Supplementary Material

A $C_3$-symmetric chiroptical molecular propeller based on hexakis(phenylethynyl)benzene with a threefold terephthalamide: stereospecific propeller generation through the cooperative transmission of point chiralities on the host and guest upon complexation

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Supplementary Figures and Table

**Fig. S1** \(^1\text{H} \) NMR spectra (400 MHz) of (a) \((R,R,R)\)-1a, (b) \((R)\)-3a, (c) 1b, and (d) 3b, measured in CDCl\(_3\) at room temperature. Nonequivalent phenylene protons [(H\(_1\)–H\(_3\)) and (H\(_4\)–H\(_6\))] and methylene protons [H\(_7\) and H\(_8\)] are not assigned in each set, respectively in spectra (a) and (b).

**Fig. S2** Energy-minimized structures for 3' [X = Y = Me] obtained by a conformational search with MacroModel software (v9.9 Monte Carlo Multiple Minimum method, MMFF*, nonsolvated, 20000 steps): (a) a nonhelical conformation (0 kJ mol\(^{-1}\)) and (b) a helical conformation (+16.6 kJ mol\(^{-1}\)).
Fig. S3  (a) UV-vis spectra of (R,R,R)-1a (bold black), (R,R,R)-4 (thin black), (R)-3a (bold red), and (R)-5 (thin red), and (b) CD spectra of (R,R,R)-1a (bold black), and (R,R,R)-4 (thin black), measured in CH₂Cl₂ at room temperature.

Fig. S4  X-ray structure of 3c [X = Y = nBu] (P2₁, Z = 4) in 3c·chloroform crystal. The crystallization solvent is omitted for clarity.
Fig. S5  (a) CD spectra of 1b (7.7 × 10^{-5} M) upon complexation with (R,R)-2 [blue lines; i) 3 equiv., ii) 6 equiv., and iii) 11 equiv.] and (S,S)-2 [red lines; iv) 3 equiv., v) 6 equiv., and vi) 12 equiv.], and CD spectra of (R,R)-2 [thin blue line, vii] and (S,S)-2 [thin red line, viii]. (b) CD spectra of 3b (3.3 × 10^{-4} M) upon complexation with (R,R)-2 [blue lines; i) 1 equiv., ii) 2 equiv., and iii) 4 equiv.] and (S,S)-2 [red lines; iv) 1 equiv., v) 2 equiv., and vi) 4 equiv.]. All spectra were measured in CH₂Cl₂ at room temperature.

Fig. S6  NMR titration curves for the diastereomeric complexation of (R)-3a with (a) (R,R)-2 ([[(R)-3a] = 1.83 mM, [(R,R)-2] = 0.82 mM), and (b) (S,S)-2 ([[(R)-3a] = 1.87 mM, [(S,S)-2] = 0.83 mM), measured in CDCl₃ at 298 K. We assumed a 1:1 ratio for these complexes, and then curve-fitted the observed data (H') to give association constants Kₐ of 6.6 × 10⁴ M⁻¹ for (R)-3a-(R,R)-2 and 6.4 × 10⁴ M⁻¹ for (R)-3a-(S,S)-2.
Fig. S7  Continuous changes in the CD spectra of \((R,R,R)\text{-}1\text{a} (8.1 \times 10^{-5} \text{ M})\) in the presence of \((R,R)\text{-}2\) and \((S,S)\text{-}2\) \([2]/[1] = 12\) in various ratios \([\text{(R,R)}\text{-}2]/\text{(S,S)}\text{-}2\); i) 0:12 \(((S,S)\text{-}2\) only, red line), ii) 3:9, iii) 6:6, and iv) 12:0 \(((R,R)\text{-}2\) only, blue line)], measured in \(\text{CH}_2\text{Cl}_2\) at room temperature. Complexation-induced CD signals showed continuous changes in the two saturated CD spectra given by the addition of \((S,S)\text{-}2\) only \((\text{Fig}.4\text{a})\) or \((R,R)\text{-}2\) only \((\text{Fig}. 3\text{a})\), with an increase in the ratio of \((R,R)\text{-}2/\text{(S,S)}\text{-}2\) (matched to mismatched). This can be explained as one of the possibilities if we assume that the association constant was comparable for the two diastereomeric complexes.

Table S1  Molar CDs \((\Delta\varepsilon)\) at 262, 296, and 326 nm induced for \((R,R,R)\text{-1a} (8 \times 10^{-5} \text{ M})\) in the presence of \((R,R)\text{-}2\) and \((S,S)\text{-}2\) in various ratios, measured in \(\text{CH}_2\text{Cl}_2\) at room temperature.

<table>
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<th>equiv.</th>
<th>([(R,R)\text{-}2]/[\text{(S,S)}\text{-}2])</th>
<th>ratio</th>
<th>Molar CDs ((\Delta\varepsilon)) at 262 nm</th>
<th>Molar CDs ((\Delta\varepsilon)) at 296 nm</th>
<th>Molar CDs ((\Delta\varepsilon)) at 326 nm</th>
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<td>-1.2</td>
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<tr>
<td></td>
<td>3</td>
<td>9</td>
<td>-9.3</td>
<td>+0.3</td>
<td>-5.3</td>
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<tr>
<td></td>
<td>6</td>
<td>6</td>
<td>-11.8</td>
<td>+0.7</td>
<td>-6.5</td>
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<tr>
<td></td>
<td>12</td>
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<td>-17.3</td>
<td>+2.1</td>
<td>-10.3</td>
</tr>
<tr>
<td>8 equiv.</td>
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<td>4</td>
<td>-12.1</td>
<td>+0.3</td>
<td>-6.5</td>
</tr>
<tr>
<td>6 equiv.</td>
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<td>6</td>
<td>-6.2</td>
<td>-0.8</td>
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<tr>
<td></td>
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<td>3</td>
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<tr>
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<td>3 equiv.</td>
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<td>-7.9</td>
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</table>

\(^{\text{x}}\) not saturated (uncomplexed \(\text{1}\) would be present in a lower-equivalent-solution.
Experimental Details of New Compound Preparation

Scheme S1  Preparation of 1a/b and 3a-c  Reagents and yields; (a) TIPSA, Pd(PPh$_3$)$_4$, CuI, Et$_3$N (79%); (b) CBr$_4$, PPh$_3$, Zn, CH$_2$Cl$_2$ (95%); (c) BuLi, THF (49%); (d) 18b, Pd(PPh$_3$)$_4$, CuI, THF, Pr$_2$NH (73%); (e) i) TFA, CH$_2$Cl$_2$ (96% for 10'), ii) 10', 21a'/b', Et$_3$N, toluene (93% for 11a/96% for 11b); (f) TBAF, Pd(PPh$_3$)$_4$, CuI, Et$_3$N, THF (2.7% for 1a/2.1% for 1b); (g) 18b/c, Pd(PPh$_3$)$_4$, CuI, THF, Pr$_2$NH (69% for 13b/85% for 13c); (h) i) TFA, CH$_2$Cl$_2$ (88% for 13b'/89% for 13c'), ii) 13b'/c', 21a'-c', Et$_3$N, toluene (97% for 14a/99% for 14b/94% for 14c); (i) TBAF, Pd(PPh$_3$)$_4$, CuI, Et$_3$N, THF (13% for 3a/18% for 3b/11% for 3c). Regarding the new compounds 18 and 21, see Scheme S3.

Preparation of 7

A suspended solution of 6' (4.99 g, 12.5 mmol), triisopropylsilylacetylene (10.0 mL, 45.0 mmol), Pd(PPh$_3$)$_4$ (433 mg, 375 μmol) and Cul (144 mg, 756 μmol) in Et$_3$N (470 mL) was refluxed for 2 d under a nitrogen atmosphere. After dilution with diethyl ether, a solid was removed by filtration through a celite pad. The filtrate was cooled down in an ice-bath, and added 1N HCl aq., and then separated. The aqueous layer was
further extracted with diethyl ether. The combined organic layer was washed with brine, and then dried over MgSO₄. Chromatographic separation on SiO₂ (0-20% dichloromethane/hexane) gave 7 (6.91 g) as a yellow solid in 79% yield.

An analytical sample was obtained as orange crystals by recrystallization from hexane.

Data of 7
mp 164.0-164.5 °C; ¹H NMR δH(400 MHz, CDCl₃, TMS)/ppm 10.75 (3H, s), 1.22-1.13 (63H, m); ¹³C NMR δC(100 MHz, CDCl₃)/ppm 189.3, 138.6, 128.1, 112.3, 98.1, 18.6, 11.2; IR (KBr) 3396, 2944, 2864, 2749, 2152, 1708, 1524 cm⁻¹; FD-LRMS m/z 704.4 ([M+2]⁺, 32%), 703.4 ([M+1]⁺, 66), 702.4 (M⁺, BP); Anal. Calcd. for C₄₂H₆₆O₃Si₃C 71.73, H 9.46, Found C 71.63, H 9.64.

Preparation of 8
To an ice-cooled suspended solution of CBr₄ (23.6 g, 71.0 mmol) and Zn powder (4.64 g, 70.9 mmol) in CH₂Cl₂ (490 mL) was added a solution of PPh₃ (18.7 g, 71.1 mmol) in CH₂Cl₂ (120 mL), and the mixture was stirred at 0 °C for 30 min. Then a solution of 7 in CH₂Cl₂ (100 mL) was added to the above solution at room temperature, and the mixture was further stirred for 2 d. After addition of SiO₂ (30 g) to the reaction mixture, a solid was removed by filtration. The filtrate was concentrated by evaporation, and then purified by column chromatography on SiO₂ (0-20% dichloromethane/hexane) to give 8 (6.44 g) as a white solid in 95% yield.

An analytical sample was obtained as a white solid by further purification through GPC (chloroform, detected by UV 254 nm and RI).

Data of 8
mp 81-83 °C; ¹H NMR δH(400 MHz, CDCl₃, TMS)/ppm 7.53 (3H, s), 1.19-1.14 (63H, m); ¹³C NMR δC(100 MHz, CDCl₃)/ppm 141.6, 135.0, 122.2, 102.5, 101.2, 96.2, 18.8, 11.2; IR (KBr) 2942, 2889, 2864, 2154, 1601, 1535 cm⁻¹; FD-LRMS m/z 1172.0 ([M+8]⁺, 85%), 1171.0 ([M+7]⁺, 59), 1170.0 ([M+6]⁺, BP), 1168.0 ([M+4]⁺, 69); Anal. Calcd. for C₄₅H₆₆Br₆Si₃C 46.17, H 5.68, Found C 46.02, H 5.56.

Preparation of 9
To a solution of 8 (3.53 g, 3.02 mmol) in THF (208 mL) was added a 1.6 M nBuLi solution in hexane (12.3 mL, 19.1 mmol) at –78 °C, and the mixture was stirred at the temperature for 50 min. After addition of 1N HCl aq. and dilution with hexane, the organic layer was separated and washed with brine, and then dried over MgSO₄. Chromatographic separation on SiO₂ (hexane) gave 9 (1.01 g) as a white solid in 49% yield.

Data of 9
mp 156-160 °C (decomp.); ¹H NMR δH(400 MHz, CDCl₃, TMS)/ppm 3.55 (3H, s), 1.20-1.10 (63H, m); ¹³C NMR δC(100 MHz, CDCl₃)/ppm 129.7, 127.1, 103.1, 102.2, 87.0, 80.5, 18.6, 11.2; IR (KBr) 3309, 2960, 2942, 2889, 2864, 2851, 2162, 2109, 1521 cm⁻¹; FD-LRMS m/z 692.5 ([M+2]⁺, 34%), 691.5 ([M+1]⁺, 66), 690.5 (M⁺, BP).

Preparation of 10
To a solution of 9 (760 mg, 1.10 mmol) and 18b (1.55 g, 3.73 mmol) in 1:1 THF/Pr₂NH (44 mL) were added
Pd(PPh₃)₄ (114 mg, 0.0987 mmol) and CuI (29 mg, 0.15 mmol) at 60 °C under a nitrogen atmosphere, and the mixture was stirred at the temperature for 36 h. After addition of diethyl ether, the resulting precipitates were removed by filtration. The filtrate was concentrated by evaporation, and then purified by column chromatography on SiO₂ (4:1 chloroform/hexane) to give 10 (1.25 g) as a white solid in 73% yield.

An analytical sample was obtained as colorless crystals by slow evaporation from hexane.

Data of 10 [X = CH₂(cHex)]

mp 247-248 °C (decomp.); ¹H NMR δH(400 MHz, CDCl₃, TMS)/ppm 7.48 (6H, d, J = 8.4 Hz), 7.16 (6H, d, J = 8.4 Hz), 3.54 (6H, d, J = 7.2 Hz), 1.76-1.58 (15H, br.m), 1.51-1.36 (3H, br.m), 1.43 (27H, s), 1.21-0.84 (78H, br.m); ¹³C NMR δC(100 MHz, CDCl₃)/ppm 154.6, 143.0, 132.1, 128.4, 127.8, 126.4, 120.2, 103.1, 102.3, 98.5, 86.8, 80.1, 55.4, 36.7, 30.7, 28.3, 26.4, 18.6, 11.2; IR (KBr) 2926, 2863, 2214, 2154, 1703, 1603, 1508, 1450 cm⁻¹; FD-LRMS m/z 1554.1 ([M+2]+, 74%), 1553.1 ([M+1]+, BP), 1552.1 (M⁺, 81), 1453.1 ([M+1–BOC+H]+, 25), 1353.0 ([M+1–BOC×2+2H]+, 15), 1252.9 ([M+1–BOC×3+3H]+, 31); Anal. Calcd. for C₉₉H₁₄₁N₃O₆Si₃C 76.54, H 9.15, N 2.70, Found C 76.58, H 9.45, N 2.52.

Preparation of 11a [X = CH₂(cHex), Y = (R)-CHMe(cHex)]

To a refluxed solution of 21a (1.05 g, 2.20 mmol) and BnNEt₃Cl (6.5 mg, 0.029 mmol) in CH₂Cl₂ (15 mL) was added SOCl₂ (0.23 mL, 3.2 mmol), and the mixture was further refluxed for 1 h. After removal of the solvent by evaporation, the resulting solid (21a') was dried in vacuo and dissolved in toluene (10 mL) [acid chloride preparation].

To a solution of 10 (1.06 g, 0.682 mmol) in CH₂Cl₂ (70 mL) was added TFA (6.7 mL), and the mixture was stirred at room temperature for 75 min, and then diluted with CH₂Cl₂ (210 mL). The diluted reaction mixture was quenched by addition of satd. NaHCO₃ aq. The organic layer was separated, and then dried over MgSO₄. Chromatographic separation on SiO₂ (2:3 dichloromethane/hexane) gave 1,3,5-tris[p-(N-cyclohexylmethylamino)phenylethynyl]-2,4,6-tris(triisopropylsilylethynyl)benzene 10' (823 mg) as a yellow solid in 96% yield [deprotection of BOC].

To a solution of 10' (823 mg, 0.657 mmol) and Et₃N (1.4 mL, 10 mmol) in toluene (11 mL) were added the freshly prepared toluene solution (10 mL) containing the acid chloride 21a’ and extra toluene (6+6 mL) at room temperature, and the mixture was stirred at 80 °C for 14 h. After addition of 1N NaOH aq., the organic layer was separated and washed with water and brine, and then dried over MgSO₄. Chromatographic separation on SiO₂ (0-10% ethyl acetate/chloroform) gave 11a (1.60 g) as a white solid in 93% yield.

An analytical sample was obtained as a white solid by further purification through GPC (chloroform, UV detected by 254 nm and RI).

Data of 11a [X = CH₂(cHex), Y = (R)-CHMe(cHex)]

mp 153-155 °C; ¹H NMR δH(400 MHz, CDCl₃, TMS)/ppm 7.48 (6H, d, J = 8.0 Hz), 7.33 (6H, d, J = 8.0 Hz), 7.10 (6H, d, J = 7.6 Hz), 7.03 (6H, d, J = 7.6 Hz), 6.88 (6H, d, J = 8.0 Hz), 6.62 (6H, d, J = 8.0 Hz), 4.41 (3H, br.s), 3.82 (3H, dd, J = 7.2, 13.6 Hz), 3.75 (3H, dd, J = 7.2, 13.6 Hz), 2.03 (3H, br.d), 1.85-1.43 (33H, br.m), 1.27-0.90 (102H, m); ¹³C NMR δC(100 MHz, CDCl₃)/ppm 169.8, 169.4, 143.6, 143.6, 134.1, 132.1, 128.4, 127.8, 126.4, 120.2, 103.1, 102.3, 98.5, 86.8, 80.1, 55.4, 36.7, 30.7, 28.3, 26.4, 18.6, 11.2; IR (KBr) 2926, 2863, 2214, 2154, 1703, 1603, 1508, 1450 cm⁻¹; FD-LRMS m/z 1554.1 ([M+2]+, 74%), 1553.1 ([M+1]+, BP), 1552.1 (M⁺, 81), 1453.1 ([M+1–BOC+H]+, 25), 1353.0 ([M+1–BOC×2+2H]+, 15), 1252.9 ([M+1–BOC×3+3H]+, 31); Anal. Calcd. for C₉₉H₁₄₁N₃O₆Si₃C 76.54, H 9.15, N 2.70, Found C 76.58, H 9.45, N 2.52.
141.0, 138.3, 138.0, 136.7, 132.5, 131.3, 128.3, 128.0, 127.6, 126.8, 121.0, 103.0, 102.5, 97.8, 92.4, 87.7, 58.9, 55.8, 41.2, 36.4, 30.9, 30.9, 30.8, 30.3, 26.3, 26.2, 26.0, 25.9, 25.8, 18.7, 16.7, 11.2; IR (KBr) 2925, 2861, 2211, 2153, 1655, 1650, 1601, 1504, 1484, 1449, 1403 cm\(^{-1}\); FD-LRMS m/z 2632.0 ([M+3]+, 69%), 2631.0 ([M+2]+, BP), 2630.0 ([M+1]+, 95), 2629.0 (M+, 57); \([\alpha]\)\(_D\)\(^{24}\) –37.7 (c 0.29 in CHCl\(_3\)); Anal. Calcd. for C\(_{150}\)H\(_{183}\)N\(_6\)O\(_6\)I\(_3\)Si\(_3\)C 68.47, H 7.01, N 3.19, Found C 68.61, H 7.21, N 3.12.

**Preparation of 11b [X = Y = CH\(_3\)(cHex)]**

To a refluxed solution of 21b (1.11 g, 2.40 mmol) and BnNEt\(_3\)Cl (12 mg, 0.053 mmol) in CH\(_2\)Cl\(_2\) (18 mL) was added SOCl\(_2\) (0.24 mL, 3.3 mmol), and the mixture was further refluxed for 10 h. After removal of the solvent by evaporation, the resulting solid (21b') was dried in vacuo and dissolved in toluene (8 mL) [acid chloride preparation].

To a solution of 10 (1.10 g, 0.710 mmol) in CH\(_2\)Cl\(_2\) (72 mL) was added TFA (7.0 mL), and the mixture was stirred at room temperature for 85 min, and then diluted with CH\(_2\)Cl\(_2\) (210 mL). The diluted reaction mixture was quenched by addition of satd. NaHCO\(_3\) aq. The organic layer was separated, and then dried over MgSO\(_4\). Chromatographic separation on SiO\(_2\) (2:3 dichloromethane/hexane) gave 10' (832 mg) as a yellow solid in 93% yield [deprotection of BOC].

To a solution of 10' (832 mg, 0.664 mmol) and Et\(_3\)N (1.4 mL, 10 mmol) in toluene (11 mL) were added the freshly prepared toluene solution (8 mL) containing the acid chloride 21b' and extra toluene (6+6 mL) at room temperature, and the mixture was stirred at 80 °C for 12 h. After addition of 1N NaOH aq., the organic layer was separated and washed with water and brine, and then dried over MgSO\(_4\). Chromatographic separation on SiO\(_2\) (0-10% ethyl acetate/chloroform) gave 11b (1.65 g) as a white solid in 96% yield.

An analytical sample was obtained as a white solid by further purification through GPC (chloroform, UV detected by 254 nm and RI).

**Data of 11b [X = Y = CH\(_3\)(cHex)]**

mp 138-140 °C; \(^1\)H NMR \(\delta\)\(_H\) (400 MHz, CDCl\(_3\), TMS)/ppm 7.49 (6H, d, \(J = 8.4\) Hz), 7.33 (6H, d, \(J = 8.0\) Hz), 7.12 (6H, d, \(J = 8.0\) Hz), 7.06 (6H, d, \(J = 8.0\) Hz), 6.90 (6H, d, \(J = 8.4\) Hz), 6.65 (6H, d, \(J = 8.4\) Hz), 3.79 (6H, d, \(J = 6.8\) Hz), 3.70 (6H, d, \(J = 7.2\) Hz), 3.75-1.48 (36H, br.m), 1.22-0.88 (93H, br.m); \(^{13}\)C NMR \(\delta\)\(_C\) (100 MHz, CDCl\(_3\))/ppm 169.4, 143.5, 143.2, 138.2, 137.3, 137.1, 132.5, 129.2, 128.3, 128.2, 128.0, 126.9, 121.1, 103.0, 102.5, 97.7, 91.3, 87.6, 55.9, 55.8, 36.4, 36.2, 30.9, 30.8, 26.3, 25.8, 25.7, 18.7, 18.5, 11.2; IR (KBr) 2924, 2861, 2212, 2155, 1654, 1650, 1602, 1505, 1485, 1449, 1406 cm\(^{-1}\); FD-LRMS m/z 2589.9 ([M+3]+, 69%), 2588.9 ([M+2]+, BP), 2587.9 ([M+1]+, 99), 2586.9 (M+, 56); Anal. Calcd. for C\(_{147}\)H\(_{177}\)N\(_6\)O\(_6\)I\(_3\)Si\(_3\)C 68.20, H 6.89, N 3.25, Found C 68.61, H 6.98, N 3.21.

**Preparation of (R,R,R)-1a [X = CH\(_3\)(cHex), Y = (R)-CHMe(cHex)]**

To a solution of 11a (217 mg, 82.5 \(\mu\)mol), Pd(PPh\(_3\))\(_4\) (143 mg, 124 \(\mu\)mol) and CuI (12 mg, 63 \(\mu\)mol) in Et\(_3\)N (83 mL) was added a solution of TBAF (0.26 mmol) in THF (8.25 mL) at 55 °C over a period of 12 h using a syringe pump under a nitrogen atmosphere, and the reaction mixture was further stirred at the temperature for 1.5 h. After removal of a solid by filtration, the filtrate was concentrated by evaporation and dissolved in
chloroform. The solution was washed with 1N HCl aq. and satd. NaHCO₃ aq., and then dried over MgSO₄.

Chromatographic separation on SiO₂ (0-20% ethyl acetate/chloroform) gave a mixture containing (R,R,R)-1a, which was further purified by GPC (chloroform, detected by UV 254 nm and RI) and PTLC (SiO₂, 20% ethyl acetate/chloroform) to give (R,R,R)-1a (3.9 mg) as a white solid in 2.7% yield.

**Data of (R,R,R)-1a** [X = CH₂(cHex), Y = (R)-CHMe(cHex)]

mp > 300 °C; ¹H NMR δH(400 MHz, CDCl₃, TMS)/ppm 7.34 (6H, d, J = 8.4 Hz), 7.28 (6H, d, J = 8.4 Hz), 7.11 (6H, d, J = 8.4 Hz), 7.08 (6H, d, J = 8.4 Hz), 6.88 (6H, d, J = 8.4 Hz), 6.84 (6H, d, J = 8.4 Hz), 4.36 (3H, br.dq), 3.84 (3H, dd, J = 7.2, 13.6 Hz), 3.73 (3H, dd, J = 6.8, 13.6 Hz), 2.00 (3H, br.d), 1.83-1.50 (33H, br.m), 1.30-0.88 (30H, br.m), 1.19 (9H, d, J = 6.8 Hz); ¹³C NMR δC(100 MHz, CDCl₃)/ppm 169.4, 169.4, 144.0, 137.1, 132.2, 128.5, 127.8, 126.6, 126.5, 120.8, 119.9, 99.3, 98.9, 86.7, 55.5, 41.5, 36.3, 30.9, 30.9, 30.7, 30.7, 26.3, 26.2, 26.0, 26.0, 25.7, 16.8; IR (KBr) 2925, 2851, 2199, 1656, 1654, 1650, 1600, 1510, 1449 cm⁻¹; FD-LRMS m/z 1778.9 (M⁺+2)²⁺, 1777.9 (M⁺+1)⁺, BP, 1776.9 (M⁺, 68); UV-Vis λmax(CH₂Cl₂)/nm (logε) 315 (5.00); CD λ(CH₂Cl₂)/nm (Δε) 418 (+0.4), 307 (-0.7), 274 (-7.9); [α]D²⁴ -62.4 (c 0.062 in CHCl₃); FD-HRMS Calcd. for C₁₂₃H₁₂₀N₂O₈ 1776.92693, Found 1776.92798.

**Preparation of 1b** [X = Y = CH₂(cHex)]

To a solution of 11b (218 mg, 84.2 μmol), Pd(PPh₃)₄ (145 mg, 126 μmol) and CuI (11 mg, 58 μmol) in Et₂N (84 mL) was added a solution of TBAF (0.27 mmol) in THF (8.35 mL) at 55 °C over a period of 12 h using a syringe pump under a nitrogen atmosphere, and the reaction mixture was further stirred at the temperature for 1.5 h. After removal of a solid by filtration, the filtrate was concentrated by evaporation and dissolved in chloroform. The solution was washed with 1N HCl aq. and satd. NaHCO₃ aq., and then dried over MgSO₄.

Chromatographic separation on SiO₂ (0-20% ethyl acetate/chloroform) gave a mixture containing 1b, which was further purified by gel permeation chromatography (GPC, chloroform, detected by UV 254 nm and RI) and preparative thin-layer chromatography (PTLC, SiO₂, 20% ethyl acetate/chloroform) to give 1b (3.0 mg) as a white solid in 2.1% yield.

**Data of 1b** [X = Y = CH₂(cHex)]

mp > 300 °C; ¹H NMR δH(400 MHz, CDCl₃, TMS)/ppm 7.33 (12H, d, J = 8.4 Hz), 7.11 (12H, s), 6.88 (12H, d, J = 7.2 Hz), 3.80 (12H, d, J = 7.2 Hz), 1.76-1.53 (36H, br.m), 1.22-0.94 (30H, br.m); ¹³C NMR δC(100 MHz, CDCl₃)/ppm 169.3, 144.0, 137.3, 132.2, 128.5, 127.8, 126.6, 120.1, 99.0, 86.7, 56.7, 36.3, 30.9, 26.3, 25.8; IR (KBr) 2925, 2851, 2200, 1656, 1649, 1600, 1510, 1449 cm⁻¹; FD-LRMS m/z 1735.8 (M⁺, 91%); CD λ(CH₂Cl₂)/nm (Δε) 315 (5.00); UV-Vis λmax(CH₂Cl₂)/nm (logε) 324 (4.99); FD-HRMS Calcd. for C₁₂₃H₁₁₄N₂O₈ 1734.87998, Found 1734.87793.

**Preparation of 13b** [X = CH₂(cHex)]

To a solution of 12⁻¹ (2.12 g, 7.50 mmol) and 18b (3.51 g, 8.46 mmol) in 1:1 THF/Pr₂NH (98 mL) were added Pd(PPh₃)₄ (261 mg, 0.226 mmol) and CuI (64 mg, 0.34 mmol) at 60 °C under a nitrogen atmosphere, and the mixture was stirred at the temperature for 2 d. After addition of hexane, the resulting precipitates were
removed by filtration. The filtrate was concentrated by evaporation, and then purified by column chromatography on SiO$_2$ (1:1-2:1 dichloromethane/hexane) to give $\mathbf{13b}$ (2.95 g) as a pale yellow oil in 69% yield.

An analytical sample was obtained as a colorless oil by further purification through GPC (chloroform, detected by UV 254 nm and RI).

**Data of $\mathbf{13b}$ [X = CH$_2$(cHex)]**

$^1$H NMR $\delta$(400 MHz, CDCl$_3$, TMS)/ppm 7.54-7.49 (2H, m), 7.48 (2H, d, $J = 8.4$ Hz), 7.31-7.24 (2H, m), 7.16 (2H, d, $J = 8.4$ Hz), 3.52 (2H, d, $J = 7.2$ Hz), 1.74-1.60 (5H, br.m), 1.52-1.41 (1H, m), 1.43 (9H, s), 1.22-1.04 (24H, m), 0.99-0.85 (2H, br.m); $^{13}$C NMR $\delta$(100 MHz, CDCl$_3$)/ppm 154.7, 142.9, 132.8, 132.0, 128.0, 127.8, 126.7, 125.9, 120.5, 105.4, 95.0, 92.8, 88.2, 80.2, 55.5, 36.8, 30.7, 28.3, 26.5, 25.8, 18.7, 11.3; IR (KBr) 2926, 2863, 2220, 2157, 1702, 1604, 1513, 1462 cm$^{-1}$; EI-LRMS m/z 569 (M$^+$, 12%), 513 ([M–tbutyl+H]$^+$, 13), 469 ([M–BOC+H]$^+$, BP); Anal. Calcd. for C$_{37}$H$_{51}$NO$_2$Si C 77.98, H 9.02, N 2.46, Found C 78.10, H 9.33, N 2.43.

**Preparation of $\mathbf{13c}$ [X = nBu]**

To a solution of $\mathbf{18c}$ (1.82 g, 4.85 mmol), Pd(PPh$_3$)$_4$ (149 mg, 0.129 mmol) and CuI (37 mg, 0.19 mmol) in 1:1 THF/iPr$_2$NH (45 mL) was added a solution of $\mathbf{12}$ (0.609 g, 2.15 mmol) in 1:1 THF/iPr$_2$NH (4 mL) at 50ºC under an argon atmosphere, and the mixture was stirred at 60 ºC for 2 h. To the reaction mixture was added the same solution of $\mathbf{12}$ (0.609 g, 2.15 mmol) in 1:1 THF/iPr$_2$NH (4 mL), and the mixture was further stirred at 60 ºC for 13 h. After removal of a solid by filtration, the filtrate was concentrated by evaporation, and then purified by column chromatography on SiO$_2$ (1:1 dichloromethane/hexane) to give $\mathbf{13c}$ (1.93 g) as a pale yellow oil in 85% yield.

An analytical sample was obtained as a pale yellow oil by further purification through GPC (chloroform, detected by UV 254 nm and RI).

**Data of $\mathbf{13c}$ [X = nBu]**

$^1$H NMR $\delta$(400 MHz, CDCl$_3$, TMS)/ppm 7.53-7.47 (2H, m), 7.49 (2H, d, $J = 8.4$ Hz), 7.31-7.22 (2H, m), 7.16 (2H, d, $J = 8.4$ Hz), 3.64 (2H, d, $J = 7.5$ Hz), 1.52 (2H, quint, $J = 7.5$ Hz), 1.44 (9H, s), 1.31 (2H, sext, $J = 7.5$ Hz), 1.12 (21H, s), 0.90 (3H, t, $J = 7.5$ Hz); $^{13}$C NMR $\delta$(75 MHz, CDCl$_3$)/ppm 154.4, 142.6, 132.7, 132.0, 128.0, 127.8, 126.5, 125.8, 120.5, 105.4, 95.0, 92.8, 88.2, 80.2, 49.5, 30.5, 28.3, 19.9, 18.7, 13.7, 11.3; IR (KBr) 2960, 2942, 2864, 2218, 1707, 1605, 1513, 1462 cm$^{-1}$; EI-LRMS m/z 569 (M$^+$, 12%), 513 ([M–butyl+H]$^+$, 13), 469 ([M–BOC+H]$^+$, BP); Anal. Calcd. for C$_{34}$H$_{47}$NO$_2$Si C 77.07, H 9.02, N 2.64, Found C 76.64, H 9.12, N 2.71.

**Preparation of $\mathbf{14a}$ [X = CH$_2$(cHex), Y = (R)-CHMe(cHex)]**

To a refluxed solution of $\mathbf{21a}$ (931 mg, 1.95 mmol) and BnNEt$_3$Cl (4.7 mg, 0.021 mmol) in CH$_2$Cl$_2$ (13 mL) was added SOCl$_2$ (0.19 mL, 2.6 mmol), and the mixture was further refluxed for 3 h. After removal of the solvent by evaporation, the resulting solid ($\mathbf{21a}'$) was dried in vacuo and dissolved in toluene (10 mL) [acid chloride preparation].
To a solution of 13b (2.08 g, 3.65 mmol) in CH$_2$Cl$_2$ (126 mL) was added TFA (12 mL), and the mixture was stirred at room temperature for 40 min, and then diluted with CH$_2$Cl$_2$ (360 mL). The diluted reaction mixture was quenched by addition of satd. NaHCO$_3$ aq. The organic layer was separated, and then dried over MgSO$_4$. Chromatographic separation on SiO$_2$ (1:4 dichloromethane/hexane) gave 1-[p-(N-cyclohexylmethylamino)phenylethynyl]-2-(trisopropylsilylethynyl)benzene 13b' (830 mg for 14a, 673 mg for 14b) as a pale yellow solid in 88% yield [deprotection of BOC].

To a solution of 13b' (830 mg, 1.77 mmol) and Et$_3$N (1.2 mL, 8.6 mmol) in toluene (8.2 mL) were added the freshly prepared toluene solution (10 mL) containing the acid chloride 21a' and extra toluene (4+3 mL) at room temperature, and the mixture was stirred at 80 °C for 1 h. After addition of 1N NaOH aq. and ethyl acetate, the organic layer was separated and washed with water and brine, and then dried over MgSO$_4$. Chromatographic separation on SiO$_2$ (0-10% ethyl acetate/chloroform) gave 14a (1.59 g) as a white solid in 97% yield.

An analytical sample was obtained as a white solid by further purification through GPC (chloroform, UV detected by 254 nm and RI).

**Data of 14a [X = CH$_2$(cHex), Y = (R)-CHMe(cHex)]**

mp 96-97 °C; $^1$H NMR $\delta$(400 MHz, CDCl$_3$, TMS)/ppm 7.57-7.45 (4H, m), 7.35 (2H, d, $J = 8.4$ Hz), 7.31-7.24 (2H, m), 7.08 (2H, br.d), 7.04 (2H, br. d), 6.88 (2H, br.d), 6.63 (2H, br.d), 4.42 (1H, br.s), 3.81-3.71 (2H, m), 2.05 (1H, br.d), 1.82-1.50 (11H, br.m), 1.29-0.89 (34H, m); $^{13}$C NMR $\delta$(100 MHz, CDCl$_3$)/ppm 169.8, 169.6, 143.3, 141.1, 138.1, 137.9, 136.9, 132.8, 132.4, 132.0, 131.4, 128.1, 128.0, 127.6, 127.2, 125.9, 125.5, 121.4, 105.3, 95.1, 92.3, 92.0, 89.3, 58.8, 55.8, 41.3, 36.3, 30.9, 30.8, 30.3, 26.3, 26.2, 25.9, 25.8, 18.7, 16.7, 11.3; IR (KBr) 2925, 2861, 2156, 1655, 1650, 1602, 1510, 1449 cm$^{-1}$; FD-LRMS m/z 930.5 ([M+2]$^+$, 25%), 929.5 ([M+1]$^+$, 67), 928.5 (M$^+$, BP); [$\alpha$]$_{D}^{23}$ –53.3 (c 0.19 in CHCl$_3$); Anal. Calcd. for C$_{54}$H$_{65}$N$_2$O$_2$Si C 69.81, H 7.05, N 3.02, Found C 69.69, H 6.98, N 3.01.

**Preparation of 14b [X = Y = CH$_2$(cHex)]**

To a refluxed solution of 21b (732 mg, 1.58 mmol) and BnNEt$_3$Cl (4.1 mg, 0.018 mmol) in CH$_2$Cl$_2$ (11 mL) was added SOCl$_2$ (0.16 mL, 2.2 mmol), and the mixture was further refluxed for 20 h. After removal of the solvent by evaporation, the resulting solid (21b') was dried in vacuo and dissolved in toluene (7 mL) [acid chloride preparation].

To a solution of 13b' (673 mg, 1.43 mmol) and Et$_3$N (1.0 mL, 7.2 mmol) in toluene (6.5 mL) were added the freshly prepared toluene solution (7 mL) containing the acid chloride 21b' and extra toluene (3+3 mL) at room temperature, and the mixture was stirred at 80 °C for 80 min. After addition of 1N NaOH aq. and ethyl acetate, the organic layer was separated and washed with water and brine, and then dried over MgSO$_4$. Chromatographic separation on SiO$_2$ (0-10% ethyl acetate/chloroform) gave 14b (1.30 g) as a white solid in 99% yield.

An analytical sample was obtained as a white solid by further purification through GPC (chloroform, UV detected by 254 nm and RI).

**Data of 14b [X = Y = CH$_2$(cHex)]**

mp 92-93 °C; $^1$H NMR $\delta$(400 MHz, CDCl$_3$, TMS)/ppm 7.54-7.49 (2H, m), 7.50 (2H, d, $J = 8.4$ Hz),
7.35 (2H, d, J = 8.4 Hz), 7.30-7.25 (2H, m), 7.11 (2H, d, J = 8.4 Hz), 7.06 (2H, d, J = 8.4 Hz), 6.90 (2H, d, J = 8.4 Hz), 6.66 (2H, d, J = 8.4 Hz), 3.77 (2H, d, J = 7.2 Hz), 3.70 (2H, d, J = 7.6 Hz), 1.75-1.47 (12H, m), 1.27-0.91 (31H, m); 13C NMR \( \delta_{(100 \text{ MHz, CDC13)/(ppm 169.7, 169.5, 143.2, 138.2, 137.3, 137.1, 132.7, 132.4, 132.0, 129.3, 128.1, 128.0, 127.2, 125.8, 125.5, 121.5, 105.2, 95.0, 92.0, 91.3, 89.3, 55.9, 55.8, 36.3, 36.2, 30.9, 30.8, 26.3, 26.3, 25.8, 25.7, 18.7, 11.3; IR (KBr) 2924, 2861, 2156, 1655, 1650, 1401, 1510, 1449 cm\(^{-1}\)); FD-LRMS m/z 916.5 ([M+2]\(^{+}\)), 915.5 ([M+1]\(^{+}\)), 835.4 (M\(^{+}\), BP); Anal. Calcd. for C\(_{55}\)H\(_{63}\)N\(_2\)O\(_2\)Si C 69.56, H 6.94, N 3.06, Found C 69.20, H 6.87, N 3.06.

Preparation of 14c [X = Y = nBu]

To a refluxed solution of 21c (1.20 g, 2.83 mmol) and BnNEt\(_2\)Cl (11 mg, 0.046 mmol) in CH\(_2\)Cl\(_2\) (20 mL) was added SOCl\(_2\) (0.28 mL, 3.8 mmol), and the mixture was further refluxed for 12 h. After removal of the solvent by evaporation, the resulting solid (21c') was dried in vacuo and dissolved in toluene (15 mL) [acid chloride preparation].

To a solution of 13c (1.53 g, 2.89 mmol) in CH\(_2\)Cl\(_2\) (100 mL) was added TFA (9.4 mL), and the mixture was stirred at room temperature for 40 min, and then diluted with CH\(_2\)Cl\(_2\) (290 mL). The diluted reaction mixture was quenched by addition of satd. NaHCO\(_3\) aq. The organic layer was separated, and then dried over MgSO\(_4\). Chromatographic separation on SiO\(_2\) (1:4 dichloromethane/hexane) gave 1-(p-(N-butylamino)phenylethynyl)-2-(triisopropylsilylethynyl)benzene 13c' (1.11 g for 9c) as a pale yellow solid in 89% yield [deprotection of BOC].

To a solution of 13c' (1.11 g, 2.58 mmol) and Et\(_3\)N (2.0 mL, 14 mmol) in toluene (12 mL) were added the freshly prepared toluene solution (15 mL) containing the acid chloride 21c' and extra toluene (5+4 mL) at room temperature, and the mixture was stirred at 80 °C for 1 h. After addition of 1N NaOH aq. and ethyl acetate, the organic layer was separated and washed with water and brine, and then dried over MgSO\(_4\). Chromatographic separation on SiO\(_2\) (0-10% ethyl acetate/chloroform) gave 14c (2.02 g) as a yellow solid in 94% yield.

An analytical sample was obtained as a white solid by recrystallization from chloroform and hexane.

Data of 14c [X = Y = nBu]

mp 140.0-140.5 °C; \(^{1}\)H NMR \( \delta_{(300 \text{ MHz, CDC13, TMS)/(ppm 7.54-7.49 (2H, m), 7.51 (2H, d, J = 8.4 Hz), 7.35 (2H, d, J = 8.4 Hz), 7.29-7.25 (2H, m), 7.12 (2H, d, J = 8.4 Hz), 7.07 (2H, d, J = 8.4 Hz), 6.89 (2H, d, J = 8.4 Hz), 6.65 (2H, d, J = 8.4 Hz), 3.88 (2H, t, J = 7.5 Hz), 3.81 (2H, t, J = 7.5 Hz), 1.61-1.47 \) ppm 169.3, 169.1, 142.9, 138.3, 137.3, 137.0, 132.8, 132.5, 132.1, 129.5, 128.2, 128.1, 128.0, 127.4, 125.9, 125.5, 121.8, 105.3, 95.1, 92.0, 91.5, 89.4, 50.1, 50.0, 29.8, 29.7, 20.1, 20.1, 18.7, 13.8, 13.8, 11.3); IR (KBr) 2955, 2941, 2863, 2155, 1631, 1602, 1511, 1484 cm\(^{-1}\)); FD-LRMS m/z 836.4 ([M+2]\(^{+}\)), 835.4 ([M+1]\(^{+}\)), 70, 834.4 (M\(^{+}\), BP); Anal. Calcd. for C\(_{47}\)H\(_{55}\)N\(_2\)O\(_2\)Si C 67.61, H 6.64, N 3.36, Found C 67.50, H 6.68, N 3.10.

Preparation of (R)-3a [X = CH\(_3\)(cHex), Y = (R)-CHMe(cHex)]

To a solution of 14a (183 mg, 197 \( \mu \)mol), Pd(PPh\(_3\))\(_4\) (43 mg, 37 \( \mu \)mol) and CuI (11 mg, 58 \( \mu \)mol) in Et\(_3\)N (100
mL) was added a solution of TBAF (0.21 mmol) in THF (9.10 mL) at 54-58 °C over a period of 1 h using a syringe pump under a nitrogen atmosphere, and the reaction mixture was further stirred at the temperature for 12 h. After removal of the solvent by evaporation, the resulting solid was dissolved in chloroform and washed with 1N HCl aq. and satd. NaHCO₃ aq., and then dried over MgSO₄. Chromatographic separation on SiO₂ (chloroform) gave a mixture containing (R)-3a, which was further purified by GPC (chloroform, detected by UV 254 nm and RI) to give (R)-3a (17 mg) as a white solid in 13% yield.

**Data of (R)-3a [X = CH₂(cHex), Y = (R)-CHMe(cHex)]**

mp > 300 °C; ¹H NMR δ (400 MHz, CDCl₃, TMS)/ppm 7.53-7.49 (2H, m), 7.37-7.32 (2H, m), 7.30 (2H, d, J = 8.4 Hz), 7.25 (2H, d, J = 8.4 Hz), 7.11 (2H, d, J = 8.8 Hz), 7.08 (2H, d, J = 8.8 Hz), 6.87 (2H, d, J = 8.4 Hz), 6.84 (2H, d, J = 8.4 Hz), 4.40 (1H, br.dq), 3.86 (1H, dd, J = 7.6, 13.6 Hz), 3.77 (1H, dd, J = 7.2, 13.6 Hz), 2.00 (1H, br.d), 1.85-1.55 (11H, br.m), 1.30-0.91 (10H, br.m), 1.21 (3H, d, J = 6.8 Hz); ¹³C NMR δ (100 MHz, CDCl₃)/ppm 169.5, 164.9, 143.5, 142.2, 138.2, 137.2, 132.0, 131.8, 130.2, 130.0, 128.5, 128.4, 128.3, 128.2, 127.0, 126.9, 126.4, 121.4, 120.5, 93.8, 93.4, 88.5, 88.5, 55.6, 41.6, 36.3, 30.9, 30.9, 30.7, 30.7, 26.3, 26.3, 26.1, 26.0, 25.8, 16.8; IR (KBr) 2924, 2851, 2213, 1655, 1649, 1639, 1633, 1599, 1511, 1449, 1446 cm⁻¹; FD-LRMS m/z 646.4 ([M+2]⁺, 15%), 645.4 ([M+1]⁺, 52), 644.4 (M⁺, BP); UV-Vis λ max(CH₂Cl₂)/nm (logε) 277 (4.62); CD λ(CH₂Cl₂)/nm (Δε) 316 (−1.1), 290 (+0.1), 271 (−1.8); [α]D²⁴ ≈ −30.8 (c 0.074 in CHCl₃); Anal. Calcd. for C₄₅H₄₂N₂O₂ C 83.82, H 6.88, N 4.34, Found C 83.81, H 6.98, N 4.30.

**Preparation of 3b [X = Y = CH₂(cHex)]**

To a solution of 14b (104 mg, 114 μmol) Pd(PPh₃)₄ (14 mg, 12 μmol) and Cul (4.9 mg, 26 μmol) in Et₃N (21 mL) was added a solution of TBAF (0.12 mmol) in THF (2.30 mL) at 83 °C over a period of 5 h using a syringe pump under a nitrogen atmosphere, and the reaction mixture was further stirred at the temperature for 15 min. After removal of the solvent by evaporation, the resulting solid was dissolved in ethyl acetate and washed with 1N HCl aq. and brine, and then dried over MgSO₄. Chromatographic separation on SiO₂ (0-10% ethyl acetate/chloroform) gave a mixture containing 3b, which was further purified by GPC (chloroform, detected by UV 254 nm and RI) to give 3b (13 mg) as a white solid in 18% yield.

**Data of 3b [X = Y = CH₂(cHex)]**

mp 287-298 °C (decomp.); ¹H NMR δ (400 MHz, CDCl₃, TMS)/ppm 7.52 (2H, dd, J = 3.2, 6.0 Hz), 7.35 (2H, dd, J = 3.2, 6.0 Hz), 7.29 (4H, d, J = 8.4 Hz), 7.11 (4H, s), 6.87 (4H, d, J = 8.4 Hz), 3.82 (4H, d, J = 7.2 Hz), 1.76-1.59 (12H, br.m), 1.22-0.94 (10H, br.m); ¹³C NMR δ (100 MHz, CDCl₃)/ppm 169.3, 143.5, 137.4, 132.1, 130.2, 128.4, 128.3, 126.9, 126.5, 120.7, 93.5, 88.5, 55.7, 36.3, 30.9, 26.3, 25.8; IR (KBr) 2923, 2850, 2214, 1654, 1649, 1644, 1633, 1599, 1512, 1449, 1446 cm⁻¹; FD-LRMS m/z 632.3 ([M+2]⁺, 15%), 631.3 ([M+1]⁺, 52), 630.3 (M⁺, BP); UV-Vis λ max(CH₂Cl₂)/nm (logε) 280 (4.62); Anal. Calcd. for C₄₅H₄₂N₂O₂ C 83.78, H 6.71, N 4.44, Found C 83.50, H 6.83, N 4.35.

**Preparation of 3c [X = Y = nBu]**

To a solution of 14c (207 mg, 248 μmol), Pd(PPh₃)₄ (29 mg, 25 μmol) and Cul (12 mg, 63 μmol) in Et₃N (45
mL) was added a solution of TBAF (0.28 mmol) in THF (5.0 mL) at 60 °C over a period of 5 h using a syringe pump under an argon atmosphere, and the reaction mixture was further stirred at the temperature for 30 min. After removal of a solid by filtration, the filtrate was concentrated. The resulting solid was dissolved in ethyl acetate and washed with 1N HCl aq. and brine, and then dried over MgSO₄. Chromatographic separation on SiO₂ (chloroform) gave a mixture containing 3c, which was further purified by GPC (chloroform, detected by UV 254 nm and RI) to give 3c (15 mg) as a white solid in 11% yield.

Single-crystals were obtained from a solution of 3c in chloroform under a hexane-diffusing atmosphere.

**Data of 3c [X = Y = nBu]**

mp > 208 °C (decomp.); ¹H NMR δₜ(300 MHz, CDCl₃, TMS)/ppm 7.52 (2H, dd, J = 3.3, 5.7 Hz), 7.35 (2H, dd, J = 3.3, 5.7 Hz), 7.30 (4H, d, J = 8.7 Hz), 7.11 (4H, s), 6.86 (4H, d, J = 8.7 Hz), 3.93 (4H, t, J = 7.5 Hz), 1.59 (4H, quint, J = 7.5 Hz), 1.35 (4H, sext, J = 7.5 Hz), 0.91 (6H, t, J = 7.5 Hz); ¹³C NMR δₜ(75 MHz, CDCl₃)/ppm 168.9, 143.1, 137.2, 132.1, 130.2, 128.5, 128.3, 126.9, 126.6, 120.9, 93.5, 88.5, 50.0, 29.8, 20.2, 13.8; IR (KBr) 2959, 2930, 2870, 2858, 2212, 1647, 1601, 1511 cm⁻¹; FD-LRMS m/z 552.3 ([M+2]⁺, 11%), 551.3 ([M+1]⁺, 44), 550.3 (M⁺, BP); Anal. Calcd. for C₃₈H₃₆N₂O₂ C 82.88, H 6.22, N 5.09, Found C 83.03, H 6.35, N 4.91.
Preparation of (R,R,R)-4 and (R)-5. Reagents and yields; (a) 19b, Pd(PPh₃)₄, CuI, THF, Et₃N (55%); (b) 19a, TBAF, Pd(PPh₃)₄, CuI, CH₃CN, Et₂NH, THF (72%); (c) 19b, Pd(PPh₃)₄, CuI, THF, Et₃N (42%); (d) 19a, TBAF, Pd(PPh₃)₄, CuI, THF, Et₃N (82%). Regarding the new compound 19, see Scheme S3.

Preparation of 15
To a solution of 9 (194 mg, 0.281 mmol) and 19b (529 mg, 1.26 mmol) in 1:2 THF/Et₃N (44 mL) were added Pd(PPh₃)₄ (97.7 mg, 0.0846 mmol) and CuI (18 mg, 0.095 mmol) at room temperature under a nitrogen atmosphere, and the mixture was stirred at 60 °C for 2 d. After dilution with diethyl ether and addition of 1N HCl aq., the organic layer was separated and washed with brine, and then dried over MgSO₄. Chromatographic separation on SiO₂ (0-20% ethyl acetate/chloroform) gave 15 (242 mg) as a white solid in 55% yield. An analytical sample was obtained as colorless crystals by recrystallization from isopropyl alcohol.

Data of 15
mp 280-281 °C (decomp.); ¹H NMR δH(400 MHz, CDCl₃, TMS)/ppm 7.32 (6H, d, J = 8.8 Hz), 7.30-7.13 (15H, m), 6.96 (6H, d, J = 8.8 Hz), 3.84 (6H, d, J = 7.2 Hz), 1.77-1.52 (15H, br.m), 1.20-0.82 (81H, m); ¹³C NMR δC(100 MHz, CDCl₃)/ppm 170.6, 144.1, 136.3, 132.4, 129.6, 128.7, 128.2, 127.9, 127.8, 127.0, 120.8, 102.9, 102.5, 97.9, 87.2, 55.7, 36.5, 31.0, 26.4, 25.9, 18.6, 11.1; IR (KBr) 2924, 2862, 2216, 2155, 1655, 1650, 1600, 1508 cm⁻¹; FD-LRMS m/z 1565.9 ([M+2]+, 75%), 1564.9 ([M+1]+, BP), 1563.9 (M⁺, 77); Anal. Calcd. for C₁₀₅H₁₂₉N₃O₃Si₃C 80.56, H 8.31, N 2.68, Found C 80.69, H 8.50, N 2.61.

Preparation of (R,R,R)-4
To a solution of 15 (199 mg, 127 μmol), 19a (189 mg, 436 μmol), Pd(PPh₃)₄ (44 mg, 38 μmol) and CuI (14 mg, 74 μmol) in 1:5 CH₃CN/Et₂NH (20 mL) was added a solution of TBAF (0.40 mmol) in 5:1:1 CH₃CN/Et₂NH/THF (2.30 mL) at 83-85 °C over a period of 10 h using a syringe pump under a nitrogen
atmosphere, and the reaction mixture was further stirred at the temperature for 0.5 h. The mixture was diluted with ethyl acetate and washed with 1N HCl aq. and brine, and then dried over MgSO$_4$. Chromatographic separation on SiO$_2$ (chloroform) gave a mixture containing (R,R,R)-4, which was further purified by PTLC (SiO$_2$, 10% ethyl acetate/chloroform) to give (R,R,R)-4 (185 mg) as a yellow solid in 72% yield.

An analytical sample was obtained as a yellow solid by reprecipitation from ethyl acetate and hexane.

**Data of (R,R,R)-4**

mp 143-149 °C (decomp.); $^1$H NMR $\delta_H$(400 MHz, CDCl$_3$, TMS)/ppm 7.42-7.14 (42H, m), 6.97 (12H, d, $J$ = 8.4 Hz), 4.43 (3H, br.), 3.85 (6H, d, $J$ = 7.2 Hz), 2.16 (3H, br.d), 1.91-1.56 (30H, br.m), 1.34-0.96 (33H, br.m), 1.27 (9H, d, $J$ = 6.8 Hz); $^{13}$C NMR $\delta_C$(100 MHz, CDCl$_3$)/ppm 170.6, 170.4, 144.8, 143.1, 137.0, 136.1, 132.4, 132.1, 129.8, 129.5, 129.4, 128.6, 127.9, 127.8, 127.5, 127.3, 127.1, 121.1, 120.5, 98.9, 98.7, 87.9, 87.7, 60.1, 56.1, 41.5, 36.5, 31.0, 30.9, 30.5, 26.3, 26.3, 26.1, 25.9, 17.0; IR (KBr) 2924, 2850, 2201, 1657, 1650, 1599, 1510 cm$^{-1}$; FD-LRMS m/z 2013.0 ([M+2]$^+$, 81%), 2012.0 ([M+1]$^+$, BP), 2011.0 (M$^+$, 61); UV-Vis $\lambda_{max}$(CH$_2$Cl$_2$)/nm (log$\varepsilon$) 368 (5.20); CD $\lambda$(CH$_2$Cl$_2$)/nm ($\Delta\varepsilon$) 358 (–3.2), 321 (–2.0), 269 (–5.3); [$\alpha$]$_D$$^2$4 $–$53.1 (c 0.059 in CHCl$_3$); FD-HRMS Calcd. for C$_{141}$H$_{138}$N$_6$O$_6$ 2011.06778, Found 2011.06341.

**Preparation of 16**

To a solution of 19b (1.52 g, 3.62 mmol), Pd(PPh$_3$)$_4$ (204 mg, 177 µmol) and CuI (33 mg, 0.17 mmol) in THF/Et$_3$N (80/170 mL) was added a solution of 12 (977 mg, 3.46 mmol) in THF (10 mL) at 50 °C over a period of 12 h using a syringe pump under a nitrogen atmosphere, and the reaction mixture was further stirred at the temperature for 2 h. After removal of the solvents by evaporation, the resulting solid was dissolved in ethyl acetate, and washed with 1N HCl aq. and brine, and then dried over MgSO$_4$. Chromatographic separation on SiO$_2$ (1:1-2:1 dichloromethane/hexane-dichloromethane) gave a colored mixture containing 16, which was suspended in hexane and collected by filtration to give 16 (828 mg) as a white solid in 42% yield. An analytical sample was obtained as colorless crystals by recrystallization from methanol.

**Data of 16**

mp 142.5-143.0 °C; $^1$H NMR $\delta_H$(400 MHz, CDCl$_3$, TMS)/ppm 7.53-7.44 (2H, m), 7.35 (2H, d, $J$ = 8.8 Hz), 7.31-7.15 (7H, m), 6.98 (2H, d, $J$ = 8.8 Hz), 3.83 (2H, d, $J$ = 7.2 Hz), 1.79-1.59 (5H, br.m), 1.25-0.99 (27H, m); $^{13}$C NMR $\delta_C$(100 MHz, CDCl$_3$)/ppm 170.6, 143.8, 136.3, 132.7, 132.3, 131.9, 129.5, 128.6, 128.0, 127.8, 127.2, 125.8, 125.5, 121.1, 105.2, 95.1, 92.1, 88.8, 55.8, 36.4, 30.9, 26.4, 25.8, 18.6, 11.2; IR (KBr) 2923, 2863, 2215, 2158, 1596, 1510 cm$^{-1}$; FD-LRMS m/z 575.4 ([M+2]$^+$, 17%), 574.4 ([M+1]$^+$, 49), 573.4 (M$^+$, BP); Anal. Calcd. for C$_{39}$H$_{47}$NOSi C 81.62, H 8.25, N 2.44, Found C 81.73, H 8.50, N 2.44.

**Preparation of (R)-5**

To a solution of 16 (278 mg, 484 µmol), 19a (316 mg, 729 µmol), Pd(PPh$_3$)$_4$ (32 mg, 28 µmol), and CuI (6.1 mg, 32 µmol) in THF/Et$_3$N (7.5/24 mL) was added a solution of TBAF (0.51 mmol) in THF (4.8 mL) at 50-55 °C over a period of 10 h using a syringe pump under a nitrogen atmosphere, and the reaction mixture was
further stirred at the temperature for 3.5 h. After removal of the solvents by evaporation, the resulting solid was dissolved in chloroform, and washed with 1N HCl aq. and satd. NaHCO$_3$ aq., and then dried over MgSO$_4$. Chromatographic separation on SiO$_2$ (chloroform) gave a colored mixture containing (R)-5, which was further purified by GPC (chloroform, detected by UV 254 nm) to give (R)-5 (292 mg) as a white solid in 83% yield.

**Data of (R)-5**

mp 93-94 °C; $^1$H NMR $\delta_H$(400 MHz, CDCl$_3$, TMS)/ppm 7.53-7.49 (2H, m), 7.35 (2H, d, $J = 8.4$ Hz), 7.34 (2H, d, $J = 8.4$ Hz), 7.32-7.11 (12H, m), 6.97 (2H, d, $J = 8.4$ Hz), 6.96 (2H, d, $J = 8.4$ Hz), 4.47 (1H, br.s), 3.83 (2H, d, $J = 7.6$ Hz), 2.15 (1H, br.d), 1.86-1.60 (10H, m), 1.33-0.94 (11H, m), 1.23 (3H, d, $J = 6.8$ Hz); $^{13}$C NMR $\delta_C$(100 MHz, CDCl$_3$)/ppm 170.7, 170.5, 144.0, 142.1, 137.1, 136.2, 132.2, 131.9, 131.8, 129.6, 129.4, 129.2, 128.7, 128.4, 128.2, 128.2, 127.8, 127.7, 127.4, 125.4, 125.3, 121.6, 121.0, 92.7, 92.6, 89.2, 88.9, 59.5, 56.0, 41.5, 36.4, 30.9, 30.8, 30.5, 26.3, 26.3, 26.1, 26.0, 25.8, 16.8; IR (KBr) 2925, 2850, 2213, 1649, 1600, 1510 cm$^{-1}$; FD-LRMS m/z 724.5 ([M+2]$^+$, 18%), 723.4 ([M+1]$^+$, 58), 722.4 (M$,^+$ BP); UV-vis $\lambda_{max}$(CH$_2$Cl$_2$)/nm (log$\varepsilon$) 291 (4.69); CD $\lambda$(CH$_2$Cl$_2$)/nm ($\Delta\varepsilon$) 344 (+0.5), 290 (–5.5); $[\alpha]_D^{23}$ –58.7 (c 0.0510 in CHCl$_3$); Anal. Calcd. for C$_{51}$H$_{50}$N$_2$O$_2$ C 84.73, H 6.97, N 3.87, Found C 84.73, H 7.15, N 3.84.
Preparation of 17a [R = (R)-CHMe(cHex)]

A mixture of 1,4-diiodobenzene (5.04 g, 15.3 mmol), (R)-1-cyclohexylethylamine (3.3 mL, 23 mmol), CuI (291 mg, 1.53 mmol), L-proline (348 mg, 3.02 mmol), K$_2$CO$_3$ (4.19 g, 30.3 mmol) and DMSO (27 mL) was stirred at 84 °C for 19 h. After dilution with ethyl acetate and water, the organic layer was separated and washed with brine, and then dried over MgSO$_4$. Chromatographic separation on SiO$_2$ (1:4 dichloromethane/hexane) gave 17a (2.75 g) as a white solid in 55% yield.

Data of 17a [R = (R)-CHMe(cHex)]

mp 48-49 °C; $^1$H NMR $\delta$(400 MHz, CDCl$_3$, TMS)/ppm 7.37 (2H, d, $J = 8.8$ Hz), 6.34 (2H, d, $J = 8.8$ Hz), 3.52 (1H, br.s), 3.25 (1H, br.m), 1.83-1.63 (5H, m), 1.46-1.36 (1H, m), 1.09 (3H, d, $J = 6.4$ Hz), 1.29-0.95 (5H, m); $^{13}$C NMR $\delta$(100 MHz, CDCl$_3$)/ppm 147.5, 137.8, 115.1, 76.5, 53.0, 42.9, 29.7, 28.4, 26.6, 26.4, 26.3, 17.3; IR (KBr) 3421, 2977, 2963, 2918, 2846, 1587, 1492 cm$^{-1}$; El-LRMS m/z 329 (M$^+$, 22%), 246 ([M–cyclohexyl]$^+$, BP); [$\alpha$]$_D^{24}$ –1.72 (c 0.56 in CHCl$_3$); Anal. Calcd. for C$_{14}$H$_{20}$NI C 51.08, H 6.12, N 4.25, Found C 51.28, H 6.15, N 4.26.

Preparation of 17b [R = CH$_2$(cHex)]

A mixture of 1,4-diodobenzene (5.00 g, 15.2 mmol), aminomethylcyclohexane (3.0 mL, 23 mmol), CuI (290 mg, 1.52 mmol), L-proline (353 mg, 3.07 mmol), K$_2$CO$_3$ (4.19 g, 30.3 mmol) and DMSO (27 mL) was stirred at 62 °C for 12 h. After dilution with ethyl acetate and water, the organic layer was separated and washed with brine, and then dried over MgSO$_4$. Chromatographic separation on SiO$_2$ (1:4 dichloromethane/hexane) gave
17b (3.77 g) as a white solid in 79% yield.

**Data of 17b [R = CH$_2$(cHex)]**

mp 62-63 °C; $^1$H NMR $\delta$(400 MHz, CDCl$_3$, TMS)/ppm 7.39 (2H, d, $J = 8.8$ Hz), 6.37 (2H, d, $J = 8.8$ Hz), 3.74 (1H, br.s), 2.91 (2H, d, $J = 3.6$ Hz), 1.84-1.63 (5H, m), 1.33-1.10 (3H, m), 1.04-0.91 (2H, m); $^{13}$C NMR $\delta$(100 MHz, CDCl$_3$)/ppm 148.1, 137.6, 114.8, 77.0, 50.3, 37.4, 31.2, 26.5, 25.9; IR (KBr) 3412, 2924, 2847, 1595, 1498 cm$^{-1}$; EI-LRMS m/z 315 (M$^+$, 43%), 232 ([M–cyclohexyl]$^+$, BP); Anal. Calcd. for C$_{13}$H$_{18}$NI C 49.54, H 5.76, N 4.44, Found C 49.47, H 5.65, N 4.41.

**Preparation of 18b [R = CH$_2$(cHex)]**

To a solution of 17b (10.7 g, 33.9 mmol) and DMAP (44 mg, 0.36 mmol) in THF (60 mL) were added (BOC)$_2$O (14 g, 64 mmol) and Et$_3$N (9.5 mL, 68 mmol), and the mixture was refluxed for 5 d. During the period, (BOC)$_2$O was added three times at an appropriate interval (7.6+7.6+7.9 g, total 106 mmol). After dilution with ethyl acetate, the solution was washed with 0.1 N HCl aq. and brine, and then dried over MgSO$_4$. Chromatographic separation on SiO$_2$ (3:7 dichloromethane/hexane) gave 18b (12.5 g) as a white solid in 88% yield.

An analytical sample was obtained as colorless crystals by recrystallization from hexane.

**Data of 18b [R = CH$_2$(cHex)]**

mp 73-74 °C; $^1$H NMR $\delta$(400 MHz, CDCl$_3$, TMS)/ppm 7.63 (2H, d, $J = 8.8$ Hz), 6.95 (2H, d, $J = 8.8$ Hz), 3.47 (2H, d, $J = 7.2$ Hz), 1.73-1.59 (5H, m), 1.49 (9H, s), 1.22-1.09 (3H, m), 0.97-0.84 (2H, m); $^{13}$C NMR $\delta$(100 MHz, CDCl$_3$)/ppm 154.7, 142.7, 137.7, 129.1, 90.2, 80.3, 55.7, 36.7, 30.7, 28.3, 26.4, 25.8; IR (KBr) 2984, 2922, 2852, 1686, 1487, 1449 cm$^{-1}$; EI-LRMS m/z 415 (M$^+$, 13%), 359 ([M–tbutyl$+H^+$], BP), 315 ([M–BOC+H$^+$], 24), 263 ([M–tbutyl–cyclohexylmethyl+2H$^+$], 27), 232 ([M–BOC–cyclohexyl$+H^+$], 65), 57 (tbutyl$^+$, 93); Anal. Calcd. for C$_{18}$H$_{26}$NO$_2$I C 52.06, H 6.31, N 3.37, Found C 51.93, H 6.18, N 3.36.

**Preparation of 18c [R = nBu]**

To a solution of 17c (5.16 g, 18.8 mmol), DMAP (22 mg, 0.18 mmol) and Et$_3$N (9.5 mL, 68 mmol) in THF (40 mL) was added (BOC)$_2$O (8.18 g, 37.5 mmol), and the mixture was refluxed for 5 d. During the period, (BOC)$_2$O was added three times at an appropriate interval (4.0+4.5+4.2 g, total 58 mmol). After dilution with ethyl acetate, the solution was washed with 0.1 N HCl aq. and brine, and then dried over MgSO$_4$. Chromatographic separation on SiO$_2$ (3:7 dichloromethane/hexane) gave 18c (5.72 g) as a white solid in 81% yield.

An analytical sample was obtained as colorless crystals by recrystallization from hexane.

**Data of 18c [R = nBu]**

mp 64.0-65.0 °C; $^1$H NMR $\delta$(300 MHz, CDCl$_3$, TMS)/ppm 7.63 (2H, d, $J = 8.4$ Hz), 6.94 (2H, d, $J = 8.4$ Hz), 3.59 (2H, t, $J = 7.5$ Hz), 1.49 (2H, quint, $J = 7.5$ Hz), 1.42 (9H, s), 1.29 (2H, sext, $J = 7.5$ Hz), 0.89 (3H, t, $J = 7.5$ Hz); $^{13}$C NMR $\delta$(75 MHz, CDCl$_3$)/ppm 154.3, 142.5, 137.8, 129.0, 90.3, 80.3, 49.6, 30.6, 28.3, 19.9, 13.8; IR (KBr) 2966, 2928, 2862, 1908, 1682, 1585, 1485 cm$^{-1}$; EI-LRMS m/z 375 (M$^+$, 33%), 321 ([M–tbutyl$+H^+$], 93).
Preparation of 19a \([R = (R)\text{-CHMe(cHex)}]\)

To an ice-cooled solution of 17a (4.10 g, 12.4 mmol), DMAP (156 mg, 1.28 mmol) and Et₃N (3.6 mL, 26 mmol) in THF (125 mL) was added BzCl (3.0 mL, 26 mmol), and the mixture was refluxed for 27 h. After removal of a solid by filtration and the solvent by evaporation, the residue was dissolved in diethyl ether. The solution was washed with 1N NaOH aq. and brine, and then dried over MgSO₄. Chromatographic separation on SiO₂ (chloroform) gave 19a (4.97 g) as a white solid in 92% yield.

An analytical sample was obtained as a white solid by suspending in hexane, followed by collection through filtration.

**Data of 19a \([R = (R)\text{-CHMe(cHex)}]\)**

mp 91.5-92.0 °C; \(^1H\) NMR \(\delta_H(400 \text{ MHz, CDCl}_3, \text{TMS})/\text{ppm} 7.52 (2H, d, J = 8.4 \text{ Hz}), 7.26-7.12 (5H, m), 6.74 (2H, d, J = 8.4 \text{ Hz}), 4.46 (1H, br.s), 2.12 (1H, br.d), 1.78-1.59 (5H, m), 1.17 (3H, d, J = 6.8 \text{ Hz}), 1.31-0.92 (5H, m); \(^13C\) NMR \(\delta_C(100 \text{ MHz, CDCl}_3)/\text{ppm} 170.8, 141.6, 137.9, 137.0, 131.4, 129.3, 128.3, 127.8, 92.0, 59.0, 41.4, 30.8, 30.4, 26.3, 26.1, 26.0, 16.81; \text{IR (KBr)} 2976, 2968, 2931, 2919, 2847, 1631, 1576 cm\(^{-1}\); \text{EI-LRMS m/z} 433 (M\(^+\), 6%), 350 ([M–cyclohexyl]+, 35), 323 ([M–cyclohexylethyl+H]+, 25), 105 (PhCO\(^+\), BP), 77 (Ph\(^+\), 15); \([\alpha]_D^{23} = -87.7 (c 0.84 \text{ in CHCl}_3); \text{Anal. Calcd. for C}_{21}H_{24}NOI C 58.21, H 5.58, N 3.23, \text{ Found C 58.28, H 5.50, N 3.21.}\)

Preparation of 19b \([R = \text{CH}_2\text{(cHex)}]\)

To an ice-cooled solution of 17b (2.88 g, 9.14 mmol), DMAP (112 mg, 0.917 mmol) and Et₃N (2.6 mL, 19 mmol) in THF (90 mL) was added BzCl (1.2 mL, 8.3 mmol), and the mixture was refluxed for 2 h. After removal of a solid by filtration, the filtrate was diluted with diethyl ether. The solution was washed with satd. NaHCO\(_3\) aq., and then dried over MgSO₄. Chromatographic separation on SiO₂ (1:1 chloroform/hexane-1:9 ethyl acetate/chloroform) gave 19b (3.65 g) as a white solid in 95% yield.

An analytical sample was obtained as colorless crystals by recrystallization from methanol.

**Data of 19b \([R = \text{CH}_2\text{(cHex)}]\)**

mp 119.0-119.5 °C; \(^1H\) NMR \(\delta_H(400 \text{ MHz, CDCl}_3, \text{TMS})/\text{ppm} 7.52 (2H, d, J = 8.4 \text{ Hz}), 7.24-7.22 (3H, m), 7.21-7.15 (2H, m), 6.77 (2H, d, J = 8.4 \text{ Hz}), 3.77 (2H, d, J = 7.2 \text{ Hz}), 1.76-1.60 (6H, m), 1.23-0.97 (5H, m); \(^13C\) NMR \(\delta_C(100 \text{ MHz, CDCl}_3)/\text{ppm} 170.6, 143.8, 138.1, 136.2, 129.6, 129.4, 128.6, 127.9, 91.0, 56.0, 36.3, 30.9, 26.4, 25.8; \text{IR (KBr)} 2921, 2916, 2845, 1634, 1577, 1483 cm\(^{-1}\); \text{EI-LRMS m/z} 419 (M\(^+\), 13%), 323 ([M–cyclohexylmethyl+H]\(^+\), 40), 105 (PhCO\(^+\), BP), 77 (Ph\(^+\), 24); \text{Anal. Calcd. for C}_{20}H_{22}NOI C 57.29, H 5.29, N 3.34, \text{ Found C 57.22, H 5.30, N 3.33.}\)

Preparation of 20a \([R = (R)\text{-CHMe(cHex)}]\)

To an ice-cooled solution of 17a (2.75 g, 8.35 mmol), DMAP (102 mg, 0.836 mmol) and Et₃N (2.4 mL, 17 mmol) in THF (80 mL) was added methyl 4-(chloroformyl)benzoate (1.99 g, 9.99 mmol), and the mixture was
refluxed for 38 h. After dilution with ethyl acetate, the resulting precipitates were removed by filtration, and the filtrate was concentrated by evaporation. The residue was dissolved in ethyl acetate, and the solution was washed with 1N HCl aq. and brine, and then dried over MgSO₄. Chromatographic separation on SiO₂ (0-10% ethyl acetate/chloroform) gave 20a (3.73 g) as a white solid in 91% yield.

An analytical sample was obtained as colorless crystals by recrystallization from 95% ethanol.

**Data of 20a** [R = (R)-CHMe(cHex)]

mp 151.0-151.5 °C; ¹H NMR δH(400 MHz, CDCl₃, TMS)/ppm 7.83 (2H, br.d, J = 8.4 Hz), 7.51 (2H, br.d, J = 8.4 Hz), 7.28 (2H, br.d, J = 8.4 Hz), 6.73 (2H, br.d, J = 8.4 Hz), 6.50 (1H, br.s), 3.87 (3H, s, J = 8.4 Hz, 8.4 Hz, 8.4 Hz), 2.11 (1H, br.d, J = 8.4 Hz, 8.4 Hz, 8.4 Hz), 1.87-1.56 (5H, br.m, J = 8.4 Hz, 8.4 Hz, 8.4 Hz), 1.32-0.92 (5H, br.m, J = 8.4 Hz, 8.4 Hz, 8.4 Hz), 1.17 (3H, d, J = 8.4 Hz, 8.4 Hz, 8.4 Hz); ¹³C NMR δC(100 MHz, CDCl₃)/ppm 169.8, 166.3, 141.4, 140.9, 138.1, 131.4, 130.5, 129.1, 128.1, 92.5, 58.9, 52.2, 41.3, 30.8, 30.3, 26.2, 26.0, 26.0, 16.8; IR (KBr) 2987, 2974, 2932, 2915, 2849, 2841, 1725, 1633, 1486 cm⁻¹; EI-LRMS m/z 491 (M⁺, 5%), 408 ([M–cyclohexyl]⁺, 24), 381 ([M–cyclohexylethyl+H]⁺, 19), 163 ([M–N(cyclohexylethyl)(4-iodophenyl)]⁺, BP); [α]D²³ = –80.9 (c 1.4 in CHCl₃); Anal. Calcd. for C₂₃H₂₆NO₃I C 56.22, H 5.33, N 2.85, Found C 56.17, H 5.25, N 2.83.

**Preparation of 20b** [R = CH₂(cHex)]

To an ice-cooled solution of 17b (2.23 g, 7.07 mmol) and Et₃N (1.0 mL, 7.2 mmol) in THF (70 mL) was added methyl 4-(chloroformyl)benzoate (1.42 g, 7.16 mmol), and the mixture was stirred at room temperature for 17 h. After removal of the solvent by evaporation, the residue was purified by column chromatography on SiO₂ (0-5% ethyl acetate/chloroform) to give 20b (3.14 g) as a white solid in 93% yield.

An analytical sample was obtained as colorless crystals by recrystallization from 95% ethanol.

**Data of 20b** [R = CH₂(cHex)]

mp 179.5-180.0 °C; ¹H NMR δH(400 MHz, CDCl₃, TMS)/ppm 7.86 (2H, d, J = 8.4 Hz), 7.52 (2H, d, J = 8.4 Hz), 7.31 (2H, d, J = 8.4 Hz), 6.76 (2H, d, J = 8.4 Hz), 3.89 (3H, s), 3.78 (2H, d, J = 8.4 Hz), 1.80-1.58 (6H, br.m), 1.23-0.97 (5H, br.m); ¹³C NMR δC(100 MHz, CDCl₃)/ppm 169.6, 166.3, 140.5, 138.4, 130.8, 129.4, 129.2, 128.4, 91.6, 55.9, 52.3, 36.3, 30.9, 26.3, 25.8; IR (KBr) 2944, 2927, 2915, 2849, 1721, 1683, 1488 cm⁻¹; EI-LRMS m/z 477 (M⁺, 20%), 381 ([M–cyclohexylethyl+H]⁺, 19), 163 ([M–N(cyclohexylethyl)(4-iodophenyl)]⁺, BP); Anal. Calcd. for C₂₂H₂₄NO₃I C 55.36, H 5.07, N 2.93, Found C 55.31, H 5.00, N 2.97.

**Preparation of 20c** [R = nBu]

To a solution of 17c (5.37 g, 19.5 mmol) and Et₃N (2.7 mL, 19 mmol) in THF (180 mL) was added methyl 4-(chloroformyl)benzoate (3.87 g, 19.5 mmol), and the mixture was refluxed for 12 h. After removal of a solid by filtration, the filtrate was concentrated and the residue was purified by column chromatography on SiO₂ (0-10% ethyl acetate/chloroform) to give 20c (8.07 g) as a white solid in 95% yield.

An analytical sample was obtained as colorless crystals by recrystallization from 99% ethanol.

**Data of 20c** [R = nBu]

mp 119.5-120.0 °C; ¹H NMR δH(300 MHz, CDCl₃, TMS)/ppm 7.86 (2H, d, J = 8.4 Hz), 7.53 (2H, d, J = 8.4 Hz), 7.28 (2H, d, J = 8.4 Hz), 6.73 (2H, d, J = 8.4 Hz), 3.87 (3H, s), 3.78 (2H, d, J = 8.4 Hz), 1.80-1.58 (6H, br.m), 1.23-0.97 (5H, br.m); ¹³C NMR δC(100 MHz, CDCl₃)/ppm 169.6, 166.3, 140.5, 138.4, 130.8, 129.4, 129.2, 128.4, 91.6, 55.9, 52.3, 36.3, 30.9, 26.3, 25.8; IR (KBr) 2944, 2927, 2915, 2849, 1721, 1683, 1488 cm⁻¹; EI-LRMS m/z 477 (M⁺, 20%), 381 ([M–cyclohexylethyl+H]⁺, 19), 163 ([M–N(cyclohexylethyl)(4-iodophenyl)]⁺, BP); Anal. Calcd. for C₂₀H₂₄NO₃I C 55.36, H 5.07, N 2.93, Found C 55.31, H 5.00, N 2.97.

**Preparation of 20d** [R = nBu]

To a solution of 17c (5.37 g, 19.5 mmol) and Et₃N (2.7 mL, 19 mmol) in THF (180 mL) was added methyl 4-(chloroformyl)benzoate (3.87 g, 19.5 mmol), and the mixture was refluxed for 12 h. After removal of a solid by filtration, the filtrate was concentrated and the residue was purified by column chromatography on SiO₂ (0-10% ethyl acetate/chloroform) to give 20d (8.07 g) as a white solid in 95% yield.

An analytical sample was obtained as colorless crystals by recrystallization from 99% ethanol.

**Data of 20d** [R = nBu]

mp 119.5-120.0 °C; ¹H NMR δH(300 MHz, CDCl₃, TMS)/ppm 7.86 (2H, d, J = 8.4 Hz), 7.53 (2H, d, J = 8.4 Hz), 7.28 (2H, d, J = 8.4 Hz), 6.73 (2H, d, J = 8.4 Hz), 3.87 (3H, s), 3.78 (2H, d, J = 8.4 Hz), 1.80-1.58 (6H, br.m), 1.23-0.97 (5H, br.m); ¹³C NMR δC(100 MHz, CDCl₃)/ppm 169.6, 166.3, 140.5, 138.4, 130.8, 129.4, 129.2, 128.4, 91.6, 55.9, 52.3, 36.3, 30.9, 26.3, 25.8; IR (KBr) 2944, 2927, 2915, 2849, 1721, 1683, 1488 cm⁻¹; EI-LRMS m/z 477 (M⁺, 20%), 381 ([M–cyclohexylethyl+H]⁺, 19), 163 ([M–N(cyclohexylethyl)(4-iodophenyl)]⁺, BP); Anal. Calcd. for C₂₀H₂₄NO₃I C 55.36, H 5.07, N 2.93, Found C 55.31, H 5.00, N 2.97.
8.4 Hz), 7.32 (2H, d, \( J = 8.4 \) Hz), 6.75 (2H, d, \( J = 8.4 \) Hz), 3.89 (3H, s), 3.89 (2H, t, \( J = 7.5 \) Hz), 1.59 (2H, quint, \( J = 7.5 \) Hz), 1.35 (2H, sext, \( J = 7.5 \) Hz), 0.91 (3H, t, \( J = 7.5 \) Hz); \(^{13}\)C NMR \( \delta (75 \text{ MHz, CDCl}_3)/\text{ppm} 169.2, 166.3, 140.7, 140.3, 138.4, 129.6, 129.2, 128.4, 91.8, 52.2, 50.1, 29.7, 20.1, 13.8; IR (KBr) 2950, 2930, 2872, 1934, 1723, 1633, 1485 cm\(^{-1}\); FD-LRMS m/z 438.1 ([M+1]\(^+\), 45%), 437.1 (M\(^+\), BP); Anal. Calcd. for C\(_{19}\)H\(_{20}\)NO\(_3\) I C 52.19, H 4.61, N 3.20, Found C 52.14, H 4.59, N 2.92.

**Preparation of 21a** [\( R = (R)\text{-CHMe(cHex)} \)]

A mixture of 20a (228 mg, 0.464 mmol), LiOH·H\(_2\)O (67 mg, 1.6 mmol), THF (5 mL), MeOH (2 mL) and water (2 mL) was stirred at room temperature for 2.5 h. After removal of the organic solvents by evaporation, the residue was acidified with 1N HCl aq., and the resulting solid was collected by filtration to give 21a (204 mg) as a white solid in 92% yield.

An analytical sample was obtained as colorless crystals by recrystallization from 95% ethanol.

**Data of 21a** [\( R = (R)\text{-CHMe(cHex)} \)]

mp 271-272 °C (decomp.); \(^1\)H NMR \( \delta (400 \text{ MHz, DMSO-\text{d}_6}, \text{TMS})/\text{ppm} 13.08 (1H, br.s), 7.74 (2H, br.d), 7.60 (2H, br.d), 7.32 (2H, br.d), 6.91 (2H, br.d), 4.38 (1H, br.s), 2.11 (1H, br.d), 1.83-1.41 (5H, br.m), 1.30-0.82 (5H, br.m), 1.10 (3H, d, \( J = 6.8 \) Hz); \(^{13}\)C NMR \( \delta (100 \text{ MHz, DMSO-\text{d}_6})/\text{ppm} 169.2, 166.8, 141.6, 140.5, 137.9, 132.2, 131.0, 128.9, 128.0, 93.5, 57.7, 41.0, 30.5, 29.9, 26.0, 25.8, 25.7, 16.7; IR (KBr) 2970, 2934, 2926, 2851, 1713, 1656, 1610, 1566, 1483 cm\(^{-1}\); FAB-LRMS m/z 476 ([M–H]\(^–\), 85%), 148 ([M–N(cyclohexylethyl)(4-iodophenyl)–H]\(^–\), BP); [\( \alpha \)]\(_D\)\(^{24}\) –78.2 (c 0.19 in CHCl\(_3\)); Anal. Calcd. for C\(_{22}\)H\(_{24}\)NO\(_3\) I C 55.36, H 5.07, N 2.93, Found C 55.14, H 4.99, N 2.89.

**Preparation of 21b** [\( R = \text{CH}_2\text{(cHex)} \)]

A mixture of 20b (2.52 g, 5.28 mmol), LiOH·H\(_2\)O (562 mg, 13.4 mmol), THF (70 mL), MeOH (20 mL) and water (20 mL) was stirred at room temperature for 1.5 h. After removal of the organic solvents by evaporation, the residue was acidified with 1N HCl aq., and the resulting solid was collected by filtration to give 21b (2.33 g) as a white solid in 95% yield.

An analytical sample was obtained as colorless crystals by recrystallization from 95% ethanol.

**Data of 21b** [\( R = \text{CH}_2\text{(cHex)} \)]

mp 256-257 °C (decomp.); \(^1\)H NMR \( \delta (400 \text{ MHz, DMSO-\text{d}_6}, \text{TMS})/\text{ppm} 13.10 (1H, br.s), 7.77 (2H, d, \( J = 8.0 \) Hz), 7.60 (2H, d, \( J = 8.4 \) Hz), 7.34 (2H, d, \( J = 8.0 \) Hz), 6.97 (2H, d, \( J = 8.4 \) Hz), 3.73 (2H, d, \( J = 7.2 \) Hz), 1.77-1.39 (6H, m), 1.20-0.86 (5H, m); \(^{13}\)C NMR \( \delta (100 \text{ MHz, DMSO-\text{d}_6})/\text{ppm} 169.0, 166.8, 142.7, 140.8, 138.1, 131.3, 130.2, 129.0, 128.3, 92.5, 54.9, 35.9, 30.4, 26.1, 25.5; IR (KBr) 2970, 2847, 1722, 1599, 1563, 1485 cm\(^{-1}\); FAB-LRMS m/z 462 ([M–H]\(^–\), 29%), 148 ([M–N(cyclohexylmethyl)(4-iodophenyl)–H]\(^–\), BP); Anal. Calcd. for C\(_{21}\)H\(_{22}\)NO\(_3\) I C 54.44, H 4.79, N 3.02, Found C 54.38, H 4.73, N 3.00.

**Preparation of 21c** [\( R = \text{nBu} \)]

To a mixture of 17c (3.94 g, 9.02 mmol), THF (95 mL) and MeOH (30 mL) was added a solution of NaOH
(926 mg, 23.2 mmol) in water (30 mL), and the mixture was stirred at room temperature for 4 h. After removal of the organic solvents by evaporation, the residue was acidified with 1N HCl aq., and the resulting solid was collected by filtration to give **21c** (3.71 g) as a white solid in 97% yield.

An analytical sample was obtained as colorless crystals by recrystallization from ethanol and water.

**Data of 21c [R = nBu]**

mp 151.0-152.0 °C; ¹H NMR δ_H (300 MHz, DMSO-d₆, TMS)/ppm 13.11 (1H, br.s), 7.78 (2H, d, J = 8.1 Hz), 7.35 (2H, d, J = 8.4 Hz), 7.61 (2H, d, J = 8.1 Hz), 6.97 (2H, d, J = 8.4 Hz), 3.82 (2H, d, J = 7.5 Hz), 1.46 (2H, quint, J = 7.5 Hz), 1.29 (2H, sext, J = 7.5 Hz), 0.86 (3H, t, J = 7.5 Hz); ¹³C NMR δ_C (75 MHz, DMSO-d₆)/ppm 168.6, 166.8, 142.4, 140.7, 138.1, 131.4, 130.4, 129.0, 128.3, 92.7, 49.0, 29.4, 19.7, 13.9; IR (KBr) 2961, 2932, 2861, 2678, 2559, 2365, 1694, 1647, 1580, 1565, 1508, 1485 cm⁻¹; FD-LRMS m/z 424.1 ([M+1⁺]+, 24%), 423.0 (M⁺, BP); Anal. Calcd. for C₁₈H₁₈NO₃I·H₂O C 48.99, H 4.57, N 3.17, Found C 49.20, H 4.50, N 2.77.

**Details of X-ray Analysis**

Crystal data of **3c**: Single-crystalline sample was obtained by recrystallization from chloroform under a hexane-diffusing atmosphere. C₃⁹H₃₅Cl₃N₂O₂, M = 670.08, colorless needle, 0.60×0.10×0.05 mm³, monoclinic P2₁, a = 9.379(3), b = 24.518(7), c = 14.931(4) Å, β = 94.889(5)°, V = 3421(2) Å³, ρ_calcd (Z = 4) = 1.301 g cm⁻³. A total of 13905 unique data (2θ_max = 55.0) were measured at T = 153 K by a Rigaku Mercury70 diffractometer (Mo-Kα radiation, λ = 0.71075 Å). Numerical absorption correction was applied (μ = 3.046 cm⁻¹). The structure was solved by the direct method (SIR92) and refined by the full-matrix least-squares method on F² with anisotropic temperature factors for non-hydrogen atoms. All the hydrogen atoms are located at the calculated positions. The final R and Rw values are 0.0450 and 0.1333 for 13905 reflections (all reflections) and 829 parameters. Estimated standard deviations for **3c** are 0.003-0.005 Å for bond lengths and 0.2-0.3° for bond angles, respectively.

**References**

