Supporting Information

Catalytic Enantioselective 1,3-Dipolar Cycloaddition of C,N-Cyclic Azomethine Imines with α,β -Unsaturated Aldehydes

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General Information. Infrared (IR) spectra were recorded on a Shimadzu IRPrestige-21 spectrometer. ^1H NMR spectra were measured on a JEOL JNM-FX400 (400 MHz) spectrometer. Data were reported as follows: chemical shifts in ppm from tetramethylsilane as an internal standard in CDCl_3 , integration, multiplicity (s = singlet, d = doublet, t = triplet, q = quartet, m = multiplet, br = broad), and coupling constants (Hz). ^{13}C NMR spectra were measured on a JEOL JNM-FX400 (100 MHz) spectrometer with complete proton decoupling. Chemical shifts were reported in ppm from the residual solvent as an internal standard. High performance liquid chromatography (HPLC) was performed on Shimadzu 10A instruments at 254 nm using 4.6 mm x 25 cm Daicel Chiral Columns. High-resolution mass spectra (HRMS) were performed on Bruker microTOF. Optical rotations were measured on a JASCO DIP-1000 digital polarimeter. For thin layer chromatography (TLC) analysis throughout this work, Merck precoated TLC plates (silica gel 60 GF₂₅₄, 0.25 mm) were used. The products were purified by flash column chromatography silica gel 60 (Merck, 230-400 mesh) or preparative thin layer chromatography silica gel (Merck, PLC 60 F₂₅₄, 0.5 mm).

In experiments requiring dry solvent, CH_2Cl_2 , toluene and THF were purchased from Kanto Chemical Co. Inc. as “Dehydrated” and further purified by passing through neutral alumina under nitrogen atmosphere. Enals were distilled prior to use. Other commercially available reagents were used as received.

The relative and absolute configuration of **2** and the relative configuration of **6** were unambiguously assigned by X-ray crystallographic analysis of **2h**, **6c'**, **6f'** and **6i'**. The stereochemistries of other cycloadducts were tentatively assigned by analogy.

General procedure for the preparation of 2-(2-bromoethyl)benzaldehyde

To a 1M solution of the corresponding 1-methoxyisochroman¹ in toluene were added 1 equiv of Bu₄NBr and 2 equiv of TMSBr at room temperature. The reaction flask was sealed with a glass stopper and then warmed to 80 °C and stirred for 4 h. The mixture was poured into saturated NaHCO₃ aq and extracted with ethyl acetate. The combined organic layers were dried over Na₂SO₄ and concentrated in vacuo. The residue was purified by column chromatography on silica gel to give the aldehyde.

2-(2-Bromoethyl)benzaldehyde

Prepared with 1-methoxyisochroman (1.05 g, 5.86 mmol), Bu₄NBr (1.89 g, 5.86 mmol) and TMSBr (1.55 mL, 11.7 mmol). The crude material was purified by column chromatography on silica gel (eluting with hexane/CH₂Cl₂ = 3:1) to give the title compound as a colorless oil (9.39 g, 4.13 mmol, 71% yield).²

2-(2-Bromoethyl)-3-methylbenzaldehyde

Prepared with 1-methoxy-5-methylisochroman (1.05 g, 5.86 mmol), Bu₄NBr (1.89 g, 5.86 mmol) and TMSBr (1.55 mL, 11.7 mmol). The crude material was purified by column chromatography on silica gel (eluting with hexane/CH₂Cl₂ = 3:1) to give the title compound as a colorless oil (9.39 g, 4.13 mmol, 71% yield).

¹H NMR (400 MHz, CDCl₃) δ 10.17 (1H, s), 7.68 (1H, dd, *J* = 7.6, 1.3 Hz), 7.44 (1H, dd, *J* = 7.7, 1.0 Hz), 7.37 (1H, dd, *J* = 7.5, 7.5 Hz), 3.62 (2H, m), 3.51 (2H, m), 2.44 (3H, s); ¹³C NMR (100 MHz, CDCl₃) δ 193.0, 138.8, 138.4, 136.1, 134.3, 132.4, 127.2, 31.8, 30.9, 19.4; IR (neat) 1692, 1580, 1460, 1315, 1236, 1215, 1024 cm⁻¹; HRMS (ESI) exact mass calcd. for C₁₀H₁₁BrO: *m/z* 248.9885 ([M + Na]⁺), found: *m/z* 248.9885 ([M + Na]⁺).

2-(2-Bromoethyl)-4-methylbenzaldehyde

Prepared with 1-methoxy-6-methylisochroman (1.05 g, 5.90 mmol), Bu₄NBr (1.90 g, 5.90 mmol) and TMSBr (1.56 mL, 11.8 mmol). The crude material was purified by column

chromatography on silica gel (eluting with hexane/benzene = 2:1) to give the title compound as a colorless oil (1.01 g, 4.45 mmol, 75% yield).

^1H NMR (400 MHz, CDCl_3) δ 10.09 (1H, s), 7.71 (1H, d, $J = 7.7$ Hz), 7.36 (1H, s), 7.28 (1H, d, $J = 7.7$ Hz), 7.14 (1H, s), 3.63-3.59 (2H, m), 3.56-3.52 (2H, m), 2.43 (3H, s); ^{13}C NMR (100 MHz, CDCl_3) δ 192.5, 144.8, 140.5, 134.9, 132.9, 131.7, 128.3, 36.4, 32.7, 21.7; IR (neat) 1692, 1607, 1570, 1445, 1431, 1292, 1263, 1234, 1202 cm^{-1} . Full characterization was performed after the derivatization to the azomethine imine (*vide infra*).

2-(2-Bromoethyl)-5-methylbenzaldehyde

Prepared with 1-methoxy-7-methylisochroman (2.49 g, 14.0 mmol), Bu_4NBr (4.51 g, 14.0 mmol) and TMSBr (3.70 mL, 28.0 mmol). The crude material was purified by column chromatography on silica gel (eluting with hexane/ CH_2Cl_2 = 3:1) to give the title compound as a colorless oil (2.38 g, 10.5 mmol, 75% yield).

^1H NMR (400 MHz, CDCl_3) δ 10.12 (1H, s), 7.62 (1H, d, $J = 1.5$ Hz), 7.36 (1H, dd, $J = 7.7, 1.2$ Hz), 7.22 (1H, d, $J = 7.5$ Hz), 3.61-3.58 (2H, m), 3.54-3.51 (2H, m), 2.42 (3H, s), 193.0, 137.6, 137.5, 134.9, 134.4, 133.7, 132.0, 35.9, 33.0, 20.8; IR (neat) 1688, 1609, 1568, 1499, 1288, 1261, 1240, 1217, 1157 cm^{-1} ; HRMS (ESI) exact mass calcd. for $\text{C}_{10}\text{H}_{11}\text{BrO}$: m/z 248.9885 ($[\text{M} + \text{Na}]^+$), found: m/z 248.9883 ($[\text{M} + \text{Na}]^+$).

2-(2-Bromoethyl)-4-methoxybenzaldehyde

Prepared with 1-methoxy-6-methoxyisochroman (288 mg, 1.48 mmol), Bu_4NBr (477 mg, 1.48 mmol) and TMSBr (391 μL , 2.96 mmol). The crude material was purified by column chromatography on silica gel (eluting with hexane/ CH_2Cl_2 = 1:1) to give the title compound as a white solid (306 mg, 1.26 mmol, 85% yield).

^1H NMR (400 MHz, CDCl_3) δ 10.00, 7.77 (1H, d, $J = 8.7$ Hz), 6.95 (1H, dd, $J = 8.5, 2.4$ Hz), 6.83 (1H, d, $J = 2.7$ Hz), 3.90 (3H, s), 3.63 (2H, m), 3.55 (2H, m); ^{13}C NMR (100 MHz, CDCl_3) δ 191.3, 163.5, 143.0, 137.4, 127.4, 118.0, 112.2, 55.6, 36.6, 32.6; IR (neat) 1684, 1599, 1566, 1429, 1325, 1290, 1244, 1207, 1138, 1105, 1094, 1036 cm^{-1} ; HRMS (ESI) exact mass calcd. for $\text{C}_{10}\text{H}_{11}\text{BrO}_2$: m/z 264.9835 ($[\text{M} + \text{Na}]^+$), found: m/z 264.9829 ($[\text{M} + \text{Na}]^+$).

Preparation of 2-(2-bromoethyl)-6-methylbenzaldehyde

To a mixture of 6-methylisochroman and 8-methylisochroman (2.34 g, 15.8 mmol, 2:1 ratio)¹ in CH_2Cl_2 (30 mL) were added methanol (770 μL , 19.0 mmol) and DDQ (3.59 g, 15.8 mmol) at room temperature. After stirring for 12 h at room temperature, the suspension was filtered off to remove the insoluble waste. The filtrate was washed with saturated NaHCO_3 aq, extracted with CH_2Cl_2 , dried over Na_2SO_4 and concentrated in vacuo. The residue was purified by column chromatography on silica gel (eluting with hexane/ethyl acetate = 20:1) to give 6-methyl-1-methoxyisochroman (1.05 g, 5.90 mmol, 37% yield) with recovery of 8-methylisochroman (663 mg, 4.48 mmol, 28% yield).

To the resulting 8-methylisochroman (663 mg, 4.48 mmol) in CH_2Cl_2 (10 mL) were added methanol (218 μL , 5.38 mmol) and DDQ (1.02 g, 4.48 mmol) at room temperature. After stirring for 96 h at room temperature, the suspension was filtered off to remove the insoluble waste. The filtrate was washed with saturated NaHCO_3 aq, extracted with CH_2Cl_2 , dried over Na_2SO_4 and concentrated in vacuo. The residue was purified by column chromatography on silica gel (eluting with hexane/ethyl acetate = 20:1) to give 8-methyl-1-methoxyisochroman as a colorless oil (720 mg, 4.04 mmol, 90% yield).

To a solution of the thus-obtained 8-methyl-1-methoxyisochroman (720 mg, 4.04 mmol) in toluene (4.0 mL) were added Bu_4NBr (1.30 g, 4.04 mmol) and TMSBr (1.07 mL, 8.08 mmol). The reaction solution was then allowed to warm to $80\text{ }^\circ\text{C}$ and stirred for 4 h. The reaction solution was then treated with saturated NaHCO_3 aq, extracted with ethyl acetate. The combined organic layers were dried over Na_2SO_4 and concentrated in vacuo. The residue was purified by column chromatography on silica gel (eluting with hexane/ethyl acetate = 20:1) to give 2-(2-bromoethyl)-6-methylbenzaldehyde as a colorless oil (596 mg, 2.63 mmol, 65% yield).

2-(2-Bromoethyl)-6-methylbenzaldehyde

^1H NMR (400 MHz, CDCl_3) δ 10.60 (1H, s), 7.40 (1H, app t, $J = 7.6$ Hz), 7.19 (1H, d, $J = 7.5$ Hz), 7.16 (1H, $J = 8.0$ Hz), 3.61 (2H, m), 3.43 (2H, d, $J = 7.1$ Hz), 2.65 (3H, s); ^{13}C NMR (100 MHz, CDCl_3) δ 193.0, 142.1, 140.8, 133.2, 132.3, 130.9, 130.2, 37.2, 33.1, 20.0; IR (neat) 1690, 1591, 1466, 1433, 1273, 1188 cm^{-1} . Full characterization was performed after the derivatization to the azomethine imine (*vide infra*).

Preparation of 5-bromo-2-(2-bromoethyl)benzaldehyde

To a stirred solution of lithium aluminum hydride (759 mg, 20 mmol) in ether (20 mL) was added a solution of 4-bromophenylacetic acid (4.30 g, 20 mmol) in ether (20 mL) dropwise at 0 °C. The reaction solution was then warmed to reflux and stirred for 1 h. To this mixture was added an aqueous solution of Rochelle salt carefully, and the organic materials were extracted with ether. The combined organic layers were dried over Na₂SO₄ and concentrated in vacuo to give a crude material of 2-(4-bromophenyl)ethanol which was used without further purification.

After the dilution of this residue in CH₂Cl₂ (20 mL), *i*Pr₂NEt (6.97 mL, 40 mmol) and MOMCl (2.28 mL, 30 mmol) were added to this solution at 0 °C. The reaction solution was then allowed to warm to room temperature and stirred for 12 h. The mixture was poured into 1N HCl and extracted with ethyl acetate. The combined organic layers were dried over Na₂SO₄ and concentrated in vacuo to give 2-(4-bromophenyl)ethyl methoxymethyl ether.

This crude material was diluted in CH₃CN (20 mL), and TMSOTf (3.62 mL, 20 mmol) then added to this mixture at 0 °C. The reaction solution was then allowed to warm to room temperature and stirred for 24 h. The mixture was then treated with NaHCO₃ aq and evaporated in vacuo to remove CH₃CN. The residue was extracted with ethyl acetate, dried over Na₂SO₄ and concentrated in vacuo. The residue was purified by column chromatography on silica gel (eluting with hexane/ethyl acetate = 20:1) to give 7-bromoisochochroman (1.96 g, 9.18 mmol, 46% yield (3 steps), ~90% purity).

To a solution of thus-obtained 7-bromoisochochroman (1.96 g, 9.18 mmol) in CH₂Cl₂ were added methanol (447 μL, 11.0 mmol) and DDQ (2.08 g, 9.18 mmol) at room temperature. After stirring for 48 h at room temperature, the suspension was filtered off to remove the insoluble waste. The filtrate was washed with saturated NaHCO₃ aq,

extracted with CH₂Cl₂, dried over Na₂SO₄ and concentrated in vacuo. The residue was purified by column chromatography on silica gel (eluting with hexane/ethyl acetate = 20:1) to give 7-bromo-1-methoxyisochroman (1.58 g, 6.48 mmol, 71% yield, ~90% purity).

To a solution of the resulting 7-bromo-1-methoxyisochroman (1.58 g, 6.48 mmol) in toluene (6.5 mL) were added Bu₄NBr (2.09 g, 6.48 mmol) and TMSBr (1.71 mL, 13.0 mmol). The reaction solution was then allowed to warm to 80 °C and stirred for 4 h. The reaction solution was then treated with saturated NaHCO₃ aq, extracted with ethyl acetate. The combined organic layers were dried over Na₂SO₄ and concentrated in vacuo. The residue was purified by column chromatography on silica gel (eluting with hexane/CH₂Cl₂ = 3:1) to give 5-bromo-2-(2-bromoethyl)benzaldehyde (1.31 g, 4.48 mmol, 69%, (22% in 5 steps), colorless oil).

5-Bromo-2-(2-bromoethyl)benzaldehyde

¹H NMR (400 MHz, CDCl₃) δ 10.10 (1H, s), 7.94 (1H, d, *J* = 2.2 Hz), 7.67 (1H, dd, *J* = 8.2, 2.2 Hz), 7.23 (1H, d, *J* = 8.2 Hz), 3.59 (2H, m), 3.52 (2H, m); ¹³C NMR (100 MHz, CDCl₃) δ 191.1, 139.3, 136.4, 136.3, 135.3, 133.6, 121.4, 35.3, 32.3; IR (neat) 1695, 1587, 1560, 1479, 1281, 1256, 1182, 1094 cm⁻¹. Full characterization was performed after the derivatization to the azomethine imine (*vide infra*).

4-Bromo-2-(2-bromoethyl)benzaldehyde

Prepared following the procedure for the synthesis of 5-bromo-2-(2-bromoethyl)benzaldehyde starting from 3-bromophenylacetic acid (4.30 g, 20 mmol).

4-Bromo-2-(2-bromoethyl)benzaldehyde was purified by column chromatography on silica gel (eluting with hexane:benzene = 2:1) (1.88 g, 6.45 mmol, 32% in 5 steps, white solid).

¹H NMR (400 MHz, CDCl₃) δ 10.11 (1H, s), 7.69 (1H, d, *J* = 8.2 Hz), 7.63 (1H, dd, *J* = 8.2, 1.7 Hz), 7.51 (1H, d, *J* = 1.7 Hz), 3.61 (2H, m), 3.54 (2H, m); ¹³C NMR (100 MHz, CDCl₃) δ 191.6, 142.2, 135.4, 135.0, 132.6, 130.9, 128.9, 35.7, 32.1; IR (neat) 1694, 1585, 1557, 1283, 1256, 1196, 1076 cm⁻¹. Full characterization was performed after the derivatization to the azomethine imine (*vide infra*).

General procedure for the preparation of *N*-benzoylimino-3,4-dihydroisoquinolinium betaine and its analogs

To a 0.5 M solution of the corresponding 2-(2-bromoethyl)benzaldehyde (1.05 equiv) in MeOH was added benzoylhydrazine (1 equiv) at room temperature. After the immediate formation of the insoluble material, this white suspension was heated to reflux and stirred for additional 1 h to give a clear solution. After cooling to room temperature, the reaction solution was treated with Et₃N (1.5 equiv), poured into water and stirred for 30 min to give a white precipitate (tentatively assigned as a methanol and/or water adduct of the corresponding *N*-benzoylimino-3,4-dihydroisoquinolinium betaine). This solid material was washed with cold ether and then dissolved in CH₂Cl₂ to give a yellow solution. This colored solution was dried over Na₂SO₄ and evaporated in vacuo to give *N*-benzoylimino-3,4-dihydroisoquinolinium betaine as a yellow solid.

***N*-Benzoylimino-3,4-dihydroisoquinolinium betaine (1a)**

Prepared with 2-(2-bromoethyl)benzaldehyde (1.37 g, 6.4 mmol) and BzNHNH₂ (831 mg, 6.1 mmol) to give the title compound as a yellow solid (1.33 g, 5.33 mmol, 87% yield).

¹H NMR (400 MHz, CDCl₃) δ 9.73 (1H, s), 8.11 (2H, m), 7.51-7.36 (6H, m), 7.30 (1H, d, *J* = 7.5 Hz), 4.28 (2H, d, *J* = 7.6 Hz), 3.26 (2H, d, *J* = 7.6 Hz); ¹³C NMR (100 MHz, CDCl₃) δ 170.9, 147.5, 137.5, 133.7, 133.0, 130.2, 129.6, 128.1, 127.9, 127.7, 127.1, 54.9, 26.8 (one peak overlaps); IR (neat) 1665, 1653, 1591, 1545, 1325, 1292 cm⁻¹; HRMS (ESI) exact mass calcd. for C₁₆H₁₄N₂O: *m/z* 251.1179 ([M + H]⁺), found: *m/z* 251.1177 ([M + H]⁺).

***N*-Benzoylimino-3,4-dihydro-5-methylisoquinolinium betaine (1b)**

Prepared with 2-(2-bromoethyl)-3-methylbenzaldehyde (477 mg, 2.1 mmol) and BzNHNH₂ (272 mg, 2.0 mmol) to give the title compound as a yellow solid (467 mg, 1.77 mmol, 88% yield).

^1H NMR (400 MHz, CDCl_3) δ 9.70 (1H, s), 8.12 (2H, m), 7.40-7.26 (6H, m), 4.27 (2H, t, $J = 7.7$ Hz), 3.15 (2H, t, $J = 7.6$ Hz), 2.32 (3H, s); ^{13}C NMR (100 MHz, CDCl_3) δ 170.9, 148.9, 137.6, 135.6, 134.9, 131.8, 130.0, 127.79, 127.76, 127.67, 127.6, 126.7, 54.4, 23.8, 18.6; IR (neat) 1665, 1591, 1547, 1321, 1292 cm^{-1} ; HRMS (ESI) exact mass calcd. for $\text{C}_{17}\text{H}_{16}\text{N}_2\text{O}$: m/z 265.1335 ($[\text{M} + \text{H}]^+$), found: m/z 265.1320 ($[\text{M} + \text{H}]^+$).

***N*-Benzoylimino-3,4-dihydro-6-methylisoquinolinium betaine (1c)**

Prepared with 2-(2-bromoethyl)-4-methylbenzaldehyde (477 mg, 2.1 mmol) and BzNHNH_2 (272 mg, 2.0 mmol) to give the title compound as a yellow solid (418 mg, 1.58 mmol, 79% yield).

^1H NMR (400 MHz, CDCl_3) δ 9.59 (1H, s), 8.11 (2H, m), 7.44-7.37 (3H, m), 7.33 (1H, d, $J = 7.7$ Hz), 7.19 (1H, d, $J = 7.7$ Hz), 7.12 (1H, s), 4.27 (2H, t, $J = 7.7$ Hz), 3.22 (2H, t, $J = 7.7$ Hz), 2.42 (3H, s); ^{13}C NMR (100 MHz, CDCl_3) δ 171.0, 149.1, 144.5, 137.7, 133.7, 130.1, 129.7, 128.8, 128.6, 127.9, 124.3, 54.7, 26.9, 21.9 (one peak overlaps); IR (neat) 1612, 1591, 1545, 1337, 1294 cm^{-1} ; HRMS (ESI) exact mass calcd. for $\text{C}_{16}\text{H}_{17}\text{N}_2\text{O}$: m/z 265.1335 ($[\text{M} + \text{H}]^+$), found: m/z 265.1327 ($[\text{M} + \text{H}]^+$).

***N*-Benzoylimino-3,4-dihydro-7-methylisoquinolinium betaine (1d)**

Prepared with 2-(2-bromoethyl)-5-methylbenzaldehyde (1.19 g, 5.25 mmol) and BzNHNH_2 (681 mg, 5.0 mmol) to give the title compound as a yellow solid (1.18 g, 4.45 mmol, 89% yield).

^1H NMR (400 MHz, CDCl_3) δ 9.60 (1H, s), 8.11 (2H, m), 7.43-7.36 (3H, m), 7.29 (1H, d, $J = 7.5$ Hz), 7.23 (1H, s), 7.17 (1H, d, $J = 7.7$ Hz), 4.25 (2H, t, $J = 7.6$ Hz), 3.19 (2H, t, $J = 7.6$ Hz), 2.38 (3H, s); ^{13}C NMR (100 MHz, CDCl_3) δ 170.6, 148.3, 137.7, 137.4, 133.7, 130.5, 129.9, 129.85, 129.81, 127.7, 127.6, 127.3, 126.6, 54.8, 26.2, 20.7; IR (neat) 1665, 1589, 1545, 1315, 1288, 1173, 1063 cm^{-1} ; HRMS (ESI) exact mass calcd. for $\text{C}_{16}\text{H}_{17}\text{N}_2\text{O}$: m/z 265.1335 ($[\text{M} + \text{H}]^+$), found: m/z 265.1330 ($[\text{M} + \text{H}]^+$).

***N*-Benzoylimino-3,4-dihydro-8-methylisoquinolinium betaine (1e)**

Prepared with 2-(2-bromoethyl)-6-methylbenzaldehyde (477 mg, 2.1 mmol) and BzNHNH_2 (272 mg, 2.0 mmol) to give the title compound as a yellow solid (406 mg, 1.53 mmol, 77% yield).

^1H NMR (400 MHz, CDCl_3) δ 9.91 (1H, s), 8.12 (2H, m), 7.44-7.34 (4H, m), 7.18 (1H, d, $J = 7.5$ Hz), 7.11 (1H, d, $J = 7.3$ Hz), 4.25 (2H, t, $J = 7.5$ Hz), 3.22 (2H, t, $J = 7.6$ Hz), 2.51 (3H, s); 171.1, 146.5, 138.4, 137.6, 134.2, 132.8, 130.1, 129.9, 127.8, 125.5, 125.3, 54.3, 27.2, 18.6 (one peak overlaps); IR (neat) 1668, 1593, 1543, 1315, 1290, 1256,

1171 cm^{-1} ; HRMS (ESI) exact mass calcd. for $\text{C}_{16}\text{H}_{17}\text{N}_2\text{O}$: m/z 265.1335 ($[\text{M} + \text{H}]^+$), found: m/z 265.1339 ($[\text{M} + \text{H}]^+$).

***N*-Benzoylimino-3,4-dihydro-6-methoxyisoquinolinium betaine (1f)**

Prepared with 2-(2-bromoethyl)-4-methoxybenzaldehyde (306 mg, 1.26 mmol) and BzNHNH_2 (163 mg, 1.20 mmol) to give the title compound as a yellow solid (155 mg, 0.55 mmol, 46% yield).

^1H NMR (400 MHz, CDCl_3) δ 9.38 (1H, s), 8.10 (2H, m), 7.43-7.36 (4H, m), 6.87 (1H, dd, $J = 8.5, 2.4$ Hz), 6.82 (1H, s), 4.24 (2H, t, $J = 7.7$ Hz), 3.88 (3H, s), 3.23 (2H, t, $J = 7.6$ Hz); ^{13}C NMR (100 MHz, CDCl_3) δ 170.9, 163.9, 149.8, 137.8, 136.2, 131.9, 129.9, 127.8, 119.5, 113.9, 113.1, 55.7, 53.8, 27.2 (one peak overlaps); IR (neat) 1609, 1589, 1549, 1329, 1283, 1256, 1130, 1026 cm^{-1} ; HRMS (ESI) exact mass calcd. for $\text{C}_{17}\text{H}_{16}\text{N}_2\text{O}_2$: m/z 281.1285 ($[\text{M} + \text{H}]^+$), found: m/z 281.1290 ($[\text{M} + \text{H}]^+$).

***N*-Benzoylimino-6-bromo-3,4-dihydroisoquinolinium betaine (1h)**

Prepared with 4-bromo-2-(2-bromoethyl)benzaldehyde (613 mg, 2.1 mmol) and BzNHNH_2 (272 mg, 2.0 mmol) to give the title compound as a yellow solid (618 mg, 1.88 mmol, 94% yield).

^1H NMR (400 MHz, CDCl_3) δ 9.74 (1H, s), 8.09 (2H, m), 7.53 (1H, dd, $J = 8.2, 1.7$ Hz), 7.46 (1H, s), 7.43-7.37 (3H, m), 7.29 (1H, d, $J = 8.2$ Hz), 4.23 (2H, t, $J = 7.4$ Hz), 3.22 (2H, t, $J = 7.5$ Hz); ^{13}C NMR (100 MHz, CDCl_3) δ 170.4, 144.1, 136.8, 135.2, 131.2, 130.9, 130.32, 130.27, 127.9, 127.8, 127.1, 126.1, 54.5, 26.4; IR (neat) 1663, 1589, 1541, 1319, 1292, 1067 cm^{-1} ; HRMS (ESI) exact mass calcd. for $\text{C}_{16}\text{H}_{13}\text{BrN}_2\text{O}$: m/z 329.0284 ($[\text{M} + \text{H}]^+$), found: m/z 329.0290 ($[\text{M} + \text{H}]^+$).

***N*-Benzoylimino-7-bromo-3,4-dihydroisoquinolinium betaine (1i)**

Prepared with 5-bromo-2-(2-bromoethyl)benzaldehyde (864 mg, 2.96 mmol) and BzNHNH_2 (384 mg, 2.82 mmol) to give the title compound as a yellow solid (735 mg, 2.23 mmol, 79% yield).

^1H NMR (400 MHz, CDCl_3) δ 9.52 (1H, s), 8.07 (2H, m), 7.57-7.54 (2H, m), 7.45-7.37 (3H, m), 7.15 (1H, m), 4.19 (2H, t, $J = 7.3$ Hz), 3.14 (2H, t, $J = 7.4$ Hz); ^{13}C NMR (100 MHz, CDCl_3) δ 169.6, 135.9, 134.9, 132.5, 131.6, 130.4, 129.7, 129.3, 128.0, 127.8, 121.4, 54.4, 26.3 (one peak overlaps); IR (neat) 1645, 1595, 1560, 1539, 1321, 1292 cm^{-1} ; HRMS (ESI) exact mass calcd. for $\text{C}_{16}\text{H}_{13}\text{BrN}_2\text{O}$: m/z 329.0284 ($[\text{M} + \text{H}]^+$), found: m/z 329.0285 ($[\text{M} + \text{H}]^+$).

Representative procedure for asymmetric 1,3-dipolar cycloaddition of *N*-benzoylimino-3,4-dihydroisoquinolinium betaines and enals (Table 1 and 2)

To a solution of (S)-1,1'-bi(2-naphthol) (28.6 mg, 0.10 mmol) in dry toluene (2.0 mL) was added $\text{Ti}(\text{O}^i\text{Pr})_4$ (14.8 μL , 0.050 mmol) and the solution was stirred for 2 h at room temperature under an argon atmosphere. After cooling the mixture to 0 °C, crotonaldehyde (82.2 μL , 1.0 mmol) and **1a** (125.1 mg, 0.50 mmol) were added subsequently to this catalyst solution. The reaction solution was stirred at the same temperature for 1 h and quenched with saturated NaHCO_3 aq. The organic layer was extracted with ethyl acetate, dried over Na_2SO_4 and concentrated in vacuo. The residue was purified by column chromatography on silica gel (eluting with hexane/ethyl acetate = 3:1) to give the cycloadduct **2a** as a white solid [151.2 mg, 0.472 mmol, 94%]. The enantiomeric purity of the product was determined after reduction of the cycloadduct (*vide infra*).

Compound 2a (Table 1, entry 4)

^1H NMR (400 MHz, CDCl_3) δ 9.96 (1H, d, J = 3.6 Hz), 7.81 (2H, m), 7.33-7.43 (3H, m), 7.10-7.21 (3H, m), 6.94 (1H, m), 4.86 (1H, dt, J = 6.6, 14.7 Hz), 4.59 (1H, d, J = 10.4 Hz), 3.33 (1H, ddd, J = 2.8, 7.4, 10.9 Hz), 3.23 (1H, ddd, J = 2.0, 5.5, 10.0 Hz), 3.16 (1H, dt, J = 3.2, 12.2 Hz), 2.97 (1H, m), 2.72 (1H, dt, J = 2.3, 16.3 Hz), 1.62 (3H, d, J = 6.3 Hz); ^{13}C NMR (100 MHz, CDCl_3) δ 198.8, 169.1, 135.1, 133.0, 132.9, 130.3, 128.6, 128.3, 127.6, 127.5, 126.9, 126.5, 66.3, 63.7, 56.4, 50.2, 29.4, 22.5; IR (neat) 1719, 1628, 1447, 1410, 1391, 1126, 910, 768, 729, 710, 696, 671 cm^{-1} ; HRMS (ESI) exact mass calcd. for $\text{C}_{20}\text{H}_{21}\text{N}_2\text{O}_2$: m/z 321.1598 ($[\text{M} + \text{H}]^+$), found: m/z 321.1586 ($[\text{M} + \text{H}]^+$); $[\alpha]_{\text{D}}^{23} = -17.7$ (c = 1.0, CHCl_3 ; 92% ee).

Reduction and HPLC analysis of the cycloadduct

To a solution of so-obtained cycloadduct **2a** (51.2 mg, 0.472 mmol) in EtOH (1.0 mL)

was added 90 wt.% NaBH₄ (19.9 mg, 0.472 mmol) at 0 °C and the solution was stirred for 30 min at the same temperature. The mixture was then poured in aqueous NH₄Cl and extracted with ethyl acetate. The combined organic layer was dried over Na₂SO₄ and evaporated under vacuum. The residue was purified by column chromatography on silica gel (eluting with hexane/ethyl acetate = 1:2) to give the alcohol **2a'** as a white solid [142.5 mg, 0.442 mmol, 94%].

Compound 2a'

¹H NMR (400 MHz, CDCl₃) δ 7.85 (2H, d, *J* = 7.0 Hz), 7.31-7.40 (3H, m), 7.15-7.18 (3H, m), 7.10 (1H, m), 4.61 (1H, m), 4.33 (1H, d, *J* = 10.9 Hz), 4.10 (1H, m), 3.94 (1H, m), 3.86 (1H, br), 3.21 (1H, m), 3.10 (1H, br), 2.94 (1H, m), 2.68 (1H, m), 2.37 (1H, m), 1.64 (3H, d, *J* = 6.0 Hz); ¹³C NMR (100 MHz, CDCl₃) δ 169.1, 135.4, 134.6, 132.9, 130.0, 128.5, 128.4, 127.5, 127.4, 126.9, 126.1, 61.8, 59.1, 58.1, 55.0, 49.7, 29.5, 22.3; IR (neat) 1611, 1570, 1450, 1422, 1088 cm⁻¹; HRMS (ESI) exact mass calcd. for C₂₀H₂₂N₂O₂: *m/z* 345.1573 ([M + Na]⁺), found: *m/z* 345.1578 ([M + Na]⁺); [α]_D²³ = -7.6 (*c* = 1.0, CHCl₃; 92% ee).

The enantiomeric purity of the product was determined by HPLC analysis (Daicel CHIRALCEL AD-H, hexane/ethanol = 4:1, flow rate = 0.5 mL/min, retention time; 19.7 min (minor) and 33.2 min (major)).

Compound 2b (Table 2, entry 1)

Prepared according to the representative procedure with crotonaldehyde (82.2 μL, 1.0 mmol) and **1b** (132.2 mg, 0.50 mmol) over the course of 1 h. The crude material was purified by column chromatography on silica gel (eluting with hexane/ethyl acetate = 4:1 to 2:1) to give **2b** as a white solid [141.6 mg, 0.423 mmol, 85% yield, exo/endo = >95:5]. The enantiomeric purity of the product was determined after the reduction of the aldehyde (*vide infra*).

¹H NMR (400 MHz, CDCl₃) δ 9.96 (1H, d, *J* = 3.6 Hz), 7.81 (2H, m), 7.44-7.34 (3H, m), 7.11-7.06 (2H, m), 6.79 (1H, d, *J* = 7.0 Hz), 4.86 (1H, m), 4.57 (1H, d, *J* = 10.2 Hz), 3.37 (1H, m), 3.29 (1H, m), 3.16 (1H, m), 5.24 (2H, m), 2.22 (3H, s), 1.65 (3H, d, *J* = 6.5 Hz); ¹³C NMR (100 MHz, CDCl₃) δ 198.9, 169.2, 136.4, 135.2, 132.7, 131.7, 130.3, 128.9, 128.3, 127.6, 126.4, 124.7, 66.3, 64.1, 56.4, 50.1, 27.0, 22.5, 19.3; IR (neat) 1719, 1628, 1447, 1410 cm⁻¹; HRMS (ESI) exact mass calcd. for C₂₁H₂₂N₂O₂: *m/z* 335.1754 ([M + H]⁺), found: *m/z* 335.1752 ([M + H]⁺); [α]_D²³ = -41.6 (*c* = 1.0, CHCl₃; 89% ee).

Compound 2b'

Prepared according to the representative procedure with **2b** (64.8 mg, 0.20 mmol) and NaBH₄ (7.6 mg, 0.20 mmol). The crude material was purified by column chromatography on silica gel (eluting with hexane/ethyl acetate = 1:2) to give the **2b'** [62.6 mg, 0.186 mmol, 93% yield].

¹H NMR (400 MHz, CDCl₃) δ 7.84 (2H, m), 7.40-7.31 (3H, m), 7.13-7.02 (3H, m), 4.57 (1H, m), 4.29 (1H, d, *J* = 10.6 Hz), 4.12 (1H, m), 3.97 (1H, m), 3.25-3.18 (3H, m), 2.70 (2H, m), 2.42 (1H, m), 2.20 (3H, s), 1.64 (3H, d, *J* = 6.3 Hz); ¹³C NMR (100 MHz, CDCl₃) δ 169.2, 136.2, 135.6, 134.4, 131.5, 130.0, 128.5, 128.3, 127.5, 126.0, 125.3, 62.1, 59.4, 58.0, 54.9, 49.6, 27.1, 22.3, 19.4; IR (neat) 3443, 1609, 1568, 1449, 1420, 1377, 1080 cm⁻¹; HRMS (ESI) exact mass calcd. for C₂₁H₂₄N₂O₂: *m/z* 337.1911 ([M + H]⁺), found: *m/z* 337.1911 ([M + H]⁺); [α]_D²³ = -33.5 (*c* = 1.0, CHCl₃; 89% ee).

The enantiomeric purity of the product was determined by HPLC analysis (Daicel CHIRALPAK AD-H, hexane/ethanol = 9:1, flow rate = 0.5 mL/min, retention time; 32.8 min (minor) and 49.9 min (major)).

Compound 2c (Table 2, entry 2)

Prepared according to the representative procedure with crotonaldehyde (82.2 μL, 1.0 mmol) and **1c** (132.2 mg, 0.50 mmol) over the course of 2 h. The crude material was purified by column chromatography on silica gel (eluting with hexane/Et₂O = 2:3) to give **2c** as a white solid [165.2 mg, 0.494 mmol, 99% yield, exo/endo = >95:5]. The enantiomeric purity of the product was determined after the reduction of the aldehyde (*vide infra*).

¹H NMR (400 MHz, CDCl₃) δ 9.95 (1H, d, *J* = 3.4 Hz), 7.81 (2H, m), 7.44-7.33 (3H, m), 6.98 (1H, d, *J* = 8.0 Hz), 6.94 (1H, s), 6.84 (1H, d, *J* = 7.7 Hz), 4.85 (1H, dq, *J* = 8.3, 6.6 Hz), 4.57 (1H, d, *J* = 10.2 Hz), 3.31 (1H, ddd, *J* = 10.3, 8.3, 3.7 Hz), 3.21 (1H, ddd, *J* = 10.4, 5.6, 2.1 Hz), 3.15 (1H, app dt, *J* = 12.0, 3.2 Hz), 2.94 (1H, ddd, *J* = 16.6, 12.2, 5.4 Hz), 2.67 (1H, app dt, *J* = 16.3, 2.4 Hz), 2.29 (3H, s), 1.64 (3H, d, *J* = 6.5 Hz); ¹³C NMR (100 MHz, CDCl₃) δ 198.9, 169.1, 137.3, 135.1, 132.9, 130.3, 130.0, 129.2, 128.4, 127.6, 127.4, 126.8, 66.5, 63.6, 56.5, 50.3, 29.4, 22.6, 21.0; IR (neat) 1719, 1630, 1574, 1447, 1406, 1121 cm⁻¹; HRMS (ESI) exact mass calcd. for C₂₁H₂₂N₂O₂: *m/z* 357.1573 ([M + Na]⁺), found: *m/z* 357.1583 ([M + Na]⁺); [α]_D²¹ = -19.4 (*c* = 1.0, CHCl₃; 92% ee). The enantiomeric purity of the product was determined after the reduction of the aldehyde (*vide infra*).

Compound 2c'

Prepared according to the representative procedure with **2c** (66.9 mg, 0.20 mmol) and NaBH₄ (7.6 mg, 0.20 mmol). The crude material was purified by column chromatography on silica gel (eluting with hexane/ethyl acetate = 1:2) to give the **2c'** as a white solid [63.6 mg, 0.189 mmol, 95% yield].

¹H NMR (400 MHz, CDCl₃) δ 7.84 (1H, d, *J* = 7.3 Hz), 7.39-7.31 (3H, m), 7.07 (1H, d, *J* = 7.5 Hz), 6.99 (1H, d, *J* = 7.7 Hz), 6.92 (1H, s), 4.56 (1H, m), 4.28 (1H, d, *J* = 10.9 Hz), 4.10 (1H, app d, *J* = 11.1 Hz), 3.94 (1H, m), 3.38 (1H, br), 3.19 (1H, m), 3.09 (1H, br), 2.90 (1H, m), 2.63 (1H, app d, *J* = 16.3 Hz), 2.36 (1H, br), 2.29 (3H, s), 1.63 (3H, d, *J* = 5.6 Hz); ¹³C NMR (100 MHz, CDCl₃) δ 169.0, 136.6, 135.5, 132.8, 131.6, 130.0, 129.0, 128.5, 127.5, 127.3, 126.9, 61.7, 59.5, 58.1, 55.1, 49.8, 29.5, 22.3, 21.0; IR (neat) 1611, 1570, 1499, 1450, 1425, 1375, 1088 cm⁻¹; HRMS (ESI) exact mass calcd. for C₂₁H₂₄N₂O₂: *m/z* 359.1730 ([M + Na]⁺), found: *m/z* 359.1743 ([M + Na]⁺); [α]_D²¹ = -13.3 (*c* = 1.0, CHCl₃; 92% ee).

The enantiomeric purity of the product was determined by HPLC analysis (Daicel CHIRALPAK AD-H, hexane/ethanol = 10:1, flow rate = 0.5 mL/min, retention time; 35.4 min (minor) and 47.5 min (major)).

Compound 2d (Table 2, entry 3)

Prepared according to the representative procedure with crotonaldehyde (82.2 μL, 1.0 mmol) and **1d** (132.2 mg, 0.50 mmol) over the course of 2 h. The crude material was purified by column chromatography on silica gel (eluting with hexane/ethyl acetate = 4:1) to give **2d** as a white solid [156.0 mg, 0.467 mmol, 93% yield, exo/endo = >95:5]. The enantiomeric purity of the product was determined after the reduction of the aldehyde (*vide infra*).

¹H NMR (400 MHz, CDCl₃) δ 9.95 (1H, d, *J* = 3.6 Hz), 7.81 (2H, m), 7.42-7.32 (3H, m), 7.00 (2H, br), 6.74 (1H, s), 4.84 (1H, dq, *J* = 6.6, 7.2 Hz), 4.55 (1H, d, *J* = 10.4 Hz), 3.32 (1H, m), 3.20 (1H, m), 3.13 (1H, m), 2.91 (1H, m), 2.67 (1H, app d, *J* = 16.2 Hz), 2.26 (3H, s), 1.63 (3H, d, *J* = 6.5 Hz); ¹³C NMR (100 MHz, CDCl₃) δ 198.9, 169.0, 136.1, 135.1, 132.7, 130.2, 129.9, 128.5, 128.35, 128.27, 127.5, 127.2, 66.2, 63.7, 56.4, 50.3, 29.0, 22.5, 20.9; IR (neat) 1719, 1630, 1447, 1408, 1377, 1125 cm⁻¹; HRMS (ESI) exact mass calcd. for C₂₁H₂₂N₂O₂: *m/z* 357.1573 ([M + Na]⁺), found: *m/z* 357.1587 ([M + Na]⁺); [α]_D²⁷ = 1.0 (*c* = 1.0, CHCl₃; 92% ee). The enantiomeric purity of the product

was determined after the reduction of the aldehyde (*vide infra*).

Compound 2d'

Prepared according to the representative procedure with **2d** (66.9 mg, 0.20 mmol) and NaBH₄ (7.6 mg, 0.20 mmol). The crude material was purified by column chromatography on silica gel (eluting with hexane/ethyl acetate = 1:2) to give **2d'** as a white solid [67.2 mg, 0.20 mmol, >99% yield].

¹H NMR (400 MHz, CDCl₃) δ 7.86 (2H, d, *J* = 7.0 Hz), 7.39-7.30 (3H, m), 7.00 (1H, s), 6.98 (2H, br), 4.64 (1H, m), 4.30 (1H, d, *J* = 10.9 Hz), 4.22 (1H, br), 4.12 (1H, m), 3.96 (1H, m), 3.18 (1H, m), 3.07 (1H, br), 2.88 (1H, m), 2.65 (1H, app d, *J* = 16.5 Hz), 2.36 (1H, m), 2.29 (3H, s), 1.65 (3H, d, *J* = 5.8 Hz); ¹³C NMR (100 MHz, CDCl₃) δ 168.9, 135.7, 135.3, 134.4, 130.0, 129.7, 128.5, 128.3, 127.8, 127.7, 127.5, 61.6, 59.0, 58.1, 55.1, 49.9, 29.1, 22.2, 21.0; IR (neat) 1724, 1611, 1570, 1504, 1449, 1425, 1125, 1088, 1069 cm⁻¹; HRMS (ESI) exact mass calcd. for C₂₁H₂₄N₂O₂: *m/z* 337.1911 ([M + H]⁺), found: *m/z* 337.1910 ([M + H]⁺); [α]_D²³ = 3.5 (*c* = 1.0, CHCl₃; 92% ee).

The enantiomeric purity of the product was determined by HPLC analysis (Daicel CHIRALPAK IA, hexane/ethanol = 9:1, flow rate = 0.5 mL/min, retention time; 16.1 min (minor) and 30.2 min (major)).

Compound 2e (Table 2, entry 4)

Prepared according to the representative procedure with crotonaldehyde (82.2 μL, 1.0 mmol) and **1e** (132.2 mg, 0.50 mmol) over the course of 2 h. The crude material was

purified by column chromatography on silica gel (eluting with hexane/Et₂O = 2:3) to give **2e** as a white solid [157.3 mg, 0.470 mmol, 94% yield, exo:endo = 84:16]. The enantiomeric purity of the product was determined after the reduction of the aldehyde (*vide infra*).

¹H NMR of the exo isomer (400 MHz, CDCl₃) δ 9.88 (1H, d, *J* = 4.8 Hz), 7.83 (2H, m), 7.44-7.34 (3H, m), 7.13 (1H, app t, *J* = 7.5 Hz), 7.01 (1H, d, *J* = 7.5 Hz), 6.98 (1H, d, *J* = 7.5 Hz), 4.94 (1H, dq, *J* = 7.8, 6.6 Hz), 4.62 (1H, d, *J* = 10.2 Hz), 3.36-3.24 (3H, m), 3.00 (1H, ddd, *J* = 17.4, 11.7, 6.1 Hz), 2.85 (1H, app dt, *J* = 16.4, 3.1 Hz), 2.14 (3H, s), 1.59 (3H, d, *J* = 6.5 Hz); ¹³C NMR (100 MHz, CDCl₃) δ 198.3, 169.3, 135.1, 133.3, 130.9, 130.5, 129.1, 128.9, 127.7, 126.6, 66.5, 63.5, 56.4, 49.9, 29.6, 21.7, 20.2 (one peak overlaps); IR (neat) 1717, 1630, 1574, 1468, 1447, 1410 cm⁻¹; HRMS (ESI) exact

mass calcd. for C₂₁H₂₂N₂O₂: m/z 357.1573 ([M + Na]⁺), found: m/z 357.1577 ([M + Na]⁺); [α]_D²³ = 7.4 (c = 1.0, CHCl₃; exo:endo = 84/16, 62% ee (exo), 22% ee (endo)).

Compound 2e'

Prepared according to the representative procedure with **2e** (66.9 mg, 0.20 mmol) and NaBH₄ (7.6 mg, 0.20 mmol). The crude material was purified by column chromatography on silica gel (eluting with hexane/ethyl acetate = 1:2) to give **2e'** as a white solid [64.7 mg, 0.192 mmol, 96% yield, exo:endo = 84/16].

Analytically pure sample of the exo **2e'** could be obtained by recrystallization from ether.

¹H NMR of the exo isomer (400 MHz, CDCl₃) δ 7.81 (2H, br), 7.41-7.32 (3H, m), 7.10 (1H, app t, J = 7.5 Hz), 7.04 (1H, d, J = 7.5 Hz), 6.95 (1H, d, J = 7.3 Hz), 4.54 (1H, br), 4.44 (1H, d, J = 7.7 Hz), 3.92 (1H, app dt, J = 11.0, 4.2 Hz), 3.81 (1H, m), 3.37 (1H, br), 3.14 (1H, app dt, J = 11.7, 5.3 Hz), 2.89 (2H, m), 2.42-2.32 (5H, m), 1.61 (3H, br); ¹³C NMR (100 MHz, CDCl₃) δ 169.3, 135.9, 135.8, 133.7, 133.1, 130.0, 128.9, 128.4, 127.6, 126.9, 126.3, 61.1, 60.0, 57.6, 56.4, 50.2, 29.4, 21.7, 19.3 (one peak overlaps); IR (neat) 1611, 1601, 1572, 1449, 1422, 1373 cm⁻¹; HRMS (ESI) exact mass calcd. for C₂₁H₂₄N₂O₂: m/z 359.1730 ([M + Na]⁺), found: m/z 359.1745 ([M + Na]⁺); [α]_D²¹ = 0.7 (c = 1.0, CHCl₃; exo:endo = 84/16, 62% ee (exo), 22% ee (endo)).

The enantiomeric purity of the product was determined by HPLC analysis (Daicel CHIRALPAK AD-H, hexane/isopropanol = 10:1, flow rate = 0.5 mL/min, retention time; 23.4 min (exo, minor), 41.4 (endo, major), 52.0 (endo, minor) and 80.2 min (exo, major)).

Compound 2f (Table 2, entry 5)

Prepared according to the representative procedure with crotonaldehyde (82.2 μ L, 1.0 mmol) and **1f** (140.2 mg, 0.50 mmol) over the course of 2 h. The crude material was purified by column chromatography on silica gel (eluting with hexane/ethyl acetate = 2:1) to give **2f** as a white solid [168.2 mg, 0.480 mmol, 96% yield, exo:endo = >95:5]. The enantiomeric purity of the product was determined after the reduction of the aldehyde (*vide infra*).

¹H NMR (400 MHz, CDCl₃) δ 9.94 (1H, d, J = 3.6 Hz), 7.81 (2H, m), 7.43-7.34 (3H, m), 6.87 (1H, d, J = 8.5 Hz), 6.72 (1H, dd, J = 8.6, 2.5 Hz), 6.63 (1H, d, J = 2.4 Hz), 4.85 (1H, dq, J = 7.8, 6.8 Hz), 4.54 (1H, d, J = 10.2 Hz), 3.76 (3H, s), 3.29 (1H, m),

3.21 (1H, ddd, $J = 10.5, 5.6, 1.9$ Hz), 3.14 (1H, m), 2.95 (1H, ddd, $J = 16.6, 12.2, 5.6$ Hz), 2.68 (1H, app d, $J = 16.2$ Hz), 1.64 (3H, d, $J = 6.5$ Hz); ^{13}C NMR (100 MHz, CDCl_3) δ 199.0, 169.1, 158.8, 135.1, 134.4, 130.3, 128.3, 128.0, 127.6, 125.0, 113.4, 112.7, 66.5, 63.3, 56.5, 55.2, 50.1, 29.7, 22.5; IR (neat) 1721, 1626, 1614, 1504, 1410, 1263, 1250 1036 cm^{-1} ; HRMS (ESI) exact mass calcd. for $\text{C}_{21}\text{H}_{22}\text{N}_2\text{O}_3$: m/z 351.1703 ($[\text{M} + \text{H}]^+$), found: m/z 351.1705 ($[\text{M} + \text{H}]^+$); $[\alpha]_{\text{D}}^{25} = -16.3$ ($c = 1.0$, CHCl_3 ; 82% ee).

Compound 2f'

Prepared according to the representative procedure with **2f** (70.0 mg, 0.20 mmol) and NaBH_4 (7.6 mg, 0.20 mmol). The crude material was purified by column chromatography on silica gel (eluting with hexane/ethyl acetate = 1:3) to give **2f'**

[69.4 mg, 0.20 mmol, 98% yield].

^1H NMR (400 MHz, CDCl_3) δ 7.84 (2H, d, $J = 7.3$ Hz), 7.40-7.31 (3H, m), 7.10 (1H, d, $J = 8.5$ Hz), 6.74 (1H, dd, $J = 8.5, 2.7$ Hz), 6.63 (1H, d, $J = 2.7$ Hz), 4.57 (1H, m), 4.27 (1H, d, $J = 10.6$ Hz), 4.08 (1H, m), 3.92 (1H, m), 3.76 (3H, s), 3.55 (1H, br), 3.18 (1H, m), 3.08 (1H, br), 2.91 (1H, m), 2.64 (1H, app d, $J = 16.2$ Hz), 2.33 (1H, m), 1.63 (3H, d, $J = 6.0$ Hz); ^{13}C NMR (100 MHz, CDCl_3) δ 169.0, 158.4, 135.5, 134.2, 130.0, 128.5, 128.4, 127.5, 126.7, 113.2, 112.3, 61.5, 59.3, 58.1, 55.2, 55.1, 49.6, 29.8, 22.3; IR (neat) 1611, 1572, 1504, 1450, 1423, 1250, 1215, 1038 cm^{-1} ; HRMS (ESI) exact mass calcd. for $\text{C}_{21}\text{H}_{24}\text{N}_2\text{O}_3$: m/z 353.1860 ($[\text{M} + \text{H}]^+$), found: m/z 353.1863 ($[\text{M} + \text{H}]^+$); $[\alpha]_{\text{D}}^{25} = -8.2$ ($c = 1.0$, CHCl_3 ; 82% ee).

The enantiomeric purity of the product was determined by HPLC analysis (Daicel CHIRALPAK AD-H, hexane/ethanol = 9:1, flow rate = 0.5 mL/min, retention time; 53.4 min (minor) and 57.6 min (major)).

Compound 2g (Table 2, entry 6)

Prepared according to the representative procedure with crotonaldehyde (82.2 μL , 1.0 mmol) and **1g** (163.9 mg, 0.50 mmol) over the course of 2 h. The crude material was purified

by column chromatography on silica gel (eluting with hexane/ethyl acetate = 4:1) to give **2g** as a white solid [186.5 mg, 0.467 mmol, 93% yield, exo/endo = >95:5]. The enantiomeric purity of the product was determined after the reduction of the aldehyde (*vide infra*).

^1H NMR (400 MHz, CDCl_3) δ 9.96 (1H, d, $J = 3.4$ Hz), 7.79 (2H, m), 7.43 (1H, m), 7.37 (2H, m), 7.31-7.28 (2H, m), 6.86 (1H, d, $J = 9.2$ Hz), 4.85 (1H, dq, $J = 8.3, 6.6$ Hz),

4.55 (1H, d, $J = 10.2$ Hz), 3.30 (1H, ddd, $J = 10.2, 8.3, 3.4$ Hz), 3.24 (1H, ddd, $J = 10.6, 5.3, 2.1$ Hz), 3.14 (1H, m), 2.96 (1H, ddd, $J = 16.8, 12.4, 5.4$ Hz), 2.70 (1H, app dt, $J = 16.4, 2.4$ Hz), 1.66 (3H, d, $J = 6.5$ Hz); ^{13}C NMR (100 MHz, CDCl_3) δ 198.6, 169.1, 135.3, 134.9, 132.0, 131.4, 130.3, 129.6, 128.5, 128.2, 127.6, 121.2, 66.0, 62.9, 56.4, 49.8, 29.2, 22.6; IR (neat) 1721, 1630, 1410, 1377, 1126 cm^{-1} ; HRMS (ESI) exact mass calcd. for $\text{C}_{20}\text{H}_{19}\text{BrN}_2\text{O}_2$: m/z 399.0703 ($[\text{M} + \text{H}]^+$), found: m/z 399.0712 ($[\text{M} + \text{H}]^+$); $[\alpha]_{\text{D}}^{20} = -18.8$ ($c = 1.0$, CHCl_3 ; 95% ee).

Compound 2g'

Prepared according to the representative procedure with **2g** (79.3 mg, 0.20 mmol) and NaBH_4 (7.6 mg, 0.20 mmol). The crude material was purified by column chromatography on silica gel (eluting with hexane/ethyl acetate = 1:2) to give **2g'** [74.9 mg, 0.187 mmol, 94% yield].

^1H NMR (400 MHz, CDCl_3) δ 7.81 (2H, d, $J = 7.0$ Hz), 7.40-7.31 (3H, m), 7.28-7.24 (2H, m), 7.06 (1H, d, $J = 8.22$ Hz), 4.60 (1H, m), 4.29 (1H, d, $J = 10.9$ Hz), 4.13 (1H, br), 4.06 (1H, app d, $J = 11.8$ Hz), 3.88 (1H, m), 3.18-3.06 (2H, m), 2.90 (1H, m), 2.64 (1H, app d, $J = 16.2$ Hz), 2.30 (1H, m), 1.62 (3H, d, $J = 6.0$ Hz); ^{13}C NMR (100 MHz, CDCl_3) δ 169.2, 135.2, 135.1, 133.5, 131.2, 130.1, 129.2, 129.0, 128.4, 127.6, 120.6, 61.3, 58.6, 57.9, 54.9, 49.3, 29.3, 22.1; IR (neat) 3410, 1611, 1601, 1572, 1449, 1422, 1088 cm^{-1} ; HRMS (ESI) exact mass calcd. for $\text{C}_{20}\text{H}_{21}\text{BrN}_2\text{O}_2$: m/z 401.0859 ($[\text{M} + \text{H}]^+$), found: m/z 401.0859 ($[\text{M} + \text{H}]^+$); $[\alpha]_{\text{D}}^{23} = -10.4$ ($c = 1.0$, CHCl_3 ; 95% ee).

The enantiomeric purity of the product was determined by HPLC analysis (Daicel CHIRALPAK AD-H, hexane/ethanol = 9:1, flow rate = 0.5 mL/min, retention time; 40.1 min (minor) and 44.9 min (major)).

Compound 2h (Table 2, entry 7)

Prepared according to the representative procedure with crotonaldehyde (82.2 μL , 1.0 mmol) and **1h** (163.9 mg, 0.50 mmol) over the course of 2 h. The crude material was purified by column chromatography on silica gel (eluting with hexane/ethyl acetate = 4:1) to give **2h** as a white solid [183.1 mg, 0.459 mmol, 92% yield, exo/endo = >95:5]. The enantiomeric purity of the product was determined after the reduction of the aldehyde (*vide infra*).

^1H NMR (400 MHz, CDCl_3) δ 9.94 (1H, d, $J = 2.90$ Hz), 7.70 (2H, d, $J = 7.3$ Hz), 7.40-7.33 (3H, m), 7.27 (1H, d, $J = 8.0$ Hz), 7.12 (1H, s), 6.96 (1H, d, $J = 8.0$ Hz), 4.81

(1H, m), 4.54 (1H, d, $J = 10.2$ Hz), 3.33-3.08 (3H, m), 2.86 (1H, m), 2.66 (app d, $J = 16.2$ Hz), 1.64 (3H, d, $J = 6.0$ Hz); ^{13}C NMR (100 MHz, CDCl_3) δ 198.5, 169.0, 135.2, 134.8, 132.0, 130.4, 130.22, 130.17, 129.6, 128.1, 127.5, 119.9, 65.7, 62.6, 56.3, 49.9, 28.9, 22.6; IR (neat) 1721, 1630, 1485, 1447, 1416, 1377, 1126 cm^{-1} ; HRMS (ESI) exact mass calcd. for $\text{C}_{20}\text{H}_{19}\text{BrN}_2\text{O}_2$: m/z 421.0522 ($[\text{M} + \text{Na}]^+$), found: m/z 421.0520 ($[\text{M} + \text{Na}]^+$); $[\alpha]_{\text{D}}^{27} = 33.7$ ($c = 1.0$, CHCl_3 ; 93% ee).

Compound 2h'

Prepared according to the representative procedure with **2h** (79.3 mg, 0.20 mmol) and NaBH_4 (7.6 mg, 0.20 mmol). The crude material was purified by column chromatography on silica gel (eluting with hexane/ethyl acetate = 1:2) to give **2h'** [75.3 mg, 0.188 mmol, 94% yield].

^1H NMR (400 MHz, CDCl_3) δ 7.82 (2H, d, $J = 7.0$ Hz), 7.41-7.32 (5H, m), 6.96 (1H, d, $J = 8.0$ Hz), 4.60 (1H, m), 4.30 (1H, d, $J = 10.6$ Hz), 4.10 (1H, app d, $J = 10.4$ Hz), 3.94 (1H, m), 3.20-3.08 (2H, m), 2.85 (1H, m), 2.64 (1H, app d, $J = 16.2$ Hz), 2.54 (1H, br), 2.35 (1H, m), 1.63 (3H, d, $J = 5.8$ Hz); ^{13}C NMR (100 MHz, CDCl_3) δ 169.2, 136.8, 135.3, 131.9, 131.9, 130.11, 130.09, 130.08, 130.0, 128.4, 127.6, 119.8, 61.2, 58.8, 58.0, 54.9, 49.5, 29.2, 22.2; IR (neat) 3424, 1607, 1568, 1485, 1445, 1420, 1404, 1377, 1086 cm^{-1} ; HRMS (ESI) exact mass calcd. for $\text{C}_{20}\text{H}_{21}\text{BrN}_2\text{O}_2$: m/z 423.0679 ($[\text{M} + \text{Na}]^+$), found: m/z 423.0686 ($[\text{M} + \text{Na}]^+$); $[\alpha]_{\text{D}}^{24} = 44.9$ ($c = 1.0$, CHCl_3 ; 93% ee).

The enantiomeric purity of the product was determined by HPLC analysis (Daicel CHIRALPAK AD-H, hexane/ethanol = 4:1, flow rate = 0.5 mL/min, retention time; 20.5 min (minor) and 63.3 min (major)).

Compound 2i (Table 2, entry 8)

Prepared according to the representative procedure with *trans*-2-hexenal (116 μL , 1.0 mmol) and **1a** (125.1 mg, 0.50 mmol) over the course of 2 h. The crude material was purified by column chromatography on silica gel (eluting with hexane/acetone = 5:1) to give **2i** as a white solid [150.4 mg, 0.432 mmol, 86% yield, *exo/endo* = >95:5]. The enantiomeric purity of the product was determined after the reduction of the aldehyde (*vide infra*).

^1H NMR (400 MHz, CDCl_3) δ 9.96 (1H, d, $J = 3.9$ Hz), 7.78 (2H, m), 7.44-7.34 (3H, m), 7.21-7.10 (3H, m), 6.92 (1H, m), 4.82 (1H, ddd, $J = 9.8, 8.0, 5.1$ Hz), 4.6 (1H, d, $J = 10.2$ Hz), 3.38 (1H, ddd, $J = 10.2, 8.0, 3.9$ Hz), 3.26 (1H, ddd, $J = 10.5, 5.4, 2.1$ Hz),

3.17 (1H, ddd, $J = 12.2, 10.7, 3.2$ Hz), 2.98 (1H, ddd, $J = 16.8, 12.7, 5.1$ Hz), 2.73 (1H, app dt, $J = 16.3, 2.5$ Hz), 2.27 (1H, m), 1.65 (1H, m), 1.41 (2H, m), 0.96 (3H, t, $J = 7.3$ Hz); ^{13}C NMR (100 MHz, CDCl_3) δ 199.3, 170.1, 135.3, 133.1, 130.3, 128.7, 128.3, 127.6, 127.5, 126.9, 126.6, 65.4, 64.1, 60.8, 50.1, 39.7, 29.5, 20.2, 13.8 (one peak overlaps); IR (neat) 1719, 1632, 1447, 1383, 1350 cm^{-1} ; HRMS (ESI) exact mass calcd. for $\text{C}_{22}\text{H}_{24}\text{N}_2\text{O}_2$: m/z 371.1730 ($[\text{M} + \text{Na}]^+$), found: m/z 371.1737 ($[\text{M} + \text{Na}]^+$); $[\alpha]_{\text{D}}^{27} = -0.2$ ($c = 1.0$, CHCl_3 ; 85% ee).

Compound 2i'

Prepared according to the representative procedure with **2i** (69.7 mg, 0.20 mmol) and NaBH_4 (7.6 mg, 0.20 mmol). The crude material was purified by column chromatography on silica gel (eluting with hexane/ethyl acetate = 2:1) to give the **2i'** [67.8 mg, 0.193 mmol, 97% yield].

^1H NMR (400 MHz, CDCl_3) δ 7.75 (2H, m), 7.40-7.30 (3H, m), 7.20-7.14 (3H, m), 7.09 (1H, m), 4.58 (1H, m), 4.29 (1H, d, $J = 10.4$ Hz), 4.08 (1H, app d, $J = 11.8$ Hz), 3.97 (1H, m), 3.24 (1H, ddd, $J = 12.4, 10.7, 3.4$ Hz), 3.16 (1H, ddd, $J = 10.3, 5.2, 1.8$ Hz), 2.98-2.90 (2H, m), 2.70 (1H, app dt, $J = 16.2, 2.5$ Hz), 2.45 (1H, m), 2.09 (1H, m), 1.76 (1H, m), 1.52 (2H, m), 0.98 (3H, t, $J = 7.3$ Hz); ^{13}C NMR (100 MHz, CDCl_3) δ 170.7, 135.9, 134.9, 133.1, 129.9, 128.4, 128.2, 127.5, 127.3, 126.9, 126.1, 62.2, 61.3, 60.4, 53.8, 49.6, 39.9, 29.6, 20.1, 14.3; IR (neat) 3410, 1612, 1572, 1450, 1422 cm^{-1} ; HRMS (ESI) exact mass calcd. for $\text{C}_{22}\text{H}_{26}\text{N}_2\text{O}_2$: m/z 373.1886 ($[\text{M} + \text{Na}]^+$), found: m/z 373.1907 ($[\text{M} + \text{Na}]^+$); $[\alpha]_{\text{D}}^{26} = 14.7$ ($c = 1.0$, CHCl_3 ; 85% ee).

The enantiomeric purity of the product was determined by HPLC analysis (Daicel CHIRALPAK AD-H, hexane/ethanol = 10:1, flow rate = 0.5 mL/min, retention time; 30.1 min (minor) and 53.8 min (major)).

Compound 2j

Prepared according to the representative procedure with *trans*-cinnamaldehyde (125.9 μL , 1.0 mmol) and **1a** (125.1 mg, 0.50 mmol) over the course of 2 h. The crude material was purified by column chromatography on silica gel (eluting with hexane/ethyl acetate = 3:1) to give **2j** as a white solid [179.4 mg, 0.469 mmol, 94% yield, *exo/endo* = >95:5]. The enantiomeric purity of the product was determined after the reduction of the aldehyde (*vide infra*).

^1H NMR (400 MHz, CDCl_3) δ 10.16 (1H, d, $J = 3.38$ Hz), 7.88 (2H, m), 7.47-7.36 (3H,

m), 7.34-7.33 (4H, m), 7.29-7.09 (4H, m), 6.96 (1H, m), 6.12 (1H, d, $J = 8.0$ Hz), 4.66 (1H, d, $J = 10.2$ Hz), 3.73 (1H, ddd, $J = 10.2, 8.1, 3.4$ Hz), 3.38 (1H, m), 3.11-3.04 (2H, m), 2.74 (1H, m); ^{13}C NMR (100 MHz, CDCl_3) δ 199.2, 170.7, 140.6, 134.9, 133.0, 132.6, 130.6, 128.7, 128.6, 127.72, 127.67, 127.5, 126.9, 126.6, 125.5, 66.8, 64.9, 63.0, 50.1, 29.3 (one peak overlaps); IR (neat) 1721, 1641, 1495, 1447, 1383, 1348 cm^{-1} ; HRMS (ESI) exact mass calcd. for $\text{C}_{25}\text{H}_{22}\text{N}_2\text{O}_2$: m/z 383.1754 ($[\text{M} + \text{H}]^+$), found: m/z 383.1785 ($[\text{M} + \text{H}]^+$); $[\alpha]_{\text{D}}^{23} = -61.2$ ($c = 1.0$, CHCl_3 ; 99% ee).

Compound 2j'

Prepared according to the representative procedure with **2j** (76.5 mg, 0.20 mmol) and NaBH_4 (7.6 mg, 0.20 mmol). The crude material was purified by column chromatography on silica gel (eluting with hexane/ethyl acetate = 1:2) to give **2j'** [74.4 mg, 0.194 mmol, 97% yield].

^1H NMR (400 MHz, CDCl_3) δ 7.86 (2H, d, $J = 7.0$ Hz), 7.44-7.14 (11H, m), 7.09 (1H, m), 5.62 (1H, d, $J = 8.7$ Hz), 4.47 (1H, d, $J = 10.6$ Hz), 4.14 (1H, m), 4.03 (1H, m), 3.29 (1H, br), 3.20 (1H, m), 3.04 (1H, m), 2.73 (1H, app dt, $J = 16.0, 2.4$ Hz), 2.66 (1H, m), 2.45 (1H, app t, $J = 4.5$ Hz); ^{13}C NMR (100 MHz, CDCl_3) δ 170.6, 142.1, 135.2, 134.2, 132.9, 130.2, 128.5, 128.4, 128.3, 127.6, 127.4, 126.9, 126.7, 126.1, 125.9, 64.4, 61.9, 58.3, 56.0, 49.8, 29.5; IR (neat) 1614, 1601, 1572, 1495, 1449, 1420, 1065, 1045 cm^{-1} ; HRMS (ESI) exact mass calcd. for $\text{C}_{25}\text{H}_{24}\text{N}_2\text{O}_2$: m/z 385.1911 ($[\text{M} + \text{H}]^+$), found: m/z 385.1929 ($[\text{M} + \text{H}]^+$); $[\alpha]_{\text{D}}^{23} = -56.8$ ($c = 1.0$, CHCl_3 ; 99% ee).

The enantiomeric purity of the product was determined by HPLC analysis (Daicel CHIRALPAK AS-H, hexane/ethanol = 9:1, flow rate = 0.5 mL/min, retention time; 16.3 min (major) and 21.8 min (minor)).

Compound 2k

Prepared according to the representative procedure with tiglic aldehyde (96.6 μL , 1.0 mmol) and **1a** (125.1 mg, 0.50 mmol) over the course of 7 h. The crude material was purified by column chromatography on silica gel (eluting with hexane/ethyl acetate = 4:1) to give **2k** as a white solid [142.0 mg, 0.425 mmol, 85% yield, exo/endo = 95:5]. The enantiomeric purity of the product was determined after the reduction of the aldehyde (*vide infra*).

^1H NMR (400 MHz, CDCl_3) δ 9.73 (1H, s), 7.80 (2H, m), 7.43-7.34 (3H, m), 7.22-7.16 (3H, m), 6.83 (1H, m), 4.90 (1H, q, $J = 6.9$ Hz), 4.74 (1H, s), 3.35 (1H, ddd, $J = 12.2$,

10.8, 3.4 Hz), 3.16 (1H, ddd, $J = 10.3, 5.6, 1.9$ Hz), 2.93 (1H, ddd, $J = 16.4, 12.4, 5.6$ Hz), 2.71 (1H, app dt, $J = 16.2, 2.7$ Hz), 1.52 (3H, d, $J = 7.0$ Hz), 1.05 (3H, s); ^{13}C NMR (100 MHz, CDCl_3) δ 200.9, 169.0, 135.2, 133.9, 131.4, 130.2, 128.5, 128.2, 127.6, 127.3, 127.0, 126.4, 65.6, 62.1, 58.0, 49.7, 29.2, 18.0, 14.4; IR (neat) 1722, 1630, 1404, 1381 cm^{-1} ; HRMS (ESI) exact mass calcd. for $\text{C}_{21}\text{H}_{22}\text{N}_2\text{O}_2$: m/z 335.1754 ($[\text{M} + \text{H}]^+$), found: m/z 335.1762 ($[\text{M} + \text{H}]^+$); $[\alpha]_{\text{D}}^{20} = -30.6$ ($c = 1.0$, CHCl_3 ; exo/endo = 95:5, 88% ee/-).

Compound 2k'

Prepared according to the representative procedure with **2k** (66.9 mg, 0.20 mmol) and NaBH_4 (7.6 mg, 0.20 mmol). The crude material was purified by column chromatography on silica gel (eluting with hexane/ethyl acetate = 1:2) to give **2k'** [62.6 mg, 0.186 mmol, 93% yield].

^1H NMR (400 MHz, CDCl_3) δ 7.78 (2H, d, $J = 7.25$ Hz), 7.39-7.30 (3H, m), 7.19-7.09 (4H, m), 4.66 (1H, br), 4.44 (1H, s), 3.72 (1H, d, $J = 10.6$ Hz), 3.68 (1H, d, $J = 10.4$ Hz), 3.39 (1H, m), 3.06 (1H, m), 2.87 (1H, ddd, $J = 16.4, 12.2, 5.6$ Hz), 2.80 (1H, br), 2.69 (1H, app d, $J = 16.0$ Hz), 1.49 (3H, br), 0.84 (3H, s); 169.1, 135.8, 134.0, 133.5, 129.9, 128.5, 128.3, 127.6, 127.3, 126.8, 126.1, 69.7, 65.1, 60.2, 52.4, 49.8, 29.3, 18.4, 18.0; IR (neat) 1611, 1601, 1572, 1423, 1389, 1065, 1051 cm^{-1} ; HRMS (ESI) exact mass calcd. for $\text{C}_{21}\text{H}_{24}\text{N}_2\text{O}_2$: m/z 337.1911 ($[\text{M} + \text{H}]^+$), found: m/z 337.1903 ($[\text{M} + \text{H}]^+$); $[\alpha]_{\text{D}}^{20} = -21.8$ ($c = 1.0$, CHCl_3 ; exo/endo = 95:5, 88% ee/-).

The enantiomeric purity of the product was determined by HPLC analysis (Daicel CHIRALPAK AS-H, hexane/ethanol = 19:1, flow rate = 0.5 mL/min, retention time; 27.7 min (minor) and 39.1 min (major)).

Compound 2l

Prepared according to the representative procedure with cyclopentene-1-carboxaldehyde (96.1 mg, 1.0 mmol) and **1a** (125.1 mg, 0.50 mmol) over the course of 2 h. The crude material was purified by column chromatography on silica gel (eluting with hexane/ethyl acetate = 3:1) to give **2l** as a white solid [160.5 mg, 0.464 mmol, 93% yield, exo/endo = 92:8]. The enantiomeric purity of the product was determined after the reduction of the aldehyde (*vide infra*).

^1H NMR (400 MHz, CDCl_3) δ 9.84 (1H, s), 7.86 (2H, d, $J = 7.25$ Hz), 7.44-7.34 (3H, m), 7.26-7.07 (3H, m), 6.84 (1H, m), 5.10 (1H, m), 5.02 (1H, s), 3.50 (1H, ddd, $J = 12.8$,

10.2, 3.1 Hz), 3.07 (1H, m), 2.90 (1H, m), 2.66 (1H, app d, $J = 16.0$ Hz), 2.55 (1H, m), 2.14 (1H, m), 2.03-1.94 (2H, m), 1.70-1.53 (2H, m); ^{13}C NMR (100 MHz, CDCl_3) δ 200.4, 167.8, 134.7, 134.1, 132.3, 130.3, 128.4, 128.4, 128.3, 127.6, 127.1, 126.6, 126.4, 73.4, 67.7, 64.1, 49.0, 35.9, 30.1, 29.6, 27.2; IR (neat) 1719, 1626, 1754, 1574, 1495, 1449, 1416, 1283, 1271, 1225 cm^{-1} ; HRMS (ESI) exact mass calcd. for $\text{C}_{22}\text{H}_{22}\text{N}_2\text{O}_2$: m/z 347.1754 ($[\text{M} + \text{H}]^+$), found: m/z 347.1751 ($[\text{M} + \text{H}]^+$); $[\alpha]_{\text{D}}^{25} = -22.3$ ($c = 1.0$, CHCl_3 ; 89% ee (exo), 86% ee (endo)).

Compound 2l'

Prepared according to the representative procedure with **2l** (69.2 mg, 0.20 mmol) and NaBH_4 (7.6 mg, 0.20 mmol). The crude material was purified by column chromatography on silica gel (eluting with hexane/ethyl acetate = 1:2) to give **2l'** as a white solid [66.7 mg, 0.192 mmol, 96% yield].

^1H NMR (400 MHz, CDCl_3) δ 7.85 (2H, br), 7.39-7.06 (7H, m), 4.95 (1H, br), 4.76 (1H, s), 4.55 (1H, br), 3.83 (2H, br), 3.46 (1H, app t, $J = 9.6$ Hz), 2.88-2.49 (4H, m), 2.02-1.20 (6H, m); ^{13}C NMR (100 MHz, CDCl_3) δ 167.7, 134.2, 134.0, 130.0, 128.5, 128.4, 128.1, 127.5, 126.6, 126.5, 126.2, 67.9, 66.8, 63.7, 62.7, 48.8, 35.4, 33.3, 29.8, 26.2; IR (neat) 1601, 1570, 1495, 1450, 1425, 1053 cm^{-1} ; HRMS (ESI) exact mass calcd. for $\text{C}_{22}\text{H}_{24}\text{N}_2\text{O}_2$: m/z 349.1911 ($[\text{M} + \text{H}]^+$), found: m/z 349.1908 ($[\text{M} + \text{H}]^+$); $[\alpha]_{\text{D}}^{25} = -12.1$ ($c = 1.0$, CHCl_3 ; exo/endo = 92:8, 89% ee/86% ee).

The enantiomeric purity of the product was determined by HPLC analysis (Daicel CHIRALPAK AS-H, hexane/ethanol = 9:1, flow rate = 0.5 mL/min, retention time; 14.9 min (endo, major), 15.8 (endo, minor), 19.8 (exo, minor) and 32.8 min (exo, major)).

Compound 2m (Table 2, entry 12)

Prepared according to the representative procedure with methacrolein (82.5 μL , 1.0 mmol) and **1a** (125.1 mg, 0.50 mmol) over the course of 1 h. The crude material was purified by column chromatography on silica gel (eluting with hexane/ethyl acetate = 3:1) to give **2m** as a white solid [156.6 mg, 0.489 mmol, 98% yield, exo/endo = 50:50]. The enantiomeric purity of the product was determined after the reduction of the aldehyde (*vide infra*).

^1H NMR of two isomers (400 MHz, CDCl_3) δ 9.78 (1H, s), 9.26 (1 H, s), 7.83 (4H, m), 7.46-7.34 (6H, m), 7.29-7.10 (7H, m), 6.89 (1H, m), 4.82 (1H, br), 4.77 (1H, s), 4.38

(1H, d, $J = 12.6$ Hz), 4.35 (1H, s), 4.08 (1H, br), 3.60 (1H, d, $J = 12.8$ Hz), 3.27 (1H, m), 3.12 (1H, m), 3.05-2.89 (4H, m), 2.80-2.65 (2 H, m), 1.66 (3H, s), 1.13 (3H, s); ^{13}C NMR (100 MHz, CDCl_3) δ 202.4, 201.0, 168.79, 168.77, 134.6, 134.3, 133.8, 133.2, 131.2, 130.7, 130.6, 129.8, 129.0, 128.64, 128.56, 128.5, 128.0, 127.7, 127.41, 127.36, 126.7, 126.4, 126.3, 72.2, 65.1, 58.9, 58.7, 51.9, 49.9, 48.2, 48.1, 28.9, 28.8, 22.0, 19.2 (one peak overlaps); IR (neat) 1721, 1632, 1449, 1422, 1396 cm^{-1} ; HRMS (ESI) exact mass calcd. for $\text{C}_{20}\text{H}_{20}\text{N}_2\text{O}_2$: m/z 321.1598 ($[\text{M} + \text{H}]^+$), found: m/z 321.1594 ($[\text{M} + \text{H}]^+$); $[\alpha]_{\text{D}}^{20} = -30.7$ ($c = 1.0$, CHCl_3 ; exo/endo = 50:50, 96% ee/98% ee).

Compound 2m'

Prepared according to the representative procedure with **2m** (64.1 mg, 0.20 mmol) and NaBH_4 (7.6 mg, 0.20 mmol). The crude material was purified by column chromatography on silica gel (eluting with hexane/ethyl acetate = 1:2) to give **2m'** as a white solid [63.7 mg, 0.198 mmol, 99% yield].

^1H NMR of two isomers (400 MHz, CDCl_3) δ 7.82-7.77 (4H, br), 7.43-7.32 (6H, m), 7.21-7.10 (8H, m), 4.57 (1H, d, $J = 10.9$ Hz), 4.41 (1H, s), 4.23-4.16 (2H, br), 3.84 (1H, d, $J = 11.8$ Hz), 3.77-3.67 (2H, m), 3.49-3.26 (5H, m), 3.09 (1H, br), 3.02-2.70 (6H, m), 2.44 (1H, t, $J = 5.3$ Hz), 1.48 (3H, s), 1.18 (1H, br), 0.93 (3H, s); ^{13}C NMR (100 MHz, CDCl_3) δ 169.7, 168.9, 134.9, 134.7, 133.5, 133.4, 133.1, 132.2, 130.4, 130.3, 128.7, 128.5, 128.3, 127.5, 127.2, 126.7, 126.5, 126.1, 125.9, 70.3, 69.8, 67.3, 65.7, 52.7, 52.3, 50.2, 49.8, 48.0, 47.4, 29.1, 28.8, 26.4, 22.3 (three peaks overlaps); IR (neat) 1612, 1574, 1495, 1452, 1425, 1047 cm^{-1} ; HRMS (ESI) exact mass calcd. for $\text{C}_{20}\text{H}_{22}\text{N}_2\text{O}_2$: m/z 323.1754 ($[\text{M} + \text{H}]^+$), found: m/z 323.1749 ($[\text{M} + \text{H}]^+$); $[\alpha]_{\text{D}}^{20} = 3.0$ ($c = 1.0$, CHCl_3 ; exo/endo = 50:50, 96% ee/98% ee).

The enantiomeric purity of the product was determined by HPLC analysis (Daicel CHIRALPAK AD-H, hexane/ethanol = 10:1, flow rate = 0.5 mL/min, retention time; 45.8 min (exo, minor), 53.3 (exo, major), 58.9 (endo, minor) and 121.9 min (endo, major)).

Compound 2n (Table 2, entry 13)

Prepared according to the representative procedure with acrolein (66.8 μL , 1.0 mmol) and **1a** (125.1 mg, 0.50 mmol) over the course of 1 h. The crude material was purified by

column chromatography on silica gel (eluting with hexane/ethyl acetate = 1:1) to give **2n** as a white solid [148.5 mg, 0.485 mmol, 97% yield, exo/endo = 61:39]. The enantiomeric purity of the product was determined after the reduction of the aldehyde (*vide infra*).

^1H NMR (400 MHz, CDCl_3) δ 9.96 (1H, d, J = 3.1 Hz), 9.42 (0.5 H, d, J = 1.5 Hz), 7.87-7.81 (3H, m), 7.46-7.17 (8H, m), 7.15-7.11 (1.5H, m), 7.05-7.03 (1H, m), 4.84 (0.5H, d, J = 9.4 Hz), 4.64 (1H, d, J = 8.9 Hz), 4.51 (1H, br), 4.38 (0.5H, br), 4.26 (0.5H, dd, J = 12.4, 4.2 Hz), 4.00 (1H, dd, J = 12.6, 10.2 Hz), 3.67 (0.5 H, m), 3.51 (1H, m), 3.09-2.92 (4H, m), 2.79-2.64 (2H, m); ^{13}C NMR (100 MHz, CDCl_3) δ 200.7, 199.2, 168.7, 168.4, 134.8, 134.4, 133.4, 133.2, 132.8, 130.7, 130.6, 130.2, 129.0, 128.7, 128.6, 128.5, 127.8, 127.7, 127.6, 127.4, 127.0, 126.8, 126.7, 64.9, 63.7, 57.8, 55.3, 48.5, 44.6, 42.4, 29.0, 28.8 (two peaks overlap); IR (neat) 1721, 1628, 1574, 1450, 1423 cm^{-1} ; HRMS (ESI) exact mass calcd. for $\text{C}_{19}\text{H}_{18}\text{N}_2\text{O}_2$: m/z 307.1441 ($[\text{M} + \text{H}]^+$), found: m/z 307.1436 ($[\text{M} + \text{H}]^+$); $[\alpha]_{\text{D}}^{17} = -2.6$ (c = 1.0, CHCl_3 ; exo/endo = 61:39, 62% ee/74% ee).

Compound **2n'**

Prepared according to the representative procedure with **2n** (61.3 mg, 0.20 mmol) and NaBH_4 (7.6 mg, 0.20 mmol). The crude material was purified by column chromatography on silica gel (eluting with hexane/ethyl acetate = 1:5) to give **2n'** as a white solid [60.9 mg, 0.197 mmol, 99% yield].

^1H NMR of two isomers (400 MHz, CDCl_3) δ 7.88 (2H, br), 7.83 (1H, br), 7.43-7.33 (4.5H, m), 7.23-7.10 (6H, m), 4.64 (0.5H, d, J = 8.2 Hz), 4.56 (1H, br), 4.33-4.09 (3H, m), 3.94 (2H, br), 3.70 (0.5H, dd, J = 12.3, 5.6 Hz), 3.53 (0.5H, m), 3.42 (0.5 H, m), 3.08-2.70 (9H, m); ^{13}C NMR (100 MHz, CDCl_3) δ 168.3, 168.2, 134.6, 132.7, 132.1, 130.4, 130.3, 128.7, 128.51, 128.46, 127.7, 127.6, 127.2, 127.0, 126.21, 126.19, 63.8, 63.3, 62.6, 61.1, 48.3, 47.3, 46.8, 45.9, 29.2, 28.9 (8 peaks overlap); IR (neat) 3412, 1611, 1572, 1493, 1454, 1427, 1217, 1040 cm^{-1} ; HRMS (ESI) exact mass calcd. for $\text{C}_{19}\text{H}_{20}\text{N}_2\text{O}_2$: m/z 309.1598 ($[\text{M} + \text{H}]^+$), found: m/z 309.1590 ($[\text{M} + \text{H}]^+$); $[\alpha]_{\text{D}}^{19} = 4.7$ (c = 1.0, CHCl_3 ; exo/endo = 61:39, 62% ee/74% ee).

The enantiomeric purity of the product was determined by HPLC analysis (Daicel CHIRALPAK IA, hexane/ethanol = 4:1, flow rate = 0.5 mL/min, retention time; 35.7 min (exo, major), 40.5 (exo, minor), 62.8 (endo, major) and 79.6 min (endo, minor)).

General procedure for the preparation of 1-(3-Bromopropyl)cyclohexanecarbaldehyde and its analogs

To a stirred solution of diisopropylamine in ether (20 mL) was added 1.6 M hexane solution of butyllithium (12.5 mL, 20.0 mmol) at 0 °C, and the mixture was stirred for 30 min at the same temperature. To this solution was then added the corresponding nitrile (20.0 mmol) dropwise. After stirring for 30 min at 0 °C, the reaction solution was cooled to -78 °C, and 1,3-dibromopropane (3.04 mL, 30.0 mmol) was added. The reaction mixture was allowed to warm gradually to 0 °C over 1 h and quenched with NH₄Cl aq. The organic layer was extracted with ether, dried over Na₂SO₄ and concentrated in vacuo. The residue was purified by column chromatography on silica gel (eluting with hexane/ethyl acetate 30/1 to 10/1) to give the alkylated compound as colorless oil.

To a ca. 1 M solution of thus-obtained nitrile in CH₂Cl₂ was added 1.1 equiv of DIBALH (1.5 M toluene solution) at -78 °C. After stirring for 1 h at the same temperature, the reaction solution was poured into 1N HCl aq and extracted with CH₂Cl₂. The combined organic layers were dried over Na₂SO₄ and concentrated in vacuo. The residue was purified by column chromatography on silica gel (eluting with pentane only to pentane/ether = 20:1) to give the corresponding aldehyde.

1-(3-Bromopropyl)cyclohexanecarbaldehyde

Prepared according to the general procedure with cyclohexanecarbonitrile (2.38 mL, 20.0 mmol) to give the title compound [1.38 g, 5.91 mmol, 30% yield].

¹H NMR (400 MHz, CDCl₃) δ 9.43 (1H, s), 3.36 (2H, t, *J* = 6.4 Hz), 1.88 (2H, m), 1.77-1.70 (2H, m), 1.62-1.50 (4H, m), 1.39-1.26 (6H, m); ¹³C NMR (100 MHz, CDCl₃) δ 206.6, 49.2, 34.5, 33.9, 30.9, 26.9, 25.7, 22.4; IR (neat) 2930, 2853, 1721, 1450 cm⁻¹. Full characterization was performed after the derivatization to the azomethine imine (*vide infra*).

1-(3-Bromopropyl)cyclopentanecarbaldehyde

Prepared according to the general procedure with cyclopentanecarbonitrile (2.09 mL, 20.0 mmol) to give the title compound [1.56 g, 7.13 mmol, 36% yield].

^1H NMR (400 MHz, CDCl_3) δ 9.46 (1H, s), 3.38 (2H, t, $J = 6.0$ Hz), 1.97 (2H, m), 1.82-1.55 (8H, m), 1.43 (2H, m); ^{13}C NMR (100 MHz, CDCl_3) δ 204.6, 57.5, 34.0, 33.8, 32.5, 28.7, 25.2; IR (neat) 2957, 2868, 1721, 1452 cm^{-1} . Full characterization was performed after the derivatization to the azomethine imine (*vide infra*).

5-Bromo-2,2-dimethylpentanal

Prepared according to the general procedure with isobutyronitrile (2.83 mL, 20.0 mmol) to give the title compound [793 mg, 4.11 mmol, 21% yield].

^1H NMR (400 MHz, CDCl_3) δ 9.46 (1H, s), 3.39 (2H, t, $J = 6.5$ Hz), 1.70 (2H, m), 1.62 (2H, m), 1.08 (6H, s); ^{13}C NMR (100 MHz, CDCl_3) δ 205.6, 45.4, 35.5, 33.7, 27.7, 21.4; IR (neat) 2965, 1778, 1724, 1470 cm^{-1} . Full characterization was performed after the derivatization to the azomethine imine (*vide infra*).

General procedure for the preparation of *N*-benzoylimino-2,3,4,5-tetrahydropyridinium bromides

To a 0.5 M solution of the aldehyde (1.05 eq) in ethanol was added benzoylhydrazine (1.0 eq) at room temperature. The reaction was then heated to 70 °C and stirred for 2 h. Removal of the organic solvent under reduced pressure gave a crude material. This material was further purified by washing with ethyl acetate to give the corresponding *N*-benzoylimino-2,3,4,5-tetrahydropyridinium bromide.

Compound 3a

Prepared according to the general procedure with 1-(3-bromopropyl)cyclohexanecarbaldehyde (734 mg, 3.15 mmol) and benzoylhydrazine (409 mg, 3.0 mmol) to give **3a** [964 mg, 2.74 mmol, 91% yield].

^1H NMR (400 MHz, CDCl_3) δ 13.6 (1H, s), 8.65 (1H, s), 8.22 (2H, d, $J = 7.5$ Hz), 7.62 (1H, t, $J = 7.4$ Hz), 7.53 (2H, app t, $J = 7.7$ Hz), 4.27 (2H, m), 2.17 (2H, m), 1.95-1.48 (12H, m); ^{13}C NMR (100 MHz, CDCl_3) δ 184.4, 164.8, 133.9, 128.9, 128.72, 128.66, 56.2, 41.2, 34.1, 26.8, 24.7, 20.1, 18.4; IR (neat) 2934, 2860, 1680, 1510, 1481, 1450, 1395, 1265, 1069 cm^{-1} ; HRMS (ESI) exact mass calcd. for $\text{C}_{17}\text{H}_{23}\text{BrN}_2\text{O}$: m/z 271.1805 ($[\text{M} - \text{Br}]^+$), found: m/z 271.1819 ($[\text{M} - \text{Br}]^+$).

Compound 3b

Prepared according to the general procedure with 1-(3-bromopropyl)cyclopentanecarbaldehyde (920 mg, 4.2 mmol) and benzoylhydrazine (545 mg, 4.0 mmol) to give **3b** [1.30 g, 3.85 mmol, 96% yield].

^1H NMR (400 MHz, CDCl_3) δ 13.5 (1H, s), 8.59 (1H, s), 8.21 (2H, m), 7.62 (1H, m), 7.52 (2H, m), 4.24 (2H, m), 2.27 (2H, m), 2.17 (2H, m), 1.97-1.83 (8H, m); ^{13}C NMR (100 MHz, CDCl_3) δ 184.1, 164.8, 133.8, 128.9, 128.8, 128.6, 55.5, 48.0, 39.0, 28.7, 25.4, 19.7; IR (neat) 2953, 2868, 1682, 1510, 1479, 1449, 1393, 1267, 1069 cm^{-1} ; HRMS (ESI) exact mass calcd. for $\text{C}_{16}\text{H}_{21}\text{BrN}_2\text{O}$: m/z 257.1648 ($[\text{M} - \text{Br}]^+$), found: m/z 257.1636 ($[\text{M} - \text{Br}]^+$).

Compound 3c

Prepared according to the general procedure with 5-bromo-2,2-dimethylpentanal (1.57 g, 8.16 mmol) and benzoylhydrazine (1.01 g, 7.42 mmol) to give **3c** [2.17 g, 6.96 mmol, 94% yield].

^1H NMR (400 MHz, CDCl_3) δ 13.6 (1H, s), 8.64 (1H, s), 8.20 (2H, m), 7.61 (1H, m), 7.51 (2H, m), 4.26 (2H, m), 2.21 (2H, m), 1.83 (2H, m), 1.53 (6H, s); ^{13}C NMR (100 MHz, CDCl_3) δ 184.6, 164.8, 133.9, 129.0, 128.7, 55.8, 37.8, 30.3, 26.4, 18.8; IR (neat) 2969, 2868, 1682, 1508, 1472, 1450, 1369, 1265 cm^{-1} ; HRMS (ESI) exact mass calcd. for $\text{C}_{14}\text{H}_{19}\text{BrN}_2\text{O}$: m/z 231.1492 ($[\text{M} - \text{Br}]^+$), found: m/z 231.1487 ($[\text{M} - \text{Br}]^+$).

Representative procedure for asymmetric 1,3-dipolar cycloaddition of *in situ* generated azomethine imines and enals (Table 3)

To a solution of (S) -1,1'-bi(2-naphthol) (14.3 mg, 0.050 mmol) in dry CH_2Cl_2 (1.0 mL) was added $\text{Ti}(\text{O}^i\text{Pr})_4$ (7.4 μL , 0.025 mmol) and the solution was stirred for 2 h at room temperature under an argon atmosphere. After cooling the mixture to $0\text{ }^\circ\text{C}$, crotonaldehyde (41.1 μL , 0.50 mmol), **3a** (87.8 mg, 0.25 mmol) and 2,6-di-*tert*-butyl-4-methylpyridine [DTBMP] (61.6 mg, 0.30 mmol) were added subsequently to this catalyst solution. The reaction solution was stirred at the same temperature for 24 h and quenched with saturated NaHCO_3 aq. The organic layer was extracted with CH_2Cl_2 , dried over Na_2SO_4 and concentrated in vacuo. The exo/endo selectivity was determined to be 81:19 by ^1H NMR analysis of the crude material (RCHO : endo δ 10.0 (broad signal), exo δ 9.63). The residue was purified by column chromatography on silica gel (eluting with hexane/ether = 1:1) to give **6a** as a colorless oil [62.6 mg, 0.184 mmol, 74% yield for the exo isomer]. The minor endo isomer, which is more polar, could be separated at this stage. The enantiomeric purity of the product was determined after reduction of the aldehyde (*vide infra*).

Compound 6a (Table 3, entry 1)

^1H NMR (400 MHz, CDCl_3) δ 9.63 (1H, d, $J = 5.1$ Hz), 7.79 (2H, m), 7.44-7.34 (3H, m), 4.61 (1H, dq, $J = 7.0, 6.8$ Hz), 3.32 (1H, d, $J = 11.4$ Hz), 3.22 (1H, ddd, $J = 11.2, 7.8, 4.9$ Hz), 2.96 (1H, m), 2.70 (1H, ddd, $J = 13.0, 11.0, 3.4$ Hz), 1.84-1.07 (17H, m); ^{13}C NMR (100 MHz, CDCl_3) δ 199.3, 168.6, 135.2, 130.1, 128.3, 127.5, 72.6, 59.5, 56.6, 52.7, 37.4, 35.6, 35.0, 27.5, 26.0, 22.0, 21.2, 21.1, 20.0; IR (neat) 2930, 2857, 1721, 1628, 1574, 1449, 1416, 1373, 1344 cm^{-1} ; HRMS (ESI) exact mass calcd. for $\text{C}_{21}\text{H}_{28}\text{N}_2\text{O}_2$: m/z 341.2224 ($[\text{M} + \text{H}]^+$), found: m/z 341.2219 ($[\text{M} + \text{H}]^+$); $[\alpha]_{\text{D}}^{23} = 43.8$ ($c = 1.0$, CHCl_3 ; 87% ee).

Reduction and HPLC analysis of the cycloadduct

To a solution of **6a** (62.6 mg, 0.184 mmol) in MeOH (1.0 mL) was added 90 wt.% NaBH₄ (7.6 mg, 0.20 mmol) at 0 °C and the solution was stirred for 30 min at the same temperature. The mixture was then poured in aqueous NH₄Cl and extracted with ethyl acetate. The combined organic layer was dried over Na₂SO₄ and evaporated under vacuum. The residue was purified by column chromatography on silica gel (eluting with hexane/ethyl acetate = 2:3) to give **6a'** as a white solid [59.2 mg, 0.173 mmol, 94%].

Compound **6a'**

¹H NMR (400 MHz, CDCl₃) δ 7.77 (2H, m), 7.38-7.29 (3H, m), 4.39 (1H, dq, *J* = 7.3, 6.6 Hz), 4.01 (1H, app dt, *J* = 11.0, 3.5 Hz), 3.73 (1H, m), 2.95 (1H, d, *J* = 11.1 Hz), 2.85-2.75 (2H, m), 2.48 (1H, m), 2.20 (1H, br), 1.77-1.16 (18H, m); ¹³C NMR (100 MHz, CDCl₃) δ 167.8, 135.6, 129.7, 128.5, 127.3, 69.2, 62.6, 59.9, 52.5, 48.1, 36.7, 35.8, 35.4, 28.0, 26.2, 23.1, 21.3, 21.2, 20.2; IR (neat) 3399, 2930, 2857, 1607, 1570, 1450, 1431, 1373 cm⁻¹; HRMS (ESI) exact mass calcd. for C₂₁H₃₀N₂O₂: *m/z* 343.2380 ([M + H]⁺), found: *m/z* 343.2376 ([M + H]⁺); [α]_D²⁰ = 41.6 (*c* = 1.0, CHCl₃; 90% ee).

The enantiomeric purity of the product was determined by HPLC analysis (Daicel CHIRALPAK AD-H, hexane/isopropanol = 10:1, flow rate = 0.5 mL/min, retention time; 16.3 min (minor) and 24.6 min (major)).

Compound **6b** (Table 3, entry 2)

Prepared according to the representative procedure with **3b** (84.3 mg, 0.25 mmol) over the course of 24 h. The exo/endo selectivity was determined to be 77:23 by ¹H NMR analysis of the crude material (RCHO: endo δ 9.99 (broad signal), exo δ 9.64). The crude material was purified by column chromatography on silica gel (eluting with hexane/ether = 1:1) to give **6b** as a colorless oil [52.3 mg, 0.160 mmol, 64% yield for the exo isomer]. The minor endo isomer, which is more polar, could be separated at this stage. The enantiomeric purity of the product was determined after the reduction of the aldehyde (*vide infra*).

¹H NMR (400 MHz, CDCl₃) δ 9.64 (1H, m), 7.82 (2H, m), 7.45-7.35 (3H, m), 4.65 (1H, m), 3.29-3.22 (2H, m), 2.98 (1H, m), 2.71 (1H, ddd, *J* = 12.0, 11.0, 4.1 Hz), 1.71-1.14 (15H, m); ¹³C NMR (100 MHz, CDCl₃) δ 199.3, 168.5, 135.2, 130.2, 128.4, 127.6, 72.4,

60.2, 56.8, 52.3, 44.6, 39.1, 38.0, 30.0, 24.0, 23.7, 22.0, 21.5; IR (neat) 2949, 2862, 1721, 1628, 1574, 1449, 1416, 1371, 1128 cm^{-1} ; HRMS (ESI) exact mass calcd. for $\text{C}_{20}\text{H}_{26}\text{N}_2\text{O}_2$: m/z 327.2067 ($[\text{M} + \text{H}]^+$), found: m/z 327.2055 ($[\text{M} + \text{H}]^+$); $[\alpha]_{\text{D}}^{20} = 35.5$ ($c = 1.0$, CHCl_3 ; 86% ee).

Compound 6b'

Prepared according to the general procedure with **6b** (52.3 mg, 0.160 mmol) and NaBH_4 (7.6 mg, 0.20 mmol). The crude material was purified by column chromatography on silica gel (eluting with hexane/ethyl acetate = 2:3) to give **6b'** as a white solid [50.4 mg, 0.153 mmol, 96% yield].

^1H NMR (400 MHz, CDCl_3) δ 7.80 (2H, m), 7.39-7.30 (3H, m), 4.36 (1H, dq, $J = 8.0, 6.6$ Hz), 3.99 (1H, ddd, $J = 11.1, 4.3, 3.2$ Hz), 3.76 (1H, m), 2.90-2.74 (2H, m), 2.50 (1H, m), 2.12 (1H, app t, $J = 4.8$ Hz), 1.73-1.32 (15H, m); ^{13}C NMR (100 MHz, CDCl_3) δ 167.9, 135.5, 129.8, 128.6, 127.3, 69.6, 61.5, 59.5, 51.9, 48.5, 44.5, 38.3, 37.6, 29.2, 23.8, 23.5, 22.7, 21.5; IR (neat) 3412, 2949, 2864, 1609, 1570, 1450, 1431, 1373 cm^{-1} ; HRMS (ESI) exact mass calcd. for $\text{C}_{20}\text{H}_{28}\text{N}_2\text{O}_2$: m/z 329.2224 ($[\text{M} + \text{H}]^+$), found: m/z 329.2227 ($[\text{M} + \text{H}]^+$); $[\alpha]_{\text{D}}^{19} = 29.0$ ($c = 1.0$, CHCl_3 ; 86% ee).

The enantiomeric purity of the product was determined by HPLC analysis (Daicel CHIRALPAK AD-H, hexane/isopropanol = 10:1, flow rate = 0.5 mL/min, retention time; 16.8 min (minor) and 36.5 min (major)).

Compound 6c (Table 3, entry 3)

Prepared according to the general procedure with **3c** (77.8 mg, 0.25 mmol) over the course of 24 h. The exo/endo selectivity was determined to be 88:12 by ^1H NMR analysis of the crude material (RCHO: endo δ 10.00 (broad signal), exo δ 9.62). The crude material was purified by column chromatography on silica gel (eluting with hexane/ether = 1:1) to give **6c** as a colorless oil [48.7 mg, 0.162 mmol, 65% yield for the exo isomer]. The minor endo isomer, which is more polar, could be separated at this stage. The enantiomeric purity of the product was determined after the reduction of the aldehyde (*vide infra*).

^1H NMR (400 MHz, CDCl_3) δ 9.62 (1H, d, $J = 4.4$ Hz), 7.80 (2H, m), 7.45-7.35 (3H, m), 4.61 (1H, dq, $J = 7.6, 6.6$ Hz), 3.24 (1H, d, $J = 11.4$ Hz), 3.18 (1H, ddd, $J = 11.7, 7.3, 4.4$ Hz), 2.97 (1H, m), 2.67 (1H, ddd, $J = 13.0, 11.0, 3.2$ Hz), 1.71-1.26 (7H, m), 1.13 (3H, s), 0.87 (3H, s); ^{13}C NMR (100 MHz, CDCl_3) δ 199.4, 168.6, 135.2, 130.2,

128.3, 127.5, 72.7, 59.8, 56.9, 52.3, 33.0, 32.5, 29.3, 28.2, 22.1, 20.9; IR (neat) 1721, 1628, 1574, 1472, 1449, 1412, 1369, 1125 cm^{-1} ; HRMS (ESI) exact mass calcd. for $\text{C}_{18}\text{H}_{24}\text{N}_2\text{O}_2$: m/z 301.1911 ($[\text{M} + \text{H}]^+$), found: m/z 301.1897 ($[\text{M} + \text{H}]^+$); $[\alpha]_{\text{D}}^{23} = 20.2$ ($c = 1.0$, CHCl_3 ; 76% ee).

Compound 6c'

Prepared according to the general procedure with **6c** (48.7 mg, 0.162 mmol) and NaBH_4 (7.6 mg, 0.20 mmol). The crude material was purified by column chromatography on silica gel (eluting with hexane/ethyl acetate = 2:3) to give **6c'** as a white solid [45.7 mg, 0.151 mmol, 93% yield].

^1H NMR (400 MHz, CDCl_3) δ 7.78 (2H, m), 7.39-7.30 (3H, m), 4.40 (1H, dq, $J = 7.3$, 6.6 Hz), 3.99 (1H, m), 3.69 (1H, m), 2.85-2.70 (4H, m), 2.40 (1H, m), 1.65-1.20 (7H, m), 1.09 (3H, s), 1.01 (3H, s); ^{13}C NMR (100 MHz, CDCl_3) δ 167.9, 135.6, 129.8, 128.5, 127.3, 69.7, 62.7, 60.1, 52.2, 48.5, 33.1, 32.9, 28.9, 28.7, 23.1, 21.2; IR (neat) 3428, 2936, 1609, 1570, 1450, 1427, 1369, 1123, 1057 cm^{-1} ; HRMS (ESI) exact mass calcd. for $\text{C}_{18}\text{H}_{26}\text{N}_2\text{O}_2$: m/z 303.2067 ($[\text{M} + \text{H}]^+$), found: m/z 303.2056 ($[\text{M} + \text{H}]^+$); $[\alpha]_{\text{D}}^{23} = 14.8$ ($c = 1.0$, CHCl_3 ; 76% ee).

The enantiomeric purity of the product was determined by HPLC analysis (Daicel CHIRALPAK OD-H, hexane/isopropanol = 20:1, flow rate = 0.5 mL/min, retention time; 18.8 min (major) and 22.0 min (minor)).

Compound 6d (Table 3, entry 4)

Prepared according to the representative procedure with **3a** (87.8 mg, 0.25 mmol) and *trans*-2-hexenal (58.0 μL , 0.50 mmol) over the course of 50 h. The exo/endo selectivity was determined to be 67:33 by ^1H NMR analysis of the crude material (RCHO : endo δ 10.01 (broad signal), exo δ 9.65). The crude material was purified by PLC (eluting with hexane/ethyl acetate = 2:1) to give **6d** as a white solid [33.6 mg, 0.091 mmol, 36% yield for the exo isomer]. The minor endo isomer, which is more polar, could be separated at this stage. The enantiomeric purity of the product was determined after the reduction of the aldehyde (*vide infra*).

^1H NMR (400 MHz, CDCl_3) δ 9.65 (1H, m), 7.76 (2H, m), 7.43-7.33 (3H, m), 4.60 (1H, m), 3.26-3.25 (2H, m), 2.97 (1H, m), 2.71 (1H, ddd, $J = 3.4$, 11.0, 13.2 Hz), 2.23 (1H, m), 1.79-1.05 (17H, m), 0.95 (3H, t, $J = 7.4$ Hz); ^{13}C NMR (100 MHz, CDCl_3) δ 199.9, 169.5, 135.5, 130.0, 128.2, 127.5, 73.2, 61.2, 58.6, 52.4, 40.0, 37.5, 35.7, 35.0, 27.6,

26.0, 21.2, 21.1, 20.3, 20.0, 13.9; IR (neat) 2931, 1722, 1630, 1574, 1447, 1416 cm^{-1} ; HRMS (ESI) exact mass calcd. for $\text{C}_{23}\text{H}_{32}\text{N}_2\text{O}_2$: m/z 369.2537 ($[\text{M} + \text{H}]^+$), found: m/z 369.2543 ($[\text{M} + \text{H}]^+$); $[\alpha]_{\text{D}}^{18} = 43.5$ ($c = 1.0$, CHCl_3 ; 75% ee).

Compound 6d'

Prepared according to the general procedure with **6d** (33.6 mg, 0.091 mmol) and NaBH_4 (7.6 mg, 0.20 mmol). The crude material was purified by PLC (eluting with hexane/ethyl acetate = 1:1) to give **6d'** as a white solid [33.6 mg, 0.91 mmol, 99% yield].

^1H NMR (400 MHz, CDCl_3) δ 7.70 (2H, m), 7.39-7.30 (3H, m), 4.42 (1H, dt, $J = 7.0$, 7.0 Hz), 3.96 (1H, d, $J = 11.4$ Hz), 3.73 (1H, m), 2.93-2.79 (3H, m), 2.47 (1H, m), 2.36 (1H, br), 2.02 (1H, m), 1.82 (1H, m), 1.71-1.26 (15H, m), 1.16 (1H, dt, $J = 13.5$, 3.6 Hz), 0.97 (3H, t, $J = 7.4$ Hz); ^{13}C NMR (100 MHz, CDCl_3) δ 170.2, 136.2, 129.5, 128.1, 127.3, 69.4, 63.2, 63.1, 52.2, 47.4, 41.5, 36.7, 35.8, 35.5, 28.0, 26.3, 21.31, 21.27, 20.8, 20.1, 14.4; IR (neat) 3404, 2930, 2859, 1612, 1572, 1450, 1433, 1377 cm^{-1} ; HRMS (ESI) exact mass calcd. for $\text{C}_{23}\text{H}_{34}\text{N}_2\text{O}_2$: m/z 393.2512 ($[\text{M} + \text{Na}]^+$), found: m/z 393.2501 ($[\text{M} + \text{Na}]^+$); $[\alpha]_{\text{D}}^{20} = 51.3$ ($c = 1.0$, CHCl_3 ; 75% ee).

The enantiomeric purity of the product was determined by HPLC analysis (Daicel CHIRALPAK AD-H, hexane/isopropanol = 10:1, flow rate = 0.5 mL/min, retention time; 19.7 (major), 22.2 (minor)).

Compound 6e (Table 3, entry 5)

Prepared according to the representative procedure with **3a** (87.8 mg, 0.25 mmol) and methacrolein (41.2 μL , 0.50 mmol) over the course of 1 h. The crude material was purified

by column chromatography on silica gel (eluting with hexane/ether = 2:3) to give **6e** as a white solid [83.6 mg, 0.246 mmol, 98% yield, exo/endo = 22:78]. The enantiomeric purity of the product was determined after the reduction of the aldehyde (*vide infra*).

^1H NMR (400 MHz, CDCl_3) broad signals, see the chart below (p. S106); ^{13}C NMR (100 MHz, CDCl_3) broad signals, see the chart below (p. S106); IR (neat) 2930, 2860, 1719, 1632, 1574, 1449, 1427 cm^{-1} ; HRMS (ESI) exact mass calcd. for $\text{C}_{21}\text{H}_{28}\text{N}_2\text{O}_2$: m/z 341.2224 ($[\text{M} + \text{H}]^+$), found: m/z 341.2237 ($[\text{M} + \text{H}]^+$); $[\alpha]_{\text{D}}^{17} = -86.5$ ($c = 1.0$, CHCl_3 ; exo/endo = 22:78, 96% ee/97% ee).

Compound 6e'

Prepared according to the general procedure with **6e** (34.0 mg, 0.10 mmol) and NaBH₄ (7.6 mg, 0.20 mmol). The crude material was purified by PLC (eluting with ethyl acetate) to give **6e'** as a white solid [29.8 mg, 0.087 mmol, 87% yield, exo/endo = 22:78].

¹H NMR (400 MHz, CDCl₃) broad signals, see the chart below (p. S107); ¹³C NMR (100 MHz, CDCl₃) broad signals, see the chart below (p. S107); IR (neat) 3387, 2932, 2862, 1614, 1574, 1447, 1420, 1043 cm⁻¹; HRMS (ESI) exact mass calcd. for C₂₁H₃₀N₂O₂: *m/z* 343.2380 ([M + H]⁺), found: *m/z* 343.2375 ([M + H]⁺); [α]_D¹⁷ = -20.6 (*c* = 1.0, CHCl₃; exo/endo = 22:78, 96% ee/97% ee).

The enantiomeric purity of the product was determined by HPLC analysis (Daicel CHIRALPAK AD-H, hexane/isopropanol = 5:1, flow rate = 0.5 mL/min, retention time; 18.3 min (exo, minor), 23.5 (endo, major), 30.5 (exo, major) and 50.2 min (endo, minor)).

Compound 6f (Table 3, entry 6)

Prepared according to the representative procedure with **3c** (77.8 mg, 0.25 mmol) and methacrolein (41.2 μL, 0.50 mmol) over the course of 1 h. The crude material was purified by column chromatography on silica gel (eluting with hexane/ether = 2:3) to give **6f** as a white solid [75.2 mg, 0.250 mmol, 99% yield, exo/endo = 11:89]. The enantiomeric purity of the product was determined after the reduction of the aldehyde (*vide infra*).

¹H NMR (400 MHz, CDCl₃) broad signals, see the chart below (p. S108); ¹³C NMR (100 MHz, CDCl₃) broad signals, see the chart below (p. S108); IR (neat) 2945, 2872, 1722, 1632, 1576, 1449, 1425, 1396, 1366 cm⁻¹; HRMS (ESI) exact mass calcd. for C₁₈H₂₄N₂O₂: *m/z* 301.1911 ([M + H]⁺), found: *m/z* 301.1899 ([M + H]⁺); [α]_D¹⁸ = -116.7 (*c* = 1.0, CHCl₃; exo/endo = 11:89, 98% ee/98% ee).

Compound 6f'

Prepared according to the general procedure with **6f** (30.0 mg, 0.10 mmol) and NaBH₄ (7.6 mg, 0.20 mmol). The crude material was purified by PLC (eluting with ethyl acetate) to give **6f'** as a white solid [27.7 mg, 0.092 mmol, 92% yield, exo/endo = 11:89].

^1H NMR (400 MHz, CDCl_3 , endo isomer) δ 7.57 (2H, br), 7.43-7.35 (3H, m), 4.09 (1H, br), 3.85 (1H, d, J = 10.9 Hz), 3.64 (1H, d, J = 8.9 Hz), 3.43 (1H, d, J = 8.9 Hz), 3.37 (1H, br), 2.82 (1H, br), 2.50 (1H, s), 2.31 (1H, m), 2.01 (1H, br), 1.56 (1H, br), 1.36-1.16 (5H, m), 1.08 (3H, s), 1.06 (3H, s); ^{13}C NMR (100 MHz, CDCl_3) δ 168.8, 136.6, 130.3, 128.2, 127.9, 80.2, 66.9, 60.3, 55.9, 45.5, 43.3, 35.8, 28.4, 21.7, 21.4, 20.7; IR (neat) 3402, 2938, 2878, 1620, 1574, 1447, 1414, 1371, 1049, 1016cm^{-1} ; HRMS (ESI) exact mass calcd. for $\text{C}_{18}\text{H}_{26}\text{N}_2\text{O}_2$: m/z 303.2067 ($[\text{M} + \text{H}]^+$), found: m/z 303.2065 ($[\text{M} + \text{H}]^+$); $[\alpha]_{\text{D}}^{20} = -56.6$ (c = 1.0, CHCl_3 ; exo/endo = 11:89, 98% ee/98% ee). The enantiomeric purity of the product was determined by HPLC analysis (Daicel CHIRALPAK AD-H, hexane/ethanol = 10:1, flow rate = 0.5 mL/min, retention time; 26.8 min (exo, minor), 28.6 (endo, major), 47.3 (exo, major) and 51.4 min (endo, minor)).

Compound 6g' (Table 3, entry 7)

Prepared according to the general procedure with **3a** (87.8 mg, 0.25 mmol) and acrolein (33.4 μL , 0.50 mmol) over the course of 1 h. Due to the susceptibility of thus-formed cycloadduct **6g**

for epimerization, the reaction solution was then directly treated with a solution of NaBH_4 (18.9 mg, 0.50 mmol) in MeOH (1 mL) at 0 $^\circ\text{C}$ for 30 min. After quenching with saturated NH_4Cl aq., the organic layer was extracted with CH_2Cl_2 , dried over Na_2SO_4 and concentrated in vacuo. The crude material was purified by column chromatography on silica gel (eluting with hexane/ether = 1:5) to give **6g'** as a white solid [80.4 mg, 0.245 mmol, 98% yield, exo/endo = 15:85].

^1H NMR (400 MHz, CDCl_3) broad signals, see the chart below (p. S110); ^{13}C NMR (100 MHz, CDCl_3) broad signals, see the chart below (p. S110); IR (neat) 3395, 2930, 2859, 1611, 1572, 1456, 1437, 1036 cm^{-1} ; HRMS (ESI) exact mass calcd. for $\text{C}_{20}\text{H}_{28}\text{N}_2\text{O}_2$: m/z 329.2224 ($[\text{M} + \text{H}]^+$), found: m/z 329.2223 ($[\text{M} + \text{H}]^+$); $[\alpha]_{\text{D}}^{15} = 6.0$ (c = 1.0, CHCl_3 ; exo/endo = 15:85, 83% ee/96% ee).

The enantiomeric purity and exo/endo selectivity of the product were determined by HPLC analysis (Daicel CHIRALPAK AD-H, hexane/ethanol = 10:1, flow rate = 1.0 mL/min, retention time; 15.2 min (exo, minor), 21.9 (endo, major), 31.8 (exo, major) and 54.5 min (endo, minor)).

Compound 6h' (Table 3, entry 8)

Prepared according to the general procedure with **3b** (84.3 mg, 0.25 mmol) and acrolein (33.4 μ L, 0.50 mmol) over the course of 1 h. Due to the susceptibility of thus-formed cycloadduct **6h** for epimerization, the reaction solution was then directly treated with a solution of NaBH₄ (18.9 mg, 0.50 mmol) in MeOH (1 mL) at 0 °C for 30 min. After quenching with saturated NH₄Cl aq., the organic layer was extracted with CH₂Cl₂, dried over Na₂SO₄ and concentrated in vacuo. The crude material was purified by column chromatography on silica gel (eluting with hexane/ether = 1:5) to give **6h'** as a white solid [76.1 mg, 0.242 mmol, 97% yield, exo/endo = 13:87].

¹H NMR (400 MHz, CDCl₃) broad signals, see the chart below (p. S111); ¹³C NMR (100 MHz, CDCl₃) broad signals, see the chart below (p. S111); IR (neat) 3404, 2947, 2862, 1611, 1570, 1454, 1437, 1030 cm⁻¹; HRMS (ESI) exact mass calcd. for C₁₉H₂₆N₂O₂: m/z 315.2067 ([M + H]⁺), found: m/z 315.2060 ([M + H]⁺); [α]_D¹⁷ = 14.4 (c = 1.0, CHCl₃; exo/endo = 13:87, 96% ee/89% ee).

The enantiomeric purity and exo/endo selectivity of the product were determined by HPLC analysis (Daicel CHIRALPAK AD-H, hexane/ethanol = 10:1, flow rate = 1.0 mL/min, retention time; 14.3 min (exo, minor), 22.5 (endo, major), 30.7 (exo, major) and 36.5 min (endo, minor)).

Compound **6i'** (Table 3, entry 9)

Prepared according to the general procedure with **3c** (77.8 mg, 0.25 mmol) and acrolein (33.4 μ L, 0.50 mmol) over the course of 1 h. Due to the susceptibility of thus-formed cycloadduct **6i** for epimerization, the reaction solution was then directly treated with a solution of NaBH₄ (18.9 mg, 0.50 mmol) in MeOH (1 mL) at 0 °C for 30 min. After quenching with saturated NH₄Cl aq., the organic layer was extracted with CH₂Cl₂, dried over Na₂SO₄ and concentrated in vacuo. The crude material was purified by column chromatography on silica gel (eluting with hexane/ether = 1:5) to give **6i'** as a white solid [69.5 mg, 0.241 mmol, 96% yield, exo:endo = 7:93].

¹H NMR (400 MHz, CDCl₃) broad signals, see the chart below (p. S112); ¹³C NMR (100 MHz, CDCl₃) broad signals, see the chart below (p. S112); IR (neat) 3393, 2947, 2868, 1614, 1574, 1449, 1418, 1389, 1373, 1030, 1007 cm⁻¹; HRMS (ESI) exact mass calcd. for C₁₇H₂₃N₂O₂: m/z 311.1730 ([M + Na]⁺), found: m/z 311.1719 ([M + Na]⁺); [α]_D¹⁸ = -67.1 (c = 1.0, CHCl₃; exo/endo = 7:93, 75% ee/97% ee).

The enantiomeric purity and exo/endo selectivity of the product were determined by HPLC analysis (Daicel CHIRALPAK AD-H, hexane/ethanol = 10:1, flow rate = 1.0 mL/min, retention time; 12.7 min (exo, minor), 18.3 (endo, major), 24.5 (exo, major) and 35.0 min (endo, minor)).

Samarium iodide-mediated reductive cleavage of the N-N bond of the cycloadduct (Scheme 1)

To a stirred solution of **2a'** (32.2 mg, 0.10 mmol) in MeOH (0.50 mL) was added a freshly prepared 0.1M THF solution of SmI_2 (4.0 mL, 0.40 mmol) at room temperature. After stirring for 30 min at room temperature, the reaction solution was poured into saturated NaHCO_3 aq and extracted with ethyl acetate. The organic extracts were washed with brine, dried over Na_2SO_4 and evaporated in vacuo. The residue was purified by column chromatography on silica gel (eluting with $\text{CH}_2\text{Cl}_2/\text{MeOH} = 10:1$ with 0.5% Et_3N) to give **7** as a colorless oil [32.4 mg, 0.10 mmol].

^1H NMR (400 MHz, CDCl_3) δ 7.39 (1H, m), 7.27-7.14 (6H, m), 7.00 (1H, m), 6.84 (1H, d, $J = 7.7$ Hz), 6.40 (1H, d, $J = 9.4$ Hz), 4.77 (1H, m), 4.41 (1H, br), 4.02 (1H, dd, $J = 11.2, 4.0$ Hz), 3.95 (1H, dd, $J = 11.4, 3.9$ Hz), 3.82 (2H, br), 3.33 (1H, ddd, $J = 13.0, 5.6, 2.4$ Hz), 2.93 (1H, ddd, $J = 13.0, 11.5, 4.2$ Hz), 2.79 (1H, ddd, $J = 16.4, 11.5, 5.1$ Hz), 2.54 (1H, app dt, $J = 16.2, 2.7$ Hz), 2.45 (1H, m), 1.25 (3H, d, $J = 6.5$ Hz); ^{13}C NMR (100 MHz, CDCl_3) δ 166.3, 138.6, 135.1, 133.7, 131.2, 130.2, 128.1, 126.5, 126.2, 125.8, 124.6, 65.8, 60.1, 48.1, 43.5, 42.8, 29.3, 21.0; IR (neat) 1636, 1574, 1531, 1487, 1452, 1350, 1315, 1294, 1121, 1069 cm^{-1} ; HRMS (ESI) exact mass calcd. for $\text{C}_{20}\text{H}_{24}\text{N}_2\text{O}_2$: m/z 325.1911 ($[\text{M} + \text{H}]^+$), found: m/z 325.1918 ($[\text{M} + \text{H}]^+$); $[\alpha]_{\text{D}}^{26} = -78.1$ ($c = 1.0$, CHCl_3 ; 92% ee).

Determination of the relative and absolute configuration of **2h by X-ray crystallographic analysis.**

The product **2h** was recrystallized from hexane/CH₂Cl₂. The single crystal was mounted on a MicroMeshTM (MiTeGen). Data of X-ray diffraction were collected by a Rigaku RAXIS-RAPID Imaging Plate two-dimensional area detector using graphite-monochromated CuK α (λ = 1.54187 Å) to a maximum 2θ value of 136.5°. The crystal structure was solved by the direct methods and refined by the full-matrix least squares using the program SHELXL-97.³ All non-hydrogen atoms were refined anisotropically. Hydrogen atoms were refined by using the riding model. The crystallographic data were summarized in the following table. The absolute configuration was determined by reference to the Flack parameter.⁴

empirical formula	C ₂₀ H ₂₁ BrN ₂ O ₂
formula weight	401.30
crystal system	orthorhombic
space group	P2 ₁ 2 ₁ 2 ₁ (#19)
<i>a</i> , Å	5.45891(10)
<i>b</i> , Å	11.3397(2)
<i>c</i> , Å	28.9935(5)
<i>V</i> , Å ³	1794.77(6)
<i>Z</i>	4
<i>D</i> _{calc} , g/cm ³	1.485
<i>T</i> , °C	−150
μ (CuK α), cm ^{−1}	32.489
no. of reflns meased	18056
no. of reflns obsd	3278
no. of reflns variable	227
R (All reflections)	0.0394
R _w (All reflections)	0.0898
Goodness of Fit	1.079
Flack Parameter (Friedel pairs = 1337)	0.00(2)

The crystal structure has been deposited at the Cambridge Crystallographic Data Centre (CCDC 721288). The data can be obtained free of charge via the Internet at

Determination of the relative configuration of 6c' by X-ray crystallographic analysis.

The product **6c'** was recrystallized from ether. The single crystal was mounted on a MicroMeshTM (MiTeGen). Data of X-ray diffraction were collected by a Rigaku RAXIS-RAPID Imaging Plate two-dimensional area detector using graphite-monochromated CuK α ($\lambda = 1.54187 \text{ \AA}$) to a maximum 2θ value of 136.5° . The crystal structure was solved by the direct methods and refined by the full-matrix least squares using the program SHELXL-97.³ All non-hydrogen atoms were refined anisotropically. Hydrogen atoms were refined by using the riding model. The crystallographic data were summarized in the following table.

empirical formula	C ₁₈ H ₂₆ O ₂ N ₂
formula weight	302.42
crystal system	orthorhombic
space group	P2 ₁ 2 ₁ 2 ₁ (#19)
<i>a</i> , Å	9.46167(17)
<i>b</i> , Å	11.9002(2)
<i>c</i> , Å	15.0505(3)
<i>V</i> , Å ³	1694.62(5)
<i>Z</i>	4
<i>D</i> _{calc} , g/cm ³	1.185
<i>T</i> , °C	−150
μ (CuK α), cm ^{−1}	6.121
no. of reflns meased	17781
no. of reflns obsd	3091
no. of reflns variable	200
R (All reflections)	0.0379
R _w (All reflections)	0.0877
Goodness of Fit	1.077
Flack Parameter (Friedel pairs = 1304)	0.1(2)

The crystal structure has been deposited at the Cambridge Crystallographic Data Centre (CCDC 728185). The data can be obtained free of charge via the Internet at www.ccdc.cam.ac.uk/conts/retrieving.html.

Determination of the relative configuration of *endo*-6f' by X-ray crystallographic analysis.

The product **6f'** was recrystallized from hexane/ether. The single crystal was mounted on a MicroMeshTM (MiTeGen). Data of X-ray diffraction were collected by a Rigaku RAXIS-RAPID Imaging Plate two-dimensional area detector using graphite-monochromated CuK α ($\lambda = 1.54187 \text{ \AA}$) to a maximum 2θ value of 136.5° . The crystal structure was solved by the direct methods and refined by the full-matrix least squares using the program SHELXL-97.³ All non-hydrogen atoms were refined anisotropically. Hydrogen atoms were refined by using the riding model. The crystallographic data were summarized in the following table.

empirical formula	C ₁₈ H ₂₆ N ₂ O ₂
formula weight	302.42
crystal system	monoclinic
space group	P2 ₁ (#4)
<i>a</i> , Å	8.35231(18)
<i>b</i> , Å	10.2400(2)
<i>c</i> , Å	9.6410(2)
β , °	91.1862(14)
<i>V</i> , Å ³	824.39(3)
<i>Z</i>	2
<i>D</i> _{calc} , g/cm ³	1.218
<i>T</i> , °C	−150
μ (CuK α), cm ^{−1}	6.291
no. of reflns measured	8785
no. of reflns obsd	2924
no. of reflns variable	200
R (All reflections)	0.0500
R _w (All reflections)	0.1148
Goodness of Fit	1.101
Flack Parameter (Friedel pairs = 1331)	0.1(3)

The crystal structure has been deposited at the Cambridge Crystallographic Data Centre (CCDC 763540). The data can be obtained free of charge via the Internet at

Determination of the relative configuration of *endo*-6i' by X-ray crystallographic analysis.

The product **6i'** was recrystallized from hexane/ether. The single crystal was mounted on a MicroMeshTM (MiTeGen). Data of X-ray diffraction were collected by a Rigaku RAXIS-RAPID Imaging Plate two-dimensional area detector using graphite-monochromated CuK α ($\lambda = 1.54187 \text{ \AA}$) to a maximum 2θ value of 136.5° . The crystal structure was solved by the direct methods and refined by the full-matrix least squares using the program SHELXL-97.³ All non-hydrogen atoms were refined anisotropically. Hydrogen atoms were refined by using the riding model. The crystallographic data were summarized in the following table.

empirical formula	C ₁₇ H ₂₄ N ₂ O ₂
formula weight	288.39
crystal system	monoclinic
space group	P2 ₁ (#4)
<i>a</i> , Å	6.10829(12)
<i>b</i> , Å	7.50970(15)
<i>c</i> , Å	17.8862(3)
β , °	93.2667(12)
<i>V</i> , Å ³	819.13(3)
<i>Z</i>	2
<i>D</i> _{calc} , g/cm ³	1.169
<i>T</i> , °C	−150
μ (CuK α), cm ^{−1}	6.109
no. of reflns meased	8758
no. of reflns obsd	2864
no. of reflns variable	191
R (All reflections)	0.0774
R _w (All reflections)	0.1580
Goodness of Fit	1.141
Flack Parameter (Friedel pairs = 1242)	0.0(4)

The crystal structure has been deposited at the Cambridge Crystallographic Data Centre (CCDC 763148). The data can be obtained free of charge via the Internet at

www.ccdc.cam.ac.uk/conts/retrieving.html.

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