Remarkably reactive dihydroindoloindoles via palladium-catalysed dearomatisation.

Robin B. Bedford, Natalie Fey, Mairi F. Haddow and Rosalind F. Sankey*

**School of Chemistry, University of Bristol, Cantock's Close, Bristol, BS8 1TS*
r.bedford@bristol.ac.uk

Supporting Information

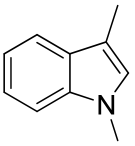
Contents

1. General conditions

All reactions were carried out under an atmosphere of nitrogen using standard Schlenk line and glovebox techniques unless otherwise specified. Solvents were dried using a Grubbs system.[1] Purification by column chromatography was carried out using Fluorochem silica gel 60 (0.040-0.063). High resolution mass spectra were recorded with a Fisons/VG Analytic Autospec System (EI and CI) and a Bruker Daltonics Apex IV (ESI). Nuclear Magnetic Resonance spectra were recorded at 400 MHz on a Jeol ECP (Eclipse) 400 spectrometer, at 300 MHz on a Jeol Lambda 300 spectrometer and also at 500 MHz on a Varian VNMR S500. DEPT, COSY, HMQC, HMBC and nOe experiments were used to confirm assignments where appropriate. The numbering of carbons and hydrogens here is for consistency across the NMR spectroscopic data and is not the same as the numbering of the substituents in the main text, which is based on the priority of the precursors **2a**. Infrared spectra were recorded on a PerkinElmer Spectrum 100 FTIR Spectrometer, only selected frequencies are reported. X-ray diffraction experiments were carried out at 100K on a Bruker APEX II diffractometer using Mo-K$_{\alpha}$ radiation (λ = 0.71073 Å). Data collections were performed using a CCD area detector from a single crystal mounted on a glass fibre. Intensities were integrated[2] from several series of exposures measuring 0.5° in ω. Absorption corrections were based on equivalent reflections using SADABS.[3] The structures were solved using ShelXS and refined against all F_o^2 data using ShelXL.[4] Hydrogen atoms bonded to nitrogen were found in the difference map and the positions allowed to freely refine. All other hydrogen atoms were calculated and refined riding in calculated positions.

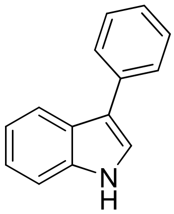
2. Synthesis and characterisation of starting materials

1,3-dimethyl-1*H*-indole. Sodium hydride, 60% w/w on oil, (0.92g, 38.4 mmol) was suspended in THF (15 ml) and cooled in an ice bath. 3-methyl indole (3.0 g, 22.9 mmol) was dissolved in THF (7 ml) and added dropwise over approximately 5 min. The solution was allowed to stir for 1 hr at 0 ºC before methyl iodide (1.5 ml, 24.0 mmol) was added dropwise over 5 min. The solution was then allowed to warm to room temperature gradually before water (10 ml) was slowly added to quench the reaction. The phases were separated and organic phase washed with water (2 x 15 ml), dried ($MgSO_4$), filtered and concentrated to dryness to yield the product as an orange oil (quantitative yield).



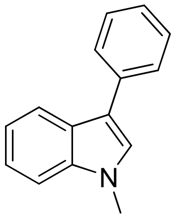
R*f* 0.50 (4:1 hexane/dichloromethane); ^{1}H NMR (300 MHz, $CDCl_3$) δ (ppm): 2.36 (d, $^4J_{HH}$ = 1.1 Hz, 3H, CH_3), 3.76 (s, 3H, CH_3), 6.85 (d, $^4J_{HH}$ = 1.1 Hz, 1H, CH), 7.14 (ddd, $^4J_{HH}$ = 1.3 Hz, $^3J_{HH}$ = 6.8 & 7.9 Hz, 1H, ArH), 7.25 (ddd, $^4J_{HH}$ = 1.3 Hz, $^3J_{HH}$ = 6.8 & 8.1 Hz, 1H, ArH), 7.31 (ddd, $^5J_{HH}$ = 0.9 Hz, $^4J_{HH}$ = 1.1 Hz, $^3J_{HH}$ = 8.1 Hz, 1H, ArH), 7.60 (ddd, $^5J_{HH}$ = 0.9 Hz, $^4J_{HH}$ = 1.1 Hz, $^3J_{HH}$ = 7.9 Hz, 1H, ArH); ^{13}C NMR (100 MHz, $CDCl_3$) δ (ppm): 9.51 (s, CH_3), 32.45 (s, CH_3), 108.96 (s, CH), 110.06 (s, Cq), 118.44 (s, CH), 118.89 (s, CH), 121.36 (s, CH), 126.46 (s, CH), 128.60 (s, Cq), 136.95 (s, Cq); MS (CI) calcd for $C_{10}H_{12}N$ $[M+H]^+$ 146.1, found 146.1.

3-phenyl-1*H*-indole. Prepared according to a literature procedure.[5] To a stirred solution of indole (0.117 g, 1.0 mmol) in dichloromethane (10 ml) was added [Ph-I-Mes][OTf] (0.614 g, 1.3 mmol, 1.3 equiv.), copper (II) triflate (0.036 g, 0.1 mmol, 10 mol%) and 2,6-di-*tert*-butylpyridine (0.29 ml, 1.3 mmol, 1.3 equiv.) and the resultant mixture was stirred for 36 hours at room temperature. The reaction was diluted with dichloromethane (20 ml) and washed with saturated aqueous sodium hydrogen carbonate (10 ml). The organic phase was separated and the aqueous phase washed with dichloromethane (20 ml). The organic phases were combined, washed with water (20 ml), dried ($MgSO_4$), filtered and concentrated to dryness to yield a brown oil. The crude product was purified using flash silica gel chromatography eluted with 10:1 hexane/ethyl acetate to yield the product as a white solid (0.130 g, 67%).



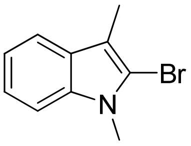
R*f* 0.17 (10:1 hexane/ethyl acetate); ^{1}H NMR (400 MHz, $CDCl_3$) δ (ppm): 7.23 (app. dt, $^4J_{HH}$ = 1.3 Hz, $^3J_{HH}$ = 8.1 Hz, 1H, ArH), 7.28 (dd, $^4J_{HH}$ = 1.3 Hz, $^3J_{HH}$ = 8.1 Hz, 1H, ArH), 7.33 (app. dt, $^4J_{HH}$ = 1.3 Hz, $^3J_{HH}$ = 7.5 Hz, 1H, ArH), 2.38 (d, $^4J_{HH}$ = 2.6 Hz, 1H, CH), 7.44-7.50 (m, 3H, ArH), 7.71 (dd, $^4J_{HH}$ = 1.3 Hz, $^3J_{HH}$ = 8.1 Hz, 2H, ArH), 7.98 (d, $^3J_{HH}$ = 7.9 Hz, 1H, ArH), 8.22 (br s, 1H, NH); ^{13}C NMR (100 MHz, $CDCl_3$) δ (ppm): 111.37 (s, ArH), 118.35 (s, Cq), 119.80 (s, ArH), 120.30 (s, ArH), 121.73 (s, CH), 122.40 (s, ArH), 125.72 (s, Cq), 125.97 (s, ArH), 127.47 (s, ArH), 128.74 (s, ArH), 135.52 (s, Cq), 136.62 (s, Cq); MS (EI) calcd for $C_{14}H_{11}N$ $[M^+]$ 193.1, found 193.1.

1-methyl-3-phenyl-1*H*-indole. Sodium hydride, 60% w/w on oil, (0.052g, 2.15 mmol) was suspended in THF (2 ml) and cooled in an ice bath and a solution of 3-phenyl indole (0.25 g, 1.28 mmol) in THF (2 ml) and added dropwise over approximately 2 min. The solution was stirred at 0 ºC for 1 hr then methyl iodide (0.08 ml, 1.34 mmol) was added dropwise over 2 min. The solution was allowed to warm to room temperature gradually before water (1 ml) was slowly added to quench the reaction. The phases were separated and the organic phase washed with water (2 x 5 ml), dried ($MgSO_4$), filtered and concentrated to dryness to yield the product as an orange oil (quantitative yield).



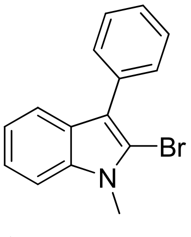
^{1}H NMR (400 MHz, $CDCl_3$) δ (ppm): 3.86 (s, 3H, CH_3); 7.23 (app. dt, $^4J_{HH}$ = 1.1 Hz, $^3J_{HH}$ = 7.9 Hz, 1H, ArH), 7.26 (s, 1H, CH), 7.29-7.34 (m, 2H, ArH), 7.40 (d, $^3J_{HH}$ = 8.1 Hz, 1H, ArH), 7.47 (t, $^3J_{HH}$ = 7.7 Hz, 2H, ArH), 7.70 (dd, $^4J_{HH}$ = 1.3 Hz, $^3J_{HH}$ = 8.3 Hz, 2H, ArH), 7.99 (d, $^3J_{HH}$ = 7.9 Hz, 1H, ArH); ^{13}C NMR (100 MHz, $CDCl_3$) δ (ppm): 32.84 (s, CH_3), 109.50 (s, ArH), 116.68 (s, Cq), 119.86 (s, ArH), 119.90 (s, ArH), 121.93 (s, ArH), 125.67 (s, ArH), 126.11 (s, Cq), 126.52 (s, CH), 127.30 (s, ArH), 128.72 (s, ArH), 135.64 (s, Cq), 137.43 (s, Cq); MS (EI) calcd for $C_{15}H_{13}N$ [M^+] 207.1, found 207.1.

2-bromo-1,3-dimethyl-1*H*-indole. Prepared by a modification of a literature procedure.[6] To a stirred solution of 1,3-dimethyl-1*H*-indole (0.5 g, 3.4 mmol) in anhydrous α,α,α-trifluorotoluene (8 ml) was added *N*-bromosuccinimide (0.67 g, 3.8 mmol) followed by more α,α,α-trifluorotoluene (2 ml). The resulting purple solution was heated at 100 ºC for 1 hr (until judged complete by TLC analysis) and then allowed to cool to room temperature before being filtered and washed through with α,α,α-trifluorotoluene (2 x 1 ml). The solution was concentrated to dryness to yield a purple oil. The crude product was purified using flash silica gel chromatography eluted with hexane/dichloromethane (10:1 to 6:1) to yield the product as a colourless oil (0.56 g, 73% yield). **Notes:** 1. the reaction yield drops significantly if the reaction is carried out on > 0.5 g scale. 2. It is important to ensure that any 2-bromo-3-(bromomethyl)-1-methyl-1*H*-indole side-product is removed during purification; as residual di-brominated material will affect the yield of the next coupling step detrimentally. 3. The product is slightly unstable and should be used as soon as possible after isolation.



R*f* 0.69 (4:1 hexane/dichloromethane); ^{1}H NMR (400 MHz, CDCl$_3$) δ (ppm): 2.32 (s, 3H, CH$_3$), 3.76 (s, 3H, CH$_3$), 7.13 (app. dt, $^4J_{HH}$ = 1.1 Hz, $^3J_{HH}$ = 7.9 Hz, 1H, ArH), 7.22 (app.dt, $^4J_{HH}$ = 1.3 Hz, $^3J_{HH}$ = 8.3 Hz, 1H, ArH), 7.28 (dd, $^4J_{HH}$ = 1.1 Hz, $^3J_{HH}$ = 8.3 Hz, 1H, ArH), 7.53 (dd, $^4J_{HH}$ = 1.3 Hz, $^3J_{HH}$ = 7.9 Hz, 1H, ArH); ^{13}C NMR (100 MHz, CDCl$_3$) δ (ppm): 9.92 (s, CH$_3$), 31.34 (s, CH$_3$), 109.06 (s, CH), 110.24 (s, Cq), 113.16 (s, Cq), 118.20 (s, CH), 119.29 (s, CH), 121.66 (s, CH), 127.66 (s, Cq), 136.69 (s, Cq); MS (CI) calcd for $C_{10}H_{11}BrN$ [M+H]$^+$ 224.0, found 224.0.

2-bromo-1-methyl-3-phenyl-1*H*-indole. Prepared by a modification of a literature procedure,[6] spectroscopic data consistent with literature.[7] To a stirred solution of 1-methyl-3-phenyl indole (0.255 g, 1.23 mmol) in anhydrous α,α,α-trifluorotoluene (4 ml) was added *N*-bromosuccinimide (0.24 g, 1.35 mmol). The resulting dark orange solution was warmed to 100 ºC for 1 hr (or until judged complete by TLC) and then allowed to cool to room temperature before being filtered and washed through with α,α,α-trifluorotoluene (2 x 1 ml). The solution was concentrated to dryness to yield a dark orange oil. The crude product was purified using flash silica gel chromatography eluted with hexane/ethyl acetate (20:1 to 15:1) to yield the product as an orange oil (0.303 g, 86%).

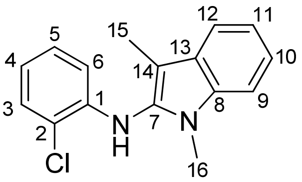


R*f* 0.53 (10:1 hexane/ethyl acetate); ^{1}H NMR (400 MHz, CDCl$_3$) δ (ppm): 3.86 (s, 3H, CH$_3$), 7.16 (app. dt, $^4J_{HH}$ = 1.0 Hz, $^3J_{HH}$ = 8.1 Hz, 1H, ArH), 7.28 (app. dt, $^4J_{HH}$ = 1.2 Hz, $^3J_{HH}$ = 8.1 Hz, 1H, ArH), 7.36-7.39 (m, 2H, ArH), 7.51 (d, $^3J_{HH}$ = 7.3 Hz, 2H, ArH), 7.65 (dd, $^4J_{HH}$ = 1.2 Hz, $^3J_{HH}$ = 8.1 Hz, 2H, ArH), 7.70 (d, $^3J_{HH}$ = 8.1 Hz, 1H, ArH); ^{13}C NMR (100 MHz, CDCl$_3$) δ (ppm): 31.63 (s, CH$_3$), 109.39 (s, ArH), 112.74 (s, Cq), 116.34 (s, Cq), 119.00 (s, ArH), 120.33 (s, ArH), 122.28 (s, ArH), 126.62 (s, ArH), 128.69 (s, Cq), 128.42 (s, ArH), 129.56 (s, ArH), 133.92 (s, Cq), 136.87 (s, Cq); MS (EI) calcd for $C_{15}H_{12}BrN$ $[M^+]$ 285.0, found 285.0.

3. Preparation and characterisation of intermediates 2a-e

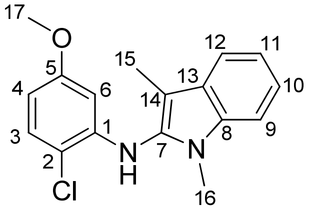
General procedure for the preparation of the precursors, 2. To a stirred mixture of NaO^tBu (0.290 g, 3.02 mmol), $Pd(OAc)_2$ (0.047 g, 0.209 mmol) and *rac*-BINAP (0.173 g, 0.278 mmol) in toluene (4 ml) charged was added a solution of 2-bromo-1,3-dimethyl-1*H*-indole (0.5 g, 2.32 mmol) in toluene (2 ml) followed by the appropriate 2-chloroaniline (2.55 mmol) and more toluene (4 ml). The reaction mixture was heated to reflux temperature for 18 hours (or until judged complete by TLC analysis). The crude mixture was filtered through a pad of Celite and washed through with dichloromethane (50 ml). The solution was concentrated to dryness to yield a brown oil which was purified using flash silica gel chromatography.

***N*-(2-chlorophenyl)-1,3-dimethyl-1*H*-indol-2-amine, 2a.**



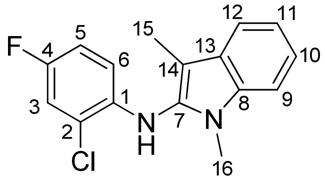
Off-white solid (0.259 g, 41%); R_f 0.36 (4:1 hexane/dichloromethane); mp 155.9-157.5 °C; ^1H NMR (400 MHz, $CDCl_3$) δ (ppm): 2.22 (s, 3H, CH_3^{15}), 3.58 (s, 3H, CH_3^{16}), 5.94 (br s, 1H, NH), 6.38 (dd, $^4J_{HH}$ = 1.5 Hz, $^3J_{HH}$ = 8.3 Hz, 1H, ArH^{12}), 6.77 (ddd, $^4J_{HH}$ = 1.5 Hz, $^3J_{HH}$ = 7.3 & 7.9 Hz, 1H, ArH^{10}), 7.04 (app. dt, $^4J_{HH}$ = 1.5 Hz, $^3J_{HH}$ = 7.3 Hz, 1H, ArH^{11}), 7.18 (ddd, $^4J_{HH}$ = 1.5 Hz, $^3J_{HH}$ = 7.7 & 7.9 Hz, 1H, ArH^5), 7.27-7.34 (m, 2H, $ArH^{3,4}$), 7.37 (dd, $^4J_{HH}$ = 1.5 Hz, $^3J_{HH}$ = 7.9 Hz, 1H, ArH^9), 7.61 (d, $^3J_{HH}$ = 7.9 Hz, 1H, ArH^6); ^{13}C NMR (100 MHz, $CDCl_3$) δ (ppm): 8.28 (s, CH_3), 28.53 (s, CH_3), 105.28 (s, Cq), 109.16 (s, ArH), 113.62 (s, ArH), 118.82 (s, Cq), 118.86 (s, ArH), 119.03 (s, ArH), 119.34 (s, ArH), 121.73 (s, ArH), 127.18 (s, Cq), 127.86 (s, ArH), 129.27 (s, ArH), 131.87 (s, Cq), 134.69 (s, Cq), 142.54 (s, Cq); HRMS (CI) calcd for $C_{16}H_{16}ClN_2$ $[M+H]^+$ 271.1002, found 271.0995; anal. calcd for $C_{16}H_{15}ClN_2$: C, 70.98; H, 5.58; N, 10.35; found: C, 70.63; H, 5.91; N, 10.00.

N-(2-chloro-5-methoxyphenyl)-1,3-dimethyl-1*H*-indol-2-amine, 2b.



White solid (0.247 g, 37%); R$_f$ 0.17 (4:1 hexane/dichloromethane); mp 143-144 °C; ^{1}H NMR (400 MHz, CDCl$_3$) δ (ppm): 2.21 (s, 3H, CH$_3^{15}$), 3.58 (s, 3H, CH$_3^{16}$), 3.63 (s, 3H, CH$_3^{17}$), 5.91 (br s, 1H, NH), 5.96 (d, $^4J_{HH}$ = 2.9 Hz, 1H, ArH^6), 6.33 (dd, $^4J_{HH}$ = 2.9 Hz , $^3J_{HH}$ =8.8 Hz, 1H, ArH^4), 7.16 (app. dt, $^4J_{HH}$ = 1.6 Hz, $^3J_{HH}$ = 7.8 Hz, 1H, ArH^{10}), 7.25 (d, $^3J_{HH}$ =8.8 Hz, 1H, ArH^3), 7.27-7.32 (m, 2H, ArH^{11,12}), 7.59 (dd, $^5J_{HH}$ = 0.8, $^4J_{HH}$ = 1.1 Hz, $^3J_{HH}$ = 7.8 Hz, 1H, ArH^9); ^{13}C NMR (100 MHz, CDCl$_3$) δ (ppm): 8.34 (s, CH$_3$), 28.58 (s, CH$_3$), 55.40 (s, CH$_3$), 99.74 (s, ArH), 104.60 (s, ArH), 105.33 (s, Cq), 109.18 (s, ArH), 110.85 (s, Cq), 118.89 (s, ArH), 118.99 (s, ArH), 121.72 (s, ArH), 127.21 (s, Cq), 129.63 (s, ArH), 131.60 (s, Cq), 134.76 (s, Cq), 143.35 (s, Cq), 159.72 (s, Cq); HRMS (EI) calcd for $C_{17}H_{17}ClN_2O$ [M$^+$] 300.1029, found 300.1028; anal. calcd for $C_{17}H_{17}ClN_2O$: C, 67.88; H, 5.70; N, 9.31; found: C, 67.63; H, 5.88; N, 9.01.

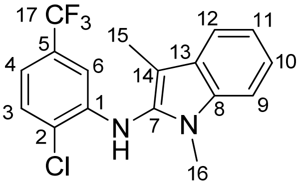
N-(2-chloro-4-fluorophenyl)-1,3-dimethyl-1*H*-indol-2-amine, 2c.



White solid (0.194 g, 30%); R$_f$ 0.28 (4:1 hexane/dichloromethane); mp 119-121 °C; ^{1}H NMR (400 MHz, CDCl$_3$) δ (ppm): 2.19 (s, 3H, CH$_3^{15}$), 3.56 (s, 3H, CH$_3^{16}$), 5.77 (br s, 1H, NH), 6.31 (dd, $^4J_{HF}$ = 5.2 Hz, $^3J_{HH}$ = 9.0 Hz, 1H, ArH^6), 6.78 (ddd, $^4J_{HH}$ = 2.9 Hz, $^3J_{HF}$ = 7.8 Hz, $^3J_{HH}$ = 9.0 Hz, 1H, ArH^5); 7.15 (dd, $^4J_{HH}$ = 2.9 Hz, $^3J_{HF}$ = 8.1 Hz, 1H, ArH^3), 7.17 (ddd, $^4J_{HH}$ = 1.7 Hz, $^3J_{HH}$ = 7.8 & 8.1 Hz, 1H, ArH^{10}), 7.26-7.33 (m, 2H, ArH^{11,12}), 7.60 (dd, $^5J_{HH}$ = 0.9 Hz, $^4J_{HH}$ = 1.1 Hz, $^3J_{HH}$ = 7.8 Hz, 1H, ArH^9); ^{13}C NMR (100 MHz, CDCl$_3$) δ (ppm): 8.24 (s, CH$_3$), 28.49 (s, CH$_3$), 105.26 (s, Cq), 109.18 (s, ArH), 113.94 (d, $^3J_{CF}$ = 7.7 Hz, ArH), 114.70 (d, $^2J_{CF}$ = 22.3 Hz, ArH), 116.40 (d, $^2J_{CF}$ = 25.4 Hz, ArH), 118.55 (d, $^3J_{CF}$ = 10.0 Hz, Cq), 118.87 (s, ArH), 119.11 (s, ArH), 121.83 (s, ArH), 127.14 (s, Cq), 132.00 (s, Cq), 134.68 (s, Cq), 139.18 (d, $^4J_{CF}$ = 3.1 Hz, Cq), 155.53 (d, $^1J_{CF}$ = 239.8 Hz, Cq); HRMS (EI) calcd for

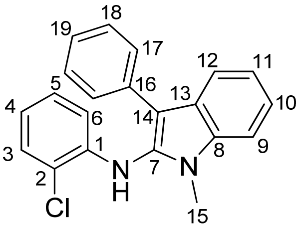
$C_{16}H_{14}ClFN_2$ [M$^+$] 288.0830, found 288.0827; anal. calcd for $C_{16}H_{14}ClFN_2$: C, 66.55; H, 4.89; N, 9.70; found: C, 65.75; H, 4.93; N, 9.21.

***N*-(2-chloro-5-(trifluoromethyl)phenyl)-1,3-dimethyl-1*H*-indol-2-amine, 2d.**



Yellow solid (0.380 g, 36%); R$_f$ 0.38 (10:1 hexane/ethyl acetate); mp 94-95 °C; ^{1}H NMR (400 MHz, $CDCl_3$) δ (ppm): 2.20 (s, 3H, CH_3^{15}), 3.58 (s, 3H, CH_3^{16}), 6.10 (br s, 1H, NH), 6.64 (d, $^4J_{HH}$ = 2.2 Hz, 1H, ArH^6); 7.03 (dd, $^4J_{HH}$ = 2.0 Hz, $^3J_{HH}$ = 8.3 Hz, 1H, ArH^4), 7.20 (ddd, $^4J_{HH}$ = 1.7 Hz, $^3J_{HH}$ = 7.8 & 8.1 Hz, 1H, ArH^{10}), 7.32 (ddd, $^4J_{HH}$ = 1.7 Hz, $^3J_{HH}$ = 7.8 & 8.1 Hz, 1H, ArH^{11}), 7.35 (dd, $^4J_{HH}$ = 1.7 Hz, $^3J_{HH}$ = 8.1 Hz, 1H, ArH^{12}), 7.47 (dd, $^5J_{HH}$ = 0.7 Hz, $^3J_{HH}$ = 8.3 Hz, 1H, ArH^3), 7.63 (dd, $^4J_{HH}$ = 1.7 Hz, $^3J_{HH}$ = 8.1 Hz, 1H, ArH^9); ^{13}C NMR (100 MHz, $CDCl_3$) δ (ppm): 8.33 (s, CH_3), 28.60 (s, CH_3), 105.65 (s, Cq), 107.64 (s, Cq), 109.35 (s, ArH), 109.92 (q, $^3J_{CF}$ = 3.9 Hz, ArH), 115.79 (q, $^3J_{CF}$ = 3.9 Hz, ArH), 119.06 (s, ArH), 119.24 (s, ArH), 122.09 (s, ArH), 123.60 (q, $^1J_{CF}$ = 272. 5 Hz, Cq), 127.09 (s, Cq), 129.72 (s, ArH), 130.45 (s, Cq), 130.60 (q, $^2J_{CF}$ = 32.3 Hz, Cq), 134.83 (s, Cq), 142.86 (s, Cq); ^{19}F NMR (470 MHz, $CDCl_3$) δ (ppm): -62.71; HRMS (EI) calcd for $C_{17}H_{14}ClF_3N_2$ [M$^+$] 338.0798, found 338.0796; anal. calcd for $C_{17}H_{14}ClF_3N_2$: C, 60.27; H, 4.17; N, 8.27; found: C, 59.70; H, 4.19; N, 8.18.

***N*-(2-chlorophenyl)-1-methyl-3-phenyl-1*H*-indol-2-amine, 2e.**

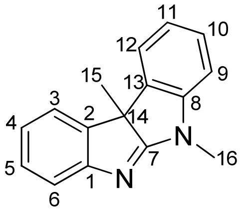


Cream solid (0.202 g, 55%); R$_f$ 0.42 (10:1 hexane/ethyl acetate); mp 133-134 °C; ^{1}H NMR (400 MHz, $CDCl_3$) δ (ppm): 3.66 (s, 3H, CH_3^{15}), 6.18 (br s, 1H, NH), 6.58 (dd, $^4J_{HH}$ = 1.3 Hz, $^3J_{HH}$ = 8.1 Hz, 1H, ArH^{12}), 6.86 (ddd, $^4J_{HH}$ = 1.5 Hz, $^3J_{HH}$ = 7.3 & 7.9 Hz, 1H, ArH^{10}), 7.13 (app. dt, $^4J_{HH}$ = 1.1 Hz, $^3J_{HH}$ = 8.3 Hz, 1H, ArH^{11}), 7.30-7.34 (m, 2H, ArH$^{5, 19}$), 7.40 (ddd, $^4J_{HH}$ = 1.3 Hz, $^3J_{HH}$ = 8.1 & 8.3 Hz, 1H, ArH^4), 7.43-7.46 (m, 4H, ArH[3,9,18]), 7.59 (dd, , $^4J_{HH}$ = 1.3 Hz, $^3J_{HH}$ = 7.7 Hz, 2H, ArH[17]), 7.95 (d, $^3J_{HH}$ = 7.3 Hz, 1H, ArH[6]); ^{13}C NMR (100 MHz, $CDCl_3$) δ (ppm): 28.80 (s, CH_3), 109.45 (s, ArH), 110.31 (s, Cq), 114.00 (s, ArH), 119.44 (s, Cq), 119.57 (s, ArH), 119.97 (s, ArH), 120.23 (s, ArH), 122.14 (s, ArH), 125.68 (s, Cq), 125.98 (s, ArH), 127.95 (s, ArH), 128.33 (s, ArH), 128.67 (s, ArH), 129.44 (s, ArH), 132.17 (s, Cq), 134.10 (s, Cq), 134.87 (s, Cq), 142.50 (s, Cq); HRMS (EI) calcd for $C_{21}H_{17}ClN_2$ [M^+] 332.1080, found 332.1092; anal. calcd for $C_{21}H_{17}ClN_2$: C, 75.78; H, 5.15; N, 8.42; found: C, 76.19; H, 5.18; N, 8.11.

4. Synthesis and characterisation of 1a-e

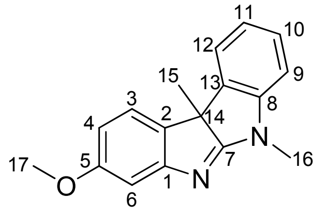
General method for the synthesis of dihydroindolo[2,3-b]indoles, 1 (Scheme 3). Anhydrous toluene (5 ml) was added to a Schlenk tube under nitrogen containing the appropriate precursor **2** (0.5 mmol), NaO^{t}Bu (0.144 g, 1.5 mmol), $Pd(OAc)_2$ (0.006 g, 0.025 mmol) and 1,3-bis(2,6-diisopropylphenyl)-2-(perfluorophenyl)imidazolidine (the SIPr carbene precursor) (0.039 g, 0.070 mmol) to give a brown solution which was stirred and heated to 100 °C for 16 hours. The resultant mixture was allowed to cool to room temperature and then concentrated under vacuum to yield a brown oil. The oil was dissolved in anhydrous THF and then filtered through Celite which had been dried in an oven overnight then under high vacuum with a heatgun. The volatiles were removed under vacuum to yield a brown oil and the spectroscopic yields of the **8** and its corresponding hydrolysis product **4** were determined by ^{1}H NMR spectroscopy using 1,3,5-trimethoxybenzene in $CDCl_3$ (0.5 mmol/ml) as an internal standard. ^{1}H and ^{13}C NMR analysis and high-resolution mass spectrometry were recorded under anhydrous conditions.

5,10b-dimethyl-5,10b-dihydroindolo[2,3-*b*]indole, 1a.



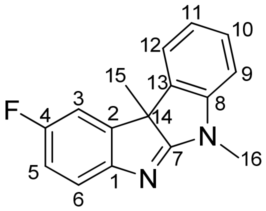
^{1}H NMR (400 MHz, $CDCl_3$) δ (ppm): 1.64 (s, 3H, CH_3[15]), 3.37 (s, 3H, CH_3[16]), 6.85 (d, $^3J_{HH}$ = 7.9 Hz, 1H, ArH[12]), 6.97-7.05 (m, 2H, ArH[10,11]), 7.26-7.28 (m, 2H, ArH[4,5]), 7.36 (d, $^3J_{HH}$ = 7.3 Hz, 1H, ArH^3), 7.44 (d, $^3J_{HH}$ = 7.3 Hz, 1H, ArH^9), 7.47 (d, $^3J_{HH}$ = 7.3 Hz, 1H, ArH^6); ^{13}C NMR (100 MHz, $CDCl_3$) δ (ppm): 30.07 (s, CH_3), 32.33 (s, CH_3), 60.30 (s, Cq), 109.80 (s, ArH), 119.01 (s, ArH), 121.43 (s, ArH), 122.02 (s, ArH), 122.17 (s, ArH), 122.80 (s, ArH), 128.14 (ArH), 128.37 (s, ArH), 134.63 (s, Cq), 140.44 (s, Cq), 150.78 (s, Cq), 158.52 (s, Cq), 191.35 (s, Cq); HRMS (EI) calcd for $C_{16}H_{14}N_2$ [M$^+$] 234.1157, found 234.1166.

8-methoxy-5,10b-dimethyl-5,10b-dihydroindolo[2,3-*b*]indole, 1b.



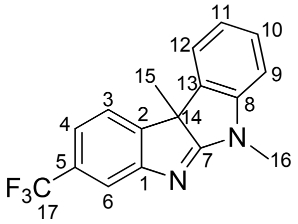
^{1}H NMR (500 MHz, $CDCl_3$) δ (ppm): 1.61 (s, 3H, $CH_3{}^{15}$), 3.35 (s, 3H, $CH_3{}^{16}$), 3.82 (s, 3H, $CH_3{}^{17}$), 6.55 (dd, $^4J_{HH}$ = 2.4 Hz, $^3J_{HH}$ = 8.2 Hz, 1H, ArH^4), 6.84 (d, $^3J_{HH}$ = 7.9 Hz, 1H, ArH^{12}), 6.97 (app. dt, $^4J_{HH}$ = 0.9 Hz, $^3J_{HH}$ = 7.3 Hz, 1H, ArH^{10}), 6.98 (d, $^4J_{HH}$ = 2.4 Hz, 1H, ArH^6), 7.26 (app. dt, $^4J_{HH}$ = 1.2 Hz, $^3J_{HH}$ = 7.9 Hz, 1H, ArH^{11}), 7.33 (d, $^3J_{HH}$ = 8.2 Hz, 1H, ArH^3), 7.40 (dd, $^4J_{HH}$ = 0.9 Hz, $^3J_{HH}$ = 7.3 Hz, 1H, ArH^9); ^{13}C NMR (126 MHz, $CDCl_3$) δ (ppm): 29.99 (s, CH_3), 32.38 (s, CH_3), 55.39 (s, CH_3), 59.70 (s, Cq), 105.75 (s, ArH), 107.10 (s, ArH), 109.74 (s, Cq), 121.45 (s, ArH), 122.11 (s, ArH), 122.74 (s, ArH), 128.01 (s, ArH), 132.39 (s, Cq), 134.90 (s, Cq), 150.55 (s, Cq), 159.93 (s, ArH), 160.41 (s, Cq), 192.25 (s, Cq); HRMS (EI) calcd for $C_{17}H_{16}N_2O$ [M$^+$] 264.1263, found 264.1254.

9-fluoro-5,10b-dimethyl-5,10b-dihydroindolo[2,3-*b*]indole, 1c.



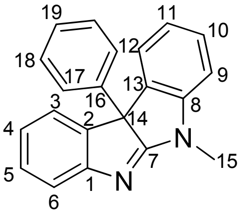
^{1}H NMR (500 MHz, $CDCl_3$) δ (ppm): 1.62 (s, 3H, $CH_3{}^{15}$), 3.34 (s, 3H, $CH_3{}^{16}$), 6.84 (d, $^3J_{HH}$ = 7.9 Hz, 1H, ArH^{12}), 6.95 (m, 1H, ArH^{10}), 6.99 (d, $^3J_{HF}$ = 7.6 Hz, 1H, ArH^3), 7.18 (dd, $^4J_{HF}$ = 2.75 Hz, $^3J_{HH}$ = 7.9 Hz, 1H, ArH^6), 7.24-7.29 (m, 2H, ArH^{5,11}), 7.39 (d, $^3J_{HH}$ = 7.3 Hz, 1H, ArH^9); ^{13}C NMR (126 MHz, $CDCl_3$) δ (ppm): 30.04 (s, CH_3), 32.17 (s, CH_3), 60.61 (s, Cq), 109.88 (s, ArH), 110.17 (d, $^2J_{CF}$ = 24.5 Hz, ArH), 114.34 (d, ${}^{2}J_{CF}$ = 23.5 Hz, ArH), 119.11 (d, ${}^{3}J_{CF}$ = 10.8 Hz, ArH), 121.47 (s, ArH), 128.33 (d, ${}^{4}J_{CF}$ = 3.9 Hz, Cq), 133.93 (s, ArH), 141.78 (d, ${}^{3}J_{CF}$ = 8.8 Hz, Cq), 150.73 (s, Cq), 154.21 (s, ArH), 156.48 (d, ${}^{1}J_{CF}$ = 235.7 Hz, Cq), 159.75 (s, Cq), 190.95 (s, Cq); ^{19}F NMR (470 MHz, CDCl$_3$) δ (ppm): -120.65; HRMS (EI) calcd for $C_{16}H_{13}FN_2$ [M$^+$] 252.1063, found 252.1065.

5,10b-dimethyl-8-(trifluoromethyl)-5,10b-dihydroindolo[2,3-*b*]indole, 1d.



^{1}H NMR (500 MHz, CDCl$_3$) δ (ppm): 1.64 (s, 3H, CH$_3^{15}$), 3.38 (s, 3H, CH$_3^{16}$), 6.89 (d, ${}^{3}J_{HH}$ = 7.9 Hz, 1H, ArH^{12}), 7.03 (d, ${}^{3}J_{HH}$ = 7.3 Hz, 1H, ArH^{4}), 7.18-7.21 (m, 2H, ArH^{10,11}), 7.24 (d, ${}^{3}J_{HH}$ = 7.6 Hz, 1H, ArH^{3}), 7.33 (s, 1H, ArH^{6}), 7.44 (d, ${}^{3}J_{HH}$ = 7.3 Hz, 1H, ArH^{9}); ^{13}C NMR (126 MHz, CDCl$_3$) δ (ppm): 30.09 (s, CH$_3$), 32.36 (s, CH$_3$), 60.50 (s, Cq), 110.16 (s, ArH), 133.92 (s, ArH), 142.13 (s, ArH), 146.09 (s, ArH), 147.58 (s, Cq), 159.27 (s, Cq), 192.24 (s, Cq) (only selected peaks reported); ^{19}F NMR (470 MHz, CDCl$_3$) δ (ppm): -62.28; HRMS (EI) calcd for $C_{17}H_{13}F_3N_2$ [M$^+$] 302.1031, found 302.1028.

5-methyl-10b-phenyl-5,10b-dihydroindolo[2,3-*b*]indole, 1e.

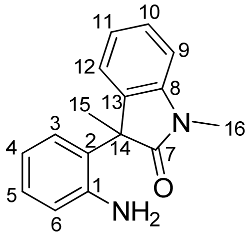


^{1}H NMR (500 MHz, CDCl$_3$) δ (ppm): 3.33 (s, 3H, CH$_3^{15}$), 6.82 (d, ${}^{3}J_{HH}$ = 7.9 Hz, 1H, ArH), 6.88 (d, ${}^{3}J_{HH}$ = 7.9 Hz, 1H, ArH), 6.93 (app. dt, ${}^{4}J_{HH}$ = 1.2 Hz, ${}^{3}J_{HH}$ = 7.6 Hz, 1H, ArH), 6.99 (m, 2H, ArH), 7.05 (app. dt, ${}^{4}J_{HH}$ = 0.9 Hz, ${}^{3}J_{HH}$ = 7.6 Hz, 1H, ArH), 7.16 (app. dt, ${}^{4}J_{HH}$ = 1.5 Hz, ${}^{3}J_{HH}$ = 6.7 Hz, 1H, ArH), 7.19-7.23 (m, 3H, ArH), 7.40 (d, ${}^{3}J_{HH}$ = 7.6 Hz, 1H, ArH), 7.44 (d, ${}^{3}J_{HH}$ = 7.3 Hz, 1H, ArH), 7.68 (dd, ${}^{4}J_{HH}$ = 0.9 Hz, ${}^{3}J_{HH}$ = 7.3 Hz, 1H, ArH); ^{13}C NMR (126 MHz, CDCl$_3$) δ (ppm): 31.13 (s, CH$_3$), 109.98, 116.94, 119.02, 121.36, 122.85, 122.90, 123.34, 124.60, 125.49, 128.17, 128.52, 128.67, 189.59 (s, Cq) (only selected peaks reported); HRMS (EI) calcd for $C_{21}H_{16}N_2$ [M$^+$] 296.1313, found 296.1315.

5. Synthesis and characterisation of 4a-e

General method for the synthesis of the hydrolysis products, 4 (Scheme 4). The method for the production of **1** was used as above, except that after heating and allowing to cool, the solution was filtered through Celite, which was then washed with dichloromethane and the solvent removed from the combined fractions under vacuum. The resultant oils were subjected to column chromatography on silica using hexane/ethyl acetate mixtures as eluent to yield the desired oxindoles **4**.

3-(2-aminophenyl)-1,3-dimethylindolin-2-one, 4a.

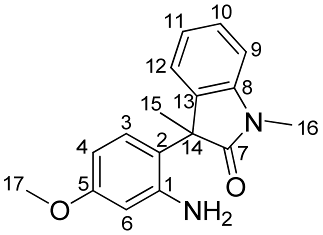


Off-white solid (0.118 g, 94% yield); R$_f$ 0.45 (1:1 hexane/ethyl acetate); mp 145.2-146.0 °C; ^{1}H NMR (400 MHz, $CDCl_3$) δ (ppm): 1.85 (s, 3H, $CH_3{}^{15}$), 3.29 (s, 3H, $CH_3{}^{16}$), 3.79 (br s, 2H, NH_2), 6.64 (dd, $^4J_{HH}$ = 1.4 Hz, $^3J_{HH}$ = 7.9 Hz, 1H, ArH^6), 6.79 (ddd, $^4J_{HH}$ = 1.3 Hz, $^3J_{HH}$ = 7.3.& 7.9 Hz, 1H, ArH^{11}), 6.95 (d, $^3J_{HH}$ = 7.9 Hz, 1H, ArH^3), 7.08-7.15 (m, 3H, ArH^{5,9,10}), 7.27 (dd, $^4J_{HH}$ = 1.5 Hz, $^3J_{HH}$ = 7.9 Hz, 1H, ArH^{12}), 7.35 (app. dt, $^4J_{HH}$ = 1.5 Hz, $^3J_{HH}$ = 7.9 Hz, 1H, ArH^4); ^{13}C NMR (100 MHz, $CDCl_3$) δ (ppm): 23.02 (s, CH_3), 26.41 (s, CH_3), 51.81 (s, Cq), 108.38 (s, ArH), 118.29 (s, ArH), 118.73 (s, ArH), 122.90 (s, ArH), 124.15 (s, ArH), 125.04 (s, Cq), 128.25 (s, 2xArH), 128.57 (s, ArH), 133.53 (s, Cq), 142.71 (s, Cq), 145.57 (s, Cq), 180.17 (s, Cq); HRMS (EI) calcd for $C_{16}H_{16}N_2O$ [M$^+$] 252.1263, found 252.1256; anal. calcd for $C_{16}H_{16}N_2O$: C, 76.16; H, 6.39; N, 11.10; found: C, 75.19; H, 6.38; N, 10.77. A single crystal was grown for X-ray analysis by layering chloroform/hexane in an NMR tube and allowing slow evaporation.

Crystal data for 4a: $C_{16}H_{16}N_2O$; A colourless plate, with dimensions 0.16×0.08×0.02 mm, gave a monoclinic space group *C*2/*c*, *a* = 23.3998(16) *b* =

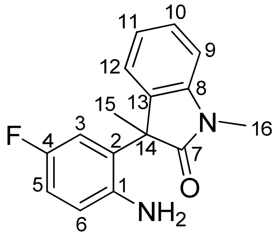
8.7381(7) c = 14.9479(10) Å, α = 90.00 β = 123.196(4) γ = 90.00°, V = 2557.6(3) $Å^3$, T = 100 K, Z = 8, μ = 0.083 mm^{-1}, $\theta_{min,max}$ = 2.08,26.37, completeness: 1.000 to θ = 26.37°, reflections: total/independent 19772/2614, R_{int} = 0.0815, final $R1$ and $wR2$ = 0.0429, 0.1050, maximum/minimum residual electron density = 0.247, -0.215 $eÅ^{-3}$, ρ_{calc} = 1.311 g cm^{-3}. Crystallographic data for this compound has been deposited with the Cambridge Crystallographic Data Centre as supplementary publication CCDC 789829. Copies of the data can be obtained free of charge on application to CCDC, 12 Union Road, Cambridge CB2 1EZ, UK (fax: (+44) 1223-336-033; email: deposit@ccdc.cam.ac.uk).

3-(2-amino-4-methoxyphenyl)-1,3-dimethylindolin-2-one, 4b.



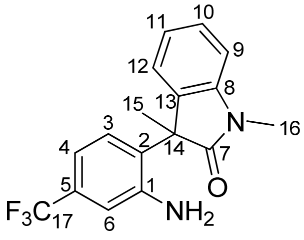
White solid (0.109 g, 77% yield); R_f 0.32 (1:1 hexane/ethyl acetate); mp 136.8-137.5 °C; ^1H NMR (400 MHz, $CDCl_3$) δ (ppm): 1.81 (s, 3H, CH_3^{15}), 3.27 (s, 3H, CH_3^{16}), 3.74 (s, 3H, CH_3^{17}), 3.89 (br s, 2H, NH_2), 6.20 (d, $^4J_{HH}$ = 2.7 Hz, 1H, ArH^6), 6.32 (dd, $^4J_{HH}$ = 2.7 Hz, $^3J_{HH}$ = 8.8 Hz, 1H, ArH^4), 6.93 (d, $^3J_{HH}$ = 7.8 Hz, 1H, ArH^9), 7.11 (app. dt, $^4J_{HH}$ = 1.0 Hz, $^3J_{HH}$ = 7.3 Hz, 1H, ArH^{11}), 7.13 (d, $^3J_{HH}$ = 8.8 Hz, 1H, ArH^3), 7.15 (dd, $^4J_{HH}$ = 1.7 Hz, $^3J_{HH}$ = 7.3 Hz, 1H, ArH^{12}), 7.34 (app. dt, $^4J_{HH}$ = 1.7 Hz, $^3J_{HH}$ = 7.3 & 7.8 Hz, 1H, ArH^{10}); ^{13}C NMR (100 MHz, $CDCl_3$) δ (ppm): 23.08 (s, CH_3), 26.41 (s, CH_3), 51.37 (s, Cq), 55.08 (s, OCH_3), 103.73 (s, ArH), 103.83 (s, ArH), 108.41 (s, ArH), 117.67 (s, Cq), 122.90 (s, ArH), 124.22 (s, ArH), 128.21 (s, ArH), 129.36 (s, ArH), 133.87 (s, Cq), 142.67 (s, Cq), 146.92 (s, Cq), 159.94 (s, Cq), 180.44 (s, Cq); HRMS (EI) calcd for $C_{17}H_{18}N_2O_2$ [M^+] 282.1368, found 282.1364; anal. calcd for $C_{17}H_{18}N_2O_2$: C, 72.32; H, 6.43; N, 9.92; found: C, 72.43; H, 6.63; N, 9.54.

3-(2-amino-5-fluorophenyl)-1,3-dimethylindolin-2-one, 4c.



Light pink solid (0.089 g, 66% yield); R$_f$ 0.36 (1:1 hexane/ethyl acetate); mp 173.2-174.1 °C; ^{1}H NMR (400 MHz, CDCl$_3$) δ (ppm): 1.81 (s, 3H, CH$_3^{15}$), 3.29 (s, 3H, CH$_3^{16}$), 3.53 (br s, 2H, NH$_2$), 6.57 (dd, $^4J_{HF}$ = 5.2 Hz, $^3J_{HH}$ = 8.6 Hz, 1H, ArH^6), 6.82 (ddd, $^4J_{HH}$ = 2.9 Hz, $^3J_{HF}$ = 7.8 Hz, $^3J_{HH}$ = 8.6 Hz, 1H, ArH^5), 6.95 (d, $^3J_{HH}$ = 7.8 Hz, 1H, ArH^9), 7.05 (dd, $^4J_{HH}$ = 2.9 Hz, $^3J_{HF}$ = 10.5 Hz, 1H, ArH^3), 7.09-7.14 (m, 2H, ArH^{11,12}), 7.35 (ddd, $^4J_{HH}$ = 3.7 Hz, $^3J_{HH}$ = 7.6 & 7.8 Hz, 1H, ArH^{10}); ^{13}C NMR (100 MHz, CDCl$_3$) δ (ppm): 23.17 (s, CH$_3$), 26.50 (s, CH$_3$), 51.58 (s, Cq), 108.51 (s, ArH), 114.97 (d, $^2J_{CF}$ = 38.4 Hz, ArH), 115.20 (d, $^2J_{CF}$ = 40.7 Hz, ArH), 119.20 (d, $^3J_{CF}$ = 7.7 Hz, ArH), 123.11 (s, ArH), 123.92 (s, ArH), 127.11 (d, $^3J_{CF}$ = 6.2 Hz, Cq), 128.53 (s, ArH), 132.93 (s, Cq), 141.40 (d, $^4J_{CF}$ = 2.3 Hz, Cq), 142.82 (s, Cq), 156.39 (d, $^1J_{CF}$ = 236.0 Hz, Cq), 179.66 (s, Cq); HRMS (EI) calcd for $C_{16}H_{15}FN_2O$ [M$^+$] 270.1168, found 270.1158; anal. calcd for $C_{16}H_{15}FN_2O$: C, 71.10; H, 5.59; N, 10.36; found: C, 70.32; H, 5.64; N, 9.94.

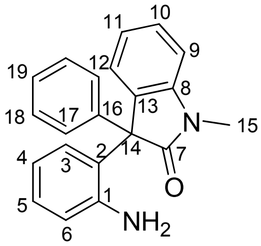
3-(2-amino-4-(trifluoromethyl)phenyl)-1,3-dimethylindolin-2-one, 4d.



Cream solid (0.047 g, 44% yield); R$_f$ 0.13 (4:1 hexane/ethyl acetate); mp 107.7-109.3 °C; ^{1}H NMR (400 MHz, CDCl$_3$) δ (ppm): 1.86 (s, 3H, CH$_3^{15}$), 3.29 (s, 3H, CH$_3^{16}$), 4.06 (br s, 2H, NH$_2$), 6.86 (d, $^4J_{HH}$ = 1.7 Hz, 1H, ArH^6), 6.97 (d, $^3J_{HH}$ = 7.3 Hz, 1H, ArH^9), 6.99 (dd, $^4J_{HH}$ = 1.7 Hz, $^3J_{HH}$ = 8.1 Hz, 1H, ArH^4), 7.12 (d, $^3J_{HH}$ = 7.3 Hz, 1H, ArH^{12}), 7.14 (app. dt, $^4J_{HH}$ = 1.0 Hz, $^3J_{HH}$ = 7.3 Hz, 1H, ArH^{11}), 7.35 (d, $^3J_{HH}$ = 8.3

Hz, 1H, ArH^{3}), 7.38 (m. 1H, ArH^{10}); ^{13}C NMR (100 MHz, CDCl$_3$) δ (ppm): 22.83 (s, CH$_3$), 26.50 (s, CH$_3$), 51.87 (s, Cq), 108.70 (s, ArH), 114.51 (q, $^{3}J_{CF}$ = 3.8 Hz, ArH), 114.98 (q, $^{3}J_{CF}$ = 3.8 Hz, ArH), 123.19 (s, ArH), 123.99 (q, $^{1}J_{CF}$ = 272.1 Hz, Cq), 124.21 (s, ArH), 128.19 (s, Cq), 128.68 (s, ArH), 128.93 (s, ArH), 130.76 (q, $^{2}J_{CF}$ = 32.3 Hz, Cq), 132.65 (s, Cq), 142.68 (s, Cq), 146.11 (s, Cq), 179.40 (s, Cq); ^{19}F NMR (470 MHz, CDCl$_3$) δ (ppm): -62.94; HRMS (EI) calcd for $C_{17}H_{15}F_3N_2O$ [M^{+}] 320.1136, found 320.1143; anal. calcd for $C_{17}H_{15}F_3N_2O$: C, 63.75; H, 4.72; N, 8.75; found: C, 63.42; H, 5.07; N, 8.63.

3-(2-aminophenyl)-1-methyl-3-phenylindolin-2-one, 4e.

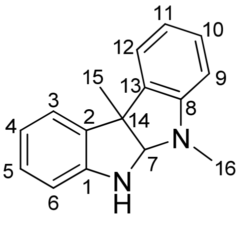


Cream solid (0.077 g, 49% yield); R$_f$ 0.52 (1:1 hexane/ethyl acetate); mp 131.1-133.2 °C; ^{1}H NMR (400 MHz, CDCl$_3$) δ (ppm): 3.31 (s, 3H, CH$_3$^{15}), 4.36 (br s, 2H, NH$_2$), 6.63 (ddd, $^{4}J_{HH}$ = 1.3 Hz, $^{3}J_{HH}$ = 7.9 & 8.1 Hz, 1H, ArH^{4}), 6.68 (dd, $^{4}J_{HH}$ = 1.3 Hz, $^{3}J_{HH}$ = 7.9 Hz, 1H, ArH^{6}), 6.85 (dd, $^{4}J_{HH}$ = 1.5 Hz, $^{3}J_{HH}$ = 7.9 Hz, 1H, ArH^{3}), 6.94 (d, $^{3}J_{HH}$ = 7.9 Hz, 1H, ArH^{19}), 7.10 (app. dt, $^{4}J_{HH}$ = 1.1 Hz, $^{3}J_{HH}$ = 7.5 Hz, 1H, ArH^{5}), 7.13 (dd, $^{4}J_{HH}$ = 1.5 Hz, $^{3}J_{HH}$ = 7.3 Hz, 1H, ArH^{9}), 7.25-7.35 (m, 7H, ArH^{10,11,12,17,18}); ^{13}C NMR (100 MHz, CDCl$_3$) δ (ppm): 26.57 (s, CH$_3$), 62.29 (s, Cq), 108.59 (s, ArH), 117.75 (s, ArH), 118.37 (s, ArH), 122.98 (s, ArH), 124.07 (s, ArH), 126.62 (s, ArH), 126.90 (s, ArH), 127.29 (s, ArH), 128.27 (s, ArH), 128.73 (s, ArH), 128.98 (s, ArH), 129.54 (s, ArH), 132.75 (s, Cq), 139.92 (s, Cq), 142.37 (s, Cq), 146.90 (s, Cq), 178.60 (s, Cq); HRMS (EI) calcd for $C_{21}H_{18}N_2O$ [M^{+}] 314.1419, found 314.1422; anal. calcd for $C_{21}H_{18}N_2O$: C, 80.23; H, 5.77; N, 8.91; found: C, 79.89; H, 5.67; N, 8.43.

6. Synthesis and characterisation of 5a-f

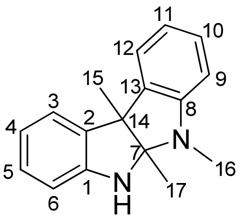
General method for the synthesis of substituted tetrahydroindolo[2,3-b]indoles, 5 (Scheme 4). A crude sample of **1a**, freshly prepared as described above on a 0.5 mmol scale, was dissolved in THF (8 ml) and then cooled to -78 °C. The solution was treated dropwise over 10 minutes with a solution of the appropriate nucleophile (see below) and then allowed to warm to room temperature slowly (overnight). The reaction was quenched carefully with water (5 ml) and the product extracted into ethyl acetate (3 x 10 ml). The organic phases were combined, washed with water (5 ml), dried over magnesium sulfate, filtered and concentrated to dryness to yield a brown oil. The crude product was purified using flash silica gel chromatography. Variable amounts (20 – 39%) of the product **4a**, formed by hydrolysis of the starting material, were also obtained.

5,10b-dimethyl-5,5a,6,10b-tetrahydroindolo[2,3-*b*]indole, 5a. Lithium triethylborohydride (Super-hydride®) (1.0 M in THF) (4.0 ml, 4.0 mmol, 8 equiv.) was used. The crude product was purified using flash silica gel chromatography eluted with hexane/ ethyl acetate (10:1 to 2:1) to yield the desired product as a beige oil (0.044 g, 37%).



R$_f$ 0.36 (4:1 hexane/ ethyl acetate); ^{1}H NMR (400 MHz, CDCl$_3$) δ (ppm): 1.66 (s, 3H, CH$_3$^{15}), 2.91 (s, 3H, CH$_3$^{16}), 4.49 (br s, 1H, NH), 5.12 (s, 1H, H^7), 6.46 (d, $^3J_{HH}$ = 7.8 Hz, 1H, ArH^9), 6.70 (dd, $^4J_{HH}$ = 1.5 Hz, $^3J_{HH}$ = 7.8 Hz, 1H, ArH^6), 6.74 (app. dt, $^4J_{HH}$ = 1.6 Hz, $^3J_{HH}$ = 7.3 Hz, 1H, ArH^{11}), 6.81 (app. dt, $^4J_{HH}$ = 1.6 Hz, $^3J_{HH}$ = 7.5 Hz, 1H, ArH^4), 7.06 (app. dt, $^4J_{HH}$ = 1.3 Hz, $^3J_{HH}$ = 7.9 Hz, 1H, ArH^5), 7.11 (app. dt, $^4J_{HH}$ = 1.3 Hz, $^3J_{HH}$ = 7.9 Hz, 1H, ArH^{10}), 7.28 (m, 2H, ArH^{3,12}); ^{13}C NMR (100 MHz, CDCl$_3$) δ (ppm): 24.96 (s, CH$_3$), 32.30 (s, CH$_3$), 55.06 (s, Cq), 92.06 (s, CH), 106.40 (s, ArH), 110.11 (s, ArH), 117.94 (s, ArH), 119.66 (s, ArH), 122.26 (s, ArH), 122.82 (s, ArH), 127.62 (s, ArH), 127.81 (s, ArH), 134.29 (s, Cq), 134.83 (s, Cq), 148.51 (s, Cq), 150.12 (s, Cq); HRMS (EI) calcd for $C_{16}H_{16}N_2$ [M^+] 236.1313, found 236.1308; IR, neat (υ cm^{-1}): 742 (s), 1019 (m), 1488 (s), 1610 (m), 2865 (w), 3369 (w).

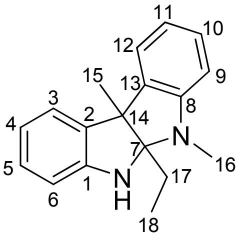
5,5a,10b-trimethyl-5,5a,6,10b-tetrahydroindolo[2,3-*b*]indole, 5b. Methyl lithium (1.6 M in diethyl ether) (1.25 ml, 2.0 mmol, 4 equiv.) was used. The crude product was purified using flash silica gel chromatography eluted with hexane/ethyl acetate (8:1 to 1:1) to yield the desired product as an off-white solid (0.094 g, 75%). Alternatively, methyl magnesium bromide (3.0 M in diethyl ether) (0.25 ml, 0.75 mmol, 1.5 equiv.) can be used to obtain the desired product **5b** in 24% spectroscopic yield (determined by ^{1}H NMR analysis using 1,3,5-trimethoxybenzene in $CDCl_3$ (0.5 mmol/ml) as an internal standard).



R_f 0.39 (4:1 hexane/ ethyl acetate); mp 102.9-104.3 °C; ^{1}H NMR (400 MHz, $CDCl_3$) δ (ppm): 1.50 (s, 3H, CH_3^{17}), 1.55 (s, 3H, CH_3^{15}), 2.84 (s, 3H, CH_3^{16}), 4.12 (br s, 1H, NH), 6.45 (d, $^3J_{HH}$ = 7.8 Hz, 1H, ArH^9), 6.63 (d, $^3J_{HH}$ = 7.8 Hz, 1H, ArH^6), 6.72 (app. dt, $^4J_{HH}$ = 1.7 Hz, $^3J_{HH}$ = 7.6 Hz, 1H, ArH^{11}), 6.81 (app. dt, $^4J_{HH}$ = 1.5 Hz, $^3J_{HH}$ = 7.6 Hz, 1H, ArH^4), 7.04 (app. dt, $^4J_{HH}$ = 1.5 Hz, $^3J_{HH}$ = 7.6 Hz, 1H, ArH^5), 7.10, (app. dt, $^4J_{HH}$ = 1.5 Hz, $^3J_{HH}$ = 7.6 Hz, 1H, ArH^{10}), 7.19 (d, $^3J_{HH}$ = 7.3 Hz, 1H, ArH^{12}), 7.29 (d, $^3J_{HH}$ = 7.1 Hz, 1H, ArH^3); ^{13}C NMR (100 MHz, $CDCl_3$) δ (ppm): 18.62 (s, CH_3), 20.82 (s, CH_3), 28.72 (s, CH_3), 56.47 (s, Cq), 93.74 (s, Cq), 106.42 (s, ArH), 109.54 (s, ArH), 117.99 (s, ArH), 119.37 (s, ArH), 122.46 (s, ArH), 122.90 (s, ArH), 127.44 (s, ArH), 127.79 (s, ArH), 134.03 (s, Cq), 134.83 (s, Cq), 148.16 (s, Cq), 149.70 (s, Cq); HRMS (EI) calcd for $C_{17}H_{18}N_2$ [M^+] 250.1470, found 250.1472; anal. calcd for $C_{17}H_{18}N_2$: C, 81.56; H, 7.25; N, 11.19; found: C, 81.16; H, 7.35; N, 10.93. A single crystal was grown for X-ray analysis by layering chloroform/hexane in an NMR tube and allowing slow evaporation.

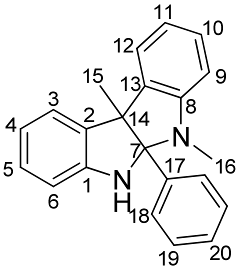
Crystal data for 7b: $C_{17}H_{18}N_2$; A yellow block, with dimensions 0.45×0.32×0.32 mm, gave a triclinic space group $P\bar{1}$, a = 11.2164(4) b = 13.3376(5) c = 18.9472(7) Å, α = 83.895(1) β = 89.499(1) γ = 76.898(1)°, V = 2744.71(17) Å^3, T = 100 K, Z = 8, μ = 0.072 mm^{-1}, $\theta_{\mathrm{min,max}}$ = 1.58,27.58, completeness: 0.994 to θ = 27.58°, reflections: total/independent 98242/12662, R_{int} = 0.0380, final $R1$ and $wR2$ = 0.0419, 0.1150, maximum/minimum residual electron density = 0.357, -0.240 eÅ^{-3}, ρ_{calc} = 1.212 g cm^{-3}. Crystallographic data for this compound has been deposited with the Cambridge Crystallographic Data Centre as supplementary publication CCDC 789828. Copies of the data can be obtained free of charge on application to CCDC, 12 Union Road, Cambridge CB2 1EZ, UK (fax: (+44) 1223-336-033; email: deposit@ccdc.cam.ac.uk).

5a-ethyl-5,10b-dimethyl-5,5a,6,10b-tetrahydroindolo[2,3-*b*]indole, 5c. Ethyl magnesium bromide (1.0 M in THF) (2.0 ml, 2.0 mmol, 4 equiv.) was used. The crude product was purified using flash silica gel chromatography eluted with hexane/ethyl acetate (20:1 to 1:1) to yield the desired product as an off-white solid (0.041 g, 31%).



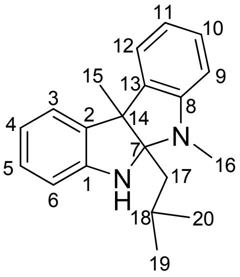
R$_f$ 0.29 (4:1 hexane/ ethyl acetate); mp 93.8-95.4 °C; ^{1}H NMR (400 MHz, $CDCl_3$) δ (ppm): 0.86 (t, $^3J_{\mathrm{HH}}$ = 7.6 Hz, 3H, CH_3^{18}), 1.62 (s, 3H, CH_3^{15}), 2.03 (2 x dq, $^2J_{\mathrm{HH}}$ = 14.9 Hz, $^3J_{\mathrm{HH}}$ = 7.6 Hz, 2H, $CH_2^{17,17'}$), 2.83 (s, 3H, CH_3^{16}), 4.16 (br s, 1H, NH), 6.36 (d, $^3J_{\mathrm{HH}}$ = 7.8 Hz, 1H, ArH^9), 6.60 (d, $^3J_{\mathrm{HH}}$ = 7.8 Hz, 1H, ArH^6), 6.67 (app. dt, $^4J_{\mathrm{HH}}$ = 1.0 Hz, $^3J_{\mathrm{HH}}$ = 7.6 Hz, 1H, ArH^{11}), 6.76 (app. dt, $^4J_{\mathrm{HH}}$ = 1.0 Hz, $^3J_{\mathrm{HH}}$ = 7.6 Hz, 1H, ArH^4), 7.00 (app. dt, $^4J_{\mathrm{HH}}$ = 1.2 Hz, $^3J_{\mathrm{HH}}$ = 7.8 Hz, 1H, ArH^5), 7.06 (app. dt, $^4J_{\mathrm{HH}}$ = 1.2 Hz, $^3J_{\mathrm{HH}}$ = 7.6 Hz, 1H, ArH^{10}), 7.16 (dd, $^4J_{\mathrm{HH}}$ = 1.2 Hz, $^3J_{\mathrm{HH}}$ = 7.3 Hz, 1H, ArH^{12}), 7.20 (dd, $^4J_{\mathrm{HH}}$ = 1.0 Hz, $^3J_{\mathrm{HH}}$ = 7.3 Hz, 1H, ArH^3); ^{13}C NMR (100 MHz, $CDCl_3$) δ (ppm): 9.32 (s, CH_3), 20.57 (s, CH_3), 26.97 (s, CH_2), 28.57 (s, CH_3), 56.52 (s, Cq), 95.74 (s, Cq), 105.19 (s, ArH), 109.11 (s, ArH), 117.33 (s, ArH), 119.28 (s, ArH), 121.72 (s, ArH), 122.48 (s, ArH), 127.40 (s, ArH), 127.71 (s, ArH), 134.30 (s, Cq), 135.95 (s, Cq), 148.11 (s, Cq), 150.31 (s, Cq); HRMS (EI) calcd for $C_{18}H_{20}N_2$ [M^+] 264.1626, found 264.1632; anal. calcd for $C_{18}H_{20}N_2$: C, 81.78; H, 7.63; N, 10.60; found: C, 81.28; H, 7.71; N, 10.20.

5,10b-dimethyl-5a-phenyl-5,5a,6,10b-tetrahydroindolo[2,3-*b*]indole, 5d. Phenyl lithium (1.8 M in dibutyl ether) (0.33 ml, 0.6 mmol, 1.2 equiv) was used. The crude product was purified using flash silica gel chromatography eluted with hexane/ethyl acetate (20:1 to 2:1) to yield the desired product as an off-white solid (0.093 g, 60%).



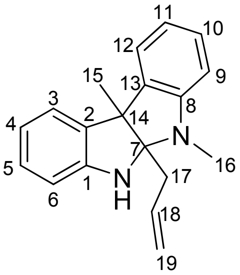
R*f* 0.23 (20:1 hexane/ ethyl acetate); mp 134.6-136.5 °C; ^{1}H NMR (400 MHz, $CDCl_3$) δ (ppm): 1.09 (s, 3H, CH_3^{15}), 2.80 (s, 3H, CH_3^{16}), 4.66 (br s, 1H, NH), 6.58 (dd, $^4J_{HH}$ = 1.0 Hz, $^3J_{HH}$ = 7.3 Hz, 1H, ArH^9), 6.74 (d, $^3J_{HH}$ = 7.8 Hz, 1H, ArH^6), 6.75 (app. dt, $^4J_{HH}$ = 1.0 Hz, $^3J_{HH}$ = 7.3 Hz, 1H, ArH^{11}), 6.82 (app. dt, $^4J_{HH}$ = 1.0 Hz, $^3J_{HH}$ = 7.3 Hz, 1H, ArH^4), 7.09 (app. dt, $^4J_{HH}$ = 1.2 Hz, $^3J_{HH}$ = 7.6 Hz, 1H, ArH^5), 7.15 (app. dt, $^4J_{HH}$ = 1.5 Hz, $^3J_{HH}$ = 7.3 Hz, 1H, ArH^{10}), 7.17 (d, $^3J_{HH}$ = 7.6 Hz, 1H, ArH^{12}), 7.27 (dd, $^4J_{HH}$ = 1.2 Hz, $^3J_{HH}$ = 7.3 Hz, 1H, ArH^3), 7.34-7.40 (m, 3H, ArH^{19,20}), 7.46 (dd, $^4J_{HH}$ = 1.2 Hz, $^3J_{HH}$ = 7.8 Hz, 2H, ArH^{18}); ^{13}C NMR (100 MHz, $CDCl_3$) δ (ppm): 22.88 (s, CH_3), 30.04 (s, CH_3), 59.55 (s, Cq), 98.86 (s, Cq), 106.48 (s, ArH), 108.18 (s, ArH), 118.21 (s, ArH), 119.33 (s, ArH), 122.70 (s, ArH), 123.12 (s, ArH), 127.63 (s, ArH), 127.93 (s, ArH), 128.13 (s, ArH), 128.44 (s, 2xArH), 134.05 (s, Cq), 134.22 (s, Cq), 139.27 (s, Cq), 149.18 (s, Cq), 150.34 (s, Cq); HRMS (EI) calcd for $C_{22}H_{20}N_2$ [M^+] 312.1626, found 312.1614; anal. calcd for $C_{22}H_{20}N_2$: C, 84.58; H, 6.45; N, 8.97; found: C, 84.45; H, 6.36; N, 8.61.

5a-isobutyl-5,10b-dimethyl-5,5a,6,10b-tetrahydroindolo[2,3-*b*]indole, 5e. *iso*-butyl lithium (1.6 M in heptanes) (1.25 ml, 2.0 mmol, 4 equiv.) was used. The crude product was purified using flash silica gel chromatography eluted with hexane/ethyl acetate (20:1 to 1:1) to yield the desired product as an off-white solid (0.085 g, 58%).



R$_f$ 0.31 (10:1 hexane/ ethyl acetate); mp 121.7-123.4 °C; ^{1}H NMR (400 MHz, CDCl$_3$) δ (ppm): 0.96 (app. t, $^3J_{HH}$ = 6.6 Hz, 6H, CH$_3^{19,20}$), 1.62 (s, 3H, CH$_3^{15}$), 1.73 (m, 1H, H^{18}), 1.82 (dd, $^3J_{HH}$ = 4.9 Hz, $^2J_{HH}$ = 14.9 Hz, H^{17}), 1.93 (dd, $^3J_{HH}$ = 5.9 Hz, $^2J_{HH}$ = 14.9 Hz, H$^{17'}$), 2.83 (s, 3H, CH$_3^{16}$), 4.12 (br s, 1H, NH), 6.41 (d, $^3J_{HH}$ = 7.8 Hz, 1H, ArH^9), 6.57 (d, $^3J_{HH}$ = 7.8 Hz, 1H, ArH^6), 6.68 (app. dt, $^4J_{HH}$ = 0.7 Hz, $^3J_{HH}$ = 7.3 Hz, 1H, ArH^{11}), 6.76 (app. dt, $^4J_{HH}$ = 1.0 Hz, $^3J_{HH}$ = 7.6 Hz, 1H, ArH^4), 7.00 (app. dt, $^4J_{HH}$ = 1.2 Hz, $^3J_{HH}$ = 7.6 Hz, 1H, ArH^5), 7.07 (app. dt, $^4J_{HH}$ = 1.2 Hz, $^3J_{HH}$ = 7.6 Hz, 1H, ArH^{10}), 7.14 (dd, $^4J_{HH}$ = 1.0 Hz, $^3J_{HH}$ = 7.1 Hz, 1H, ArH^{12}), 7.24 (dd, $^4J_{HH}$ = 0.7 Hz, $^3J_{HH}$ = 7.3 Hz, 1H, ArH^3); ^{13}C NMR (100 MHz, CDCl$_3$) δ (ppm): 21.06 (s, CH$_3$), 23.80 (s, CH), 24.62 (s, CH$_3$), 25.15 (s, CH$_3$), 29.44 (s, CH$_3$), 42.90 (s, CH$_2$), 57.46 (s, Cq), 95. 67 (s, Cq), 106.24 (s, ArH), 108.67 (s, ArH), 117.69 (s, ArH), 119.01 (s, ArH), 122.07 (s, ArH), 122.23 (s, ArH), 127.34 (s, ArH), 127.75 (s, ArH), 134.62 (s, Cq), 135.72 (s, Cq), 148.19 (s, Cq), 149.99 (s, Cq); HRMS (EI) calcd for $C_{20}H_{24}N_2$ [M$^+$] 292.1939, found 292.1942; anal. calcd for $C_{20}H_{24}N_2$: C, 82.15; H, 8.27; N, 9.58; found: C, 82.23; H, 8.17; N, 9.36.

5a-allyl-5,10b-dimethyl-5,5a,6,10b-tetrahydroindolo[2,3-*b*]indole, 5f. Allyl magnesium bromide (1.0 M in diethyl ether) (2.0 ml, 2.0 mmol, 4 equiv.) was used. The crude product was purified using flash silica gel chromatography eluted with hexane/ethyl acetate (10:1 to 1:1) to yield the desired product as a yellow/orange oil (0.105 g, 76%).



R_f 0.29 (4:1 hexane/ ethyl acetate); ^{1}H NMR (400 MHz, $CDCl_3$) δ (ppm): 1.63 (s, 3H, CH_3^{15}), 2.73 (app. ddt, $^4J_{HH}$ = 1.5 Hz, $^3J_{HH}$ = 6.9 Hz, $^2J_{HH}$ = 15.2 Hz, 1H, H^{17}), 2.80 (app. ddt, $^4J_{HH}$ = 1.2 Hz, $^3J_{HH}$ = 7.1 Hz, $^2J_{HH}$ = 15.2 Hz, 1H, $H^{17'}$), 2.85 (s, 3H, CH_3^{16}), 4.27 (br s, 1H, NH), 5.05 (app. dq, $^4J_{HH}$ = 1.2 Hz, $^3J_{HHcis}$ = 10.0 Hz, $^2J_{HH}$ = 3.2 Hz, 1H, H^{19}), 5.16 (app. dq, $^4J_{HH}$ = 1.5 Hz, $^3J_{HHtrans}$ = 17.1 Hz, $^2J_{HH}$ = 3.4 Hz, 1H, $H^{19'}$), 5.77 (dddd, $^3J_{HH}$ = 6.9 & 7.1 Hz, $^3J_{HHcis}$ = 10.0 Hz, $^3J_{HHtrans}$ = 17.1 Hz, 1H, H^{18}), 6.40 (d, $^3J_{HH}$ = 7.8 Hz, 1H, ArH^9), 6.60 (ddd, $^5J_{HH}$ = 0.5 Hz, $^4J_{HH}$ = 1.0 Hz, $^3J_{HH}$ = 7.8 Hz, 1H, ArH^6), 6.68 (app. dt, $^4J_{HH}$ = 1.0 Hz, $^3J_{HH}$ = 7.3 Hz, 1H, ArH^{11}), 6.77 (app. dt, $^4J_{HH}$ = 1.0 Hz, $^3J_{HH}$ = 7.6 Hz, 1H, ArH^4), 7.01 (app. dt, $^4J_{HH}$ = 1.2 Hz, $^3J_{HH}$ = 7.6 Hz, 1H, ArH^5), 7.07 (app. dt, $^4J_{HH}$ = 1.2 Hz, $^3J_{HH}$ = 7.6 Hz, 1H, ArH^{10}), 7.15 (ddd, $^5J_{HH}$ = 0.5 Hz, $^4J_{HH}$ = 1.2 Hz, $^3J_{HH}$ = 7.3 Hz, 1H, ArH^{12}), 7.23 (ddd, $^5J_{HH}$ = 0.5 Hz, $^4J_{HH}$ = 1.2 Hz, $^3J_{HH}$ = 7.6 Hz, 1H, ArH^3); ^{13}C NMR (100 MHz, $CDCl_3$) δ (ppm): 21.03 (s, CH_3), 29.30 (s, CH_3), 38.74 (s, CH_2), 57.14 (s, Cq), 94.26 (s, Cq), 106.00 (s, ArH), 109.30 (s, ArH), 117.80 (s, ArH), 118.52 (s, CH_2), 119.38 (s, ArH), 122.05 (s, ArH), 122.50 (s, ArH), 127.50 (s, ArH), 127.81 (s, ArH), 133.25 (s, CH), 134.20 (s, Cq), 135.44 (s, Cq), 148.01 (s, Cq), 150.00 (s, Cq); HRMS (EI) calcd for $C_{19}H_{20}N_2$ [M^+] 276.1626, found 276.1627; IR, neat (υ cm^{-1}): 742 (s), 917 (w), 1018 (m), 1489 (s), 1611 (m), 2961 (w) 3367 (w).

7. Computational details

Geometries for **1a***, **4a***, **6*** and **7*** were optimised *in vacuo* with the popular B3LYP density functiona[8-11] implemented as described in ref. 12, as implemented in Jaguar,[13] using a 6-31G* basis set for all atoms and standard convergence criteria. Test calculations exploring functional, basis set and solvation effects did not yield substantially different structural and energetic results, and the relative energy differences between products **4a*** and **7*** were preserved. Table S1 gives key structural parameters for DFT-optimised geometries of **1a***, **4a***, **6*** and **7*** and a comparison with the X-ray structural data for **4a**. The Cartesian Coordinates in Å for all optimised geometries (B3LYP/6-31G*; E(H_2O) = -76.40701 a.u.) for the structures are:

1a*

-727.614707 a.u.

N1	3.0858713070	-0.2161187403	4.3039962333
N2	2.8880033125	1.5479493817	2.6514184500
C3	2.4515883965	0.7704736007	3.5849655062
C4	0.9479230753	0.6826239700	3.7922196111
C5	0.8278315216	-0.7864977945	4.1616050383
C6	-0.2578897969	-1.6347368659	4.3017415083
H7	-1.2539618149	-1.3085691646	4.0132935540
C8	-0.0546137474	-2.9311209725	4.8012865117
H9	-0.8959398990	-3.6119951048	4.8936029538
C10	1.2211036962	-3.3485979503	5.1784143562
H11	1.3655489638	-4.3530535370	5.5674121365
C12	2.3292752361	-2.4977812920	5.0616789463
H13	3.3196834552	-2.8331973703	5.3541120794
C14	2.1166038328	-1.2233391290	4.5496056853
C15	4.5077994095	-0.4874535704	4.1916069435
H16	5.0035181260	0.4277184909	3.8648011791
H17	4.7073142754	-1.2803436553	3.4580834626

H18	4.9140097739	-0.7905267376	5.1622192997
C19	0.5155023375	1.5410991627	5.0223540565
H20	-0.5710668308	1.4806888416	5.1444316666
H21	0.7908525801	2.5898088123	4.8750959510
H22	0.9879625713	1.1711603691	5.9380709737
C23	0.5195140298	1.4010884659	2.5247145260
C24	1.6996688120	1.9897372480	1.9993887558
C25	1.6362701255	2.8512135714	0.9095495403
H26	2.5426078731	3.2978345086	0.5118534598
C27	0.3829108977	3.1110715575	0.3397836165
H28	0.3165900514	3.7728528758	-0.5202301814
C29	-0.7801531957	2.5350367240	0.8547288065
H30	-1.7394853127	2.7450767254	0.3899136899
C31	-0.7179931351	1.6847669677	1.9710647121
H32	-1.6287695492	1.2526803467	2.3798076314

4a*

-804.072323 a.u.

N1	3.1076696818	-0.1003434984	4.5747941319
N2	2.2951553111	0.0327348802	1.3646470726
H3	2.5835456084	-0.2699421323	0.4409480430

H4	2.1164367801	-0.7706619652	1.9575134217
O5	3.1135120592	2.1783949701	4.1699882935
C6	2.5392786329	1.1085606626	4.1828469556
C7	1.0313266748	0.8454775253	3.8814811033
C8	0.9575155684	-0.6709161089	4.0012970381
C9	-0.0896553428	-1.5517550738	3.7781105249
H10	-1.0474785262	-1.1843561160	3.4181462087
C11	0.1070648281	-2.9221269958	4.0094786266
H12	-0.7054024368	-3.6218311419	3.8357268842
C13	1.3434545945	-3.3895698374	4.4569212316
H14	1.4861298946	-4.4528654462	4.6309429760
C15	2.4140068184	-2.5133611058	4.6804773202
H16	3.3757600762	-2.8847905340	5.0211396084
C17	2.2004311599	-1.1568847918	4.4479330021
C18	4.5016727215	-0.2308317367	4.9398548197
H19	4.9336782969	0.7713915578	4.9244956839
H20	5.0373831633	-0.8667942926	4.2241617179
H21	4.6055989866	-0.6590293893	5.9436239803
C22	0.2688221959	1.4825641097	5.0699184600
H23	-0.8069852572	1.2986345196	4.9892356906
H24	0.4537392955	2.5600249101	5.1072535561

H25	0.6142356514	1.0418151642	6.0104951776
C26	0.6135189290	1.4070114140	2.5191488475
C27	1.2524369875	0.9718377722	1.3284850804
C28	0.8830284053	1.5403667951	0.1003585273
H29	1.3841354477	1.2003954309	-0.8043078813
C30	-0.1025336361	2.5187166074	0.0233285894
H31	-0.3664680688	2.9425611767	-0.9422796076
C32	-0.7502005422	2.9384759823	1.1820532872
H33	-1.5271529046	3.6964026817	1.1408557304
C34	-0.3852482625	2.3804135541	2.4077845002
H35	-0.8894000348	2.7314301707	3.3008826086

6*

-575.192109 a.u.

N1	3.1161266546	-0.1428684969	4.3882115489
N2	2.8955055268	1.4932449886	2.6206003013
C3	2.4759424132	0.7659385659	3.6093856097
C4	0.9796804551	0.7290100747	3.8750004092
C5	0.8143773773	-0.7772258410	4.1829412045
C6	2.1452857554	-1.1154926696	4.9216752085
C7	4.5270557904	-0.4444448666	4.2688524363

H8	5.0004801149	0.3552355038	3.6956037681
H9	4.6896749779	-1.3974723610	3.7443051237
H10	4.9994943033	-0.5075755126	5.2566460256
C11	0.6040186144	1.5908273591	5.1051234988
H12	-0.4833966234	1.5893285810	5.2408093963
H13	0.9274864366	2.6265880716	4.9657605584
H14	1.0650472483	1.2077141125	6.0228529277
C15	0.5218686971	1.4119314930	2.6018500585
C16	1.6968377926	1.9242746013	1.9896600201
C17	1.6079607266	2.7140035034	0.8466534868
H18	2.5079535883	3.1004143767	0.3775883548
C19	0.3382046749	2.9827306497	0.3193815110
H20	0.2531424661	3.5924118318	-0.5770766970
C21	-0.8185444377	2.4836882198	0.9216477237
H22	-1.7916104956	2.7023451625	0.4901065257
C23	-0.7302002251	1.7004346209	2.0839545219
H24	-1.6338520402	1.3230460934	2.5586127560
H25	-0.0654700555	-1.0110633834	4.7908894900
H26	0.7515026409	-1.3505565876	3.2517452619
H27	2.4892033273	-2.1361098917	4.7094668722
H28	2.0470272734	-1.0222514816	6.0118434473

7*

-651.639947 a.u.

N1	3.1091899999	-0.2266656854	4.4860812886
N2	2.4573620228	0.3342000579	1.2728966235
H3	2.6468182640	-0.1172606299	0.3890402078
H4	2.7112120613	-0.2245702940	2.0732016140
O5	3.2493271965	2.0432734020	4.0804418116
C6	2.6052330407	1.0110878358	4.1315455607
C7	1.0834198921	0.8592718132	3.8731752974
C8	0.8671577429	-0.6826521267	3.9410779660
C9	2.0733489814	-1.2215733783	4.7364818917
C10	4.4455646303	-0.3666347064	5.0280330180
H11	5.0020417901	0.5383340670	4.7761548207
H12	4.9485367505	-1.2401230852	4.5967205267
H13	4.4248537071	-0.4810574139	6.1215205573
C14	0.4160911709	1.5342975002	5.0926311386
H15	-0.6701446733	1.3995408681	5.0780765644
H16	0.6462556863	2.6030530177	5.1163359917
H17	0.7892852667	1.0901395618	6.0231473972
C18	0.6459514820	1.4584135012	2.5333558451

C19	1.3038920103	1.1158241482	1.3204851519
C20	0.8145502653	1.6273186099	0.1048128019
H21	1.3310908681	1.3609837957	-0.8157109772
C22	-0.2874343070	2.4710550651	0.0623466737
H23	-0.6375260803	2.8499906655	-0.8946678655
C24	-0.9286237657	2.8310728029	1.2458500243
H25	-1.7868030449	3.4967544219	1.2345688698
C26	-0.4535495987	2.3227710529	2.4537925471
H27	-0.9651227058	2.6127625629	3.3646026429
H28	-0.0861900359	-0.9400840001	4.4113410455
H29	0.8596788028	-1.1130675785	2.9355834143
H30	2.3965373353	-2.2132574122	4.3969729230
H31	1.8604202296	-1.2981434824	5.8149843668

E(H_2O) = -76.40701 a.u.)

Table S1. Key structural parameters for DFT-optimised geometries of 1a*, 4a*, 6* and 7* and comparative X-ray data for 4a

Bond Lengths (Å)	**1a***	**4a*** (X-ray data for **4a**)	**6***	**7***
C1-C2	1.415	1.407 (1.393)	1.559	1.542
C2-N3	1.419	1.398 (1.406)	1.474	1.458
N3-C4	1.376	1.392 (1.367)	1.357	1.383
C4-N5	1.291		1.297	
N5-C6	1.426	1.404 (1.391)	1.422	1.394
C6-C7	1.420	1.420 (1.406)	1.421	1.422
C7-C8	1.519	1.532 (1.532)	1.516	1.531
C8-C4	1.520	1.560 (1.548)	1.520	1.551
C8-C1	1.520	1.523 (1.519)	1.546	1.558
Angles (°)				
C1-C2-N3	110.8	109.9 (109.7)	104.3	103.2
C2-N3-C4	106.5	111.4 (111.3)	109.8	111.3
N3-C4-C8	110.1	107.6 (108.3)	110.3	108.2
C4-C8-C1	99.6	101.5 (101.4)	99.4	103.0
C8-C1-C2	107.9	109.0 (109.3)	102.4	105.1
C4-N5-C6	103.6		103.6	
C2-N3-C9	123.3	125.4 (124.2)	122.3	121.7
C9-N3-C4	123.0	122.9 (124.4)	123.5	121.2

8. References

1. A. B. Pangborn, M. A. Giardello, R. H. Grubbs, R. K. Rosen and F. J. Timmers, *Organometallics*, 1996, **15**, 1518.
2. SAINT V7.68A or V7.66A, Bruker AXS, Madison, WI.
3. G. M. Sheldrick, SADABS V2008/1, University of Göttingen, Germany.
4. G. M. Sheldrick, *Acta Cryst.*, 2008, *A64*, 112.
5. R. J. Phipps, N. P. Grimster and M. J. Gaunt, *J. Am. Chem. Soc.*, 2008, **130**, 8172.
6. P. Zhang, R. Lui and J. M. Cook, *Tetrahedron Lett.*, 1995, **36**, 3103.
7. T. Hino, M. Tonozuka and M. Nakagawa, *Tetrahedron*, 1974, **30**, 2123.
8. J. C. Slater, *Quantum Theory of Molecules and Solids, Vol. 4: The Self-Consistent Field for Molecules and Solids*, McGraw-Hill, New York, 1974.
9. A. D. Becke, *Phys. Rev. A*, 1988, **38**, 3098.
10. S. H. Vosko, L. Wilk and M. Nusair, *Can. J. Phys.*, 1980, **58**, 1200.

11. C. Lee, W. Yang and R. G. Parr, *Phys. Rev. B*, 1988, **37**, 785.
12. B. Miehlich, A. Savin, H. Stoll and H. Preuss, *Chem. Phys. Lett.*, 1989, **157**, 200.
13. L. L. C. Schrödinger, Jaguar, version 6.0, 2005 (New York, NY).