SUPPORTING INFORMATION

Bifunctional Thiosquaramide Catalyzed Asymmetric Reduction of Dihydro-β-carbolines and Enantioselective Synthesis of (−)-Coerulescine and (−)-Horsfiline by Oxidative Rearrangement

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Experimental Section.

General

All the solvents were of commercial grade and were purified prior to use when necessary. NMR spectra were measured on Bruker 400 MHz for $^1$H and 100 MHz for $^{13}$C spectra, respectively, and calibrated to either TMS ($\delta = 0$ for $^1$H) or residual DMSO ($\delta = 2.50$ for $^1$H), residual CHCl$_3$ ($\delta = 7.26$ for $^1$H and $\delta = 77.23$ for $^1$H and $\delta = 39.51$ for $^{13}$C). Spin multiplicities are described as s (singlet), br s (broad singlet), d (doublet), dd (double doublet), t (triplet), td (triple doublet), q (quartet), or m (multiplet). Coupling constants are reported in hertz (Hz). TLC analyses were performed with silica gel plates (0.25 mm, E. Merck, 60 F254) using iodine and a UV lamp for visualization. Specific rotations were measured on a Perkin-Elmer 341MC polarimeter. Enantiomeric excesses were determined on a HP-1100 instrument (chiral column; mobile phase: hexane/i-PrOH/diethylamine). Mass spectra were recorded by electrospray ionization mass spectrometry (ESI-MS). HRMS was performed on a Varian QFT-ESI instrument. IR spectra were measured on Bruker FT-IR Equinox 55 and Bruker TENSOR 27 instruments.

3-(Benzy lamino)-4-butoxycyclobut-3-ene-1,2-dione (13a).\textsuperscript{1}

![Chemical structure of 3-(Benzy lamino)-4-butoxycyclobut-3-ene-1,2-dione (13a).]

To a stirred solution of dibutylsquarate 12 (500 mg, 2.21 mmol, 1.00 equiv) in CH$_2$Cl$_2$ (10 mL) was added benzylamine (0.25 mL, 2.32 mmol, 1.05 equiv) dropwise at 0 °C. The mixture was stirred at room temperature for 16 h. The solvent was evaporated in vacuo and the residue was chromatographed on silica gel (60-120 mesh) using CH$_2$Cl$_2$ to 10% MeOH in CH$_2$Cl$_2$ to afford the desired product 13a (550 mg, 96%) as a white solid. The product observed as two rotamers in DMSO at room temperature in a ratio of 0.54:0.46 in $^1$H NMR spectrum. $^1$H NMR (400 MHz, DMSO-$d_6$): $\delta$ 0.86 – 0.93 (m, 3H), 1.28 – 1.42 (m, 2H), 0.86 – 0.93 (m, 3H), 1.64 – 1.74 (m, 2H), 4.48 (d, $J = 5.6$ Hz, 1H), 4.63 (t, $J = 6.5$ Hz, 2H), 4.69 (d, $J = 5.9$ Hz, 1H), 7.28 – 7.32 (m, 3H), 7.36 – 7.39 (m, 2H), 9.06 (br s, 0.46H), 9.29 (br s, 0.54H); $^{13}$C NMR (100 MHz, DMSO-$d_6$): $\delta$ 13.5, 18.1, 31.5, 46.9, 47.3, 72.5, 127.3, 127.5, 128.6, 138.1, 138.4, 172.0, 172.6, 176.9, 177.5, 182.2, 182.5, 189.1, 189.5; IR (KBr): 3214.79, 2954.81, 1813.62, 1714.85, 1641.49, 1307.39, 1058.33, 734.25 cm$^{-1}$; HRMS (ESI) calcd for C$_{15}$H$_{17}$NNaO$_3$ m/z 282.1106 [M + Na]$^+$, found 282.0894.
3-Butoxy-4-(tert-butylamino)cyclobut-3-ene-1,2-dione (13b).\(^1\)

To a stirred solution of dibutylsquarate 12 (500 mg, 2.21 mmol, 1.00 equiv) in CH\(_2\)Cl\(_2\) (10 mL) was added tert-butylamine (0.24 mL, 2.32 mmol, 1.05 equiv) dropwise at 0 °C. The mixture was stirred at room temperature for 6 h. The solvent was evaporated in vacuo and the residue was chromatographed on silica gel (60-120 mesh) using CH\(_2\)Cl\(_2\) to 10% MeOH in CH\(_2\)Cl\(_2\) to afford the desired product 13a (382 mg, 78%) as a white solid. The product observed as two rotamers in DMSO at room temperature in a ratio of 0.56:0.44 in \(^1\)H NMR spectrum.

\(^1\)H NMR (400 MHz, DMSO-\(d_6\)): \(\delta\) 0.92 (t, \(J = 7.3\) Hz, 3H), 1.31 (s, 9H), 1.40 (td, \(J = 14.9, 7.5\) Hz, 2H), 1.73 (dt, \(J = 14.3, 6.5\) Hz, 2H), 4.64 (s, 0.88H), 4.71 (s, 1.22H), 8.59 (s, 0.44H), 8.75 (s, 0.56H); \(^{13}\)C NMR (100 MHz, DMSO-\(d_6\)): \(\delta\) 13.4, 18.2, 29.6, 30.0, 31.5, 52.3, 52.9, 72.2, 72.4, 171.2, 172.9, 175.3, 178.3, 181.8, 182.7, 187.9, 189.9.; IR (KBr): 3143.97, 2937.01, 1796.46, 1622.82, 1351.00, 1192.92 cm\(^{-1}\); HRMS (ESI) calcd for C\(_{12}\)H\(_{19}\)NO\(_3\) m/z 225.1365 [M]\(^+\), found 225.1363.

3-(Benzylamino)-4-butoxycyclobut-3-ene-1,2-dithione (14a).\(^1\)

To a stirred solution of 13a (400 mg, 1.54 mmol, 1.0 equiv) in dry CH\(_2\)Cl\(_2\) (10 mL) was added Lawesson’s reagent (624 mg, 1.54 mmol, 1.0 equiv). The reaction mixture was stirred at room temperature for 3 h. The solvent evaporated and chromatographed on silica gel column (60-120 mesh) in DCM to afford product 14a (224 mg, 50%) as an orange solid. The product exists as two rotamers in DMSO at room temperature. \(^1\)H NMR (400 MHz, DMSO-\(d_6\)): \(\delta\) 0.90 (t, \(J = 7.3\) Hz, 3H), 1.31 (s, 9H), 1.40 (td, \(J = 14.9, 7.5\) Hz, 2H), 1.73 (dt, \(J = 14.3, 6.5\) Hz, 2H), 4.64 (s, 0.88H), 4.71 (s, 1.22H), 8.59 (s, 0.44H), 8.75 (s, 0.56H); \(^{13}\)C NMR (100 MHz, DMSO-\(d_6\)): \(\delta\) 13.4, 18.2, 29.6, 30.0, 31.5, 52.3, 52.9, 72.2, 72.4, 171.2, 172.9, 175.3, 178.3, 181.8, 182.7, 187.9, 189.9.; IR (KBr): 3143.97, 2937.01, 1796.46, 1622.82, 1351.00, 1192.92 cm\(^{-1}\); HRMS (ESI) calcd for C\(_{15}\)H\(_{18}\)NOS\(_2\) m/z 292.0824 [M + H]\(^+\), found 292.0827.
Synthesis of 3-(benzylamino)-4-butoxycyclobut-3-ene-1,2-dithione (14b).\(^1\) To a stirred solution of 13b (300 mg, 1.33 mmol, 1.0 equiv) in dry CH\(_2\)Cl\(_2\) (10 mL) was added Lawesson’s reagent (538 mg, 1.33 mmol, 1.0 equiv). The reaction mixture was stirred at room temperature for 5 h. The solvent evaporated and passed through a silica gel column (60-120 mesh) in DCM to afford product 14b (307 mg, 90%) as an orange solid. The product exists as two rotamers in DMSO at room temperature in a ratio of 0.86:0.14.\(^1\) H NMR (400 MHz, DMSO-\(d_6\)): \(\delta\) 0.93 (t, \(J = 7.3\) Hz, 3H), 1.40 (s, 8H), 1.41 – 1.48 (m, 2H), 1.54 (s, 1H), 1.78 – 1.84 (m, 2H), 5.17 (t, \(J = 6.5\) Hz, 0.28H), 5.26 (t, \(J = 6.3\) Hz, 1.72H), 9.45 (s, 0.86H), 9.62 (s, 0.14H);\(^13\)C NMR (100 MHz, DMSO-\(d_6\)): \(\delta\) 13.4, 17.9, 18.1, 29.6, 30.9, 31.7, 54.1, 54.9, 73.5, 173.5, 181.2, 205.0, 218.5; IR (KBr): 3210.90, 3164.61, 2964.05, 1688.67, 1513.85, 1432.85, 1324.86, 1238.08 cm\(^{-1}\); HRMS (ESI) calcd for C\(_{12}\)H\(_{20}\)N\(_{2}\)O\(_2\) m/z 258.0981 [M + H]\(^+\), found 258.0983.

\((1R,2R)-N1,N1\)-dimethylcyclohexane-1,2-diamine (15).\(^2\) Diamine 15 was prepared as mentioned in the literature.

3-(Benzylamino)-4-(((1R,2R)-2-(dimethylamino)cyclohexyl)amino)cyclobut-3-ene-1,2-dione (11a). To a stirred solution of 13a (100 mg, 0.34 mmol, 1.00 equiv) in CH\(_2\)Cl\(_2\) (10 mL) at 0 °C was added 15 (48.79 mg, 0.34 mmol, 1.0 equiv) in 2 mL CH\(_2\)Cl\(_2\). The reaction mixture was stirred at room temperature for 4 h. The solvent most was evaporated and the residue was washed with ice-cold CH\(_2\)Cl\(_2\) to afford the desired product 11a (90.72 mg, 72%) as white solid.\(^1\) H NMR (400 MHz, DMSO-\(d_6\)): \(\delta\) 1.16 – 1.23 (m, 4H), 1.51 – 1.92 (m, 3H), 2.06 (br s, 1H), 2.16 (s, 6H), 2.32 (m, 1H), 3.75 (s, 1H), 4.72 (br s, 2H), 7.31 (br s, 1H), 7.36 – 7.38 (m, 5H), 7.84 (br s, 1H);\(^13\)C NMR (100 MHz, DMSO-\(d_6\)): \(\delta\) 21.4, 24.3, 24.4, 34.7, 46.8, 54.0, 66.1, 127.4, 127.7, 128.6, 138.9, 167.1, 167.5, 181.9, 182.2; IR (KBr): 3502.88, 3185.49, 2935.23, 1797.61, 1644.48, 1585.70, 1430.16, 1348.69 cm\(^{-1}\); HRMS (ESI) calcd for C\(_{19}\)H\(_{26}\)N\(_{3}\)O\(_2\) m/z 328.2020 [M + H]\(^+\), found 328.2013.
3-(Benzylamino)-4-(((1R,2R)-2-(dimethylamino)cyclohexyl)amino)cyclobut-3-ene-1,2-dithione (11b).\(^1\)

To a stirred solution of 14a (150 mg, 0.51 mmol, 1.00 equiv.) in CH\(_2\)Cl\(_2\) (10 mL) at 0 °C was added 15 (73.2 mg, 0.51 mmol, 1.00 equiv.) in 2 mL CH\(_2\)Cl\(_2\). The reaction mixture was at room temperature for 1 h. The solvent most was evaporated and the orange solid was washed with Et\(_2\)O to afford the desired product 11b (120 mg, 65%) as an orange solid. The product exists as two rotamers in DMSO at room temperature in a ratio of 0.90:0.10.\(^1\)\(^H\) NMR (400 MHz, DMSO-\(d_6\)): \(\delta\) 1.20 – 1.22 (m, 3H), 1.31 – 1.36 (m, 1H), 1.64 (br s, 1H), 1.74 (br s, 1H), 1.89 (br s, 1H), 2.10 (m, 1H), 2.26 (s, 6H), 2.50 (m, 1H), 4.55 – 4.71 (m, 0.1H), 4.81 (m, 0.9H), 5.10 – 5.39 (m, 1.8H), 5.60 – 5.71 (m, 0.2H), 7.34 – 7.45 (m, 5H), 8.65 (br s, 1H), 8.98 (br s, 1H); \(^1^3\)C NMR (100 MHz, DMSO-\(d_6\)): \(\delta\) 22.1, 24.1, 24.3, 24.5, 24.7, 30.6, 35.3, 46.5, 50.9, 54.0, 65.3, 66.4, 128.2, 128.45, 129.2, 137.8, 170.53, 170.9, 203.4, 204.4; IR (KBr): 3176.46, 2933.80, 1713.23, 1571.75, 1450.72, 1280.37 cm\(^{-1}\); HRMS (ESI) calcd for C\(_{19}\)H\(_{26}\)N\(_3\)S\(_2\) m/z 360.1563 [M + H]\(^+\), found 360.1572.

3-(tert-Butylamino)-4-(((1R,2R)-2-(dimethylamino)cyclohexyl)amino)cyclobut-3-ene-1,2-dione (11c).\(^1\)

To a stirred solution of 13b (100 mg, 0.44 mmol, 1.00 equiv) in CH\(_2\)Cl\(_2\) (10 mL) at 0 °C was added 15 (63.11 mg, 0.44 mmol, 1.00 equiv) in 2 mL CH\(_2\)Cl\(_2\). The reaction mixture was stirred at room temperature for 18 h. The solvent most was evaporated and the residue was washed with ice-cold CH\(_2\)Cl\(_2\) to afford the desired product 11c (110.68 mg, 85%) as white solid. \(^1\)H NMR (400 MHz, DMSO-\(d_6\)): \(\delta\) 1.28 – 1.12 (m, 4H), 1.38 (s, 9H), 1.63 (m, 1H), 1.72 (m, 1H), 1.81 (m, 1H), 2.03 (m, 1H), 2.17 (s, 6H), 2.30 (m, 1H), 3.79 (m, 1H), 7.41 (d, \(J = 7.6\) Hz, 1H), 7.59 (s, 1H); \(^1^3\)C NMR (100 MHz, DMSO-\(d_6\)): \(\delta\) 21.2, 24.3, 24.4, 30.3, 35.0, 52.1, 54.1, 66.2, 167.5, 167.9, 180.4, 181.9; IR (KBr): 3207.96, 2934.87, 1791.35, 1647.94, 1570.98, 1446.34, 1363.82, 1214.60 cm\(^{-1}\); HRMS (ESI) calcd for C\(_{16}\)H\(_{28}\)N\(_3\)O\(_2\) m/z 294.2176 [M + H]\(^+\), found 294.2186.
3-(tert-Butylamino)-4-(((1R,2R)-2-(dimethylamino)cyclohexyl)amino)cyclobut-3-ene-1,2-dithione (11d).  

To a stirred solution of 14b (100 mg, 0.38 mmol, 1.00 equiv) in CH$_2$Cl$_2$ (10 mL) at 0 °C was added 15 (55.25 mg, 0.38 mmol, 1.0 equiv) in 2 mL CH$_2$Cl$_2$. The reaction mixture was at room temperature for 1 h. The solvent was evaporated and the orange solid was washed with ice-cold CH$_2$Cl$_2$ to afford the desired product 11d (94.83 mg, 75%) as an orange solid. $^1$H NMR (400 MHz, DMSO-$d_6$): $\delta$ 1.15 – 1.28 (m, 3H), 1.30 – 1.40 (m, 1H), 1.60 (s, 9H), 1.74 (m, 1H), 1.87 (d, $J = 9.8$ Hz, 1H), 2.05 (d, $J = 10.1$ Hz, 1H), 2.23 (s, 6H), 2.50 (s, 1H), 4.92 (m, 1H), 8.71 (s, 0.9H), 8.71 (br s, 1H); $^{13}$C NMR (100 MHz, DMSO-$d_6$): $\delta$ 21.0, 24.1, 31.1, 35.3, 53.8, 54.5, 65.6, 170.6, 171.2, 201.8, 204.5; IR (KBr): 3453.44, 3172.72, 2933.85, 1696.12, 1566.08, 1464.04, 1332.43 cm$^{-1}$; HRMS (ESI) calcd for C$_{16}$H$_{28}$N$_3$S$_2$ m/z 326.1719 [M + H]$^+$, found 326.1723.

**General procedure for the synthesis of DHBCs 17a, 17b and 17c.**

To a stirred solution of tryptamine (16a, 1 mmol) in DCM (10 vol) was added triethylamine (2 mmol) followed by corresponding acid chloride (1.1 mmol) at 0 °C. The reaction was stirred for 6 h, diluted with cold water after completion of starting material and extracted twice with DCM. The combined organic phase was washed once with 1N HCl solution and once with cold water before dried over with Na$_2$SO$_4$. The solvents were removed under reduced pressure and the obtained amides were reacted directly with POCl$_3$ (3 mmol) in the mixture of dry toluene and acetonitrile (3:1). The reaction mixture was heated to reflux for 2 h, cooled to room temperature, and then concentrated. The residue was basified with cold 20% NaOH solution up to pH = 10 and extracted twice with DCM and dried over Na$_2$SO$_4$. After the concentration of solvent, the resulting viscous oil was purified by chromatography (10% MeOH/CHCl$_3$) to afford DHBCs 17a, 17b and 17c.

**General procedure for the synthesis of DHBCs 17d, 17e and 17f.**

To a stirred solution of tryptamine (16a, 1 mmol) and corresponding acids (1.1 mmol) in DCM (10 vol) were added EDC.HCl (1.2 mmol), HOBt (1.2 mmol) followed by
triethylamine (3 mmol) at 0 °C. The reaction mixture was stirred at room temperature for 18 h and diluted with DCM, washed with water and brine solution. Then the organic phase was dried over Na₂SO₄ and concentrated in vacuo to afford the corresponding amides which were reacted directly with POCl₃ (3 mmol) in the mixture of dry toluene and acetonitrile (3:1). The reaction mixture was heated to reflux for 2 h, cooled to room temperature, and then concentrated. The residue was basified with cold 20% NaOH solution up to pH = 10 and extracted twice with DCM and dried over Na₂SO₄. After the concentration of solvent, the resulting viscous oil was purified by chromatography (10% MeOH/CHCl₃) to afford DHBCs 17d, 17e and 17f.

1-Methyl-4,9-dihydro-3H-pyrido[3,4-b]indole (17a). Yellow solid, 317 mg, yield 92%; ¹H NMR (400 MHz, CDCl₃): δ 2.42 (s, 3H), 2.86 (t, J = 8.4 Hz, 2H), 3.81 (t, J = 8.3 Hz, 2H), 7.11 (t, J = 7.5 Hz, 1H), 7.22 – 7.24 (m, 1H), 7.41 (d, J = 8.3 Hz, 1H), 7.55 (d, J = 8.0 Hz, 1H), 9.42 (br s, 1H) ppm; ¹³C NMR (100 MHz, CDCl₃): δ 19.4, 21.6, 47.2, 112.4, 117.6, 120.3, 120.6, 125.2, 125.4, 128.8, 137.7, 159.4 ppm; FT-IR (KBr): 3417.24, 2933.20, 1620.26, 1548.56, 744.86 cm⁻¹. HRMS (ESI) calcd for C₁₂H₁₂N₂ m/z 184.1000 [M]+, found 184.1004.

1-Ethyl-4,9-dihydro-3H-pyrido[3,4-b]indole (17b). Pale yellow solid, 330 mg, yield 89%; ¹H NMR (400 MHz, CDCl₃): δ 1.30 (t, J = 7.4 Hz, 3H), 2.74 (q, J = 7.4 Hz, 2H), 2.91 (t, J = 8.4 Hz, 2H), 3.89 (t, J = 8.4 Hz, 2H), 7.10–7.63 (m, 4H), 8.81 (br s, 1H) ppm; ¹³C NMR (100 MHz, CDCl₃): δ 10.9, 19.3, 28.4, 48.2, 111.9, 116.8, 120.0, 120.3, 124.4, 125.6, 128.6, 136.6, 161.7 ppm; FT-IR (KBr): 3428.81, 2936.01, 1630.87, 1540.68, 744.39 cm⁻¹; HRMS (ESI) calcd for C₁₃H₁₅N₂ m/z 199.1230 [M + H]⁺, found 199.1228.
1-Isopropyl-4,9-dihydro-3H-pyrido[3,4-b]indole (17c).

Pale yellow solid, 357 mg, yield 90%; \( ^1 \)H NMR (400 MHz, CDCl\(_3\)): \( \delta \) 1.37 (d, \( J = 6.9 \) Hz, 6H), 2.99 (t, \( J = 8.5 \) Hz, 2H), 3.56 (dt, \( J = 13.6, 6.8 \) Hz, 1H), 3.92 (t, \( J = 8.5 \) Hz, 2H), 7.13 (t, \( J = 7.5 \) Hz, 1H), 7.29 (t, \( J = 7.8 \) Hz, 1H), 7.58 (dd, \( J = 7.9, 4.9 \) Hz, 2H), 10.87 (br s, 1H) ppm; \(^{13}\)C NMR (100 MHz, CDCl\(_3\)): \( \delta \) 19.5, 20.4, 42.9, 45.2, 113.3, 120.2, 120.6, 120.8, 121.15, 124.9, 126.7, 139.5, 170.2 ppm; FT-IR (KBr): 3416.10, 2966.83, 1601.20, 1544.81, 742.12 cm\(^{-1}\); HRMS (ESI) calcd for C\(_{14}\)H\(_{17}\)N\(_2\) m/z 213.1386 [M + H]+, found 213.1388.

1-Isobutyl-4,9-dihydro-3H-pyrido[3,4-b]indole (17d).

Pale yellow solid, 394 mg, yield 93%; \(^1\)H NMR (400 MHz, CDCl\(_3\)): \( \delta \) 0.95 (d, \( J = 6.6 \) Hz, 6H), 2.14 (q, \( J = 13.5, 6.7 \) Hz, 1H), 2.53 (d, \( J = 7.4 \) Hz, 2H), 2.84 (t, \( J = 8.4 \) Hz, 2H), 3.87 (t, \( J = 8.3 \) Hz, 2H), 7.12 (t, \( J = 7.5 \) Hz, 1H), 7.23 (d, \( J = 8.0 \) Hz, 1H), 7.37 (d, \( J = 8.2 \) Hz, 1H), 7.58 (d, \( J = 8.0 \) Hz, 1H), 8.97 (br s, 1H) ppm; \(^{13}\)C NMR (100 MHz, CDCl\(_3\)): \( \delta \) 19.5, 22.8, 27.2, 44.8, 48.2, 112.1, 116.9, 120.0, 120.3, 124.5, 125.6, 129.1, 136.8, 160.9 ppm; FT-IR (KBr): 3419.17, 2925.48, 1619.91, 1534.08, 741.80 cm\(^{-1}\); HRMS (ESI) calcd for C\(_{15}\)H\(_{19}\)N\(_2\) m/z 227.1543 [M + H]+, found 227.1553.

1-Phenyl-4,9-dihydro-3H-pyrido[3,4-b]indole (17e).

Pale yellow solid, 419 mg, yield 91%; \(^1\)H NMR (400 MHz, DMSO-d\(_6\)): \( \delta \) 2.89 (t, \( J = 8.2 \) Hz, 2H), 3.92 (t, \( J = 8.2 \) Hz, 2H), 7.10 (t, \( J = 7.4 \) Hz, 1H), 7.23 (t, \( J = 7.5 \) Hz, 1H), 7.45 (d, \( J = 8.2 \) Hz, 1H), 7.59 – 7.53 (m, 3H), 7.64 (d, \( J = 7.9 \) Hz, 1H), 7.83 – 7.74 (m, 2H), 11.14 (br s, 1H) ppm; \(^{13}\)C NMR (100 MHz, DMSO-d\(_6\)): 19.1, 48.6, 113.0, 116.6, 119.7, 119.8, 123.9, 125.0, 127.7, 128.2, 128.7, 129.9, 137.2, 137.7, 158.8 ppm; FT-IR (KBr): 3419.17, 2933.44, 1616.40, 1534.08, 741.80 cm\(^{-1}\); HRMS (ESI) calcd for C\(_{17}\)H\(_{14}\)N\(_2\) m/z 246.1157 [M]+, found 246.1153.
1-(2,3-dihydrobenzofuran-5-yl)-4,9-dihydro-3H-pyrido[3,4-b]indole (17f).

Yellow solid, 459 mg, yield 85%; $^1$H NMR (400 MHz, DMSO-$d_6$ + CDCl$_3$): $\delta$ 2.90 (t, $J = 7.8$ Hz, 2H), 3.18 (t, $J = 7.8$ Hz, 2H), 3.89 (t, $J = 8.0$ Hz, 2H), 4.55 (t, $J = 8.0$ Hz, 2H), 6.78 (d, $J = 8.0$ Hz, 1H), 7.07 (t, $J = 7.2$ Hz, 1H), 7.19 (t, $J = 7.2$ Hz, 1H), 7.40 (d, $J = 8.8$ Hz, 1H), 7.54 (dd, $J = 15.4$, $8.3$ Hz, 2H), 7.63 (s, 1H), 10.14 (br s, 1H) ppm; $^{13}$C NMR (100 MHz, CDCl$_3$): $\delta$ 19.4, 29.4, 47.8, 71.9, 109.3, 112.3, 118.8, 120.1, 120.6, 125.0, 125.3, 125.5, 127.7, 128.2, 128.9, 137.2, 159.4, 162.3 ppm; FT-IR (KBr): 3401.82, 2929.34, 1610.27, 1535.06, 742.46 cm$^{-1}$; HRMS (ESI) calcd for C$_{19}$H$_{17}$N$_2$O $m/z$ 289.1335 [M + H]$^+$, found 289.1343.

General procedure for the thiosquaramide 11b catalyzed asymmetric reduction of DHBCs to form chiral THBCs 18a-f.

To a solution of DHBC (17, 1 mmol) in DCE (10 vol) was added thiosquaramide 11b (10 mol%) and stirred at room temperature for 1 h. Then the reaction mixture was cooled to 10 $^\circ$C and added PdCl$_2$ (15 mol%) followed Et$_3$SiH (4 mmol), the reaction mixture was stirred at same temperature for 24 h. Upon completion of starting material, the reaction mixture was filtered on celite pad, washed with DCM and evaporated in vacuo. The crude product was purified by preparative TLC using 5% MeOH/DCM to afford the chiral THBCs 18a-f.

(R)-1-Methyl-2,3,4,9-tetrahydro-1H-pyrido[3,4-b]indole (18a).$^3$

Cream solid, 7.3 mg, yield 73%; $[\alpha]_D = +50$ (c 1.0, MeOH); Chiral HPLC: 95% ee, Chiralcel OD-H, n-hexane/2-propanol/diethylamine = 90/10/0.1, flow rate: 1.0 mL/min, $\lambda = 254$ nm, $R_t = 6.1$ min (major) and 8.3 min (minor); $^1$H NMR (400 MHz, CDCl$_3$): $\delta$ 1.39 (d, $J = 6.7$ Hz, 3H), 2.75 – 2.63 (m, 2H), 3.02 – 2.96 (m, 1H), 3.33 – 3.28 (m, 1H), 4.11 (q, $J = 6.6$ Hz, 1H), 7.10 – 7.02 (m, 2H), 7.24 (d, $J = 7.8$ Hz, 1H) 7.42 (d, $J = 7.6$ Hz, 1H), 7.82 (br s, 1H) ppm; $^{13}$C NMR (100 MHz, CDCl$_3$): $\delta$ 20.8, 22.8, 42.9, 48.3, 108.6, 110.8, 118.2, 119.5, 121.6, 127.6, 135.7, 137.2 ppm; FT-IR (KBr): 3409.53, 2977.65, 1614.15, 1502.37. 1738.75 cm$^{-1}$; HRMS (ESI) calcd for C$_{12}$H$_{15}$N$_2$ $m/z$ 187.1230 [M + H]$^+$, found 187.1236.
(R)-1-Ethyl-2,3,4,9-tetrahydro-1H-pyrido[3,4-b]indole (18b).3b,4

Cream solid, 8.6 mg, yield 85%; \([\alpha]_D = +59\ (c\ 1.0,\ MeOH)\); Chiral HPLC: 92% ee, Chiralcel OD-H, n-hexane/2-propanol/diethylamine = 90/10/0.1, flow rate: 1.0 mL/min, \(\lambda = 254\ nm\), \(R_t = 4.7\ min\) (major) and 7.9 min (minor); \(^1\)H NMR (400 MHz, CDCl\(_3\)):\ \(\delta 1.07\ (t, J = 7.4\ Hz, 3H), 1.75 – 1.68\ (m, 2H), 1.97 – 1.91\ (m, 1H), 2.78 – 2.75\ (m, 2H), 3.08 – 3.01\ (m, 1H), 3.41 – 3.35\ (m, 1H), 4.03 – 4.01\ (m, 1H), 3.08 – 3.01\ (m, 1H), 7.18 – 7.09\ (m, 2H), 7.31\ (d, J = 7.9\ Hz, 1H), 7.50\ (d, J = 7.6\ Hz, 1H), 7.87\ (br s, 1H) ppm; \(^13\)C NMR (100 MHz, CDCl\(_3\)):\ \(\delta 10.3, 22.8, 27.8, 42.7, 54.0, 109.2, 110.8, 118.1, 119.4, 121.5, 127.6, 135.7, 136.3\ ppm; FT-IR (KBr): 3409.53, 2929.34, 1621.84, 1590.27, 741.40 cm\(^{-1}\); HRMS (ESI) calcd for C\(_{13}\)H\(_{17}\)N\(_2\) m/z 201.1386 [M + H]\(^+\), found 201.1394.

(R)-1-Isopropyl-2,3,4,9-tetrahydro-1H-pyrido[3,4-b]indole (18c).3b,5

Off white solid, 8.8 mg, yield 88%; \([\alpha]_D = +55.7\ (c\ 1.0,\ MeOH)\); Chiral HPLC: 93% ee, Chiralcel OD-H, n-hexane/2-propanol/diethylamine = 90/10/0.1, flow rate: 1.0 mL/min, \(\lambda = 254\ nm\), \(R_t = 8.0\ min\) (major) and 11.6 min (minor); \(^1\)H NMR (400 MHz, DMSO-\(d_6\) + CDCl\(_3\)):\ \(\delta 0.81\ (d, J = 6.6\ Hz, 3H), 1.09\ (d, J = 6.5\ Hz, 3H), 2.30 – 2.33\ (m, 1H), 2.68 – 2.81\ (m, 2H), 2.94 – 3.00\ (m, 1H), 3.41\ (d, J = 12.3\ Hz, 1H), 3.96 – 4.00\ (m, 1H), 6.93 – 7.09\ (m, 2H), 7.28\ (t, J = 8.0\ Hz, 1H), 7.37\ (d, J = 7.5\ Hz, 1H), 9.30\ (s, 1H) ppm; \(^13\)C NMR (100 MHz, CDCl\(_3\)):\ \(\delta 17.0, 19.1, 21.6, 31.5, 42.4, 57.8, 109.9, 110.7, 118.1, 119.5, 121.8, 127.2, 133.5, 135.8\ ppm; FT-IR (KBr): 3415.31, 2929.34, 1627.64, 1566.40, 736.09 cm\(^{-1}\); HRMS (ESI) calcd for C\(_{14}\)H\(_{19}\)N\(_2\) m/z 215.1543 [M + H]\(^+\), found 215.1547.

(R)-1-Isobutyl-2,3,4,9-tetrahydro-1H-pyrido[3,4-b]indole (18d).3b

Cream solid, 6.5 mg, yield 65%; \([\alpha]_D = +33.8\ (c\ 1.0,\ MeOH)\); Chiral HPLC: 86% ee, Chiralcel OD-H, n-hexane/2-propanol/diethylamine = 95/5/0.1, flow rate: 0.8 mL/min, \(\lambda = 254\ nm\), \(R_t = 6.4\ min\) (major) and 9.0 min (minor); \(^1\)H NMR (400 MHz, CDCl\(_3\)):\ \(\delta 0.99 – 1.07\ (m, 6H), 1.59 – 1.64\ (m, 3H), 1.97 – 2.02\ (m, 1H), 2.71 – 2.81\ (m,
2H), 3.01 – 3.07 (m, 1H), 3.35 – 3.38 (m, 1H), 4.12 (br s, 1H), 7.09 – 7.17 (m, 2H), 7.30 (d, \( J = 7.8 \) Hz, 1H), 7.50 (d, \( J = 7.5 \) Hz, 1H), 7.80 (br s, 1H) ppm; \(^{13}\)C NMR (100 MHz, CDCl\(_3\)): \( \delta \) 21.8, 22.8, 23.9, 24.7, 42.5, 44.5, 50.6, 108.9, 110.7, 118.1, 119.4, 121.5, 127.7, 135.7, 136.8 ppm; FT-IR (KBr): 3415.31, 2927.41, 1449.68, 1240.00, 736.09 cm\(^{-1}\); HRMS (ESI) calcd for C\(_{15}\)H\(_{21}\)N\(_2\) m/z 229.1699 \([\text{M + H}]^+\), found 229.1703.

(R)-1-Phenyl-2,3,4,9-tetrahydro-1\(H\)-pyrido[3,4-b]indole (18e).\(^3\)

Cream solid, 7.3 mg, yield 73%; \([\alpha]_D = -3.8\) (c 1.0, CHCl\(_3\)); Chiral HPLC: 91% ee, Chiralcel OD-H, n-hexane/2-propanol/diethylamine = 85/15/0.1, flow rate: 1.0 mL/min, \( \lambda = 254 \) nm, \( R_t = 2.9 \) min (minor) and 4.5 min (major); \(^1\)H NMR (400 MHz, CDCl\(_3\)): \( \delta \) 2.15 (s, 1H), 2.81 – 2.85 (m, 1H), 2.90 – 2.97 (m, 1H), 3.10 – 3.17 (m, 1H), 3.35 – 3.38 (m, 1H), 5.15 (s, 1H), 7.10 – 7.20 (m, 3H), 7.31 – 7.36 (m, 5H), 7.56 (d, \( J = 7.2 \) Hz, 1H), 7.67 (br s, 1H) ppm; \(^{13}\)C NMR (100 MHz, CDCl\(_3\)): \( \delta \) 22.6, 42.9, 58.1, 110.3, 110.9, 118.3, 119.5, 121.8, 127.5, 128.3, 128.6, 128.9, 134.5, 136.0, 141.8 ppm; FT-IR (KBr): 3411.46, 2935.21, 1561.09, 1454.06, 742.46 cm\(^{-1}\); HRMS (ESI) calcd for C\(_{17}\)H\(_{17}\)N\(_2\) m/z 249.1386 \([\text{M + H}]^+\), found 249.1392.

(R)-1-(2,3-dihydrobenzofuran-5-yl)-2,3,4,9-tetrahydro-1\(H\)-pyrido[3,4-b]indole (18f).\(^{3b,6}\)

Cream solid, 7.0 mg, yield 70%; \([\alpha]_D = +20.3\) (c 1.0, MeOH); Chiral HPLC: 96% ee, Chiralcel OD-H, n-hexane/2-propanol/diethylamine = 85/15/0.1, flow rate: 1.0 mL/min, \( \lambda = 254 \) nm, \( R_t = 4.9 \) min (minor) and 6.9 min (major); \(^1\)H NMR (400 MHz, CDCl\(_3\)): \( \delta \) 2.79 – 2.83 (m, 1H), 2.89 – 2.96 (m, 1H), 3.10 – 3.14 (m, 3H), 3.35 – 3.38 (m, 1H), 4.55 (t, \( J = 8.7 \) Hz, 2H), 5.08 (s, 1H), 6.74 (d, \( J = 8.1 \) Hz, 1H), 7.04 (d, \( J = 8.1 \) Hz, 1H), 7.09 – 7.17 (m, 3H), 7.21 (d, \( J = 7.3 \) Hz, 1H), 7.55 (d, \( J = 7.3 \) Hz, 1H), 7.72 (s, 1H) ppm; \(^{13}\)C NMR (100 MHz, CDCl\(_3\)): \( \delta \) 22.6, 29.7, 43.0, 57.8, 71.5, 109.2, 110.1, 110.9, 118.3, 119.4, 121.7, 125.1, 127.5, 127.8, 128.5, 133.9, 135.0, 135.9, 160.1 ppm; FT-IR (KBr): 3394.10, 2916.64, 1690.70, 1490.70, 142.46 cm\(^{-1}\); HRMS (ESI) calcd for C\(_{19}\)H\(_{19}\)N\(_2\)O m/z 291.1492 \([\text{M + H}]^+\), found 291.1498.
2,3,4,9-Tetrahydro-1H-pyrido[3,4-b]indole (19a).

To a stirred solution of tryptamine (16a, 1.0 g, 6.2 mmol, 1 equiv.) in AcOH/MeOH (10/1, 10 mL) was added polyformaldehyde (0.20 g, 6.8 mmol, 1.1 equiv.). The reaction mixture was then heated to 80 °C for 1 h and cooled to room temperature and basified to pH 9–10 using aqueous ammonia solution. The basic solution was extracted with CH₂Cl₂ and the combined organic phases were washed with brine solution, dried over with Na₂SO₄, filtered, and concentrated to give the desired product (990 mg, 93%) as a pale yellow solid. ¹H NMR (400 MHz, CDCl₃ + DMSO-d₆): δ 2.74 (t, J = 5.5 Hz, 2H), 3.17 (t, J = 5.6 Hz, 2H), 4.02 (s, 2H), 7.11 – 6.99 (m, 2H), 7.32 – 7.28 (m, 1H), 7.44 (d, J = 7.5 Hz, 1H), 9.35 (s, 1H) ppm; ¹³C NMR (100 MHz, CDCl₃ + DMSO-d₆): δ 22.4, 43.2, 43.9, 107.7, 110.8, 117.5, 118.7, 120.8, 127.4, 133.2, 135.8 ppm; IR (KBr): 3397.52, 3298.17, 2922.40, 1584.24, 1449.13, 1238.27 cm⁻¹; HRMS (ESI) cald for C₁₁H₁₃N₂ m/z 173.1073 [M + H]⁺, found 173.1078.

2-Methyl-2,3,4,9-tetrahydro-1H-pyrido[3,4-b]indole (20a).

To a stirred solution of tetrahydro-β-carboline 19a (0.50 g, 2.9 mmol, 1 equiv.) in MeOH (10 mL) was added NaCNBH₃ (0.36 g, 5.8 mmol, 2 equiv.) and treated with 3.2 mL of formaldehyde solution (27% in water). The reaction mixture was stirred for 2 h and added 2N HCl (50 mL) then stirred for 15 min. The reaction mixture was basified with concentrated NaOH solution (pH = 11). The basic solution was extracted with CH₂Cl₂ and the combined organic phases were washed with brine solution, dried over with Na₂SO₄, filtered, and concentrated to give crude product, which was purified by silica gel column chromatography using CH₂Cl₂/MeOH (10:1) to obtain desire product 20a (481 mg, 89%) as off-white solid. ¹H NMR (400 MHz, CDCl₃ + DMSO-d₆): δ 2.49 (s, 3H), 2.82 – 2.77 (m, 4H), 7.08 – 6.99 (m, 2H), 3.58 (s, 2H), 7.28 (d, J = 7.3 Hz, 1H), 7.42 (d, J = 7.6 Hz, 1H), 9.69 (s, 1H) ppm; ¹³C NMR (100 MHz, CDCl₃ + DMSO-d₆): δ 21.5, 45.7, 52.4, 53.0, 106.9, 110.8, 117.5, 118.5, 120.6, 127.0, 132.4, 136.1 ppm; IR (KBr): 3138.73, 3298.17, 2922.40, 1584.24, 1449.13, 1238.27 cm⁻¹; HRMS (ESI): cald for C₁₂H₁₅N₂ m/z 187.1230 [M + H]⁺, found 187.1235.
(−)-Coerulescine (5).\(^9\)

To a stirred solution of 20a (30 mg, 0.16 mmol, 1.0 equiv) in mixture of THF/water/AcOH (1:1:1, 0.6 mL) was added thiosquaramide 11b (5.7 mg, 10 mol%) and stirred for 10 min. Then the reaction mixture was cooled to 0 °C and added NBS (28.7 mg, 0.16 mmol, 1 equiv.). The reaction mixture was then stirred for 20 min at 0 °C. After complete consumption of starting material, the reaction mixture was basified with cold saturated NaHCO\(_3\) solution. The basic solution was extracted with CH\(_2\)Cl\(_2\) and the combined organic phases were washed with brine solution, dried over with Na\(_2\)SO\(_4\), filtered, and concentrated to give crude product, which was purified by silica gel column chromatography using CH\(_2\)Cl\(_2\)/MeOH/TEA (10:1:0.5) to obtain desire product (27.6 mg, 85%) as colorless thick liquid. \([\alpha]\)\(^{25}\)_D = −1.37 \(（c = 0.4, \text{ MeOH}）\); Chiral HPLC: 98% ee, Chiralcel OD-H, hexane/iPrOH 95/5, flow rate 1 mL/min; \(\lambda = 254\) nm, Rt = 2.7 (major) and 3.6 min (minor); \(^1\)H NMR (400 MHz, CDCl\(_3\)): \(\delta 2.14 – 2.07\) (m, 1H), 2.44 – 2.39 (m, 1H), 2.47 (s, 3H), 2.92 – 2.78 (m, 3H), 3.04 – 2.98 (m, 1H), 6.91 (d, \(J = 7.7\) Hz, 1H), 7.03 (t, \(J = 7.5\) Hz, 1H), 7.18 (t, \(J = 7.6\) Hz, 1H), 7.39 (d, \(J = 7.4\) Hz, 1H), 9.20 (s, 1H) ppm; \(^13\)C NMR (100 MHz, CDCl\(_3\)): \(\delta 38.0, 41.9, 53.8, 56.9, 66.5, 109.7, 122.8, 123.3, 128.0, 136.3, 140.5, 183.4\) ppm; IR (KBr): 3137.01, 2932.14, 2778.87, 1715.99, 1616.97, 1470.48, 1345.05 cm\(^{-1}\); HRMS (ESI): cald for C\(_{12}\)H\(_{15}\)N\(_2\)O \(m/z 203.1179\) [M + H]\(^+\), found: 203.1185.

6-Methoxy-2,3,4,9-tetrahydro-1H-pyrido[3,4-b]indole (19b).\(^7\)

To a stirred solution of 5-methoxytryptamine (16b, 1.0 g, 5.2 mmol, 1 equiv.) in AcOH/MeOH (10/1, 10 mL) was added polyformaldehyde (189 mg, 6.3 mmol, 1.2 equiv.). The reaction mixture was then heated to 80 °C for 1 h and cooled to room temperature and basified to pH 9–10 using aqueous ammonia solution. The basic solution was extracted with CH\(_2\)Cl\(_2\) and the combined organic phases were washed with brine solution, dried over with Na\(_2\)SO\(_4\), filtered, and concentrated to give crude product, which was purified by silica gel column chromatography using CH\(_2\)Cl\(_2\)/MeOH (10:1) to obtain desire product 19b (797 mg, 75%)
as a pale yellow solid. \(^1\)H NMR (400 MHz, DMSO–d\(_6\)): \(\delta\) 2.55 (t, \(J = 5.6\) Hz, 2H), 2.96 (t, \(J = 5.6\) Hz, 2H), 3.73 (s, 3H), 3.82 (s, 2H), 6.62 (dd, \(J = 8.7, 2.5\) Hz, 1H), 6.84 (d, \(J = 2.4\) Hz, 1H), 7.13 (d, \(J = 8.6\) Hz, 1H), 10.43 (s, 1H) ppm; \(^{13}\)C NMR (100 MHz, DMSO–d\(_6\)): \(\delta\) 22.1, 42.6, 43.34, 55.2, 99.5, 106.7, 109.5, 111.1, 127.5, 130.4, 134.9, 152.8 ppm; IR (KBr): 3290.94, 3152.20, 2746.74, 1702.47, 1592.25, 1450.71, 1322.48, 1218.88 cm\(^{-1}\); HRMS (ESI): cald for C\(_{12}\)H\(_{15}\)N\(_2\)O m/z 203.1179 [M + H]\(^+\), found 203.1189.

6-Methoxy-2-methyl-2,3,4,9-tetrahydro-1\(H\)-pyrido[3,4-\(b\)]indole (20b).\(^8\)

To a stirred solution of tetrahydro-\(\beta\)-carboline 19b (0.50 g, 2.4 mmol, 1 equiv.) in MeOH (10 mL) was added NaCNBH\(_3\) (0.30 g, 4.9 mmol, 2 equiv.) and treated with 3.2 mL of formaldehyde solution (27% in water). The reaction mixture was stirred for 2 h and added 2N HCl (50 mL) then stirred for 15 min. The reaction mixture was basified with concentrated NaOH solution (pH = 11). The basic solution was extracted with CH\(_2\)Cl\(_2\) and the combined organic phases were washed with brine solution, dried over with Na\(_2\)SO\(_4\), filtered, and concentrated to give crude product, which was purified by silica gel column chromatography using CH\(_2\)Cl\(_2\)/MeOH (10:1) to obtain desire product (491 mg, 92%) as pale yellow solid. \(^1\)H NMR (400 MHz, DMSO–d\(_6\)): \(\delta\) 2.39 (s, 3H), 2.66 (s, 4H), 3.50 (s, 2H), 3.73 (s, 3H), 6.64 (dd, \(J = 8.7, 2.4\) Hz, 1H), 6.85 (d, \(J = 2.3\) Hz, 1H), 7.15 (d, \(J = 8.7\) Hz, 1H), 10.51 (s, 1H) ppm; \(^{13}\)C NMR (100 MHz, DMSO–d\(_6\)): \(\delta\) 21.3, 45.4, 52.1, 52.6, 55.3, 99.7, 105.9, 109.7, 111.3, 127.0, 130.8, 133.6, 152.9 ppm; IR (KBr): 3140.10, 2787.63, 1589.47, 1485.34, 1377.25, 1221.25 cm\(^{-1}\); HRMS (ESI): cald for C\(_{13}\)H\(_{17}\)N\(_2\)O m/z 217.1335 [M + H]\(^+\), found 217.1337.

(–)-Horsfiline (6).\(^9\)

To a stirred solution of 20b (30 mg, 0.13 mmol, 1.0 equiv) in mixture of THF/water/AcOH (1:1:1, 0.6 mL) was added thiosquaramide 11 (4.9 mg, 10 mol%) and stirred for 10 min. Then the reaction mixture was cooled to 0 °C and added NBS (24.7 mg, 0.13 mmol, 1 equiv.). The reaction mixture was then stirred for 20 min at 0 °C. After complete consumption of starting material, the reaction mixture was basified with cold
saturated NaHCO₃ solution. The basic solution was extracted with CH₂Cl₂ and the combined organic phases were washed with brine solution, dried over with Na₂SO₄, filtered, and concentrated to give crude product, which was purified by silica gel column chromatography using CH₂Cl₂/MeOH/TEA (10:1:0.5) to obtain desire product (29.0 mg, 90%) as white solid. [α]²⁵D = −5.01 (c = 0.8, MeOH); Chiral HPLC: 93.0% ee, Chiralcel OD-H, hexane/iPrOH 95/5, flow rate 1 mL/min; λ = 254 nm, Rt = 4.4 (major) and 6.2 (minor); ¹H NMR (400 MHz, CDCl₃): δ 2.12 – 2.03 (m, 1H), 2.44 – 2.37 (m, 1H), 2.45 (s, 3H), 2.74 (q, J = 16.3, 1H), 2.89 – 2.83 (m, 2H), 3.04 – 2.99 (m, 1H), 3.80 (s, 3H), 6.77 – 6.71 (m, 2H), 7.04 (s, 1H), 7.42 (s, 1H) ppm; ¹³C NMR (100 MHz, CDCl₃): δ 38.1, 41.9, 54.3, 56.9, 56.8, 66.4, 110.0, 110.4, 112.5, 133.7, 137.7, 183.2, 156.2 ppm; IR (KBr): 3166.37, 2935.55, 2782.39, 1701.84, 1601.31, 1479.17, 1318.78, 1206.04 cm⁻¹; HRMS (ESI): cald for C₁₃H₁₇N₂O₂ m/z 233.1285 [M + H]⁺, found: 233.1288.

References.


$^{1}$H NMR (400 MHz, DMSO-$d_6$) for compound 13a.

$^{13}$C NMR (100 MHz, DMSO-$d_6$) for compound 13a.
$^1$H NMR (400 MHz, DMSO-$d_6$) for compound 13b.

$^{13}$C NMR (100 MHz, DMSO-$d_6$) for compound 13b.
$^1$H NMR (400 MHz, DMSO-$d_6$) for compound 14b.

$^{13}$C NMR (100 MHz, DMSO-$d_6$) for compound 14b.
$^1$H NMR (400 MHz, DMSO-$d_6$) for compound 11a.

$^{13}$C NMR (100 MHz, DMSO-$d_6$) for compound 11b.
$^1$H NMR (400 MHz, DMSO-$d_6$) for compound 11b.

$^{13}$C NMR (100 MHz, DMSO-$d_6$) for compound 11b.
$^1$H NMR (400 MHz, DMSO-$d_6$) for compound 11c.

$^{13}$C NMR (100 MHz, DMSO-$d_6$) for compound 11c.
$^1$H NMR (400 MHz, DMSO-$d_6$) for compound 11d.

$^{13}$C NMR (100 MHz, DMSO-$d_6$) for compound 11d.
$^{1}$H NMR (400 MHz, CDCl$_3$) for compound 17a.

$^{13}$C NMR (100 MHz, CDCl$_3$) for compound 17a.
$^1$H NMR (400 MHz, CDCl$_3$) for compound 17c.

$^{13}$C NMR (100 MHz, CDCl$_3$) for compound 17c.
$^1$H NMR (400 MHz, CDCl$_3$) for compound 17d.

$^{13}$C NMR (100 MHz, CDCl$_3$) for compound 17d.
$^1$H NMR (400 MHz, DMSO-$d_6$) for compound 17e.

$^{13}$C NMR (100 MHz, DMSO-$d_6$) for compound 12e.
\[ \text{H NMR (400 MHz, DMSO-}d_6 + \text{CDCl}_3 \text{) for compound 17f.} \]

\[ \text{C NMR (100 MHz, CDCl}_3 \text{) for compound 17f.} \]
$^1$H NMR (400 MHz, CDCl$_3$) for compound 18a.

$^{13}$C NMR (100 MHz, CDCl$_3$) for compound 18a.
\[^1\text{H}\text{ NMR} (400 \text{ MHz, CDCl}_3)\] for compound 18b.

\[^{13}\text{C}\text{ NMR} (100 \text{ MHz, CDCl}_3)\] for compound 18b.
$^1$H NMR (400 MHz, DMSO-$d_6$ + CDCl$_3$) for compound 18c.

$^{13}$C NMR (100 MHz, CDCl$_3$) for compound 18c.
$^1$H NMR (400 MHz, CDCl$_3$) for compound 18d.

$^{13}$C NMR (100 MHz, CDCl$_3$) for compound 18d.
$^{1}$H NMR (400 MHz, CDCl$_3$) for compound $^{18}$e.

$^{13}$C NMR (100 MHz, CDCl$_3$) for compound $^{18}$e.
$^{1}H$ NMR (400 MHz, CDCl$_3$) for compound 18f.

$^{13}C$ NMR (100 MHz, CDCl$_3$) for compound 18f.
$^{1}$H NMR (400 MHz, CDCl$_3$ + DMSO-$d_6$) for compound 19a.

$^{13}$C NMR (100 MHz, CDCl$_3$ + DMSO-$d_6$) for compound 19a.
$^1$H NMR (400 MHz, CDCl$_3$ + DMSO-$d_6$) for compound 20a.

$^{13}$C NMR (100 MHz, CDCl$_3$ + DMSO-$d_6$) for compound 20a.
$\text{H NMR (400 MHz, CDCl}_3$) for (–)-coerulescine (5).
$^1$H NMR (400 MHz, DMSO–$d_6$) for compound 19b.

$^{13}$C NMR (100 MHz, DMSO–$d_6$) for compound 19b.
$^{1}$H NMR (400 MHz, DMSO–$d_6$) for compound 20b.

$^{13}$C NMR (100 MHz, DMSO–$d_6$) for compound 20b.
$^1$H NMR (400 MHz, CDCl$_3$) for (−)-horsfiline (6).

$^{13}$C NMR (100 MHz, CDCl$_3$) for (−)-horsfiline (6).
HPLC chromatogram for racemic-18a.

HPLC chromatogram for (R)-18a.

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<th>Altura [mV]</th>
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HPLC chromatogram for racemic-18b.

HPLC chromatogram for (R)-18b.
HPLC chromatogram for racemic-18c.

HPLC chromatogram for (R)-18c.
HPLC chromatogram for racemic-18d.

HPLC chromatogram for (R)-18d.
HPLC chromatogram for racemic-18e.

HPLC chromatogram for (R)-18e.
HPLC chromatogram for racemic-18f.

HPLC chromatogram for (R)-18f.
HPLC chromatogram for (±)-coerulescine (5).
HPLC chromatogram for (±)-horsfiline (6).

HPLC chromatogram for (-)-horsfiline (6).