105 (2), 75 (100), 47 (10). Anal. Calcd for $C_{12}H_{16}O_3Se$: C, 50.19; H, 5.62. Found: C, 50.26; H, 5.71.

1,1-Dimethoxy-3-(phenylseleno)-2-pentanone (25): oil; 5 h; ^1H NMR δ 7.55–7.4 (m, 2 H), 7.4–7.15 (m, 3 H), 5.0 (s, 1 H), 3.95 (t, 1 H, J = 7.3 Hz), 3.35 (s, 3 H), 3.3 (s, 3 H), 2.0–1.5 (m, 2 H), 0.95 (t, 3 H, J = 7.3 Hz); ^{13}C NMR δ 199.5, 135.9, 128.9, 128.7, 126.8, 101.3, 54.3, 53.9, 47.6, 23.1, 12.4; MS, m/e (rel intens) 302 (1), 232 (1), 157 (5), 121 (6), 75 (100), 47 (12). Anal. Calcd for $C_{13}H_{18}O_3Se$: C, 51.84; H, 6.02. Found: C, 51.78; H, 5.95.

1,1-Dimethoxy-4-methyl-3-(phenylseleno)-2-pentanone (26): oil; 6 h; ^1H NMR δ 7.55–7.35 (m, 2 H), 7.35–7.1 (m, 3 H), 4.9 (s, 1 H), 3.75 (d, 1 H, J = 10.1 Hz), 3.4 (s, 3 H), 3.35 (s, 3 H), 2.05 (dspt, 1 H, J = 6.6 and 10.1 Hz), 1.2 (d, 3 H, J = 6.6 Hz), 0.95 (d, 3 H, J = 6.6 Hz); ^{13}C NMR δ 198.9, 135.5, 129.1, 128.6, 127.8, 101.7, 55.3, 54.4, 54.1, 27.9, 21.3, 20.9; MS, m/e (rel intens) 316 (1), 232 (1), 159 (2), 157 (4), 121 (5), 75 (100), 55 (2), 47 (11). Anal. Calcd for $C_{14}H_{20}O_3Se$: C, 53.34; H, 6.39. Found: C, 53.40; H, 6.31.

1,1-Dimethoxy-3-(phenylseleno)-2-hexanone (27): oil; 6 h; ^1H NMR δ 7.55–7.35 (m, 2 H), 7.35–7.15 (m, 3 H), 5.0 (s, 1 H), 4.05 (t, 1 H, J = 7.5 Hz), 3.4 (s, 3 H), 3.35 (s, 3 H), 2.0–1.1 (m, 4 H), 0.9 (t, 3 H, J = 7.5 Hz); ^{13}C NMR δ 199.7, 136.1, 129.1, 128.8, 101.4, 54.4, 54.1, 45.6, 31.9, 21.1, 13.7; MS, m/e (rel intens) 316 (1), 121 (6), 91 (2), 75 (100), 55 (5), 47 (12). Anal. Calcd for $C_{14}H_{20}O_3Se$: C, 53.34; H, 6.39. Found: C, 53.17; H, 6.47.

1,1-Dimethoxy-3-(phenylseleno)-2-heptanone (28): oil; 4 h; ^1H NMR δ 7.55–7.4 (m, 2 H), 7.4–7.2 (m, 3 H), 4.95 (s, 1 H), 4.05 (t, 1 H, J = 7.2 Hz), 3.4 (s, 3 H), 3.35 (s, 3 H), 1.9–1.1 (m, 6 H), 0.85 (t, 3 H, J = 7.2 Hz); ^{13}C NMR δ 199.7, 136.0, 129.0, 128.7, 126.8, 101.4, 54.3, 54.0, 45.8, 30.0, 29.4, 22.2, 13.8; MS, m/e (rel intens) 330 (1), 157 (3), 121 (4), 75 (100), 47 (6). Anal. Calcd for $C_{15}H_{22}O_3Se$: C, 54.71; H, 6.73. Found: C, 54.63; H, 6.64.

1,1-Dimethoxy-3-hexen-2-one (29). This compound was obtained from the reaction of **27** with hydrogen peroxide, according to the procedure described above for the reaction of **26**: oil; 1 h; ^1H NMR δ 7.15 (dt, 1 H, J = 6.7 and 16.6 Hz), 6.4 (d, 1 H, J = 16.6 Hz), 4.6 (s, 1 H), 3.4 (s, 6 H), 2.1 (quintet, 2 H, J = 6.7 Hz), 1.05 (t, 3 H, J = 6.7 Hz); ^{13}C NMR δ 193.6, 151.9, 124.1, 103.9, 54.5, 26.0, 12.1; MS, m/e (rel intens) 158 (1), 127 (2), 99 (2), 83 (4), 76 (5), 75 (100), 55 (7). Anal. Calcd for $C_8H_{14}O_3$: C, 60.75; H, 8.92. Found: C, 60.69; H, 9.05.

2,3,3-Trimethoxytetrahydrofuran (31): oil; 3 h; ^1H NMR δ 4.65 (s, 1 H), 4.15–3.85 (m, 2 H), 3.45 (s, 3 H), 3.35 (s, 3 H), 3.3 (s, 3 H). 2.3–1.9 (m, 2 H); ^{13}C NMR δ 108.9, 102.3, 64.9, 54.4, 51.05, 48.8, 30.3; MS, m/e (rel intens) 147 (1), 131 (20), 103 (44), 102 (100), 101 (24), 75 (32), 72 (24), 59 (47), 57 (77), 55 (22), 47 (10). Anal. Calcd for $C_7H_{14}O_4$: C, 51.85; H, 8.70. Found: C, 51.71; H, 8.82.

2,3,3-Trimethoxy-5,5-dimethyltetrahydrofuran (32): oil; 3 h; ^1H NMR δ 4.7 (s, 1 H), 3.45 (s, 3 H), 3.35 (s, 3 H), 3.3 (s, 3 H), 2.15 (d, 1 H, J = 12.0 Hz), 1.95 (d, 1 H, J = 12.0 Hz), 1.4 (s, 3 H), 1.35 (s, 3 H); ^{13}C NMR δ 109.2, 103.2, 80.3, 53.6, 50.3, 48.2, 41.8, 31.3, 28.9; MS, m/e (rel intens) 175 (2), 159 (1), 130 (12), 127 (12), 115 (100), 103 (23), 101 (21), 88 (13), 75 (12), 73 (23), 59 (22), 57 (4), 55 (9). Anal. Calcd for $C_9H_{18}O_4$: C, 56.83; H, 9.54. Found: C, 56.72; H, 9.41.

2,3,3-Trimethoxy-5-phenyltetrahydrofuran (33): oil; 2.5 h; ^1H NMR δ 7.3 (br s, 5 H), 5.15 (dd, 1 H, J = 6.0 and 10.8 Hz), 4.78 (s, 1 H), 3.5 (s, 3 H), 3.35 (s, 6 H), 2.5 (dd, 1 H, J = 6.0 and 12.6 Hz), 2.1 (dd, 1 H, J = 10.8 and 12.6 Hz); ^{13}C NMR δ 142.0, 128.4, 127.8, 126.6, 108.6, 102.9, 79.7, 55.0, 51.1, 49.1, 39.0; MS, m/e (rel intens) 178 (46), 147 (10), 121 (100), 105 (16), 104 (24), 103 (41), 91 (25), 77 (15), 75 (11), 59 (24). Anal. Calcd for $C_{13}H_{18}O_4$: C, 65.53; H, 7.61. Found: C, 65.61; H, 7.72.

1-Phenyl-2-(phenylseleno)ethanone (34). This product was isolated when the reaction was stopped after 0.5 h: oil;[45] ^1H NMR δ 7.95–7.75 (m, 2 H), 7.55–7.15 (m, 8 H), 4.15 (s, 2 H); ^{13}C NMR δ 196.0, 134.0, 133.1, 129.2, 128.7, 128.6, 128.0, 32.6; MS, m/e (rel intens) 276 (35), 157 (6), 105 (100), 91 (14), 77 (37).

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Registry No. **3**, 6956-56-5; **4**, 54149-77-8; **5**, 127255-96-3; **6**, 21160-23-6; **7**, 127255-97-4; **8**, 127255-98-5; **9**, 127255-99-6; **10**, 127256-00-2; **11**, 127256-01-3; **12**, 55980-64-8; **13**, 127256-02-4; **14**, 127256-03-5; **15**, 127256-04-6; **16**, 56830-13-8; **17**, 38568-52-4; **18**, 55055-97-5; **19**, 127308-53-6; **20**, 127256-05-7; **21**, 6344-10-1; **22**, 6344-11-2; **23**, 66318-58-9; **24**, 127256-06-8; **25**, 127256-07-9; **26**, 127256-08-0; **27**, 127256-09-1; **28**, 127256-10-4; **29**, 127256-11-5; **30**, 127256-12-6; **31**, 127256-13-7; **32**, 127256-14-8; **33**, 127256-15-9; **34**, 35050-01-2; $PhCOCH_3$, 98-86-2; p-MeC_6H_4Ac, 122-00-9; p-PhC_6H_4Ac, 92-91-1; p-$O_2NC_6H_4Ac$, 100-19-6; o-HOC_6H_4Ac, 118-93-4; $PhCH{=}CHCOCH_3$, 122-57-6; $H_3CCOCH{=}C(CH_3)_2$, 141-79-7; $H_3CCOCH(CH_3)_2$, 563-80-4; $(CH_3)_3CCOCH_3$, 75-97-8; $EtOCOC(CH_3)_2COCH_3$, 597-04-6; $H_3C(CH_2)_3COCH_3$, 591-78-6; $H_3C(CH_2)_4COCH_3$, 110-43-0; $MeOCO(CH_2)_2COCH_3$, 6234-45-3; $H_3CCH_2COCH_3$, 78-93-3; $H_3C(CH_2)_2COCH_3$, 107-87-9; $HO(CH_2)_2COCH_3$, 590-90-9; $H_3CCOCH_2C(CH_3)_2OH$, 123-42-2; $HOCH(Ph)CH_2COCH_3$, 5381-93-1; $PhCH(OMe)CH_2SePh$, 63603-28-1; diphenyl diselenide, 1666-13-3; 2-acetylnaphthalene, 93-08-3; 2-furyl methyl ketone, 1192-62-7; 2-thienyl methyl ketone, 88-15-3; 3-thienyl methyl ketone, 1468-83-3; 1-(1-cyclohexenyl)ethanone, 932-66-1; 4-(2,6,6-trimethyl-2-cyclohexen-1-yl)-3-buten-2-one, 6901-97-9; 1-(1-cyclohexyl)ethanone, 823-76-7; 3-hydroxypregn-5-en-20-one, 38372-24-6.

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New Synthesis of the 6*H*-Pyrido[4,3-*b*]carbazoles Ellipticine and Olivacine via Cycloaddition of 2-Phenylsulfonyl 1,3-Dienes to Indoles

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An efficient synthesis of the antitumor alkaloids ellipticine and olivacine, starting from indole, was developed. The cycloaddition of 3-(phenylsulfonyl)-2,4-hexadiene or 2-(phenylsulfonyl)-1,3-pentadiene to the magnesium salt of indole was followed by C–C–N chain addition via a Michael reaction. Subsequent Bischler–Napieralski cyclization and aromatization afforded ellipticine and olivacine, respectively.

Ellipticine, olivacine, and other 6*H*-pyrido[4,3-*b*]carbazoles have received much attention because of their antitumor activity.[1] As a consequence a great number of syntheses of ellipticine and related pyridocarbazole alka-

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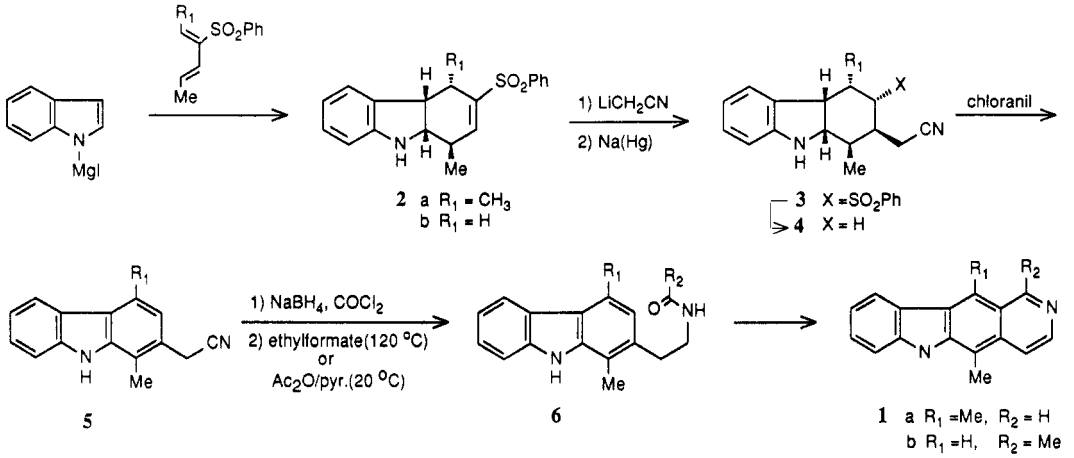
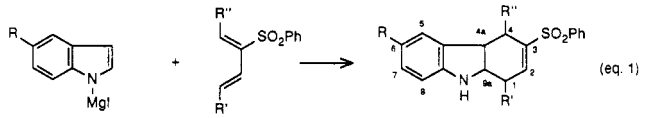
Scheme I

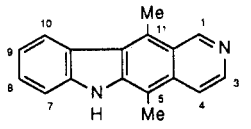


loids have been reported.[2,3]

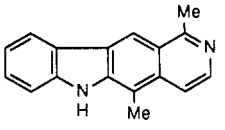
We recently reported a procedure for the [4 + 2] cycloaddition of 2-phenylsulfonyl 1,3-dienes to the magnesium salt of indole (eq 1).[4] The reaction is regioselective, giving a single regioisomer, and constitutes an efficient



method for the synthesis of carbazole systems. The vinyl sulfone functionality in the C ring is of importance for further functionalization.[5] It occurred to us that Michael addition of a C–C–N unit may constitute a useful route toward ellipticine (**1a**) and olivacine (**1b**). In this paper we report an expedient synthesis of **1a** and **1b** via the cycloaddition of 2-phenylsulfonyl 1,3-dienes to indole.



1a



1b

Results and Discussion

The reaction sequence is outlined in Scheme I. Reaction of 3-(phenylsulfonyl)-2,4-hexadiene with indolylmagnesium iodide at 20 °C afforded after workup the tetrahydrocarbazole product **2a** in 73% yield as a 7:1 mixture of diastereoisomers. Michael addition of the lithium salt of acetonitrile in THF at −60 to −78 °C provided the desired C–C–N elaboration of the C ring, and **3a** was isolated in 98% yield as a mixture of diastereoisomers. Elimination of the sulfone to give **4a** in 94% yield was accomplished by sodium amalgam reduction in buffered methanol.[6] For the aromatization of **4**, several methods were tried. The best method proved to be use of chloranil in xylene at 140 °C,[7] which gave **5a** in 64% yield. The use of DDQ gave a lower yield, and palladium on charcoal was very slow, even in refluxing mesitylene. The nitrile **5a** was transformed into **6a** by reduction to the amine by $CoCl_2/NaBH_4$[8] (97%) and subsequent formylation by ethyl formate (70%). The overall yield for the transformation of **5a** to **6a** was 68%. Nitrile **5a** has previously been reduced to the amine.[9] Compound **6a** was already known,[10,11] and its Bischler–Napieralski cyclization to dihydroellipticine and subsequent aromatization (Pd/C) to ellipticine has been reported in an overall yield of 77%.[11]

The same sequence was repeated with cycloadduct **2b**, which was obtained in 84% yield from (*E*)-2-(phenylsulfonyl)-1,3-pentadiene and indole. The transformation from **2b** to **5b** proceeded in an overall yield of 41%. Nitrile **5b** was transformed to **6b** in 54% yield via reduction ($NaBH_4/CoCl_2$) and subsequent acetylation of the amine. The Raney nickel reduction of **5b** to the amine has also been reported to give a good yield.[12a] Again, **6b** is a known[11,12] compound, and its Bischler–Napieralski cyclization and aromatization to olivacine has been reported in an overall yield of 81%.[11] Cyclization and aromatization of **6b** to **1b** was repeated by us in 82% yield following the original procedure.[12a]

The present synthesis of the 6*H*-pyrido[4,3-*b*]carbazoles ellipticine (**1a**) and olivacine (**1b**) starts from indole and readily available[13–15] 2-phenylsulfonyl 1,3-dienes. The strategy is simple and direct and leads to the key intermediates **6a** and **6b** in a few steps in an overall yield of 29% and 22%, respectively. The subsequent cyclizations and aromatizations, which have been described[11] previously, take place in good yields (75–80%).

In the present strategy there is no problem with re-

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gioisomers since the first step (to **2**) is highly regioselective. Further, the approach offers an entry to a number of substituted derivatives of ellipticine and olivacine by a suitable choice of substituted indoles and/or 2-phenylsulfonyl 1,3-dienes as starting material.

Experimental Section

General Methods. Melting points were recorded on a Leitz melting point microscope and are uncorrected. NMR spectra were recorded on a Varian XL 300 spectrometer with $CDCl_3$ as solvent and TMS as internal standard, unless stated otherwise. Spectral assignments were made with the aid of two-dimensional proton–proton and proton–carbon correlation spectroscopy and NOE measurements, which will be published separately.[16] IR spectra were recorded on a Perkin-Elmer 1600 FTIR spectrometer by using a 0.1-mm KBr cell with chloroform as solvent. Elemental analyses were performed by Analytische Laboratorien, Engelskirchen, West Germany. Ether and THF were distilled from sodium–benzophenone. Toluene was distilled from calcium hydride. Commercial methanol (99.9%, p.a.) was used directly. In cases where a mixture of diastereoisomers were formed, spectral data are given for the major isomer. Flash chromatography was performed either on silica gel 60, 230–400 ASTM, obtained from Merck, or on aluminum oxide, type 507 C neutral, obtained from Fluka.

Indolylmagnesium iodide[17] was prepared and stored in toluene/ether solution. It was stable for weeks at room temperature under nitrogen. Methyl iodide (750 μL, 12 mmol) in 25 mL of dry ether was added dropwise to magnesium turnings (300 mg, 12 mmol) so that reflux was maintained. The reaction mixture was then stirred for 1 h. Indole (1.6 g, 14 mmol) in 25 mL of dry toluene was then added dropwise with stirring under nitrogen. Methane was evolved immediately.

1,4-Dimethyl-3-(phenylsulfonyl)-1,4,4a,9a-tetrahydrocarbazole (2a).[4] A 2:1 mixture of (*2E,4E*)- and (*2Z,4E*)-3-(phenylsulfonyl)-2,4-hexadiene[15] (1.31 g, 5.9 mmol) in 30 mL of dry toluene was added to a stirred solution of the above indolylmagnesium iodide (12 mmol) in toluene/ether, 1:1 (25 mL), at room temperature. Stirring was continued for 24 h under nitrogen. The reaction was quenched by addition of ammonium chloride (aqueous), and the phases were separated. The aqueous phase was extracted with EtOAc. The combined organic phases were washed with brine and dried with $MgSO_4$. Evaporation under reduced pressure and flash chromatography (EtOAc/hexane, 20:80) of the resulting oil gave 1.46 g (73%) of a 7:1 mixture of two diastereoisomers of the adduct. Spectral data of major diastereoisomer (see Scheme I): IR 3396, 1304, 1152 cm^{-1}; ^1H NMR δ 7.96–7.46 (m, 5 H, Ar H), 7.02 (dd, 1 H, H-7), 6.96 (d, 1 H, H-5), 6.91 (d, J = 2 Hz, 1 H, H-2), 6.69 (dd, 1 H, H-6), 6.56 (d, 1 H, H-8), 4.19 (br s, 1 H, N–H), 3.79 (dd, J = 10.5, 6 Hz, 1 H, H-9a), 3.38 (dd, J = 10.5, 6 Hz, 1 H, H-4a), 2.96 (m, 1 H, H-4), 2.67 (m, 1 H, H-1), 1.35 (d, J = 7 Hz, 3 H, Me-1), 0.58 (d, J = 7 Hz, 3 H, Me-4); ^{13}C NMR δ 151.1, 146.0, 142.5, 139.2, 133.3, 129.1, 128.7, 128.0, 128.0, 124.7, 118.8, 109.3, 65.9, 46.7, 36.3, 32.5, 20.2, 13.0. Anal. Calcd for $C_{20}H_{21}NO_2S$: C, 70.76; H, 6.25. Found: C, 70.52; H, 6.19. ^1H NMR data for the minor isomer are given in ref 4.

2-(Cyanomethyl)-1,4-dimethyl-1,2,3,4,4a,9a-hexahydro-3-(phenylsulfonyl)carbazole (3a). To a stirred solution of *n*-butyllithium in hexane (5.13 mL, 2.22 M, 11.4 mmol) and THF (5 mL) was added diisopropylamine (1.60 mL, 11.4 mmol) at −10 °C. When addition was complete, stirring was continued for another 30 min at the same temperature, and then the solution was cooled to −78 °C and acetonitrile (600 μL, 11.4 mmol) was added dropwise. A white precipitate soon appeared, and stirring was continued for 1 h at −78 °C. The substrate **2a**[18] (1.29 g, 3.80 mmol) in 5 mL of dry THF was added during ca. 15 min at −60 to −78 °C. The reaction mixture was stirred for 30 min at −78 °C before quenching and workup as for **2a**, but CH_2Cl_2 was used for extraction: crude yield, 1.42 g (98%) of a mixture of diastereoisomers. Spectral data of major diastereoisomer obtained after HPLC purification (cf. Scheme I):[19] IR 3467, 2256, 1306, 1147 cm^{-1}; ^1H NMR δ 8.0–7.6 (m, 5 H, Ar H), 7.04 (ddd, 1 H, H-7), 6.86 (d, 1 H, H-5), 6.69 (ddd, 1 H, H-6), 6.62 (d, 1 H, H-8), 4.1–4.0 (br s, 1 H, N–H), 3.95 (dd, 1 H, H-9a), 3.47 (dd, J = 6, 10 Hz, 1 H, H-4a), 3.36 (dd, J = 4.5, 8 Hz, 1 H, H-3), 2.95 (m, 1 H, H-2), 2.80–2.46 (m, 3 H, H-1, CH_2CN), 2.22 (m, 1 H, H-4), 1.17 (d, J = 7 Hz, 3 H, Me-1), 0.96 (d, J = 7 Hz, 3 H, Me-4); ^{13}C NMR δ 150.8, 138.3, 134.2, 129.6, 129.3, 128.3, 128.2, 124.5, 119.1, 118.6, 109.7, 67.2, 61.6, 45.1, 34.6, 31.9, 31.2, 19.7, 16.0, 12.0.

2-(Cyanomethyl)-1,4-dimethyl-1,2,3,4,4a,9a-hexahydrocarbazole (4a). The substrate **3a**[18] (2.73 g, 7.20 mmol) and Na_2HPO_4 (99.95%, 4.0 g, 28 mmol) were dissolved in 20 mL of MeOH (99.9%) and cooled to 0 °C under nitrogen, and then pulverized Na(Hg) (10.8 g, 6%) was added. The reaction mixture was stirred for 1 h at room temperature and then quenched by addition of water. Extraction with CH_2Cl_2, washing of the organic phase with brine, drying ($MgSO_4$), filtration through silica, and evaporation gave 1.64 g (94%) of **4a**. Recrystallization afforded a pure sample of the predominant diastereoisomer: mp 177–178 °C (from EtOAc); IR 3691, 2256 cm^{-1}; ^1H NMR δ 7.22 (d, 1 H), 7.04 (m, 1 H), 6.73 (ddd, 1 H), 6.66 (d, 1 H), 3.8 (br s, 1 H, N–H), 3.48 (dd, 1 H, H-9a), 3.29 (dd, 1 H, H-4a), 2.48–2.43 (m, 1 H, H-2), 2.34 (dd, 2 H, CH_2CN), 2.18 (m, 1 H, H-4), 1.95 (m, 1 H, H-1), 1.75 (m, 1 H, H-3), 1.50 (m, 1 H, H-3′), 1.05 (d, J = 7 Hz, 3 H, Me-4), 0.95 (d, J = 7 Hz, 3 H, Me-1); ^{13}C NMR δ 151.1, 131.0, 127.2, 125.0, 119.2, 118.8, 110.1, 65.4, 43.8, 34.0, 32.2, 31.5, 28.7, 18.8, 14.4. Anal. Calcd for $C_{16}H_{20}N_2$: C, 79.96; H, 8.39. Found: C, 79.80; H, 8.35.

2-(Cyanomethyl)-1,4-dimethylcarbazole (5a).[7] Chloranil (1.78 g, 7.24 mmol) was added to **4a** (580 mg, 2.41 mmol) in xylene (15 mL) under nitrogen. The solution was heated to reflux for 4 h. It was then filtered through a short plug of alumina, and the plug was washed with benzene/CH_2Cl_2, 1:1. The filtrate was evaporated under reduced pressure. Flash chromatography on alumina (benzene/CH_2Cl_2, 1:1) of the residue afforded 360 mg (64%): mp 233–235 °C from benzene (lit[9] mp 226–231 °C); ^1H NMR (acetone-d_6) δ 10.41 (br s, 1 H, N–H), 8.17 (d, 1 H), 7.57 (d, 1 H), 7.42 (ddd, 1 H), 7.22 (ddd, 1 H), 7.03 (s, 1 H, H-3), 4.03 (s, 2 H, CH_2CN), 2.84 (s, 3 H), 2.59 (s, 3 H); ^{13}C NMR (acetone-d_6) δ 141.4, 140.7, 131.4, 126.8, 125.9, 124.6, 123.1, 122.1, 121.9, 119.8, 119.3, 116.7, 111.7, 21.6, 20.4, 13.0.

1,4-Dimethyl-2-(2-formamidoethyl)carbazole (6a).[8,10] The substrate **5a** (830 mg, 3.54 mmol) and $CoCl_2$ (920 mg, 7.08 mmol) were dissolved in MeOH (100 mL) and cooled to 0 °C. $NaBH_4$ (1.34 g, 35.4 mmol) was added in portions. A black precipitate formed, and hydrogen was evolved. The reaction mixture was stirred for 30 min, and then 2 M HCl (22.0 mL, 42.5 mmol) was added. Stirring was continued for 30 min until the black precipitate had dissolved. The solvent was evaporated under reduced pressure. An excess of 2 M NH_3 (aqueous) was added to the residue, and the mixture was extracted with CH_2Cl_2. The organic phase was washed with brine and then dried over $MgSO_4$. Evaporation gave the amine (815 mg) as a brown oil, which was dissolved in 5 mL of THF and treated with 20 mL of ethyl formate in a sealed tube at 120 °C for 36 h. After evaporation of the solvent, the residue was chromatographed with $CHCl_3$ on alumina, to yield 643 mg (68%) of **6a**: IR 3473, 1684 cm^{-1}; ^1H NMR δ 8.38 (s, 1 H), 8.12 (m, 2 H), 7.46–7.32 (m, 2 H), 7.42 (m, 2 H), 7.23 (m, 1 H), 6.78 (s, 1 H), 5.74 (br s, 1 H), 3.54 (m, 2 H), 2.95 (t, 2 H), 2.80 (s, 3 H), 2.43 (s, 3 H); ^{13}C NMR δ 161.3, 139.6, 139.5, 133.2, 130.4, 124.8, 124.2, 122.6, 122.2, 120.1, 119.3, 115.2, 110.5, 38.9, 32.8, 20.3, 12.7.

5,11-Dimethyl-6*H*-pyrido[4,3-*b*]carbazole (Ellipticine, 1a). Compound **6a** was converted to ellipticine (**1a**) according to the published procedure.[11,12a] The product was characterized by its spectral data: ^1H NMR (DMSO-d_6) δ 11.39 (s, 1 H, N–H), 9.68 (s, 1 H, H-1), 8.41 (d, 1 H, H-3), 8.36 (d, 1 H, H-10), 7.90 (d, 1 H, H-4), 7.53 (m, 2 H, H-7, 8), 7.25 (ddd, 1 H, H-9), 3.23 (s, 3 H, Me-11), 2.77 (s, 3 H, Me-5); ^{13}C NMR (DMSO-d_6) δ 149.7, 142.7, 140.6, 140.5, 132.5, 128.1, 127.2, 123.8, 123.4, 123.2, 122.0, 119.2, 116.0, 110.7, 108.1, 14.4, 12.0.

***r*-1-Methyl-3-(phenylsulfonyl)-1,4,*t*-4a,*t*-9a-tetrahydro-**

(16) Gogoll, A.; Plobeck, N. A. *Magn. Reson. Chem.* In press.
(17) Sundberg, R. J. *The Chemistry of Indoles*; Academic Press: New York, 1970; p 19.
(18) A mixture of diastereoisomers. The major diastereoisomer is shown in Scheme I.
(19) The stereochemical assignment is reported separately.[16]

carbazole (2b).[4] A solution of (*E*)-2-(phenylsulfonyl)-1,3-pentadiene[14] was prepared from (*E*)-2-(phenylsulfonyl)-1-(chloromercurio)-3-pentene (10.85 g, 24.40 mmol). The mercury adduct was suspended in 80 mL of ether, and 2 M NaOH (37 mL, 73 mmol) was added. After the reaction mixture was stirred vigorously for 15 min, the ether phase was decanted through a short silica column and diluted with 100 mL of dry toluene. The aqueous phase was extracted with another 20 mL of ether, which was passed through the column. The combined organic phases were dried with $MgSO_4$ three times and then with molecular 4-Å sieves, for 3 h in the freezer. This solution was added to indolylmagnesium iodide (40 mmol) in 100 mL of ether/toluene, 1:1, at 0 °C during 5 min. The reaction mixture was then stirred for another 5 min before quenching with ammonium chloride (aqueous). Workup was performed as for **2a**. Flash chromatography (EtOAc/hexane, 30:70) gave 4.54 g of **2b** (84% from the mercury adduct) as a colorless oil, which solidified on drying in vacuo: IR 3389, 1305, 1152 cm^{-1}; ^1H NMR δ 7.86–7.46 (m, 5 H, Ar H), 7.03–6.95 (m, 2 H, H-2, 7), 6.88 (d, 1 H, H-5), 6.65 (ddd, 1 H, H-6), 6.58 (d, 1 H, H-8), 4.0 (br s, 1 H, N–H), 3.56 (dd, J = 5.5, 8.5 Hz, 1 H, H-9a), 3.42 (dd, 1 H, H-4a), 2.81 (ddd, J = 1, 7.5, 16.5 Hz, 1 H, H-4β), 2.39 (m, 1 H, H-1), 2.16 (ddd, J = 7, 16.5 Hz, 1 H, H-4α), 1.26 (d, J = 7.5 Hz, 3 H, Me-1); ^{13}C NMR δ 149.6, 142.5, 139.3, 138.9, 133.2, 131.4, 129.1, 127.9, 127.8, 123.5, 119.1, 109.7, 64.3, 39.7, 35.4, 25.4, 18.6. Anal. Calcd for $C_{19}H_{19}NO_2S$: C, 70.12; H, 5.90. Found: C, 69.90; H, 5.76.

***r*-2-(Cyanomethyl)-1,2,3,4,*t*-4a,*t*-9a-hexahydro-*c*-1-methyl-*t*-3-(phenylsulfonyl)carbazole (3b).** When the procedure for **3a** was followed, **2b** (2.37 g, 7.3 mmol) gave 2.55 g (95%) of **3b** as white crystals:[19] mp 214–216 °C (from EtOAc); IR 3389, 2256, 1306, 1147 cm^{-1}; ^1H NMR δ 7.90–7.55 (m, 5 H, Ar H), 7.04 (ddd, 1 H, H-7), 6.93 (d, 1 H, H-5), 6.68 (ddd, 1 H, H-6), 6.63 (d, 1 H, H-8), 4.05–3.85 (br s, N–H), 3.79 (dd, 1 H, H-9a), 3.29 (m, 1 H, H-4a), 3.18 (m, 1 H, H-3), 2.97–2.69 (m, 3 H, H-2, CH_2CN), 2.32 (m, 1 H, H-1), 1.80–1.65 (m, 2 H, H-4), 1.13 (d, J = 7 Hz, 3 H, Me-1); ^{13}C NMR δ 149.7, 136.8, 134.2, 131.5, 129.4, 128.9, 128.2, 124.0, 119.0, 118.3, 109.8, 62.1, 61.8, 38.7, 34.8, 32.7, 28.0, 19.5, 14.9. Anal. Calcd for $C_{21}H_{22}N_2O_2S$: C, 68.82; H, 6.05. Found: C, 68.88; H, 6.17.

***r*-2-(Cyanomethyl)-1,2,3,4,*t*-4a,*t*-9a-hexahydro-*c*-1-methylcarbazole (4b).** Compound **3b** (2.32 g, 6.33 mmol) was dissolved in 100 mL of dry methanol/THF, 1:1. Na_2HPO_4 (3.60 g, 25.3 mmol) was added and then Na(Hg) (9.5 g, 6%) in portions at 0 °C. The reaction mixture was stirred for 4 h at 25 °C. Workup as for **4a** gave 1.29 g (90%): IR 3386, 2247 cm^{-1}; ^1H NMR δ 7.10 (d, 1 H, H-8), 7.05 (ddd, 1 H, H-6), 6.74 (ddd, 1 H, H-7), 6.69 (d, 1 H, H-5), 3.58 (dd, J = 3, 6.5 Hz, 1 H, H-9a), 3.02 (m, 1 H, H-4a), 2.32 (s, 3 H, H-2, CH_2CN), 2.12 (m, 1 H, H-1), 1.84 (m, 1 H, H-4), 1.53–1.38 (m, 3 H, CH_2-3, H-4), 0.98 (d, J = 7.2 Hz, 3 H, Me-1); ^{13}C NMR δ 149.7, 134.5, 127.3, 123.3, 122.6, 119.0, 110.0, 66.3, 37.5, 33.8, 32.9, 28.0, 23.7, 20.6, 12.85. Anal. Calcd for $C_{15}H_{18}N_2$: C, 79.60; H, 8.02. Found: C, 79.40; H, 7.94.

2-(Cyanomethyl)-1-methylcarbazole (5b). The procedure was the same as for **5a**, but reaction was complete after a 2-h reflux. **4b** (1.29 g, 5.7 mmol) gave after flash chromatography (benzene/CH_2Cl_2, 1:1) 720 mg (57%) of **5b** as pale brown crystals: mp 173–175 °C (from benzene) (lit.[12a] mp 172–176 °C); ^1H NMR δ 8.04 (d, 2 H, N–H), 7.89 (d, 1 H), 7.48–7.39 (m, 2 H), 7.25 (m, 1 H), 7.18 (d, 1 H), 3.82 (s, 2 H, H-11), 2.50 (s, 3 H, Me-1); ^{13}C NMR δ 139.7, 139.3, 126.2, 126.1, 125.1, 123.4, 123.0, 120.5, 119.8, 118.3, 118.0, 117.8, 110.8, 22.0, 13.2.

2-(2-Acetamidoethyl)-1-methylcarbazole (6b). The amine was prepared as for **6a**. **5b** (720 mg, 3.27 mmol) in MeOH (150 mL) gave the amine as a brown oil, which was acetylated with acetic anhydride/pyridine, 1:1 (30 mL), at room temperature for 1 h. After evaporation, the residue was washed with dilute acetic acid and water. Flash chromatography (EtOAc) gave 470 mg (54%) of **6b** as a brown powder: IR 3473, 1665 cm^{-1}; ^1H NMR (acetone-d_6) δ 10.30 (br s, 1 H, N–H), 8.06 (d, 1 H), 7.87 (d, 1 H), 7.52 (d, 1 H), 7.36 (ddd, 1 H), 7.28 (br s, 1 H), 7.16 (ddd, 1 H), 7.04 (d, 1 H), 3.45 (m, 2 H), 3.00 (m, 2 H), 2.60 (s, 3 H), 1.92 (s, 3 H); ^{13}C NMR (acetone-d_6) δ 170.0, 141.1, 141.0, 135.6, 125.8, 124.4, 122.0, 122.0, 120.6, 119.5, 119.1, 118.1, 111.7, 41.3, 34.3, 23.0, 13.2.

1,5-Dimethyl-6*H*-pyrido[4,3-*b*]carbazole (Olivacine, 1b). This compound was prepared according to the published procedure.[12a] Compound **6b** (75 mg, 0.28 mmol) was refluxed with $POCl_3$ (400 μL) in toluene for 1 h. The solvent was evaporated, and the residue was extracted several times with hot 0.2 M HCl, filtered, and made alkaline with ammonia (aqueous). The precipitate was filtered off and dissolved in boiling chloroform. The chloroform phase was dried (K_2CO_3), filtered, and evaporated to yield 94 mg of dihydroolivacine, which was heated to reflux in decalin (10 mL) for 1.5 h with palladium on carbon (10%, 100 mg). The reaction mixture was cooled to 0 °C, and the product and the catalyst were filtered off and washed with a little cold hexane. The product was then dissolved in boiling chloroform. Filtration and evaporation gave 57 mg (82%) of olivacine (**1b**), which was characterized by its spectral data: ^1H NMR (DMSO-d_6) δ 11.37 (s, 1 H, N–H), 8.91 (s, 1 H, H-11), 8.37 (d, 1 H, H-10), 8.24 (d, 1 H, H-3), 7.79 (d, 1 H, H-4), 7.53 (m, 2 H, H-7,8), 7.23 (ddd, 1 H, H-9), 3.03 (s, 3 H, Me-1), 2.81 (s, 3 H, Me-5); ^{13}C NMR (DMSO-d_6) δ 158.7, 142.5, 140.5, 139.5, 132.4, 127.6, 124.7, 122.7, 121.8, 121.4, 119.0, 114.9, 114.7, 111.0, 110.8, 23.0, 12.4.

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Registry No. **1a**, 519-23-3; **1b**, 484-49-1; **2a**, 127472-64-4; **2b**, 127472-67-7; **3a**, 127472-65-5; **3b**, 127472-68-8; **4a**, 127472-66-6; **4b**, 127472-69-9; **5a**, 57412-01-8; **5b**, 100880-19-1; **6a**, 94822-10-3; **6b**, 61253-30-3; (*E*,*E*)-MeCH=C(SO_2Ph)CH=CHMe, 102860-21-9; (*Z*,*E*)-MeCH=C(SO_2Ph)CH=CHMe, 118160-43-3; (*E*)-CH_2=C(SO_2Ph)CH=CHMe, 102860-19-5; (*E*)-ClHgCH_2CH-(SO_2Ph)CH=CHMe, 102815-50-9; 1-indolylmagnesium iodide, 13884-15-6.