Supporting Information for:

Triphenylphosphine-Mediated Reductive Cyclization of 2-Nitrobiphenyls: A Practical and Convenient Synthesis of Carbazoles

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Experimental Information:

Materials and Characterization: All reagents were used as received. All ^{1}H NMR and ^{13}C NMR spectra were recorded on a spectrometer operating at 300 MHz or 75 MHz, respectively, with tetramethylsilane (TMS) as an internal standard. Gravity chromatography was done using ICN silica gel DCC 60 Å. P950 Ligroin is a commercially available industrial solvent mixture of low-boiling hydrocarbons (bp 40–60 °C) with properties similar to hexanes. CH_2Cl_2 was distilled over CaH_2 immediately before use. All reactions were conducted under N_2 atmosphere, unless otherwise specified. Elemental analyses are the average of two runs. Melting points are uncorrected.

General Synthesis 1: 2-nitrobiphenyl derivatives via Suzuki-Miyaura cross coupling: A mixture of the desired 2-halonitrobenzene, phenylboronic acid (1.1 equiv.), and 2 M (aq) K_2CO_3 (2 equiv.) was taken up in toluene (1.4 mL per mmol of halogen) and sparged with bubbling N_2 for 5 min. At that time, $Pd(PPh_3)_4$ (0.01 equiv.) was added and sparging continued for an additional 10 min before the flask was closed and the contents heated to reflux. Upon complete consumption of the halogen starting material (4–24 h), the reaction was cooled, filtered, and washed with Et_2O (~150 mL). The organic mixture was washed with H_2O (2 × 50 mL) and brine, dried over $MgSO_4$, and concentrated in vacuo. Chromatography of the residue gave the pure product.

General Synthesis 2. Carbazoles by PPh_3-mediated reductive cyclization: A mixture of the desired 2-nitrobiphenyl derivatives and PPh_3 (2.5 equiv.) was taken up in 1,2-

dichlorobenzene (o-DCB) (2 mL per mmol of nitro) under N_2 and heated to reflux, with vigorous stirring, using a heating mantle equipped with a sand bath. The reaction was stopped upon complete consumption of the nitrobiphenyl starting material, at which point the reaction was cooled and the solvent stripped under high vacuum. The residue was either chromatographed directly, or slurried with P950 ligroin (~2.5 mL per mL of o-DCB used) to precipitate PPh_3O. Upon removal of the PPh_3O by filtration, the filtrate was concentrated, and if necessary, chromatographed to yield the pure product.

4,4'-Dibromo-2-nitrobiphenyl (5): A mixture of fuming HNO_3 (15 mL) and AcOH (15 mL) was added portionwise to a suspension of 4,4'-Dibromobiphenyl (9.00 g, 28.85 mmol) in CH_2Cl_2 (25 mL) and Ac_2O (150 mL). Over the course of the addition, the reaction turned increasingly orange and warmed slightly, and the solid began to dissolve. After 18 h, the reaction had darkened considerably, and TLC showed complete disappearance of the starting material. The reaction was poured into H_2O (1.4 L) containing NaOH (35 g) to partially neutralize the acid, resulting in the formation of a tacky yellow precipitate. The mixture was divided into two equal volumes that were each in turn extracted with CH_2Cl_2 (4 × 75 mL). The combined organic layers (600 mL) were washed vigorously with H_2O (3 × 100 mL) and brine, dried over $MgSO_4$, and concentrated *in vacuo* to a yellow solid. MeOH (300 mL) was added, the solvent stripped to form a thick slurry (approx 25–50 mL MeOH remaining), and subsequently filtered. The pale yellow solid was washed with ice cold MeOH (100 mL) and dried (8.50 g, 83% yield). ^{1}H NMR ($CDCl_3$) δ 7.16 (ABq, 2H), 7.28 (d, J = 8 Hz, 1H), 7.56

(ABq, 2H), 7.75 (dd, *J* = 2 Hz, 8 Hz, 1H), 8.02 (d, *J* = 2 Hz, 1H). Spectroscopic data and analytical characterization are consistent with the literature.[1]

***N*-butyl-4-chloro-3-nitrobiphenyl carboxamide (6):** To an ice cold mixture of 4-chloro-3-nitrobenzoic acid (1.50 g, 7.44 mmol) and *N*-hydroxysuccinimide (0.94 g, 8.19 mmol) in freshly distilled CH_2Cl_2, DDC (1.80 g, 9.30 mmol) was added. After 5 min the ice bath was removed and the reaction allowed to warm to room temperature with the development of the thick white precipitate. After 90 min, n-butylamine (2.72 g, 37.20 mmol) was added in a single portion, where upon the reaction turned bright yellow. After 15 min, the reaction was filtered, washed with CH_2Cl_2 (20 mL), and the resulting filtrate diluted with EtOAc (150 mL), washed with 0.5 M NaOH (3 × 50 mL), 1 M HCl (3 × 50 mL) and brine, dried over $MgSO_4$, and concentrated to dryness. Chromatography (50:50 CH_2Cl_2:EtOAc) gave the product as a yellow solid contaminated with a small amount of DCC. Slurrying the solid with ice cold cyclohexane (50 mL), followed by filtration afforded the pure product as a yellow powder (1.73 g, 91% yield). ^{1}H NMR ($CDCl_3$) δ 0.97 (t, *J* = 7.4 Hz, 3H), 1.42 (sextet, *J* = 8.1 Hz, 2H), 1.62 (quintet, *J* = 2.9 Hz, 2H), 3.48 (q, *J* = 5.9 Hz, 2H), 6.17 (bs, 1H), 7.63 (d, J = 8.4 Hz, 1H), 7.94 (dd, *J* = 2.2 Hz, 8.4 Hz, 1H), 8.24 (d, *J* = 2.0 Hz, 1H). Spectroscopic data and analytical characterization are consistent with the literature.[2]

4-Methoxy-2-nitrobiphenyl (7): Prepared according to general synthesis 1 from 4-bromo-3-nitroanisole (5.00 g, 21.55 mmol). Chromatography (65:35 P950 ligroin:CH_2Cl_2) gave the product as a pale yellow solid (4.89 g, 99% yield). ^{1}H NMR

($CDCl_3$) δ 3.19 (s, 3H), 7.16 (dd, *J* = 2.5 Hz, 8.3 Hz, 1H), 7.27 (m, 7H). Spectroscopic data and analytical characterization are consistent with the literature.[3]

4-Fluoro-2-nitrobiphenyl (8): Prepared according to general synthesis 1 from 2-chloro-5-fluoronitrobenzene (1.50 g, 8.45 mmol). Chromatography (90:10 P950 ligroin:CH_2Cl_2) gave the product as a yellow solid (1.01 g, 55% yield). ^{1}H NMR ($CDCl_3$) δ 7.28–7.46 (m, 7H), 7.60 (dd, *J* = 2.6 Hz, 8.1 Hz, 1H). Spectroscopic data and analytical characterization are consistent with the literature.[4]

4-Trifluoromethyl-2-nitrobiphenyl (9): Prepared according to general synthesis 1 from 2-chloro-5-trifluoronitrobenzene (1.50 g, 6.65 mmol). Chromatography (90:10 P950 ligroin:CH_2Cl_2) gave the product as a yellow solid (1.62 g, 91% yield). ^{1}H NMR ($CDCl_3$) δ 7.34 (dd, *J* = 2.6 Hz, 6.5 Hz, 2H), 7.44–7.50 (m, 3H), 7.63 (d, *J* = 7.9 Hz, 1H), 7.89 (dd, *J* = 1.3 Hz, 8.1 Hz, 1H), 8.15 (d, *J* = 1.1 Hz, 1H). Spectroscopic data and analytical characterization are consistent with the literature.[3b,5]

4-Cyano-2-nitrobiphenyl (10): Prepared according to the general synthesis 1 from 4-chloro-3-nitrobenzonitrile (2.00 g, 10.95 mmol). Chromatography (gradient of 50:50 to 0:100 P950 ligroin:CH_2Cl_2) gave the product as a pale yellow powder (2.26 g, 92% yield). ^{1}H NMR ($CDCl_3$) δ 7.29–7.34 (m, 2H), 7.45–7.51 (m, 3H), 7.61 (d, *J* = 7.9 Hz, 1H), 7.90 (dd, *J* = 1.7 Hz, 8.0 Hz, 1H), 8.14 (d, *J* = 1.5 Hz 1H). Spectroscopic data and analytical characterization are consistent with the literature.[6]

4-Formyl-2-nitrobiphenyl (11): Prepared according to general synthesis 1 from 4-chloro-2-nitrobenzaldehyde (2.00 g, 10.78 mmol). Chromatography (35:65 P950 ligroin:CH_2Cl_2) gave the product as a yellow solid (2.12 g, 87% yield). ^{1}H NMR ($CDCl_3$) δ 7.34 (dd, *J* = 2.6 Hz, 4.4 Hz, 2H), 7.42–7.51 (m, 3H), 7.65 (d, *J* = 7.9 Hz, 1H), 8.13 (dd, *J* = 1.6 Hz, 7.9 Hz, 1H), 8.33 (d, *J* = 1.6 Hz, 1H), 10.11 (s, 1H). Spectroscopic data and analytical characterization are consistent with the literature.[6]

4-Acetyl-2-nitrobiphenyl (12): Prepared according to general synthesis 1 from 4-chloro-3-nitroacetophenone (2.00 g, 10.02 mmol). Chromatography (gradient of 40:60 to 0:100 P950 ligroin:CH_2Cl_2) gave the product as a yellow solid (2.26 g, 95% yield). ^{1}H NMR ($CDCl_3$) δ 2.69 (s, 3H), 7.29–7.38 (m, 2H), 7.41–7.51 (m, 3H), 7.58 (d, *J* = 8.1 Hz, 1H), 8.19 (dd, *J* = 1.8 Hz, 7.9 Hz, 1H), 8.39 (d, *J* = 1.6 Hz, 1H). Spectroscopic data and analytical characterization are consistent with the literature.[7]

4-Carbomethoxy-2-nitrobiphenyl (14): Prepared according to general synthesis 1 from methyl-4-chloro-5-nitrobenzoate (8.00 g, 37.11 mmol). Chromatography (50:50 then 0:100 P950 ligroin:CH_2Cl_2) gave the product as a yellow solid (8.25 g, 86% yield). ^{1}H NMR ($CDCl_3$) δ 3.99 (s, 3H), 7.31–7.36 (m, 2H), 7.42–7.48 (m, 3H), 7.55 (d, *J* = 7.9 Hz, 1H), 8.26 (dd, *J* = 1.3 Hz, 8.1 Hz, 1H), 8.50 (d, *J* = 1.9 Hz, 1H). Spectroscopic data and analytical characterization are consistent with the literature.[8]

2-Nitrobiphenyl-4-carboxylic acid (16): To a solution of KOH (2.62 g, 46.65 mmol) in MeOH (25 mL) was added 4-carbomethoxy-2-nitrobiphenyl (6.00 g, 23.32 mmol). The

reaction was stirred vigorously and developed a precipitate within 6 h, which was diluted with additional MeOH (20 mL) to facilitate stirring. An additional equivalent of KOH (1.30 g, 23.21 mmol) and the reaction continued overnight. After 19 h, the reaction was diluted with H_2O (200 mL) and acidified with concentrated HCl (~ 7 mL) to pH = 2. The mixture was extracted with EtOAc (3 × 100 mL). The combined layers were dried over $MgSO_4$ and concentrated to dryness, yielding a fluffy, light yellow powder (5.67 g, quantitative yield). ^{1}H NMR ($CDCl_3$) δ 7.33–7.39 (dd, *J* = 2.4 Hz, 6.0 Hz, 2H), 7.44–7.50 (m, 3H), 7.61 (d, *J* = 7.9 Hz, 1H), 8.34 (dd, *J* = 1.6 Hz, 8.0 Hz, 1H), 8.57 (d, *J* = 1.7 Hz, 1H). Spectroscopic data and analytical characterization are consistent with the literature.[9]

4-Hydroxy-2-nitrobiphenyl (18): To an ice cold solution of 4-methoxy-2-nitrobiphenyl (2.00 g, 8.72 mmol) in freshly distilled CH_2Cl_2 (17.5 mL), BBr_3 (3.28 g, 13.09 mmol) was added dropwise via syringe. Upon complete addition, the ice bath was removed and the reaction continued at room temperature for 5 h. At that time, the dark reaction mixture was diluted with Et_2O (100 mL), and the resulting orange solution was carefully treated with 0.5 M HCl (100 mL). The layers were separated and the aqueous layer extracted with additional Et_2O (2 × 50 mL). The combined organic layers were washed with brine, dried over $MgSO_4$, and concentrated *in vacuo*. The purple residue was chromatographed (0:100, then 5:95 Et_2O:CH_2Cl_2) to give the product as an orange powder (1.45 g, 77% yield). ^{1}H NMR ($CDCl_3$) δ 5.16 (s, 1H), 7.09 (dd, *J* = 2.7 Hz, 8.4 Hz, 1H), 7.26–7.31 (m, 3H), 7.32–7.35 (m, 1H), 7.36–7.45 (m, 3H). Spectroscopic data and analytical characterization are consistent with a commercially available sample.[10]

2-*tert*-Butylcarbazole (19): Prepared according to general synthesis 2 using 4'-*tert*-butyl-2-nitrobiphenyl (9.00 g, 35.24 mmol). Chromatography (75:25 P950:CH_2Cl_2) gave the product as a flaky, tan-colored solid (5.29 g, 67% yield). ^{1}H NMR ($CDCl_3$) δ 1.42 (s, 9H), 7.17–7.23 (m, 1H), 7.29–7.44 (m, 4H), 7.97–8.04 (m, 3H). Spectroscopic data and analytical characterization are consistent with the literature.[11,12]

2-Methoxycarbazole (20): Prepared according to general synthesis 2 using 4-methoxy-2-nitrobiphenyl (1.00 g, 4.36 mmol). Chromatography (75:25, then 0:100 P950 ligroin:CH_2Cl_2) gave the product as an off-white solid (0.78 g, 91 % yield). ^{1}H NMR ($CDCl_3$) δ 3.91 (s, 3H), 6.86 (dd, *J* = 2.4 Hz, 8.5 Hz, 1H), 6.92 (d, *J* = 2.0 Hz, 1H), 7.15–7.43 (m, 3H), 7.90–8.02 (m, 2H). Spectroscopic data and analytical characterization are consistent with the literature.[3a,13]

2,7-Dibromocarbazole (21): Prepared according to general synthesis 2 using 4,4'-dibromo-2-nitrobiphenyl (1.02 g, 2.86 mmol). Chromatography (75:25 P950 ligroin:CH_2Cl_2) gave the product as a flaky, lustrous, off-white solid (0.70 g, 75% yield). ^{1}H NMR ($CDCl_3$) δ 7.36 (dd, *J* = 1.6 Hz, 8.5 Hz, 2H), 7.58 (d, *J* = 1.6 Hz, 2H), 7.88 (d, *J* = 8.5 Hz, 2H), 8.05 (s, 1H). Spectroscopic data and analytical characterization are consistent with the literature.[1]

2-Fluorocarbazole (22): Prepared according to general synthesis 2 using 4-fluoro-2-nitrobiphenyl (0.92 g, 4.24 mmol). Chromatography (75:25, then 50:50 P950

ligroin:CH_2Cl_2) gave the product as a light-brown solid (0.71 g, 91% yield). ^{1}H NMR ($CDCl_3$) δ 6.93–7.02 (m, 1H), 7.10 (dd, *J* = 2.4 Hz, 9.6 Hz, 1H), 7.21–7.29 (m, 1H), 7.35–7.45 (m, 2H), 7.94–8.12 (m, 3H). Spectroscopic data and analytical characterization are consistent with the literature.[14]

2-Trifluoromethylcarbazole (23): Prepared according to general synthesis 2 using 4-trifluoromethyl-2-nitrobiphenyl (1.00 g, 3.74 mmol). Chromatography (75:25, then 0:100 P950 ligroin:CH_2Cl_2) gave the product as a gold colored solid (0.75 g, 85% yield). ^{1}H NMR ($CDCl_3$) δ 7.27–7.32 (m, 1H), 7.47–7.54 (m, 3H), 7.71 (s, 1H), 8.12 (d, *J* = 8.8 Hz, 1H), 8.15 (d, *J* = 8.2 Hz, 1H), 8.23 (bs, 1H). Spectroscopic data and analytical characterization are consistent with the literature.[15]

2-Cyanocarbazole (24): Prepared according to general synthesis 2 using 4-cyano-2-nitrobiphenyl (1.00 g, 4.46 mmol). Chromatography (gradient of 40:60 to 0:100 P950 ligroin:CH_2Cl_2) gave the product as a tan solid (0.64 g, 75% yield). ^{1}H NMR ($CDCl_3$) δ 7.28–7.45 (m, 1H), 7.48–7.54 (m, 3H), 7.76 (t, *J* = 0.7 Hz, 1H), 8.12 (d, *J* = 7.0 Hz, 1H), 8.14 (d, *J* = 7.4 Hz, 1H), 8.31 (bs, 1H). Spectroscopic data and analytical characterization are consistent with the literature.[16]

2-Formylcarbazole (25): Prepared according to general synthesis 2 using 4-formyl-2-nitrobiphenyl (1.00 g, 4.40 mmol). Chromatography (gradient of 0:100 to 10:90 EtOAc:CH_2Cl_2) gave the product as a light brown powder (0.67 g, 78% yield). ^{1}H NMR ($CDCl_3$) δ 7.27–7.33 (m, 1H), 7.46–7.56 (m, 2H), 7.78 (dd, *J* = 1.4 Hz, 8.1 Hz, 1H), 7.99

(t, *J* = 0.7 Hz, 1H), 8.14 (dd, *J* = 0.8 Hz, 7.8 Hz, 1H), 8.21 (d, *J* = 8.1 Hz, 1H), 8.31 (bs (1H), 10.14 (s, 1H). Spectroscopic data and analytical characterization are consistent with the literature.[17]

2-Acetylcarbazole (26): Prepared according to general synthesis 2 using 4-acetyl-2-nitrobiphenyl (1.00 g, 4.15 mmol). Chromatography (40:60, then 0:100 P950:CH_2Cl_2) gave a product contaminated with trace impurities. A second chromatography was done, eluting with 5:95 Et_2O:CH_2Cl_2, gave the pure product as a fine brown powder (0.70 g, 81 % yield). ^{1}H NMR ($CDCl_3$) δ 2.67 (s, 3H), 7.20 (td, *J* = 1.1 Hz, 6.8 Hz, 1H), 7.45 (td, *J* = 1.1 Hz, 7.0 Hz, 1H), 7.54 (d, *J* = 8.3 Hz, 1H), 7.78 (dd, *J* = 1.5 Hz, 8.3 Hz, 1H), 8.07 (d, *J* = 0.9 Hz, 1H), 8.19 (d, *J* = 7.1 Hz, 1H), 8.22 (d, *J* = 8.3 Hz, 1H). Spectroscopic data and analytical characterization are consistent with the literature.[18]

2-Benzoylcarbazole (27): Prepared according to general synthesis 2 using 4-benzoyl-2-nitrobiphenyl (1.00 g, 3.30 mmol). Chromatography (gradient of 0:100 to 10:90 EtOAc:CH_2Cl_2) gave the product as a tan-colored solid (0.89 g, 99% yield). ^{1}H NMR ($CDCl_3$) δ 7.27–7.32 (m, 1H), 7.45–7.55 (m, 4H), 7.58–7.65 (m, 1H), 7.71 (dd, *J* = 1.4 Hz, 8.1 Hz, 1H), 7.84–7.87 (m, 2H), 7.96 (s, 1H), 8.15 (d, *J* = 8.1 Hz, 2H), 8.27 (bs, 1H). Spectroscopic data and analytical characterization are consistent with the literature.[19]

Methyl carbazole-2-carboxylate (28): Prepared according to general synthesis 2 using methyl-2-nitrobiphenyl-4-carboxylate (1.00 g, 3.63 mmol). Chromatography (10:90, then 0:100 P950 ligroin:CH_2Cl_2) gave the product as a white solid (0.74 g, 90% yield).

^{1}H NMR ($CDCl_3$) δ 3.98 (s, 3H), 7.25–7.31 (m, 1H), 7.47–7.52 (m, 2H), 7.94 (dd, *J* = 1.3 Hz, 8.3 Hz, 1H), 8.09–8.19 (m, 3H), 8.25 (bs, 1H). Spectroscopic data and analytical characterization are consistent with the literature.[3a,8]

***N*-Butyl carbazole-2-carboxamide (29):** Prepared according to general synthesis 2 using *N*-butyl-2-nitrobiphenyl-4-carboxamide (1.00 g, 3.35 mmol). Chromatography (gradient of 0:100 to 4:96 MeOH:CH_2Cl_2, 1% step) gave the product as a mixture with PPh_3O. A second column, eluting with a gradient of 7:93 to 10:90 MeOH:CH_2Cl_2 failed to isolate the pure product. A third column, eluting with 25:75 Et_2O:CH_2Cl_2, again failed to isolate the pure product apart from the PPh_3O, despite of excellent chromatographic resolution on TLC.

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