New Approach to 3-Oxygenated Carbazoles. Synthesis of Hyellazole and 4-Deoxycarbazomycin B[1]

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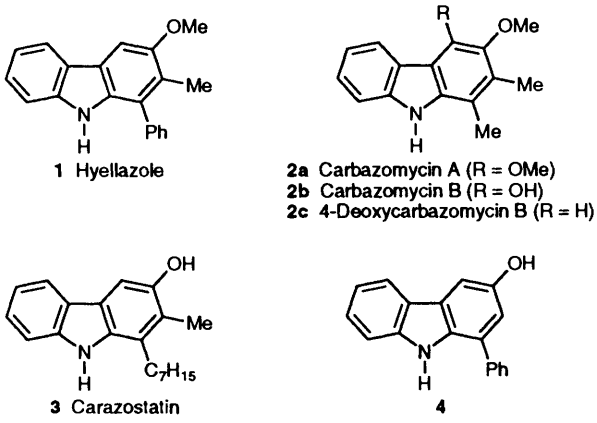
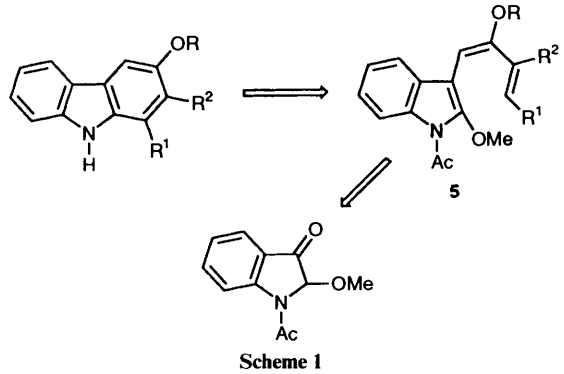
3-Oxygenated carbazoles are prepared in 4 steps from 1-acetyl-2-methoxy-1,2-dihydroindol-3-one **6** by Wittig reaction with phosphonium ylides **10** to afford the 3-alkylindoles **11**, followed by silylation to the silyl enol ethers **12**. Electrocyclic reaction of the enol ethers **12** followed by desilylation give the 3-hydroxycarbazoles **15**. The carbazoles **15a,b** were converted into the carbazole alkaloid hyellazole **1** and 4-deoxycarbazomycin B **2c**, respectively.

Carbazoles with an oxygen substituent at the 3-position constitute the framework of carbazole alkaloids; hyellazole **1** isolated from the blue-green alga *Hyella caespitosa*,[2] carbazomycins **2** produced by *Streptoverticillium ehimense*,[3] and carazostatin **3**, found in *Streptomyces chromofuscus*.[4] The antibiotic activity of carbazomycin B **2b** and the antioxidative action of carazostatin **3** have made this class of compounds interesting synthetic targets for several research groups.[5-12] We have developed a new synthesis of 3-oxygenated carbazoles based on the simple strategy shown in Scheme 1. This approach



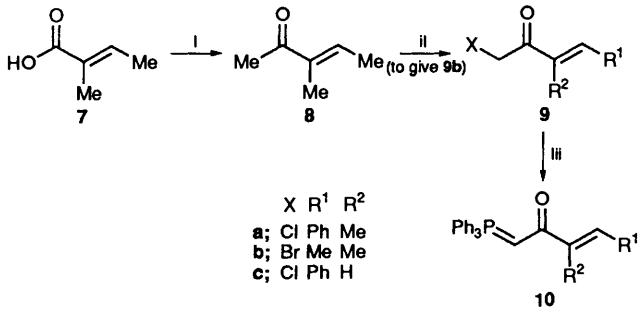


Scheme 1

involves electrocyclic reaction of 3-butadienylindoles **5** which has, surprisingly, found little use in carbazole syntheses to date.[13] We now report full details of this work which has resulted in the synthesis of hyellazole **1**, 4-deoxycarbazomycin B **2c**, and the related compound **4**.

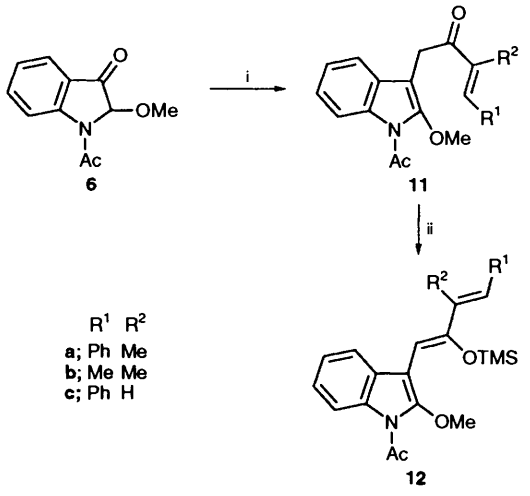
Results and Discussion

The preparation of 3-butadienylindoles **5** for the electrocyclic reaction is based on our recently described method for synthesis of 3-alkylindoles by Wittig reaction of readily available 1,2-dihydroindol-3-one.[14] The ylides **10** were prepared by the usual procedure from triphenylphosphine and α-halogeno ketones **9a**,[15] **9b** and **9c**.[16] Attempts to prepare bromide **9b**, according to the procedure for the preparation of chloride **9a**[15] resulted in very poor yield. The halogeno ketone **9b** was, however, obtained by the following method; methylation of tiglic acid **7** with methyllithium followed by bromination of the obtained 3-methylbut-3-en-2-one **8** with 5,5-dibromo-2,2-dimethyl-4,6-dioxo-1,3-dioxane (Scheme 2).[17]



Scheme 2 *Reagents and conditions*: i, MeLi, − 78 °C, Et_2O; ii, 5,5-dibromo-2,2-dimethyl-4,6-dioxo-1,3-dioxane, HBr, CCl_4; iii, (1) Ph_3P, (2) Na_2CO_3, MeOH or NaOH, CH_2Cl_2

The Wittig reaction of 1-acetyl-2-methoxy-1,2-dihydroindol-3-one **6** with the ylides **10** in refluxing 1,4-dioxane or toluene gave the corresponding 3-alkylindoles **11** in good yield (Scheme 3). The indoles **11** were treated with trimethylsilyl iodide (TMSI) in the presence of 1,1,1,3,3,3-hexamethyldisilazane (HMDS) at room temperature to give TMS enol ethers **12** in 80–98% yield. The structures were established by spectral data, and the stereochemistry of the TMS enol ether moiety was elucidated by NOE experiments. In the case of the enol ether **12a**, irradiation of the ene proton (H^a) strongly enhanced the signal of the methyl group, confirming the *Z* configuration of the enol ether moiety, and at the same time an enhancement of the signal due to the proton at the 4-position (H^b) of the indole nucleus was also observed. This indicated that the enol ether **12a** exists predominantly in the conformer shown in Fig 1. The stereoselective formation of *Z* enol ethers **12a,b** is consistent with the results of the silylation of the ketones by using TMSI–HMDS, which favours production of the thermodynamically controlled products.[18] However, silylation of the indole **11c** gave a mixture of *E*- and *Z*-silyl enol ethers **12c** (2:1). The difference in their selectivities should be due to the bulk of the substituent (R^2) in compounds **12**.



Scheme 3 *Reagents and conditions*: i, ylide **10**, 1,4-dioxane or toluene; ii, TMSI, HMDS, CH_2Cl_2, room temp

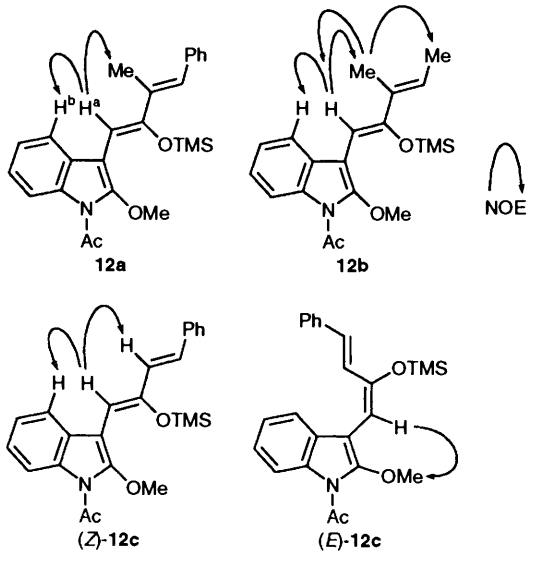
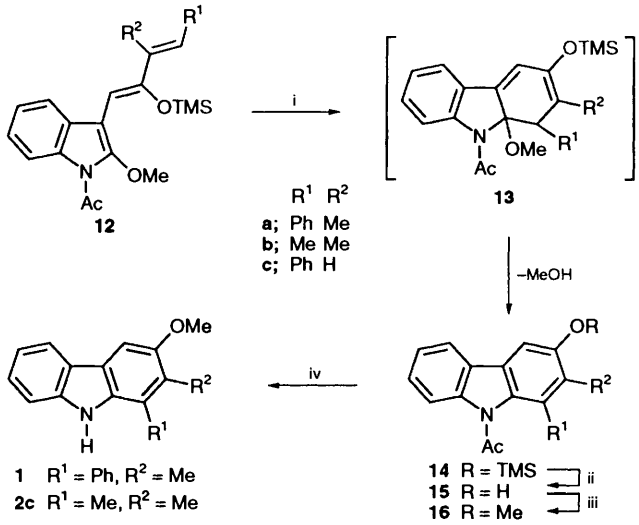


Fig. 1 TMS = $SiMe_3$

The electrocyclization of the enol ethers **12** was initially attempted by heating compound **12a** in boiling xylenes (b.p. 140 °C) and *o*-dichlorobenzene (b.p. 180 °C). However, only decomposition of the starting material was observed. On heating of compound **12a** in a higher boiling solvent such as *cis*-decalin (b.p. 195 °C), it smoothly isomerized, cyclized, and released methanol from an intermediate **13a** to give the desired 3-siloxycarbazole **14a** and the desilylated product **15a** in 53 and 13% yield respectively (Scheme 4). The removal of the silyl group from compound **14a** was carried out by treatment with tetrabutylammonium fluoride (TBAF) to afford the 3-hydroxycarbazole **15a** (81%). Similar cyclization of silylenol ethers **12b,c** *via* intermediates **13b,c**, followed by desilylation of the siloxycarbazoles **14b,c**, gave the corresponding 3-hydroxycarbazoles **15b** (40%) and **15c** (60%), respectively. Although, in general, electron-donating groups act as an undesirable factor for a thermal hexatriene cyclization,[19] the cyclization of compounds **12** which have electron-donating groups went smoothly to completion. This may be due to the ready release of methanol from the intermediate **13**, leading to aromatization.

The 3-hydroxycarbazoles **15** were converted into hyellazole **1**, 4-deoxycarbazomycin B **2c**, and compound **4**, respectively. The carbazole **15c** was treated with sodium hydroxide and catalytic tetrabutylammonium hydrogen sulfate in (TBAHS) in



Scheme 4 *Reagents and conditions*: i, heat in *cis*-decalin; ii, TBAF, THF, 0 °C; iii, Me_2SO_4, NaOH, Bu_4N^+ HSO_4^-, C_6H_6; or MeI, Na_2CO_3, acetone; iv, NaOH, Bu_4N^+ HSO_4^-, C_6H_6.

refluxing benzene to give the 3-hydroxycarbazole **4**. Treatment of the carbazole **15a** with dimethyl sulfate and sodium hydroxide (to give the methyl ether **16a**) followed by deacetylation with sodium hydroxide afforded hyellazole **1** (72%). The spectral data of hyellazole **1** thus obtained were identical with those of natural[2] and synthetic samples.[5,6,8,10]

In a similar manner, methylation of 3-hydroxycarbazole **15b** with methyl iodide in the presence of potassium carbonate (to give the methyl ether **16b**) followed by deacetylation with sodium hydroxide afforded 4-deoxycarbazomycin B **2c**, whose spectral data closely match those described in the literature.[3,7,8,9]

Experimental

All m.p.s are uncorrected, and were measured on a Yanagimoto micromelting point apparatus. The b.p. was determined with a Buchi GKP-50 apparatus. The UV spectrum for hyellazole **1** was measured on a Hitachi 124 spectrometer. IR spectra were recorded with a Hitachi 270-30 spectrophotometer. NMR spectra were determined with JEOL PMX-60, JNM-GX 270, or GX-400 spectrometers with tetramethylsilane as internal standard. *J* Values are given in Hz. Mass spectra were obtained with a JEOL JMS-DX302 instrument with a direct inlet system operating at 70 eV. Elemental analyses were obtained by using a Perkin-Elmer Model 240B elemental analyser. Column chromatography was carried out on silica gel (Kanto Chemical Co. Inc., 100–200 mesh and Merck, 400 mesh). 1-Acetyl-2-methoxy-1,2-dihydroindol-3-one **6**[20] and (*E*)-2-oxo-4-phenylbut-3-enylidene(triphenyl)phosphorane **10c**[16] were prepared according to the reported procedure.

(E)-3-*Methylpent*-3-*en*-2-*one* **8**.—A solution of methyllithium (0.7 mol dm^{-3}; 400 cm^3, 0.28 mol) was added to a solution of tiglic acid **7** (14 g, 0.14 mol) in dry diethyl ether (320 cm^3) at 0 °C, and the mixture was stirred at the same temperature for 2 h. To the resulting mixture at 0 °C was gradually added 0.4 mol dm^{-3} hydrochloric acid (560 cm^3), and the mixture was extracted with diethyl ether. The extract was washed with brine, dried over Na_2SO_4 and concentrated. The residue was distilled under reduced pressure to give the pentenone **8** (10.4 g, 75%) as an oil, b.p.48 °C(50mmHg)(lit.,[21] 138–139 °C); ν_{max}($CHCl_3$)/cm^{-1} 1662 (C=O) and 1647 (C=C); δ_H(60 MHz; $CDCl_3$) 1.75 (3 H, s, Me), 1.85 (3 H, d, *J* 7, Me), 2.28 (3 H, s, COMe) and 6.72 (1 H, q, *J* 7, –CH=).

(E)-1-*Bromo*-3-*methylpent*-3-*en*-2-*one* **9b**.—To a solution of the pentenone **8** (2.95 g, 30.1 mmol) and 5,5-dibromo-2,2-dimethyl-4,6-dioxo-1,3-dioxane (9.15 g, 30.1 mmol) in carbon tetrachloride (60 cm^3) was added 47% hydrobromic acid (10 drops). The mixture was heated under reflux for 5 h. After cooling, the resulting mixture was neutralized with aq. $NaHCO_3$ and extracted with chloroform. The extract was dried over $MgSO_4$ and concentrated. The residue was chromatographed on silica gel with hexane–chloroform (1 : 1) as eluent to give the bromide **9b** (3.1 g, 58%) as an oil; ν_{max}(neat)/cm^{-1} 1667 (C=O) and 1645; δ_H(60 MHz; $CDCl_3$) 1.82 (3 H, s, Me), 1.92 (3 H, d, *J* 7, Me), 4.15 (2 H, s, CH_2Br) and 6.80 (1 H, q, *J* 7, –CH=).

(E)-3-*Methyl*-2-*oxo*-4-*phenylbut*-3-*enylidene*(*triphenyl*)*phosphorane* **10a**.—A solution of (*E*)-1-chloro-3-methyl-4-phenylbut-3-en-2-one **9a**[15] (4.32 g, 22.3 mmol) and triphenylphosphine (5.9 g, 22.3 mmol) in dry tetrahydrofuran (THF) (40 cm^3) was heated under reflux for 12 h. After cooling, crystals that had precipitated were collected (7.0 g). The crystals were dissolved in methanol (20 cm^3), and 5.5% aq. Na_2CO_3 (18.5 cm^3) was added to the solution. The mixture was stirred at room temperature for 30 min. After removal of the solvent, the residue was extracted with chloroform (100 cm^3). The extract was washed with water, dried over $MgSO_4$, and concentrated to give the *phosphorane* **10a** (5.68 g, 61%), m.p. 164–166 °C (from EtOAc) (Found: C, 83.1; H, 5.9. $C_{29}H_{25}OP$ requires C, 82.84; H, 5.99%); ν_{max}($CHCl_3$)/cm^{-1} 1653 and 1623; δ_H(60 MHz; $CDCl_3$) 2.18 (3 H, s, Me) and 7.15–8.0 (22 H, m, ArH and –CH=); *m*/*z* 420 (M^+, 15%), 419 (50), 303 (100), 275 (48) and 262 (31).

(E)-3-*Methyl*-2-*oxopent*-3-*enylidene*(*triphenyl*)*phosphorane* **10b**.—A solution of the bromide **9b** (2.05 g, 11.6 mmol) and triphenylphosphine (2.52 g, 9.6 mmol) in chloroform (20 cm^3) was kept at room temperature. After 46 h, the mixture was concentrated to give a solid, which was washed with diethyl ether and dried to give crystals (3.37 g). To a solution of the crystals in methylene dichloride (56 cm^3) was added 33% aq. NaOH (7 cm^3). The mixture was vigorously stirred at room temperature for 1 h and extracted with methylene dichloride (100 cm^3). The extract was washed with water, dried over $MgSO_4$, and concentrated. The residue was chromatographed on silica gel with ethyl acetate to give the *phosphorane* **10b** (0.94 g, 27%), m.p. 129–131.5 °C (from MeOH–Et_2O) (Found: C, 80.3; H, 6.5. $C_{24}H_{23}OP$ requires C, 80.43; H, 6.47%); ν_{max}($CHCl_3$)/cm^{-1} 1652, 1449, 1443, 1402 and 1109; δ_H(60 MHz; $CDCl_3$) 1.73 (3 H, d, *J* 7, Me), 1.92 (3 H, s, Me), 3.89 (1 H, br, –CH=), 6.55 (1 H, q, *J* 7, –CH=) and 7.15–8.0 (15 H, m, ArH); *m*/*z* 358 (M^+, 42%), 343 (29), 303 (100), 275 (21), 262 (36) and 183 (27).

(E)-1-(1-*Acetyl*-2-*methoxyindol*-3-*yl*)-3-*methyl*-4-*phenylbut*-3-*en*-2-*one* **11a**.—A solution of 1-acetyl-2-methoxy-1,2-dihydroindol-3-one **6** (0.94 g, 4.6 mmol) and the phosphorane **10a** (2.9 g, 6.9 mmol) in dry 1,4-dioxane (10 cm^3) was heated under reflux for 7.5 h. The solvent was evaporated off and the residue was chromatographed on silica gel with methylene dichloride to give the *indole* **11a** (1.35 g, 85%), m.p. 126–127 °C (from EtOH) (Found: C, 75.8; H, 6.0; N, 4.0. $C_{22}H_{21}NO_3$ requires C, 76.05; H, 6.1; N, 4.0%); ν_{max}($CHCl_3$)/cm^{-1} 1702 (C=O), 1670 (C=O) and 1636 (C=C); δ_H(400 MHz; $CDCl_3$) 2.15 (3 H, d, *J* 1.2, MeC=), 2.66 (3 H, s, COMe), 4.0 (3 H, s, OMe), 4.16 (2 H, s, CH_2CO), 7.23 (1 H, dt, *J* 1.2 and 7.3, ArH), 7.27 (1 H, dt, *J* 1.5 and 7.3, ArH), 7.3–7.45 (6 H, m, ArH), 7.76 (1 H, d, *J* 1.2, =CH–) and 8.37 (1 H, dd, *J* 1.2 and 7.3, ArH); δ_C(100 MHz; $CDCl_3$) 13.3, 25.6, 32.7, 63.5, 99.5, 116.4, 117.9, 123.7, 124.4, 128.0, 128.5, 128.7, 129.8, 131.9, 135.7, 136.8, 139.6, 148.9, 169.2 and 198.6; *m*/*z* 347 (M^+, 10%), 202 (25), 160 (100), 145 (15) and 117 (11).

(E)-1-(1-*Acetyl*-2-*methoxyindol*-3-*yl*)-3-*methylpent*-3-*en*-2-*one* **11b**.—A solution of the indol-3-one **6** (0.44 g, 2.2 mmol) and the phosphorane **10b** (1.17 g, 3.25 mmol) in dry toluene (6 cm^3) was refluxed for 5 h. The solvent was evaporated off, and the residue was chromatographed on silica gel with methylene dichloride to give the *indole* **11b** (0.59 g, 96%), m.p. 95–96 °C (Found: C, 71.5; H, 4.85; N, 6.75. $C_{17}H_{19}NO_3$ requires C, 71.55; H, 4.9; N, 6.7%); ν_{max}($CHCl_3$)/cm^{-1} 1700 (C=O), 1671 (C=O) and 1641 (C=C); δ_H(400 MHz; $CDCl_3$) 1.82 (3 H, d, *J* 1.2, Me), 1.90 (3 H, d, *J* 7.1, Me), 2.64 (3 H, s, COMe), 3.95 (3 H, s, OMe), 4.00 (2 H, s, CH_2), 6.98 (1 H, dq, *J* 1.2 and 6.9, =CH=), 7.15–7.3 (3 H, m, ArH) and 8.35 (1 H, d, *J* 7.5, ArH); δ_C(100 MHz; $CDCl_3$) 11.2, 14.9, 25.6, 32.0, 63.4, 99.5, 116.3, 117.9, 123.6, 124.3, 128.1, 131.8, 138.0, 138.2, 148.9, 169.2 and 197.8; *m*/*z* 285 (M^+, 20%), 202 (18), 160 (100), 145 (16) and 117 (12).

1-(1-*Acetyl*-2-*methoxyindol*-3-*yl*)-4-*phenylbut*-3-*en*-2-*one* **11c**.—A solution of the indol-3-one **6** (2.02 g, 10 mmol) and the phosphorane **10c** (6.12 g, 15 mmol) in dry toluene (20 cm^3) was heated under reflux for 5.5 h. The mixture was concentrated under reduced pressure, and the residue was chromatographed on silica gel (methylene dichloride) to give a mixture of *E* and *Z* isomers (95:5) of the *indole* **11c** (2.29 g, 69%), m.p. 117–118 °C (from hexane) (Found: C, 75.65; H, 5.7; N, 4.15. $C_{21}H_{19}NO_3$ requires C, 75.65; H, 5.75; N, 4.2%); ν_{max}($CHCl_3$)/cm^{-1} 1698 (C=O), 1632 and 1613; δ_H(270 MHz; $CDCl_3$) 2.65 (3 H, s, COMe), 3.95 (2 H, s, CH_2), 4.00 (3 H, s, OMe), 6.84 (1 H, d, *J* 16.2, –CH=), 7.2–7.6 (8 H, m, ArH), 7.70 (1 H, d, *J* 16.2, –CH=) and 8.37 (1 H, d, *J* 7.6, ArH). Signals due to *Z*-isomer of the indole **11c** also appeared, at (*inter alia*) δ 2.62 (3 H, s, COMe), 3.78 (2 H, s, CH_2), 3.93 (3 H, s, OMe), and 6.29 (d, *J* 12.9, –CH=); δ_C(68 MHz; $CDCl_3$) 25.8, 36.2, 63.4, 98.2, 116.5, 117.7, 123.8, 124.5, 128.0, 128.4, 129.0, 130.7, 131.8, 134.2, 143.7, 149.3, 169.3 and 196.4; *m*/*z* 333 (M^+, 24%), 202 (27), 160 (100) and 145 (20).

1-*Acetyl*-2-*methoxy*-3-[(1Z,3E)-3-*methyl*-4-*phenyl*-2-(*trimethylsiloxy*)*buta*-1,3-*dienyl*]*indole* **12a**.—A solution of the indole **11a** (1.0 g, 2.3 mmol) and HMDS (0.7 g, 4.35 mmol) in dry methylene dichloride (45 cm^3) was stirred at room temperature for 30 min under argon. After cooling of the solution to −20 °C, TMSI (0.64 g, 3.2 mmol) was added. The reaction mixture was stirred at −20 °C for 10 min and at room temperature for 2 h. The resulting mixture was concentrated under reduced pressure to give a residue, which was crystallized from ethanol to give the *silylenol ether* **12a** (0.96 g, 80%), m.p. 107–109 °C (Found: C, 71.3; H, 6.9; N, 3.3. $C_{25}H_{29}NO_3Si$ requires C, 71.55; H, 7.0; N, 3.3%); ν_{max}($CHCl_3$)/cm^{-1} 1697 (C=O) and 1629 (C=C); δ_H(400 MHz; $CDCl_3$) − 0.04 (9 H, s, $SiMe_3$), 2.20 (3 H, d, *J* 0.9, MeC=), 2.68 (3 H, s, COMe). 4.06 (3 H, s, OMe), 6.1 (1 H, s, –CH=), 7.09 (1 H, s, –CH=), 7.25–7.35 (3 H, m, ArH), 7.35–7.5 (4 H, m, ArH), 7.52 (1 H, m, ArH) and 8.42 (1 H, m, ArH); δ_C(100 MHz; $CDCl_3$) 0.2, 15.0, 26.5, 60.9, 98.8, 100.1, 116.0, 119.0, 123.5, 123.7, 126.7, 127.7, 128.2, 129.3, 131.4, 133.5, 137.9, 148.0, 153.4 and 169.8; *m*/*z* 419 (M^+, 28%), 388 (22), 362 (23), 346 (48), 272 (25) and 73 (100).

1-*Acetyl*-2-*methoxy*-3-[(1Z,3E)-3-*methyl*-2-(*trimethylsiloxy*)-*penta*-1,3-*dienyl*]*indole* **12b**.—A solution of the indole **11b** (2.32 g, 8.14 mmol) and HMDS (3.04 g, 18.9 mmol) in dry methylene dichloride (120 cm^3) was kept at room temperature for 30 min under argon, and was then cooled to −20 °C. TMSI (2.79 g, 13.95 mmol) was added to the solution. The reaction mixture was stirred at the same temperature for 10 min and at room temperature for 2 h. After concentration, the residue was

purified by column chromatography on silica gel with ethyl acetate–hexane (1:15) as eluent to give the *silylenol ether* **12b** (2.85 g, 98%), m.p. 84–85 °C (from EtOH) (Found: C, 67.2; H, 7.75; N, 3.85. $C_{20}H_{27}NO_3Si$ requires C, 67.2; H, 7.6; N, 3.9%); $\nu_{max}(CHCl_3)/cm^{-1}$ 1698 (C=O) and 1634 (C=C); δ_H(400 MHz; $CDCl_3$) − 0.13 (9H,s, $SiMe_3$), 1.79 (3 H, d, *J* 7, Me), 1.93 (3 H, s, Me), 2.64 (3 H, s, COMe), 4.00 (3 H, s, OMe), 5.84 (1 H, s, –CH=), 6.08 (1 H, q, *J* 7.1, –CH=), 7.2–7.25 (2 H, m, ArH), 7.41 (1 H, m, ArH) and 8.34 (1 H, m, ArH); δ_C(100 MHz; $CDCl_3$) 0.1, 13.2, 13.9, 26.5, 60.6, 97.5, 98.8, 115.9, 118.9, 123.3, 123.4, 123.6, 128.8, 131.4, 132.4, 147.7, 153.5 and 169.8; *m/z* 357 (M^+, 49%), 300 (49), 284 (49), 210 (44) and 73 (100).

1-*Acetyl*-2-*methoxy*-3-[(1Z,3E)- *and* (1E,3E)-4-*phenyl*-2-(*trimethylsiloxy*)*buta*-1,3-*dienyl*]*indole* **12c**.—A solution of the indole **11c** (0.28 g, 0.84 mmol) and HMDS (0.54 g, 1.95 mmol) in dry methylene dichloride (13 cm^3) was kept at room temperature for 30 min, and was then cooled to −20 °C. TMSI (0.15 g, 1.44 mmol) was added to the solution. The reaction mixture was stirred at the same temperature for 10 min and at room temperature for 2 h. After concentration, the residue was purified by column chromatography on silica gel with ethyl acetate–hexane (1:15) as eluent to give the *silylenol ether* **12c** (*ZE*:*ZZ* 2:1; 0.32 g, 95%) as a yellow oil (Found: M^+, 405.1758. $C_{24}H_{27}NO_3Si$ requires M, 405.1760); $\nu_{max}(CHCl_3)/cm^{-1}$ 1700 (C=O) and 1624 (C=C); δ_H(270 MHz; $CDCl_3$) −0.16 (3 H, s, $SiMe_3$ of *Z*-isomer), 0.24 (6 H, s, $SiMe_3$ of *E*-isomer), 2.50 (1 H, s, COMe of *Z*-isomer), 2.52 (2 H, s, COMe of *E*-isomer), 3.85 (2 H, s, OMe of *E*-isomer), 3.87 (1 H, s, OMe of *Z*-isomer), 5.69 (2/3 H, s, –CH= of *E*-isomer), 5.77 (1/3 H, s, –C= of *Z*-isomer), 6.69 (2/3 H, s, CH=CH of *Z*-isomer), 6.76 (2/3 H, d, *J* 15.7, –CH= of *E*-isomer), 6.78 (2/3H, d, *J* 15.7, –CH= of *E*-isomer), 7.0–7.2 (7 H, m, ArH), 7.3–7.35 (1 H, m, ArH) and 8.2–8.27 (1 H, m, ArH); δ_C(68 MHz; $CDCl_3$) 0.2, 0.4, 26.5, 61.1, 61.3, 98.3, 98.9, 102.2, 104.6, 115.9, 116.1, 118.0, 119.1, 122.9, 123.5, 123.7, 124.0, 126.6, 126.8, 126.9, 127.7, 127.9, 128.1, 128.6, 128.7, 128.8, 128.9, 130.6, 131.4, 136.8, 147.7, 148.1, 151.0, 151.3 and 169.6; *m/z* 405 (M^+, 100%), 390 (40), 363 (31), 348 (75), 258 (24) and 73 (47).

9-*Acetyl*-2-*methyl*-1-*phenyl*-3-(*trimethylsiloxy*)-9H-*carbazole* **14a** *and* 9-*Acetyl*-2-*methyl*-1-*phenyl*-9H-*carbazol*-3-*ol* **15a**; *Thermal Cyclization of the Indole* **12a**.—A solution of the silylenol ether **12a** (0.36 g, 0.87 mmol) in dry *cis*-decalin (10 cm^3) was refluxed for 5.5 h under argon. The reaction mixture was concentrated under reduced pressure, and the residue was chromatographed on silica gel. Elution with chloroform–hexane (1:1) gave the siloxycarbazole **14a** (0.18 g, 53%), $\nu_{max}(CHCl_3)/cm^{-1}$ 1700 (C=O); δ_H(60 MHz; $CDCl_3$) 0.37 (9 H, s, $SiMe_3$), 1.63 (3 H, s, Me), 2.20 (3 H, s, COMe), 7.05–7.5 (9 H, m, ArH) and 7.65–8.03 (1 H, m, ArH). Further elution with the same solvent gave the *hydroxycarbazole* **15a** (0.04 g, 13%), m.p. 218 °C (from benzene) (Found: 80.0; H, 5.25; N, 4.5, $C_{21}H_{17}NO_2$ requires C, 80.0; H, 5.4; N, 4.45%); $\nu_{max}(CHCl_3)/cm^{-1}$ 3612, 3420 (OH) and 1700 (C=O); δ_H(270 MHz; $CDCl_3$) 1.65 (3 H, s, Me), 2.29 (3 H, s, COMe), 5.22 (1 H, br, OH), 7.25–7.55 (8 H, m, ArH), 7.84 (1 H, dd, *J* 1.0 and 7.6, ArH) and 8.07 (1 H, dd, *J* 1.0 and 7.2, ArH); δ_C(68 MHz; $CDCl_3$) 14.1, 26.4, 104.8, 114.6, 119.3, 122.7, 123.0, 125.2, 126.6, 127.3, 127.7, 129.0, 130.4, 130.7, 132.6, 138.7, 140.4, 151.5 and 173.0; *m/z* 315 (M^+, 19%) and 273 (100).

9-*Acetyl*-2-*methyl*-1-*phenyl*-9H-*carbazol*-3-*ol* **15a**; *Desilylation of the Siloxycarbazole* **14a**.—The siloxycarbazole **14a** (0.76 g, 1.96 mmol) was treated with TBAF (0.62 g, 2.39 mmol) in THF (35 cm^3) at 0 °C for 10 min. The resulting mixture was extracted with chloroform (200 cm^3), and the extract was dried over $MgSO_4$ and concentrated to give the hydroxycarbazole **15a** (0.5 g, 81%), whose IR and ^1H NMR spectra were identical with those of the sample obtained in the preceding experiment.

9-*Acetyl*-1,2-*dimethyl*-9H-*carbazol*-3-*ol* **15b**.—A solution of the silylenol ether **12b** (0.47 g, 1.3 mmol) in dry *cis*-decalin (24 cm^3) was refluxed for 37 h. The reaction mixture was concentrated under reduced pressure, and the residue was treated with a solution of TBAF (0.35 g, 1.32 mmol) in THF (10 cm^3) at room temperature for 25 min. The solvent was evaporated off and the residue was chromatographed on silica gel with methylene dichloride–hexane (15:1) as eluent to give the *carbazole* **15b** (0.13 g, 40%), m.p. 165–167 °C (from Et_2O) (Found: M^+, 253.1100. $C_{16}H_{15}NO_2$ requires *M*, 253.1103); $\nu_{max}(CHCl_3)/cm^{-1}$ 3660, 3420 (OH) and 1698 (C=O); δ_H(270 MHz; $CDCl_3$) 2.32 (3 H, s, Me), 2.36 (3 H, s, Me), 2.59 (3 H, s, COMe), 5.15 (1 H, br, OH), 7.26 (1 H, s, ArH), 7.31 (1 H, ddd, *J* 1.0, 7.3 and 7.5, ArH), 7.41 (1 H, ddd, *J* 1.3, 7.3 and 8.2, ArH), 7.77 (1 H, dd, *J* 1.0 and 7.5, ArH) and 8.01 (1 H, d, *J* 8.2, ArH); δ_C(68 MHz; $CDCl_3$) 12.5, 18.7, 26.6, 103.1, 115.1, 119.6, 123.4, 123.7, 126.2, 126.4, 126.8, 126.9, 134.3, 140.7, 151.3 and 171.6; *m/z* 253 (M^+, 36%), 211 (100), 196 (11), 180 (11) and 167 (14).

9-*Acetyl*-1-*phenyl*-9H-*carbazol*-3-*ol* **15c**.—A solution of the silylenol ether **12c** (0.41 g, 1 mmol) in dry *cis*-decalin (10 cm^3) was refluxed for 7 h. After removal of solvent, the residue was chromatographed on silica gel with chloroform–hexane (4:1) as eluent to give the silyloxycarbazole **14c** as an oil (0.27 g), $\nu_{max}(CHCl_3)/cm^{-1}$ 1700 (C=O) and 1618 (C=C); δ_H(60 MHz; $CDCl_3$) 0.37 (9 H, s, SiMe3), 1.70 (3 H, s, COMe) and 6.9–8.4 (11 H, m, ArH).

The oil was diluted with THF (12 cm^3), and then the solution was treated with TBAF (0.25 g, 0.8 mmol) at 0 °C for 10 min. The reaction mixture was extracted with methylene dichloride (100 cm^3), and the extract was washed with water, dried over $MgSO_4$, and concentrated under reduced pressure. The residue was purified by column chromatography on silica gel with methylene dichloride to give the *carbazole* **15c** (0.17 g, 60%), m.p. 193–196 °C (from benzene) (Found: C, 79.75; H, 4.8; N, 4.6. $C_{20}H_{15}NO_2$ requires C, 79.7; H, 5.0; N, 4.65%); ν_{max}(KBr)/cm^{-1} 3186 (OH), 1656 (C=O) and 1621; δ_H(270 MHz; $CDCl_3$) 1.73 (3 H, s, COMe), 5.03 (1 H, br, OH), 6.99 (1 H, d, *J* 2.3, ArH), 7.3–7.6 (8 H, m, ArH), 7.92 (1 H, d, *J* 7.0, ArH) and 8.23 (1 H, d, *J* 7.3, ArH); δ_C(68 MHz; $CDCl_3$) 26.2, 105.0, 115.3, 117.0, 119.7, 123.4, 125.2, 127.7, 127.9, 128.0, 129.6, 130.0, 131.4, 140.4, 140.9, 152.9 and 172.4; *m/z* 301 (M^+, 27%), 259 (100), 230 (12) and 228 (10).

1-*Phenyl*-9H-*carbazol*-3-*ol* **4**.—A mixture of the carbazole **15c** (15 mg, 0.05 mmol), 33% aq. NaOH (0.5 cm^3), and TBAHS (1 mg) in benzene (2 cm^3) was vigorously stirred under reflux for 1.5 h. The mixture was extracted with ethyl acetate (10 cm^3). The extract was washed with water, dried over $MgSO_4$, and concentrated under reduced pressure. The residue was chromatographed on silica gel with hexane–ethyl acetate (4:1) as eluent to give the hydroxycarbazole **4** (12.4 mg, 97%) as an oil (Found M^+, 259.0993. $C_{18}H_{13}NO$ requires *M*, 259.0989); $\nu_{max}(CHCl_3)/cm^{-1}$ 3622 (OH) and 3492 (NH); δ_H(270 MHz; $CDCl_3$) 4.85 (1 H, br, OH), 7.00 (1 H, d, *J* 2.6, ArH), 7.19 (1 H, ddd, *J* 2.3, 6.0 and 7.9, ArH), 7.34–7.4 (2 H, m, ArH), 7.44 (1 H, d, *J* 7.3, ArH), 7.49 (1 H, d, *J* 2.6, ArH), 7.53 (2 H, t, *J* 7.3, ArH), 7.65 (2 H, d, *J* 7.3, ArH), 8.00 (1 H, d, *J* 7.9, ArH) and 8.12 (1 H, br, NH); δ_C(68 MHz; $CDCl_3$) 104.9, 110.8, 114.6, 119.1, 120.5, 123.2, 124.5, 125.7, 126.1, 127.7, 128.3, 129.2, 132.3, 138.5, 140.3 and 149.6; *m/z* 259 (M^+, 100%), 230 (14) and 129 (11).

Hyellazole **1**.—A mixture of the hydroxycarbazole **15a** (0.32

g, 1 mmol), dimethyl sulfate (0.15 g, 1.2 mmol), TBAHS (0.03 g, 0.01 mmol), and 50% aq. NaOH (1 cm^3) in benzene (10 cm^3) was vigorously stirred at room temperature for 10 min. The reaction mixture was extracted with methylene dichloride (200 cm^3), and the extract was washed with water, dried over $MgSO_4$, and evaporated under reduced pressure to give the curd product **16a**.

The product **16a** was diluted with benzene (10 cm^3), and 50% aq. NaOH (1 cm^3) and TBAHS (0.03 g, 0.1 mmol) were added to the solution. The mixture was heated under reflux, with vigorous stirring for 1.5 h, and extracted with methylene dichloride (200 cm^3). The extract was washed with water and dried over $MgSO_4$. Work-up of the extract gave a residue, which was chromatographed on silica gel with methylene dichloride–hexane (1:1) as eluent to give hyellazole **1** (0.2 g, 72%), m.p. 137–138 °C (from hexane) (lit.,[2,5b,8] m.p. 133–134 °C; lit.,[10] m.p. 132–133 °C) (Found: C, 83.7; H, 5.8; N, 4.9. Calc. for $C_{20}H_{17}NO$: C, 83.6; H, 5.95; N, 4.9%); λ_{max}(EtOH)/nm 351 (ε/dm^3 mol^{-1} cm^{-1} 5760), 339 (4300), 305 (18 300), 296 (13 900), 265 (16 400), 251 (20 900), 239 (31 900), 234 (32 300) and 225 (31 800); $\nu_{max}(CHCl_3)/cm^{-1}$ 3490 (NH), 1458, 1426, 1308, 1212, 1156 and 1149; δ_H(60 MHz; [$^2H_6$]acetone) 2.1 (3 H, s, Me), 3.93 (3 H, s, OMe), 6.9–7.55 (9 H, m, ArH), 7.97 (1 H, d, *J* 8, ArH) and 9.28 (1 H, br, NH); δ_H(400 MHz; $CDCl_3$) 2.21 (3 H, s, Me), 3.99 (3 H, s, OMe), 7.18 (1 H, ddd, *J* 1.2, 7.0 and 7.9, ArH), 7.27 (1 H, d, *J* 7.6, ArH), 7.32 (1 H, dt, *J* 1.2 and 8.0, ArH), 7.4–7.6 (5 H, m, ArH), 7.52 (1 H, s, ArH), 7.61 (1 H, br s, NH) and 8.03 (1 H, d, *J* 7.6, ArH); δ_C(100 MHz; $CDCl_3$) 13.7, 56.2, 100.4, 110.6, 118.9, 119.9, 120.4, 123.7, 123.9, 125.1, 125.6, 127.6, 128.9, 129.0, 129.89, 129.93, 133.3, 137.6, 139.5 and 152.8; *m/z* 287 (M^+, 100), 272 (67), 254 (21), 143 (10) and 120 (12).

9-*Acetyl*-3-*methoxy*-1,2-*dimethyl*-9H-*carbazole* **16b**.—A mixture of the carbazole **15b** (36 mg, 0.14 mmol), methyl iodide (0.3 cm^3), and potassium carbonate (0.3 g, 2.18 mmol) in acetone (3 cm^3) was heated under reflux with vigorous stirring for 6 h. The mixture was diluted with diethyl ether (20 cm^3), filtered, and concentrated. The residue was chromatographed on silica gel with ethyl acetate–hexane (1:3) as eluent to give the *methoxycarbazole* **16b** (37.5 mg, 98%), m.p. 104–105 °C (from hexane–diethyl ether) (lit.,[8b] oil) (Found: M^+, 267.1263. $C_{17}H_{17}NO_2$ requires *M*, 267.1259); $\nu_{max}(CHCl_3)/cm^{-1}$ 1697 (C=O) and 1600; δ_H(270 MHz; $CDCl_3$) 2.31 (3 H, s, Me), 2.36 (3 H, s, Me), 2.58 (3 H, s, COMe), 3.95 (3 H, s, OMe), 7.28 (1 H, s, ArH), 7.32 (1 H, ddd, *J* 1.3, 7.2 and 7.6, ArH), 7.40 (1 H, ddd, *J* 1.3, 7.2 and 7.9, ArH), 7.87 (1 H, dd, *J* 1.3 and 7.6, ArH) and 8.02 (1 H, dd, *J* 1.3 and 7.9, ArH); δ_C(68 MHz; $CDCl_3$) 12.5, 18.6, 26.6, 56.0, 98.6, 115.0, 119.3, 123.3, 125.8, 126.0, 126.1, 126.6, 127.0, 134.1, 140.5, 155.3 and 171.4; *m/z* 267 (M^+, 58%), 225 (96), 210 (100), 180 (27) and 167 (15).

3-*Methoxy*-1,2-*dimethyl*-9H-*carbazole* (4-*Deoxycarbazomycin B*) **2c**.—A mixture of the acetylcarbazole **16b** (19 mg, 0.07 mmol), TBAHS (1 mg), 35% aq. NaOH (0.1 cm^3), and benzene (1 cm^3) was heated under reflux with vigorous stirring for 1.5 h. The reaction mixture was extracted with ethyl acetate (15 cm^3), and the extract was washed with water, dried over $MgSO_4$, and concentrated under reduced pressure. The residue was purified by column chromatography on silica gel with chloroform to give 4-*deoxycarbazomycin B* **2c** (13 mg, 86%), m.p. 137–138 °C (from hexane–diethyl ether) (lit.,[3] 129–130 °C; lit.,[7] 129–131 °C; lit.,[8] 120–121 °C; lit.,[9] 130–132 °C) (Found: M^+, 225.1150. $C_{15}H_{15}NO$ requires *M*, 225.1154); $\nu_{max}(CHCl_3)/cm^{-1}$ 3498 (NH), 1497, 1458, 1430, 1309, 1275, 1162, 1149, 1114 and 1103; δ_H(270 MHz; $CDCl_3$) 2.34 (3 H, s, Me), 2.44 (3 H, s, Me), 3.94 (3 H, s, OMe), 7.18 (1 H, ddd, *J* 1.3, 6.6 and 7.0, ArH), 7.3–7.45 (2 H, m, ArH), 7.38 (1 H, s, ArH), 7.75 (1 H, br, NH) and 8.03 (1 H, d, *J* 7.9, ArH); δ_C(68 MHz; $CDCl_3$) 12.3, 13.9, 56.3, 99.0, 110.7, 118.9, 119.0, 119.9, 120.1, 124.1, 124.2, 124.9, 134.1, 139.6 and 152.6; *m/z* 225 (M^+, 41%), 210 (100), 180 (55), 167 (66) and 152 (12).

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