 2936, 1724, 1610, 1476, 1368, 1320, 1254, 1219, 1163, 1133, 1028, 839, 767 cm⁻¹; HRMS (ESI): calcd for C₁₉H₂₄NO₄⁺ [M + H⁺]: 330.1705, found: 330.1712.

5-(3-Methoxy-4-methylphenyl)pentanal (4a):

To a stirred solution of 2-methoxy-4-iodotoluene (**3**) (100 mg, 0.40 mmol) in dry DMF (2.5 mL) were added LiCl (17.1 mg, 0.40 mmol), LiOAc·2H₂O (123 mg, 1.21 mmol), *n*-Bu₄NCl (224 mg, 0.81 mmol), PdOAc₂ (2.7 mg, 12.1 μ mol) and 4-penten-1-ol (0.05 mL, 0.44 mmol) at room temperature.¹¹ After three days the reaction was quenched with H₂O (3 mL), extracted with Et₂O (3 $\times$ 5 mL), dried over MgSO₄ and concentrated *in vacuo*. Flash column chromatography (silica, Et₂O/hexanes, 1:2) provided 52.0 mg (0.25 mmol, 63%) of **4a** as a yellow oil. **4a**: R_f = 0.40 (silica, Et₂O/hexanes, 1:2); ¹H NMR (500 MHz, CDCl₃): δ = 9.76 (t, J = 1.8 Hz, 1 H), 7.04 (d, J = 7.5 Hz, 1 H), 6.68 (dd, J = 7.5, 1.4 Hz, 1 H), 6.65 (d, J = 1.4 Hz, 1 H), 3.83 (s, 3 H), 2.61 (t, J = 7.0 Hz, 2 H), 2.45 (dt, J = 7.0, 1.8 Hz, 2 H), 2.19 (s, 3 H), 1.72–1.66 (m, 4 H) ppm; ¹³C NMR (125 MHz, CDCl₃): δ = 202.9, 158.1, 141.2, 130.8, 124.4,

120.5, 110.7, 55.7, 44.2, 36.1, 31.4, 22.2, 16.2 ppm; IR (film): $\nu_{\max}$ = 2934, 2858, 2720, 1721, 1613, 1583, 1509, 1463, 1412, 1255, 1153, 1132, 1040, 994, 851, 813, 735 cm^{-1} ; HRMS (ESI): calcd for $\text{C}_{13}\text{H}_{19}\text{O}_2^+$ [$\text{M} + \text{H}^+$]: 207.1379, found: 207.1381.

(S)-6-Methoxy-7-methyl-1,2,3,4-tetrahydronaphthalene-1-carbaldehyde (4b):

Following general procedure D, 5-(3-methoxy-4-methylphenyl)pentanal (**4a**) (175.0 mg, 0.85 mmol) was reacted with (2*R*,5*R*)-2-*tert*-butyl-5-benzyl-3-methylimidazolidin-4-one (20 mol%) to yield 97.0 mg (0.48 mmol, 56%) of aldehyde **4b** as a colorless oil after flash column chromatography (silica, Et_2O /hexanes, 1:2). **4b**: R_f = 0.47 (silica, Et_2O /hexanes, 1:2); *ee* (90%) was determined by HPLC analysis of the corresponding alcohol [Chiralcel OD-H, hexanes/*i*-PrOH, 98:2], 1 mL/min: (*R*) t_r = 12.45 min, (*S*) t_r = 13.70 min]; $[\alpha]_D^{20}$ = -16.2 (c = 0.08, CHCl_3); ^1H NMR (500 MHz, CDCl_3): δ = 9.62 (d, J = 2.3 Hz, 1 H), 6.89 (s, 1 H), 6.60 (s, 1 H), 3.81 (s, 3 H), 3.49 (dt, J = 3.6, 2.3 Hz, 1 H), 2.75 (t, J = 6.3 Hz, 2 H), 2.18 (s, 3 H), 2.17–2.13 (m, 1 H), 1.94–1.88 (m, 1 H), 1.81–1.76 (m, 2 H) ppm; ^{13}C NMR (125 MHz, CDCl_3): δ = 202.3, 156.8, 136.4, 131.5, 124.9, 122.0, 110.9, 55.3, 50.9, 29.3, 23.2, 20.6, 15.8 ppm; IR (film): $\nu_{\max}$ = 3686, 2967, 2923, 2870, 1724, 1512, 1254, 1055, 1033, 1012 cm^{-1} ; HRMS (ESI): calcd for $\text{C}_{13}\text{H}_{17}\text{O}_2^+$ [$\text{M} + \text{H}^+$]: 205.1223, found: 205.1226.

(S)-Methyl 6-methoxy-7-methyl-1,2,3,4-tetrahydronaphthalene-1-carboxylate (5):

To a solution of aldehyde **4b** (21.3 mg, 0.10 mmol) in acetonitrile (0.04 mL) were added NIS (70.4 mg, 0.31 mmol), K_2CO_3 (43.2 mg, 0.31 mmol) and methanol (33.4 mg, 1.04 mmol).¹² The resultant mixture was stirred for 24 h at room temperature in the dark. After completion, the reaction was quenched with sat. aq. $\text{Na}_2\text{S}_2\text{O}_3$ (3 mL), extracted with

Et₂O (3×10 mL), dried over MgSO₄ and concentrated *in vacuo*. Column chromatography (silica, Et₂O/hexanes, 1:2) provided 20.4 mg (0.09 mmol, 84%) of **5** as a colorless oil. **5**: *R_f* = 0.40 (silica, Et₂O/hexanes, 1:2); [α]_D²⁰ = −8.1 (*c* = 0.47, CHCl₃); ¹H NMR (500 MHz, C₆D₆): δ = 7.10 (s, 1 H), 6.34 (s, 1 H), 3.73 (t, *J* = 5.8 Hz, 1 H), 3.36 (s, 3 H), 3.35 (s, 3 H), 2.75–2.44 (m, 2 H), 2.26 (s, 3 H), 2.18–2.12 (m, 1 H), 2.01–1.93 (m, 1 H), 1.78–1.71 (m, 1 H), 1.58–1.49 (m, 1 H) ppm; ¹³C NMR (125 MHz, CDCl₃): δ = 175.8, 156.5, 135.5, 131.2, 124.6, 124.4, 110.3, 55.2, 51.9, 44.0, 29.3, 26.9, 20.7, 15.9 ppm; IR (film): ν_{max} = 2946, 1735, 1615, 1509, 1464, 1314, 1254, 1196, 1159, 1109, 1029, 832 cm^{−1}; HRMS (ESI): calcd for C₁₄H₁₉O₃⁺ [*M* + *H*⁺]: 235.1329, found: 235.1326.

(S)-2-(6-Methoxy-7-methyl-1,2,3,4-tetrahydronaphthalen-1-yl)propan-2-ol (6):

Under a dry argon atmosphere, the ester **5** (9.3 mg 39.69 μ mol) was dissolved in dry THF (0.5 mL) and cooled down to 0 °C. A solution of MeMgBr (3 M in ether, 26.5 μ L, 79.4 μ mol) was added and the mixture was warmed to room temperature and stirred for 16 h. After completion, the reaction was quenched by adding sat. aq. NH₄Cl (0.5 mL). The aqueous layer was extracted with ethyl acetate (3 × 2 mL), dried over MgSO₄ and concentrated *in vacuo*. Column chromatography (silica, Et₂O/hexanes, 1:1) provided 6.0 mg (25.6 μ mol, 65%) of tertiary alcohol **6** as a colorless oil. **6**: *R_f* = 0.47 (silica, Et₂O/hexanes, 1:1); [α]_D²⁰ = +10.6 (*c* = 0.30, CHCl₃); ¹H NMR (500 MHz, C₆D₆): δ = 7.36 (s, 1 H), 6.43 (s, 1 H), 3.41 (s, 3 H), 2.76 (t, *J* = 6.7 Hz, 1 H), 2.66–2.53 (m, 2 H), 2.34 (s, 3 H), 2.01–1.94 (m, 1 H), 1.79–1.72 (m, 1 H), 1.65–1.58 (m, 1 H), 1.49–1.41 (m, 1 H), 1.15 (s, 3 H), 1.94 (s, 3 H), 1.02 (bs, 1 H) ppm; ¹³C NMR (125 MHz, C₆C₆): δ = 156.6, 138.3, 133.8, 128.8, 123.5, 110.4, 74.1, 54.8, 47.7, 30.6, 29.9, 26.6, 26.2, 22.2, 16.4 ppm; IR (film): ν_{max} = 3437, 2929, 1614, 1575, 1506, 1464, 1403, 1370, 1322,

1255, 1208, 1107, 1031, 948, 892, 834 cm^{-1} ; HRMS (ESI): calcd for $\text{C}_{15}\text{H}_{22}\text{O}_2\text{Na}^+$ $[\text{M} + \text{Na}^+]$: 257.1512, found: 257.1511.

(R)-1-Isopropyl-6-methoxy-7-methyl-1,2,3,4-tetrahydronaphthalene (demethyl calamenene, 7):

To a stirred solution of tertiary alcohol **6** (3.2 mg, 13.7 μmol) and Et_3SiH (11 μL , 0.07 mmol) in dry CH_2Cl_2 (0.6 mL) at -10°C was added a solution of $\text{BF}_3 \cdot \text{Et}_2\text{O}$ (5 μL , 0.04 mmol). The reaction mixture was stirred at -5°C for 1 h and then diluted with CH_2Cl_2 (3 mL) and quenched by adding sat. aq. Na_2CO_3 (0.6 mL). The organic phase was separated, dried over anhydrous Na_2SO_4 , filtered and concentrated *in vacuo*.¹³ The residue was chromatographed (silica, Et_2O /hexanes, 1:1) to give 2.6 mg (11.9 μmol , 87%) of the demethyl calamenene as a colorless oil. **7**: $R_f = 0.79$ (silica, Et_2O /hexanes, 1:1); $[\alpha]_D^{20} = -12.0$ ($c = 0.13$, CHCl_3); ^1H NMR (400 MHz, CDCl_3): $\delta = 6.96$ (s, 1 H), 6.51 (s, 1 H), 3.79 (s, 3 H), 2.74–2.59 (m, 3 H), 2.27–2.18 (m, 1 H), 2.17 (s, 3 H), 1.94–1.86 (m, 1 H), 1.80–1.74 (m, 1 H), 1.66–1.56 (m, 2 H), 1.00 (d, $J = 6.9$ Hz, 3 H), 0.73 (d, $J = 6.8$ Hz, 3 H) ppm; ^{13}C NMR (150 MHz, CDCl_3): $\delta = 155.3, 136.3, 131.8, 130.3, 123.4, 110.1, 55.2, 42.7, 31.4, 30.2, 23.4, 21.7, 21.3, 17.3, 16.0$ ppm; IR (film): $\nu_{\text{max}} = 2930, 2865, 1615, 1508, 1464, 1403, 1319, 1253, 1206, 1103, 1057, 1033, 885, 834$ cm^{-1} ; HRMS (ESI): calcd for $\text{C}_{15}\text{H}_{23}\text{O}^+$ $[\text{M} + \text{H}^+]$: 219.1743, found: 219.1739.

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IV. ^1H and ^{13}C NMR Spectra of Compounds

^1H NMR spectrum
(CDCl_3 , 400 MHz)

^{13}C NMR spectrum
(CDCl_3 , 100 MHz)

^1H NMR spectrum
(CDCl_3 , 400 MHz)

^{13}C NMR spectrum
(CDCl_3 , 100 MHz)

^1H NMR spectrum
(CDCl_3 , 400 MHz)

^{13}C NMR spectrum
(CDCl_3 , 100 MHz)

^1H NMR spectrum
(CDCl_3 , 500 MHz)

^{13}C NMR spectrum
(CDCl_3 , 125 MHz)

^1H NMR spectrum
(CDCl_3 , 500 MHz)

^{13}C NMR spectrum
(CDCl_3 , 125 MHz)

^1H NMR spectrum
(CDCl_3 , 500 MHz)

^{13}C NMR spectrum
(CDCl_3 , 125 MHz)

^1H NMR spectrum
(CDCl_3 , 500 MHz)

^{13}C NMR spectrum
(CDCl_3 , 125 MHz)

^1H NMR spectrum
(CDCl_3 , 400 MHz)

^{13}C NMR spectrum
(CDCl_3 , 100 MHz)

^1H NMR spectrum
(CDCl_3 , 500 MHz)

^{13}C NMR spectrum
(CDCl_3 , 125 MHz)

^1H NMR spectrum
(CDCl_3 , 400 MHz)

^{13}C NMR spectrum
(CDCl_3 , 100 MHz)

^1H NMR spectrum
(CDCl_3 , 500 MHz)

^{13}C NMR spectrum
(CDCl_3 , 125 MHz)

^1H NMR spectrum
(CDCl_3 , 400 MHz)

^{13}C NMR spectrum
(CDCl_3 , 150 MHz)

^1H NMR spectrum
(CDCl_3 , 500 MHz)

^{13}C NMR spectrum
(CDCl_3 , 125 MHz)

^1H NMR spectrum
(CDCl_3 , 500 MHz)

^{13}C NMR spectrum
(CDCl_3 , 125 MHz)

^1H NMR spectrum
(CDCl_3 , 500 MHz)

^{13}C NMR spectrum
(CDCl_3 , 125 MHz)

¹³C NMR spectrum
(CDCl₃, 150 MHz)

^1H NMR spectrum
(CDCl_3 , 400 MHz)

^{13}C NMR spectrum
(CDCl_3 , 125 MHz)

^1H NMR spectrum
(CDCl_3 , 500 MHz)

^{13}C NMR spectrum
(CDCl_3 , 125 MHz)

^1H NMR spectrum
(CDCl_3 , 500 MHz)

^{13}C NMR spectrum
(CDCl_3 , 125 MHz)

^1H NMR spectrum
(CDCl_3 , 400 MHz)

^{13}C NMR spectrum
(CDCl_3 , 100 MHz)

^1H NMR spectrum
(CDCl_3 , 400 MHz)

^{13}C NMR spectrum
(CDCl_3 , 150 MHz)

^1H NMR spectrum
(CDCl_3 , 400 MHz)

^{13}C NMR spectrum
(CDCl_3 , 100 MHz)

^1H NMR spectrum
(CDCl_3 , 500 MHz)

^{13}C NMR spectrum
(CDCl_3 , 125 MHz)

^1H NMR spectrum
(CDCl_3 , 400 MHz)

^{13}C NMR spectrum
(CDCl_3 , 100 MHz)

^1H NMR spectrum
(CDCl_3 , 500 MHz)

^{13}C NMR spectrum
(CDCl_3 , 125 MHz)

^1H NMR spectrum
(CDCl_3 , 500 MHz)

^{13}C NMR spectrum
(CDCl_3 , 125 MHz)

^1H NMR spectrum
(CDCl_3 , 400 MHz)

^{13}C NMR spectrum
(CDCl_3 , 100 MHz)

^1H NMR spectrum
(CDCl_3 , 600 MHz)

^{13}C NMR spectrum
(CDCl_3 , 150 MHz)

^1H NMR spectrum
(CDCl_3 , 400 MHz)

^{13}C NMR spectrum
(CDCl_3 , 100 MHz)

^1H NMR spectrum
(CDCl_3 , 400 MHz)

^{13}C NMR spectrum
(CDCl_3 , 100 MHz)

^1H NMR spectrum
(CDCl_3 , 500 MHz)

^{13}C NMR spectrum
(CDCl_3 , 125 MHz)

^1H NMR spectrum
(CDCl_3 , 500 MHz)

^{13}C NMR spectrum
(CDCl_3 , 125 MHz)

^1H NMR spectrum
(CDCl_3 , 500 MHz)

^{13}C NMR spectrum
(CDCl_3 , 125 MHz)

^1H NMR spectrum
(C_6D_6 , 500 MHz)

^{13}C NMR spectrum
(CDCl_3 , 150 MHz)

^1H NMR spectrum
(CDCl_3 , 400 MHz)

^{13}C NMR spectrum
(CDCl_3 , 150 MHz)

III. HPLC Traces

Each aldehyde and corresponding alcohol were prepared in both enantiomeric forms and random mixtures of enantiomers were made for chiral HPLC analysis to determine corresponding retention times and enantiomeric excesses.

	column	t_r (R)	t_r (S)	ee [%]
(S)	5% OD	12.15 min	13.93 min	91
(R)	5% OD	12.38 min	13.32 min	93

	column	t_r (R)	t_r (S)	ee [%]
Mixture	5% OD	11.77 min	13.43 min	-

(R) | 5% OD 11.78 min 13.62 min 97

	column	t_r (R)	t_r (S)	ee [%]
(S)	5% OD	18.45 min	23.68 min	94
(R)	5% OD	17.48 min	25.38 min	94

	column	t_r (R)	t_r (S)	ee [%]
Mixture	5% OD	11.88 min	13.63 min	-
(R)	5% OD	11.85 min	13.80 min	86

	column	t_r (R)	t_r (S)	ee [%]
(R)	5% OD	10.70 min	13.00 min	89
(S)	5% OD	10.73 min	12.73 min	92

	column	t_r (R)	t_r (S)	ee [%]
Mixture	5% OD	11.18 min	12.50 min	-
(R)	5% OD	11.03 min	12.48 min	85

	column	t_r (R)	t_r (S)	ee [%]
Mixture (R)	2% OD	66.98 min	72.20 min	-
	2% OD	65.67 min	74.03 min	86

	column	t_r (R)	t_r (S)	ee [%]
Mixture (R)	20% AD	41.63 min	63.08 min	-
	20% AD	41.63 min	62.87 min	87

	column	t_r (R)	t_r (S)	ee [%]
Mixture (S)	5% OD	7.75 min	8.82 min	-
	5% OD	7.87 min	8.80 min	98

	column	t_r (R)	t_r (S)	ee [%]
Mixture (S)	2% OD	12.55 min	14.15 min	-
	2% OD	12.67 min	14.25 min	94

	column	t_r (R)	t_r (S)	ee [%]
Mixture	2% OD	12.37 min	13.67 min	-
(S)	2% OD	12.45 min	13.70 min	90