An Efficient Synthesis of Coumestrol and Coumestans by Iodocyclization and Pd-Catalyzed Intramolecular Lactonization

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General. The ^1H and ^{13}C NMR spectra were recorded at 300 and 75.5 MHz. Thin layer chromatography was performed using commercially prepared 60-mesh silica gel plates, and visualization was effected with short wavelength UV light (254 nm). All melting points are uncorrected.

Reagents. All reagents were used directly as obtained commercially unless otherwise noted.

2-(2-Methoxyphenylethynyl)phenyl acetate. A mixture of 2-ethynylanisole (6.0 mmol), 2-iodophenyl acetate (5.0 mmol), CuI (0.06 mmol) and $\text{PdCl}_2(\text{PPh}_3)_2$ (0.12 mmol) in a mixture of Et_3N (2.0 equiv) and DMF (50 mL) was heated at 60 °C for 2 h. The precipitate was filtered off and the filtrate was concentrated under reduced pressure. The residue was extracted with Et_2O and the combined extracts were washed successively with water and satd aq NaCl. The organic solution was dried over anhydrous Na_2SO_4 and evaporated. The residue was purified by flash chromatography on silica gel (4:1 hexane/ EtOAc) to give the above product (96%) as a yellow oil: ^1H NMR (CDCl_3) δ 2.37 (s, 3H), 3.87 (s, 3H), 6.88 (d, $J = 8.7$ Hz, 1H), 6.92 (td, $J = 7.5, 0.9$ Hz, 1H), 7.11 (dd, $J = 8.1, 1.5$ Hz, 1H), 7.20 (td, $J = 7.5, 1.5$ Hz, 1H), 7.26-7.35 (m, 2H), 7.46 (dd, $J = 7.5, 1.8$ Hz, 1H), 7.59 (dd, $J = 7.5, 1.8$ Hz, 1H); ^{13}C NMR (CDCl_3) δ 21.0, 55.8, 88.3, 90.9, 110.9, 112.3, 118.0, 120.6, 122.4, 126.0, 129.4, 130.2, 133.1, 133.7, 151.6, 160.1, 169.1; IR (neat) 1771 cm^{-1} ; HRMS calcd for $\text{C}_{17}\text{H}_{14}\text{O}_3$ 266.0946, found 266.0943.

2-(2-Acetoxyphenyl)-3-iodobenzo[*b*]furan (1). This compound was prepared according to a literature procedure.² A solution of 2-(2-methoxyphenylethynyl)phenyl

acetate (2.50 mmol) in dry CH₂Cl₂ (10 mL) was stirred at room temperature for 1 min. 2.5 Equiv of I₂ was added and the resulting mixture was allowed to stir at 25 °C for 12 h. Satd aq Na₂S₂O₃ (5 mL) was added to the mixture, which was further stirred for 2 min. The resulting mixture was then extracted with Et₂O. The combined organic solution was washed successively with water and satd aq NaCl, dried over anhydrous Na₂SO₄, and concentrated under vacuum. The residue was purified by flash chromatography on silica gel (4:1 hexane/ EtOAc) to afford **1** as a yellow oil (95%): ¹H NMR (CDCl₃) δ 2.21 (s, 3H), 7.25 (dd, *J* = 8.1, 1.2 Hz, 1H), 7.32-7.40 (m, 3H), 7.44-7.53 (m, 3H), 7.82 (dd, *J* = 7.8, 1.8 Hz, 1H); ¹³C NMR (CDCl₃) δ 21.3, 65.4, 111.4, 122.1, 123.3, 123.7, 123.8, 126.0, 126.1, 131.2, 131.7, 131.9, 148.8, 152.3, 154.6, 169.4; IR (neat) 1771 cm⁻¹; HRMS calcd for C₁₆H₁₁IO₃ 377.9758, found 377.9753.

2-(2-Acetoxyphenyl)-3-iodobenzothiophene (3). This compound was prepared from 2-(2-thiomethoxyphenylethynyl)phenyl acetate by following a literature procedure³ and was obtained as a yellow oil (99%): ¹H NMR (CDCl₃) δ 2.08 (s, 3H), 7.20-7.26 (m, 1H), 7.34-7.52 (m, 5H), 7.78-7.85 (m, 2H); ¹³C NMR (CDCl₃) δ 21.2, 83.0, 122.3, 123.3, 125.6, 125.8, 126.2, 126.3, 128.1, 130.7, 132.9, 138.3, 139.7, 141.3, 148.7, 169.2; IR (neat) 1768 cm⁻¹; HRMS calcd for C₁₆H₁₁IO₂S 393.9524, found 393.9519.

2-(2-Acetoxyphenyl)-3-iodo-1-methylindole (5). This compound was prepared according to a literature procedure.⁴ A solution of 2-(2-dimethylaminophenylethynyl)phenyl acetate (1.0 mmol) in dry CH₂Cl₂ (20 mL) was stirred at room temperature for 1 min. 2.0 Equiv of I₂ was added and the resulting mixture was allowed to stir at 25 °C for 12 h. Satd aq Na₂S₂O₃ (10 mL) was added to the mixture, which was further stirred for 8 h. The resulting mixture was then extracted with

Et₂O. The combined extracts were washed successively with water and satd aq NaCl, dried over anhydrous Na₂SO₄, and concentrated under vacuum. The residue was purified by flash chromatography on silica gel (4:1 hexane/EtOAc) to afford compound **5** as a yellow solid (78%): mp 134-135 °C; ¹H NMR (CDCl₃) δ 2.01 (s, 3H), 3.66 (s, 3H), 7.25-7.39 (m, 4H), 7.41-7.46 (m, 2H), 7.54-7.62 (m, 2H); ¹³C NMR (CDCl₃) δ 21.1, 32.0, 60.3, 110.2, 120.9, 121.7, 123.16, 123.23, 125.6, 126.3, 130.5, 131.0, 133.0, 137.9, 138.2, 149.8, 169.2; IR (neat) 1765, 1462 cm⁻¹; HRMS calcd for C₁₇H₁₄INO₂ 391.0069, found 391.0075.

2-(2-Iodo-1-naphthyl)phenyl acetate (7). This compound was prepared according to a literature procedure⁵. A solution of 2-(3-hydroxy-4-phenylbut-1-ynyl)phenyl acetate (0.3 mmol) in dry CH₃CN (3.0 mL) was stirred at room temperature for 1 min. I₂ (3.0 equiv.) and NaHCO₃ (3.0 equiv.) were added and the resulting mixture was allowed to stir at 25 °C for 4 h. Satd aq Na₂S₂O₃ (5.0 mL) was added to the mixture, which was further stirred for 2 min. The resulting mixture was then extracted with Et₂O, washed successively with water and satd aq NaCl, dried over anhydrous Na₂SO₄, and concentrated under vacuum. The residue was purified by flash chromatography on silica gel (1:1 hexane/ EtOAc) to afford compound **7** as a colorless oil: ¹H NMR (CDCl₃) δ 1.75 (s, 3H), 7.27-7.60 (m, 8H), 7.84 (d, *J* = 8.1 Hz, 1H), 7.98 (d, *J* = 8.7 Hz, 1H); ¹³C NMR (CDCl₃) δ 20.8, 99.0, 123.4, 126.3, 126.6, 127.2, 128.1, 129.6, 129.7, 132.1, 132.9, 133.4, 135.7, 135.9, 140.3, 148.6, 168.9; IR (neat) 1764, 1261 cm⁻¹; HRMS calcd for C₁₈H₁₃IO₂ 387.9960, found 387.9964.

2-(3-Iodoquinolin-4-yl)phenyl acetate (9). This compound was prepared according to a literature procedure⁶ and was obtained as a yellow solid: mp 98-100 °C;

^1H NMR (CDCl_3) δ 1.78 (s, 3H), 7.23-7.27 (m, 1H), 7.36 (dd, J = 0.9, 8.1 Hz, 1H), 7.40-7.46 (m, 3H), 7.58 (dt, J = 1.7, 7.8 Hz, 1H), 7.69-7.75 (m, 1H), 8.11 (d, J = 8.7 Hz, 1H), 9.24 (s, 1H); ^{13}C NMR (CDCl_3) δ 20.8, 96.8, 123.5, 126.5, 126.7, 127.8, 128.8, 129.7, 130.1, 130.5, 131.0, 133.1, 147.1, 147.9, 148.8, 156.7, 168.4; IR (neat) 1766, 1484 cm^{-1} ; HRMS calcd for $\text{C}_{17}\text{H}_{12}\text{INO}_2$ 388.9913, found 388.9920.

6-(2-Acetoxyphenyl)-5-iodo-2H-pyranone (11). This compound was prepared according to a literature procedure⁷ and was obtained as a yellow solid: mp 136-137 °C; ^1H NMR (CDCl_3) δ 2.23 (s, 3H), 6.12 (d, J = 9.9 Hz, 1H), 7.23-7.28 (m, 1H), 7.33 (d, J = 7.8 Hz, 1H), 7.48-7.53 (m, 2H), 7.59 (d, J = 9.6 Hz, 1H); ^{13}C NMR (CDCl_3) δ 70.0, 116.4, 123.5, 125.9, 127.0, 131.3, 132.2, 148.4, 152.3, 159.1, 160.5, 168.7; IR (neat) 1766, 1617 cm^{-1} ; HRMS calcd for $\text{C}_{13}\text{H}_9\text{IO}_4$ 355.9546, found 355.9552.

General procedure for palladium-catalyzed intramolecular lactonization.

DMF (1.0 mL), $\text{PdCl}_2(\text{PPh}_3)_2$ (0.0125 mmol), K_2CO_3 (0.5 mmol), and the aryl iodide (0.25 mmol) were stirred under an Ar atmosphere at room temperature for 5 min. The mixture was flushed with CO and the flask was fitted with a balloon of CO. The reaction mixture was heated at the specified temperature with vigorous stirring for 6 h. The reaction mixture was then cooled to room temperature, diluted with diethyl ether (35 mL) and washed with brine (30 mL). The aqueous layer was extracted with diethyl ether (15 mL). The organic layers were combined, dried over anhydrous Na_2SO_4 , filtered, and the solvent removed under reduced pressure. The residue was purified by column chromatography on a silica gel column.

Coumestan (2). This compound was obtained as a white solid (99%): mp 180-181 °C (lit.⁸ mp 181-182 °C); ^1H NMR (CDCl_3) δ 7.39-7.53 (m, 4H), 7.59-7.69 (m, 2H),

8.04 (dd, $J = 7.8, 1.5$ Hz, 1H), 8.13-8.16 (m, 1H); ^{13}C NMR (CDCl_3) δ 106.1, 112.0, 112.9, 117.7, 122.1, 123.7, 124.9, 125.4, 127.0, 132.1, 153.9, 155.8, 158.3, 160.2; IR (neat) 1737 cm^{-1} ; HRMS calcd for $\text{C}_{15}\text{H}_8\text{O}_3$ 236.0476, found 236.0473. The spectral properties were identical to those previously reported.⁸

11-Thiacoumestan (4). This compound was obtained as a light yellow solid (76%): mp 216-217 °C (lit.⁹ mp 217-217.5 °C). The spectral properties were identical to those previously reported.⁹

11-Methylbenzopyrano[4,3-*b*]indol-6-one (6). This compound was obtained as a light yellow solid (75%): mp 251-252 °C (lit.¹⁰ mp 248 °C). The spectral properties were identical to those previously reported.¹⁰

Naphtho[2,1-*c*]coumarin (8). This compound was obtained as a white solid (95%): mp 124-125 °C (lit.¹¹ mp 126-127 °C). The spectral properties were identical to those previously reported.¹¹

6*H*-Chromeno[3,4-*c*]quinolin-6-one (10). This compound was obtained as a white solid (73%): mp 98-100 °C; ^1H NMR (CDCl_3) δ 7.43-7.52 (m, 2H), 7.62-7.68 (m, 1H), 7.74-7.80 (m, 1H), 7.90-7.96 (m, 1H), 8.28 (dd, $J = 8.4, 0.9$ Hz, 1H), 8.57 (dd, $J = 8.4, 1.2$ Hz, 1H), 8.82 (d, $J = 8.4$ Hz, 1H), 9.67 (s, 1H); ^{13}C NMR (CDCl_3) δ 114.2, 117.5, 118.7, 122.3, 125.0, 126.8, 128.5, 128.8, 131.3, 132.3, 132.6, 141.1, 150.3, 151.2, 153.3, 160.6; IR (neat) $1729, 1592\text{ cm}^{-1}$; HRMS calcd for $\text{C}_{16}\text{H}_9\text{NO}_2$ 247.0633, found 247.0638.

2*H*,5*H*-Pyrano[3,2-*c*]chromene-2,5-dione (12). This compound was obtained as a yellow solid (31%): mp 245-247 °C; ^1H NMR (CDCl_3) δ 6.44 (d, $J = 9.9$ Hz, 1H), 7.40-7.46 (m, 2H), 7.70 (dt, $J = 1.4, 8.1$ Hz, 1H), 7.99-8.10 (m, 2H); ^{13}C NMR (CDCl_3)

δ 103.4, 113.2, 115.5, 117.5, 123.7, 125.4, 134.7, 141.1, 153.6, 158.1, 158.9, 162.1; IR (neat) 1722, 1629 cm^{-1} ; HRMS calcd for $\text{C}_{12}\text{H}_6\text{O}_4$ 214.0266, found 214.0270.

Synthesis of coumestrol.

4-Bromo-3-methoxyphenyl tosylate (14). A mixture of 4-bromoresorcinol (10.0 g, 53.0 mmol), K_2CO_3 (22.0 g, 159 mmol) and TsCl (11.1 g, 58.0 mmol) in acetone (150 mL) was refluxed for 21 h. MeI (15.0 g, 106 mmol) was added to the mixture, which was further refluxed for 3 h. The inorganic precipitate was filtered off and the filtrate was concentrated under reduced pressure. The residue was diluted with water and extracted with EtOAc . The combined organic extracts were washed with water and satd aq NaCl , dried over anhydrous Na_2SO_4 , and concentrated under vacuum. The residue was further purified by flash chromatography on silica gel (3:1 hexane/ EtOAc) to give 4-bromo-3-methoxyphenyl tosylate (15.0 g, 79%) as white powder: mp 69-71 $^\circ\text{C}$ (lit.¹ mp 69-72 $^\circ\text{C}$); ^1H NMR (CDCl_3) δ 2.46 (s, 3H), 3.79 (s, 3H), 6.41 (dd, $J = 8.5, 2.5$ Hz, 1H), 6.60 (d, $J = 2.5$ Hz, 1H), 7.33 (d, $J = 8.5$ Hz, 2H), 7.41 (d, $J = 8.5$ Hz, 1H), 7.72 (d, $J = 8.5$ Hz, 2H); IR (neat) 1380, 1280, 1180 cm^{-1} . The spectral properties were identical to those previously reported.¹

4-Ethynyl-3-methoxyphenyl tosylate (15). A mixture of 4-bromo-3-methoxyphenyl tosylate (2.0 g, 5.6 mmol), trimethylsilyl acetylene (0.66 g, 6.72 mmol), CuI (10 mg, 0.06 mmol) and $\text{PdCl}_2(\text{PPh}_3)_2$ (85 mg, 0.12 mmol) in a mixture of Et_3N (5 mL) and DMF (20 mL) was heated at 100 $^\circ\text{C}$ for 6 h. The precipitate was filtered off and the filtrate was concentrated under reduced pressure. The residue was extracted with Et_2O and the combined extracts were washed with water and satd aq NaCl . The organic solution was dried over anhydrous Na_2SO_4 and evaporated. The residue was purified by

flash chromatography on silica gel (5:1 hexane/EtOAc) to give the TMS acetylene of compound **15** (2.05 g, 98%) as a colorless solid: mp 104-106 °C (lit.¹ mp 105-107 °C); ¹H NMR (CDCl₃) δ 0.24 (s, 9H), 2.44 (s, 3H), 3.75 (s, 3H), 6.45 (dd, *J* = 8.4, 2.2 Hz, 1H), 6.54 (d, *J* = 2.2 Hz, 1H), 7.30 (d, *J* = 8.5 Hz, 3H), 7.69 (d, *J* = 8.4 Hz, 2H); IR (neat) 1380, 1280, 1180 cm⁻¹. The spectral properties were identical to those previously reported.¹

A solution of the trimethylsilyl acetylene of compound **15** (1.12 g, 3.00 mmol) and TBAF (1.0 M solution in THF; 3.0 mL, 3.00 mmol) in THF (60 mL) was vigorously stirred at room temperature for 5 min. Water was added to the mixture, which was extracted with Et₂O. The organic solution was washed with water and satd aq NaCl, dried over Na₂SO₄ and evaporated. The residue was purified by chromatography on silica gel (3:1 hexane/EtOAc) to afford **15** (0.90 g, 99%) as viscous yellow oil: ¹H NMR (CDCl₃) δ 2.45 (s, 3H), 3.30 (s, 1H), 3.79 (s, 3H), 6.48 (dd, *J* = 8.4, 2.2 Hz, 1H), 6.59 (d, *J* = 2.2 Hz, 1H), 7.32 (d, *J* = 8.5 Hz, 2H), 7.33 (d, *J* = 8.5 Hz, 1H), 7.72 (d, *J* = 8.4 Hz, 2H); IR (neat) 1380, 1280, 1180 cm⁻¹; HRMS calcd for C₁₆H₁₄O₄S 302.0615, found 302.0611.

2,4-Diacetoxy-2'-methoxy-4'-tosyloxy-diphenylacetylene (19). A mixture of 4-ethynyl-3-methoxyphenyl tosylate (5.00 mmol), 2,4-diacetoxy-1-iodobenzene¹ (6.00 mmol), CuI (0.06 mmol) and PdCl₂(PPh₃)₂ (0.12 mmol) in a mixture of *i*-Pr₂NH (6.00 mmol) and DMF (25 mL) was heated at 60 °C for 1 h. Water was added to the mixture, which was extracted with Et₂O and the combined extracts were washed with water and satd aq NaCl. The organic solution was dried over Na₂SO₄ and evaporated. The residue was purified by flash chromatography on silica gel (1:1 hexane/EtOAc) to give **19** (96%)

as a yellow solid: mp 234-236 °C; ^1H NMR (CDCl_3) δ 2.29 (s, 3H), 2.34 (s, 3H), 2.44 (s, 3H), 3.78 (s, 3H), 6.49 (dd, $J = 8.4, 2.4$ Hz, 1H), 6.59 (d, $J = 2.0$ Hz, 1H), 6.97 (d, $J = 2.4$ Hz, 1H), 7.01 (dd, $J = 8.4, 2.4$ Hz, 1H), 7.30-7.33 (m, 3H), 7.54 (d, $J = 8.4$ Hz, 1H), 7.72 (d, $J = 8.0$ Hz, 1H); ^{13}C NMR (CDCl_3) δ 21.0, 21.3, 21.9, 56.1, 88.6, 89.6, 106.1, 111.4, 114.4, 115.2, 116.4, 119.4, 128.8, 130.0, 132.2, 133.4, 134.0, 145.8, 150.7, 151.1, 152.0, 160.8, 168.4, 168.8; IR (neat) 1770, 1768 cm^{-1} ; HRMS calcd for $\text{C}_{26}\text{H}_{22}\text{O}_8\text{S}$ 494.1041, found 494.1036.

2-(2,4-Diacetoxyphenyl)-3-iodo-6-(tosyloxy)benzo[*b*]furan (20). A solution of **19** (2.50 mmol) in dry CH_2Cl_2 (10 mL) was stirred at room temperature for 1 min. 2.5 Equiv of I_2 was added and the resulting mixture was allowed to stir at 25 °C for 12 h. Satd aq $\text{Na}_2\text{S}_2\text{O}_3$ (5 mL) was added to the mixture, which was further stirred for 2 min. The resulting mixture was then extracted with Et_2O . The combined organic extracts were washed with water and satd aq NaCl , dried over anhydrous Na_2SO_4 and concentrated under vacuum. The residue was purified by silica gel chromatography (1:1 hexane/ EtOAc) to afford **20** as a yellow solid (98%): mp > 300 °C (dec); ^1H NMR (CDCl_3) δ 2.18 (s, 3H), 2.33 (s, 3H), 2.45 (s, 3H), 6.99 (dd, $J = 8.4, 2.1$ Hz, 1H), 7.10-7.18 (m, 3H), 7.33 (t, $J = 7.2$ Hz, 3H), 7.73 (d, $J = 8.4$ Hz, 2H), 7.78 (d, $J = 8.4$ Hz, 1H); ^{13}C NMR (CDCl_3) δ 21.2, 21.4, 21.9, 64.9, 106.1, 117.4, 118.9, 119.4, 120.2, 122.4, 128.8, 130.1, 130.7, 132.2, 132.3, 145.8, 148.1, 149.2, 152.4, 153.3, 153.7, 168.8; IR (neat) 1770 cm^{-1} ; HRMS calcd for $\text{C}_{16}\text{H}_{11}\text{IO}_3$ 605.9851, found 605.9846.

Coumestrol (21). 2-(2,4-Diacetoxyphenyl)-3-iodo-6-(tosyloxy)benzo[*b*]furan (**20**) was used as the starting material employing our standard procedure for palladium-catalyzed intramolecular lactonization. This afforded coumestrol **21** (20%) and

coumestrol tosylate **22** (60%). Coumestrol tosylate **22** was isolated as a white solid: mp >360 °C; ¹H NMR (CD₃OD) δ 2.46 (s, 3H), 6.87-6.88 (m, 1H), 6.91-6.95 (m, 2H), 7.03-7.07 (m, 1H), 7.41-7.44 (m, 3H), 7.72 (d, *J* = 8.1 Hz, 2H), 7.88 (t, *J* = 9.0 Hz, 2H).

A mixture of the coumestrol derivative **22** (0.10 mmol) and *n*-Bu₄NF (0.10 mmol) in DMF (5 mL) was stirred at 100 °C for 2 h. The resulting mixture was diluted with water and extracted with diethyl ether (2 x 15 mL). The combined organic extracts were dried over anhydrous Na₂SO₄ and evaporated to afford coumestrol as a white solid in a 99% yield: mp >360 °C (lit.¹ mp 385 °C); ¹H NMR (DMSO-*d*₆) δ 6.90-6.96 (m, 3H), 7.16 (d, *J* = 1.8 Hz, 1H), 7.70 (d, *J* = 8.4 Hz, 1H), 7.86 (d, *J* = 8.4 Hz, 1H); ¹³C NMR (DMSO-*d*₆) δ 98.7, 102.1, 103.0, 104.2, 113.7, 114.0, 114.6, 120.6, 122.7, 154.6, 155.9, 157.0, 157.6, 159.5, 161.2; IR (neat) 3500-2850, 1703 cm⁻¹; HRMS calcd for C₁₅H₈O₅ 268.0375, found 268.0371. The spectral properties were identical to those previously reported.¹

Synthesis of “Plicadin”

6-Iodo-2,2'-dimethyl-2*H*-chromen-5-yl acetate (25). A solution of carbamate **23**¹² (1.32 g, 3.3 mmol) in 10 wt. % methanolic KOH (60 mL) was stirred at a gentle reflux for 48 h. The mixture was allowed to cool to room temperature and concentrated. The residue was dissolved in H₂O (80 mL) and the pH was adjusted to 7 with 3M HCl. The neutral aqueous solution was extracted with EtOAc. The combined organic extracts were dried over anhydrous Na₂SO₄ and concentrated. The residue was purified by silica gel chromatography (3:1 hexane/EtOAc) to afford **24** as a yellow oil (57%): ¹H NMR (CDCl₃) δ 1.42 (s, 6H), 5.24 (s, 1H), 5.59 (d, *J* = 9.9 Hz, 1H), 6.25 (d, *J* = 8.7 Hz, 1H), 6.66 (d, *J* = 9.9 Hz, 1H), 7.32 (d, *J* = 8.4 Hz, 1H); ¹³C NMR (CDCl₃) δ 28.0, 75.2, 76.4,

109.9, 111.8, 117.4, 130.0, 136.8, 150.3, 154.8; IR (neat) 3478, 1633 cm^{-1} ; HRMS calcd for $\text{C}_{11}\text{H}_{11}\text{IO}_2$ 301.9804, found 301.9808.

Acetic anhydride (0.17 mL, 1 equiv) was added to a solution of **24** (0.563 g, 1.86 mmol) in pyridine (9.3 mL) at 0 °C. The solution was warmed to room temperature and stirred for 2 h. The solvent was removed and the residue was dissolved in CHCl_3 (20 mL). The solution was washed with 3M HCl (9 mL) and H_2O (10 mL), dried (MgSO_4) and concentrated. The residue was purified by silica gel chromatography (6:1 hexane/EtOAc) to afford **25** as a yellow oil (0.574 g, 90%): ^1H NMR (CDCl_3) δ 1.42 (s, 6H), 2.37 (s, 3H), 5.64 (d, J = 9.9 Hz, 1H), 6.26 (d, J = 9.9 Hz, 1H), 6.52 (d, J = 8.4 Hz, 1H), 7.48 (d, J = 8.7 Hz, 1H); ^{13}C NMR (CDCl_3) δ 28.1, 21.3, 76.8, 79.8, 116.4, 116.73, 116.74, 132.4, 138.0, 147.1, 154.4, 168.3; IR (neat) 1771, 1594 cm^{-1} ; HRMS calcd for $\text{C}_{13}\text{H}_{13}\text{IO}_3$ 343.9910, found 343.9914.

6-[2-Methoxy-4-(tosyloxy)phenylethynyl]-2,2-dimethyl-2H-chromen-5-yl acetate (26). This compound was prepared according the same procedure as used to prepare compound **19** and was obtained as a yellow oil (60%): ^1H NMR (CDCl_3) δ 1.43 (s, 6H), 2.36 (s, 3H), 2.44 (s, 3H), 3.76 (s, 3H), 5.67 (d, J = 10.2 Hz, 1H), 6.33 (d, J = 9.9 Hz, 1H), 6.46 (dd, J = 2.3, 8.1 Hz, 1H), 6.57 (d, J = 2.1 Hz, 1H), 6.65 (d, J = 8.7 Hz, 1H), 7.25-7.33 (m, 4H), 7.71 (d, J = 8.1 Hz, 1H); ^{13}C NMR (CDCl_3) δ 20.8, 28.2, 56.2, 77.1, 87.8, 89.8, 106.1, 109.8, 112.0, 114.4, 114.5, 115.1, 116.1, 128.8, 130.0, 132.0, 132.3, 132.8, 133.8, 145.8, 147.7, 150.3, 154.4, 160.6, 168.7; IR (neat) 1772, 1601 cm^{-1} .

6-(3-Iodo-6-[(4-methylphenyl)sulfonyl]oxy)-1-benzofuran-2-yl)-2,2-dimethyl-2H-chromen-5-yl acetate (27). This compound was prepared by following the same procedure as used to prepare compound **20** and was obtained as a light yellow

oil (78%): ^1H NMR (CDCl_3) δ 1.48 (s, 6H), 2.17 (s, 3H), 2.44 (s, 3H), 5.72 (d, $J = 10.2$ Hz, 1H), 6.33 (d, $J = 10.2$ Hz, 1H), 6.80 (d, $J = 8.4$ Hz, 1H), 6.97 (dd, $J = 2.0, 8.4$ Hz, 1H), 7.07 (d, $J = 2.1$ Hz, 1H), 7.29-7.33 (m, 3H), 7.52 (d, $J = 8.7$ Hz, 1H), 7.71 (d, $J = 8.4$ Hz, 1H); ^{13}C NMR (CDCl_3) δ 20.8, 22.0, 28.4, 63.6, 77.3, 106.0, 114.5, 115.3, 115.7, 116.1, 118.7, 122.2, 128.8, 130.1, 130.8, 131.5, 132.1, 132.3, 144.8, 145.8, 147.9, 153.6, 154.5, 155.8, 168.9; IR (neat) 1725 cm^{-1} .

2,2-Dimethyl-6-oxo-2*H*,6*H*-benzofuro[3,2-*c*]pyrano[2,3-*h*]chromen-9-yl 4-methylbenzenesulfonate (28). Compound **27** was used as the starting material employing our standard procedure for palladium-catalyzed intramolecular lactonization. This afforded lactone **28** (61%) as a white solid: mp $176\text{-}177\text{ }^\circ\text{C}$; ^1H NMR (CDCl_3) δ 1.50 (s, 6H), 2.46 (s, 3H), 5.77 (d, $J = 10.2$ Hz, 1H), 6.85 (d, $J = 8.4$ Hz, 1H), 6.90-6.98 (m, 2H), 7.30-7.34 (m, 2H), 7.43 (d, $J = 2.1$ Hz, 1H), 7.70-7.73 (m, 3H), 7.91 (d, $J = 8.4$ Hz, 1H); ^{13}C NMR (CDCl_3) δ 22.0, 28.4, 78.1, 102.8, 105.7, 107.2, 110.2, 114.4, 115.5, 119.9, 121.7, 122.0, 123.0, 128.8, 130.1, 131.3, 132.2, 146.0, 147.9, 154.9, 157.1, 158.0, 162.3; IR (neat) $1744, 1603\text{ cm}^{-1}$; HRMS calcd for $\text{C}_{27}\text{H}_{20}\text{O}_7\text{S}$ 488.0930, found 488.0937.

“Plicadin” (29). Compound **28** was converted to “plicadin” by following the same procedure as used to prepare lactone **21**. This afforded “plicadin” (94%) as a yellow solid: mp $290\text{-}291\text{ }^\circ\text{C}$ (sublim). The spectral properties were identical to those previously reported.¹²

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