[4 + 2]Cycloaddition of indole derivatives with bismaleimides: a route to new biscarbazoles

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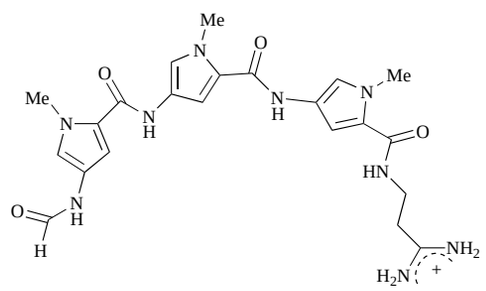
New results for the reaction of *in situ* generated *N*-acylindole-2,3-quinodimethanes and donor-/acceptor-substituted 3-vinylindoles with some bismaleimides are described. By a [4 + 2]cycloaddition process, a variety of biscarbazoles are formed *endo*-selectively. These conformationally flexible molecules constitute a new class of compounds believed to have potential as DNA minor groove binding ligands.

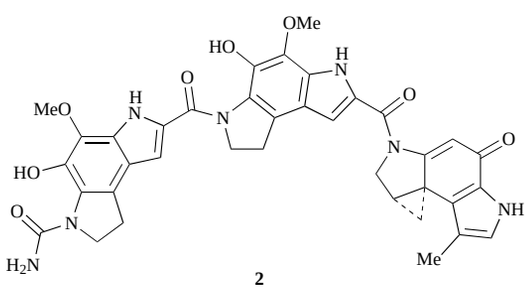
Introduction

In recent years DNA minor groove-binding ligands possessing pronounced sequence specificity for the oligonucleotide matrix derived from natural sources or from synthesis have often been studied because of their sequence-recognizing ability, their ability to control transcription processes in the presence of DNA binding proteins and, on the molecular level, for the elucidation of binding modes and of specific structural parameters.[1–3] Some outstanding examples of these ligands with pronounced antitumour activity are distamycin A **1**[3,4] or (+)-CC 1065 **2**,[3,5]



1

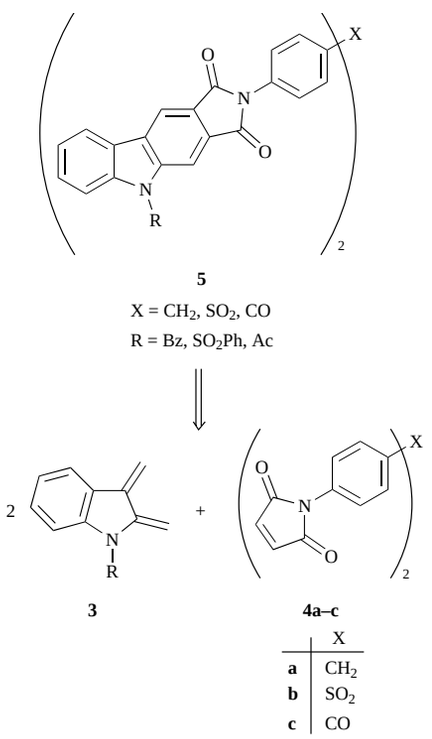
Distamycin A



2

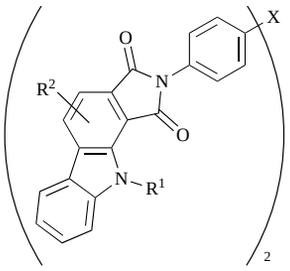
(+)-CC-1065

respectively. Both compounds are able to adopt a convex and helical conformation and thus bind to the minor groove of DNA by fitting the helical curvature of the DNA ('isohelicity'[3]). The complexes formed are stabilized by hydrogen bonds, and additionally by electrostatic, van der Waals and hydrophobic forces.[3] Additionally, the cyclopropane moiety of drug **2** is able to alkylate the N-3 of adenine in double-stranded DNA.[5] With these leading drugs in mind and additionally considering the DNA intercalative potential of anellated carbazoles,[3,8] we have now focused our synthetic attention on the structurally related biscarbazoles of type **5** and **7** (Schemes 1 and 2) or the partially hydrogenated analogues thereof. On the basis of our investigations on pericyclic reactions to give carbazole derivatives and carbazole alkaloids,[6–8] the Diels–Alder reactions of appropriate indole-2,3-quinodimethanes **3** or 3-vinylindoles **6** with some bisdienophiles as linking structural elements represents an interesting strategy leading to these new compounds on the basis of retrosynthetic analysis (Schemes 1 and 2).



Scheme 1

In this context, the Diels–Alder reactions of *N*-benzoylindole-2,3-quinodimethane with some mono dienophiles and a bisdienophile were earlier reported by our group.[9–11] Although the general success of this cycloaddition strategy has been documented fairly well, continued investigation of this type of reaction has particular interest in heterocyclic and medicinal chemistry. Thus, in continuation of these studies on pericyclic reactions with indole derivatives, we report some new Diels–Alder reactions of *in situ* generated *N*-substituted indole-2,3-quinodimethanes **3** and of 3-vinylindoles **6** with several bismaleimides **4** according to the strategy outlined in Schemes 1 and 2. The scope and limitation of this route are now being explored in respect of the flexibility of the reactant functionalities. The stereochemistry of the primary [4 + 2]cycloadducts



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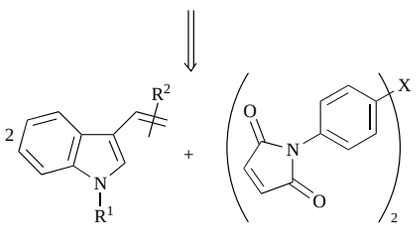
X = CH_2, CO, SO_2
R^2 = Me, OMe, CO_2Me
R^1 = Me, SO_2Ph



6 **4a–c**

Scheme 2

obtained were investigated in detail to rationalize the reaction mechanism. In a further study, the conformational properties of the new biscarbazoles to form a helical shape for optimal DNA minor groove binding and/or DNA intercalation[1,3] were investigated. In this context the present paper presents some preliminary results.

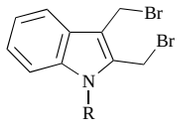
Results and discussion

Synthetic aspects

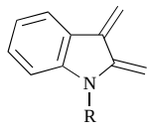
The *N*-substituted indole-2,3-quinodimethanes **3a–c** were generated *in situ* from the respective *N*-substituted 2,3-bis-(bromomethyl)indoles **8a–c** in the presence of sodium iodide *via* the 2,3-bis(iodomethyl) derivative, in accordance with the method we have already reported,[10–11] but with some variations in the reaction conditions. In a molar ratio of 2:1 of **3** and **4**, the indole-2,3-quinodimethanes **3** were readily captured by the bismaleimides **4a–c** to give rise to double Diels–Alder adducts **9a–i** with two pyrrolo[*b*]anellated carbazole structures in 60–70% yield. In all cases, the *meso* forms were produced (TLC reaction control supported by HPLC analysis; see also structural aspects).

In the case of the Diels–Alder reactions of 3-vinylindoles **6a–c** with bismaleimides **4**, we expected the formation of new pyrrolo[*a*]anellated biscarbazoles of type **7**, with a more convex molecular structure. The respective 3-vinylindoles **6a–c** were readily available from a known Wittig procedure developed by us.[8] Thus, the 3-isopropenyl-1-phenylsulfonyl-1*H*-indole **6a** reacted stereoselectively with the bismaleimide **4a** in a 2:1 ratio at room temperature to furnish the *endo*,*endo*-bis and *endo*-mono-[4 + 2]cycloadducts **10a** and **11a**. Similarly, the *E*/*Z* mixture (ratio 2:1) of the 3-vinylindole **6b** also reacted stereoselectively with the bismaleimide **4a** at room temperature to give a mixture of double and mono *endo*-Diels–Alder products **10b** and **11b**. The results confirm that the *E*-isomer of **6b** should be the more reactive isomer, because the *E* stereochemistry is preserved formally in the cycloadducts.[6] Furthermore, the selective reaction of the mono cycloadduct **11b** with the corresponding vinylindole **6b** was monitored by TLC and the formation of the biscarbazole **10b** from the monocarbazole **11b** could be detected.

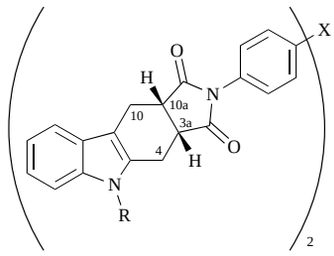
The electronically less reactive 3-vinylindole **6c** reacted with the bisdienophile **4a** only under reflux in chloroform to afford exclusively a double Diels–Alder cycloadduct **12**. In this case,



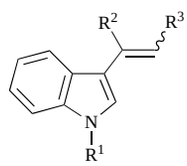
8 R
a Bz
b SO_2Ph
c Ac



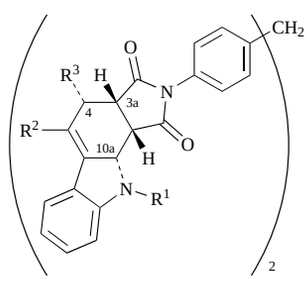
3 R
a Bz
b SO_2Ph
c Ac



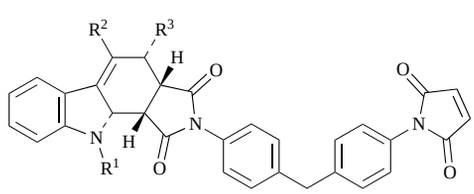
meso–**9**	**a**	**b**	**c**	**d**	**e**	**f**	**g**	**h**	**i**
X	CH_2	CH_2	CH_2	SO_2	SO_2	SO_2	CO	CO	CO
R	Bz	SO_2Ph	Bz	Bz	SO_2Ph	Ac	Bz	SO_2Ph	Ac



6	R^1	R^2	R^3
a	SO_2Ph	Me	H
b	SO_2Ph	H	OMe (*E*/*Z* = 2:1)
c	Me	H	CO_2Me (*E*)



meso–**10**	R^1	R^2	R^3
a	SO_2Ph	Me	H
b	SO_2Ph	H	OMe

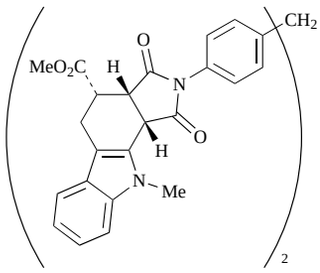


11	R^1	R^2	R^3
a	SO_2Ph	Me	H
b	SO_2Ph	H	OMe

the primarily formed cycloadduct undergoes double-bond isomerization to give rise to the dimeric and 'indolized' carbazole **12** by a formal [1,3]-H shift in the cycloadduct primarily formed.

Structural aspects

From the double Diels–Alder adducts **9**, a maximum of 16 stereoisomers is possible by formation of 4 stereocentres. On the basis of *cis*-selectivity in the repetitive Diels–Alder step,[6] a total of 3 stereoisomers would be expected: a *meso* form with C_s-symmetry and a pair of enantiomers with C_1-symmetry.



meso–**12**

However, from the Diels–Alder reaction of the 3-vinylindoles **6a** and **6c**, 6 or in the case of the β-methoxy substituted educt **6b**, 8 new stereocentres are generated in the products. Thus, a theoretical maximum of 64 or 256 stereoisomers is possible with all combinations. In the reaction of the 3-vinylindoles **6a** and **6c**, 2 *meso* forms with C_s and 6 pairs of enantiomers with C_1-symmetry could be formed. In the Diels–Alder reaction of the β-methoxy substituted 3-vinylindole **6b**, 4 *meso* forms (C_s) and 28 pairs of enantiomers (C_1) are to be expected. However, in accordance with the Diels–Alder *cis*-selectivity and *endo*-stereoselectivity and on the basis of ^{1}H and ^{13}C NMR investigations (600 MHz ^{1}H, 400 MHz ^{1}H and 100.6 MHz ^{13}C NMR spectra exhibit only one set of signals) we are sure, that in all cases *meso* forms of biscarbazoles **9**, **10** and **12** are produced under the given conditions as main products.

The constitution of the [*b*]- and [*a*]-anellated biscarbazoles **9**, **10** and **12** and monocarbazoles **11** was first of all elucidated in more detail, by routine high resolution ^{1}H and ^{13}C NMR spectroscopy. The stereochemistry of compounds **9**–**12** was established by detailed NMR studies and by comparison of NMR data previously reported for similar stereo compounds of anellated carbazoles.[6,7,13–15] Proton-proton decoupling experiments, spin-echo experiments, 1D NOE studies and application of several 2D NMR techniques allowed unequivocal characterization of all the compounds.

For example, in the case of the Diels–Alder products **9**, only one set of signals is formed for the two pyrrolo[*b*]carbazole moieties, even in the 600 MHz ^{1}H NMR spectra. On the basis of symmetry considerations, the *meso* form is thus valid. The two-proton ABX-spin systems in both cyclohexene rings were differentiated by NOE studies (Fig. 1) in combination with H,H-COSY, H,C-COSY and HMBC experiments. A coupling constant between 3a-H and 10a-H of 8.5–8.9 Hz (600 MHz) confirms the *cis* configuration in all carbazoles **9**. This value is fairly supported by the computer-generated model (AM1 geometry[18]) for compound **9c** (Fig. 1) using the Altona equation[16] [dihedral angle H–C(3a)–C(10a)–H = 13.8°] (calculated value J = 7.8 Hz). Additionally, in the case of the biscarbazole **9c** the six aliphatic proton spin system in both anellated carbazole rings was simulated by the RACCOON program.[20] For example the calculated coupling constant between 3a-H and 10a-H of 8.8 Hz on the basis of correspondence of experimental and theoretical frequencies and relative intensities in the spectrum fairly complete the configurational analysis of this new class of compounds.

In the case of pyrro[*a*]anellated biscarbazoles **10** and **12**, and monocarbazoles **11**, it is to be expected that the 10b-H and 3a-H would be *cis* disposed due to the nature of a concerted Diels–Alder reaction. The relatively low coupling constants, $J_{10b,3a}$ of 8.2–8.9 Hz, are consistent with the *cis* assignment. Vicinal coupling constants, $J_{10b,10a}$ of 4.8–6.0 Hz for compounds **10** and **11** established that the 10a-H and 10b-H are also orientated *cis* and therefore the cycloadditions were *endo* for all reactions studied. These coupling constant values are also supported fairly well by computer-generated model of molecule **10a** (Fig. 1, AM1 calculations[18]) using the Altona equation[16] [$J_{10b,3a}$ calculated value = 8.0 Hz for dihedral angle H–C(10b)–C(3a)–H = 8°; $J_{10b,10a}$ calculated value = 4.68 Hz for dihedral angle H–C(10b)–C(10a)–H = 44.1°]. These proton assignments are also in agreement with the NOE enhancement observed, *e.g.* for derivative **10a**. Fig. 1 shows the high diagnostic value of the ^{1}H{^{1}H}-NOE measurements, performed for unequivocal clarification of the relative configuration of the cycloadducts. The important NOE observed between 10b-H and 3a-H for compound **10a** is indicative of a *cis* configuration. Furthermore, this is accompanied by a very strong NOE between 10b-H and the downfield 10a-H and the strong NOE detected is indicative of a 10b-H and 10a-H *cis* relationship.

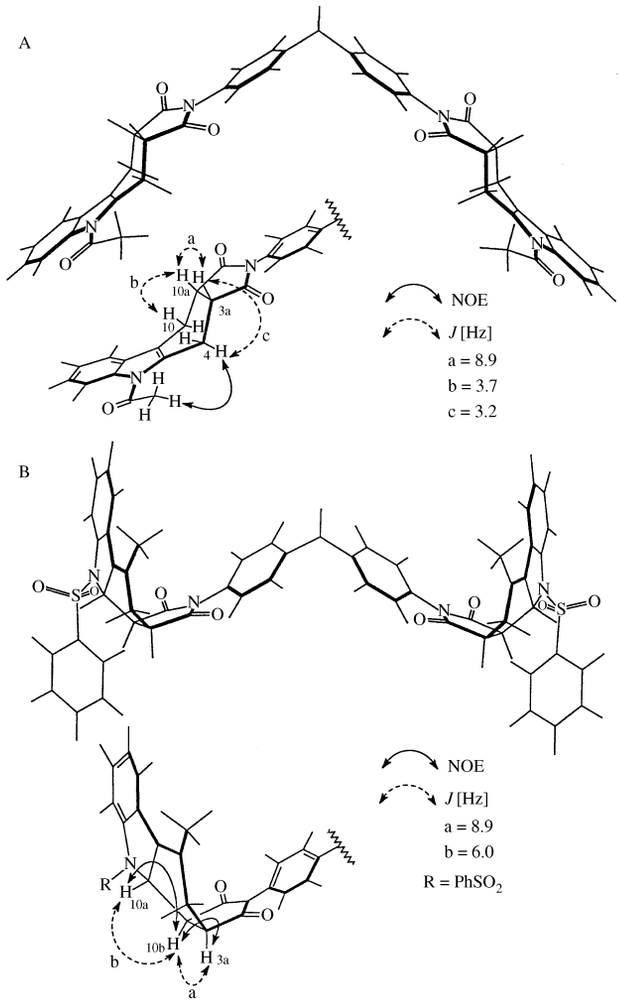


Fig. 1 AM1-minimized local conformation of biscarbazole **9c** (A) and biscarbazole **10a** (B).[18,19] NOE and some coupling constants[20] are given for constitutional and configurational analysis. Only some relevant hydrogen atoms are depicted in the formula.

Construction of Dreiding models of the biscarbazoles **9**, **10** and **12** and preliminary calculations of some conformational families by the molecular mechanics method[17] revealed that these compounds are able to adopt a helical conformation with the potential to bind into the minor groove of DNA. In an expanded project, further studies involving incorporation of several other substituents in the carbazole domain and in the 'bridge' of the molecules (including dehydrogenations)[21,22] are being worked on. DNA-binding studies, computer molecular modelling[23] and cell biological investigations are planned in the future to establish the structure–activity relationships of this new class of compounds.[3]

Experimental

General details

^{1}H and ^{13}C NMR spectra were recorded at room temperature on Bruker AC 200, 400 and Bruker AMX 600 spectrometers

using Me_4Si as internal reference; *J* values are given in Hz. The abbreviation pt refers to pseudo triplet (overlapped dd). The EI (70 eV) mass spectra were recorded on a Varian MAT 7 spectrometer and FD mass spectra were measured on a Varian CH 7a spectrometer. Ionisation modes are indicated in parentheses. Elemental analyses were performed using a Carlo Erba Strumentazione 1106 apparatus. Mps were measured with an Electrothermal 8200 instrument. Flash column chromatography was performed on Merck 60 silica gel (particle size: 0.040–0.063 mm). HPLC was performed on a Merck Hitachi L-6200 instrument with a LiChrospher® RP-18 (5 μm), 250 × 4 mm analytical column using as eluent methanol–water (4:1). The light petroleum used boiled in the range 40–60 °C. All reactions were performed in highly pure, anhydrous solvents under argon atmosphere. The yields given refer to analytically pure compounds. Substantial product loss occurred during chromatographic work-up.

General procedure for the preparation of compounds 9

To a solution of the appropriate bismaleimide **4** (0.22–1.45 mmol) and powdered sodium iodide (200 mg) in dimethylformamide or dimethoxyethene was added a solution of 2,3-bis(bromomethyl)indole **8** (0.45–2.9 mmol) in dimethylformamide or dimethoxyethane. The reaction mixture was stirred at 65 °C for 1 h after which it was treated with sodium thiosulfate and then filtered. The filtrate was concentrated to a volume of 5–10 ml under reduced pressure and the residue obtained was washed with water to give a precipitate. This was filtered off and washed with methanol. The resulting residue was purified by flash column chromatography using light petroleum–ethyl acetate as eluent (ratio 1:2).

***meso*-*N*,*N*′-Methylenedi-*p*-phenylenebis(5-benzoyl-1,2,3,3a,4,5,10,10a-octahydropyrrolo[3,4-*b*]carbazole-1,3-dione) 9a**

This compound was obtained from *in situ* generated *N*-benzoylindole-2,3-quinodimethane **3a** from *N*-benzoyl-2,3-bis(bromomethyl)indole **8a** (1.0 g, 2.45 mmol) as starting educt and the bismaleimide **4a** (400 mg, 1.11 mmol). The crude product was purified by flash column chromatography using gradient light petroleum–ethyl acetate as eluent (ratio 1:2); yield 60% (1.25 g), mp 228–233 °C (from ethanol) (Found: C, 77.33; H, 4.15; N, 6.68. $C_{55}H_{40}N_4O_6$ requires C, 77.51; H, 4.74; N, 6.57%); δ_H(400 MHz; $CDCl_3$) 3.03–3.10 (4H, m, ^2J 16.6 and ^3J 8.4, 2 × 10-Hβ and 10-Hα), 3.28–3.52 (6H, m, 2 × 4-Hβ, 2 × 10a-H and 2 × 3a-H), 3.92–3.96 (4H, d, ^2J 18.9, 2 × 4-Hα and ArCH_2Ar), 7.01–7.09 (4H, d, ^3J 8.37, 2 × 2H-phenyl), 7.11–7.26 (12H, m, 2 × 2H-phenyl, 2 × 8-H, 2 × 7-H, 2 × 9-H and 2 × 6-H), 7.46–7.50 (4H, t, 2 × 3′-H and 2 × 5′-H), 7.61–7.64 (2H, dd, 2 × 4′-H) and 7.65–7.67 (4H, d, 2 × 2′-H and 2 × 6′-H); δ_C(100.6 MHz; $CDCl_3$) 21.15 (2 × C-10), 23.70 (2 × C-4), 39.15 (2 × C-10a), 40.08 (2 × C-3a), 41.04 (ArCH_2Ar), 114.81 (2 × C-6), 115.40 (2 × C-9b), 117.91 (2 × C-9), 123.06 (2 × C-8), 123.97 (2 × C-7), 126.22 (2 × 2 × C_t-phenyl), 128.43 (2 × C-9a), 128.87 (2 × 2 × C_t-phenyl), 129.43 (2 × 2 × C_t-phenyl), 129.57 (2 × 2 × C_t-phenyl), 130.02 (2 × C_q), 132.84 (2 × C_t), 133.41 (2 × C_q), 135.37 (2 × C_q), 136.82 (2 × C_q), 140.8 (2 × C_q), 168.8 (2 × C=O, COPh), 177.77 (2 × C-1) and 178.35 (2 × C-3); *m/z* (FD) 853 (M^+, 100%), 749 (8) and 426 (22).

***meso*-*N*,*N*′-Methylenedi-*p*-phenylenebis(5-phenylsulfonyl-1,2,3,3a,4,5,10,10a-octahydropyrrolo[3,4-*b*]carbazole-1,3-dione) 9b**

This compound was obtained from *in situ* generated *N*-phenylsulfonylindole-2,3-quinodimethane **3b** from *N*-phenylsulfonyl-2,3-bis(bromomethyl)indole **8b** (200 mg, 0.45 mmol) and as the starting educt the bismaleimide **4a** (80 mg, 0.22 mmol). The product was purified by flash column chromatography using gradient light petroleum–ethyl acetate as eluent (ratio 1:2); yield 70% (290 mg), mp 151–155 °C (from ethanol) (Found: C, 68.56; H, 4.33; N, 5.86; S, 6.44. $C_{53}H_{40}N_4O_8S_2$ requires C, 68.84; H, 4.32; N, 6.05; S, 6.93%); δ_H(600 MHz; $CDCl_3$) 2.92–2.96 (2H, m, ^2J 15.35 and ^3J 8.07, 2 × 10-Hβ), 3.26–3.31 (2H, m, ^2J 17.91 and ^3J 8.6, 2 × 4-Hβ), 3.31–3.34 (2H, d, ^2J 16.37 and ^3J 3.17, 2 × 10-Hα), 3.45–3.49 (2H, ddd, ^3J 8.6, 2 × 10a-H), 3.54–3.57 (2H, ddd, ^3J 7.03, 2 × 3a-H), 3.94 (2H, s, ArCH_2Ar), 4.05–4.08 (2H, d, ^2J 17.51, 2 × 4-Hα), 6.86–6.87 (4H, d, ^3J 8.42, 2 × 2H-phenyl), 7.11–7.13 (4H, d, ^3J 8.43, 2 × 2H-phenyl), 7.24–7.35 (8H, m, 2 × 8-H, 2 × 7-H, 2 × 9-H, 2 × 6-H), 7.35–7.41 (4H, m, 2 × 3′-H and 2 × 5′-H), 7.8–7.81 (2H, d, 2 × 4′-H) and 8.16–8.17 (4H, d, 2 × 2′-H and 2 × 6′-H); δ_C(150.9 MHz; $CDCl_3$) 20.70 (2 × C-10), 22.60 (2 × C-4), 38.50 (2 × C-10a), 39.65 (2 × C-3a), 41.04 (ArCH_2Ar), 114.53 (2 × C-6), 116.47 (2 × C-9b), 118.24 (2 × C-9), 123.61 (2 × C-8), 124.77 (2 × C-7), 126.25 (2 × 2 × C_t-phenyl), 126.47 (2 × 2 × C_t-phenyl), 128.65 (2 × C-9a), 129.28 (2 × 2 × C_t-phenyl), 129.37 (2 × 2 × C_t-phenyl), 129.98 (2 × C_q), 132.20 (2 × C_q), 133.66 (2 × C_q), 136.33 (2 × C_t), 138.51 (2 × C_q), 140.83 (2 × C_q), 177.81 (2 × C-1) and 178.17 (2 × C-3); *m/z* (FD) 924 (M^+, 100%), 784 (4), 701 (4), 641 (7) and 462 (16).

***meso*-*N*,*N*′-Methylenedi-*p*-phenylenebis(5-acetyl-1,2,3,3a,4,5,10,10a-octahydropyrrolo[3,4-*b*]carbazole-1,3-dione) 9c**

This compound was obtained from *in situ* generated *N*-acetylindole-2,3-quinodimethane **3c** from *N*-acetyl-2,3-bis(bromomethyl)indole **8c** (400 mg, 1.16 mmol) as the starting educt and the bismaleimide **4a** (200 mg, 0.58 mmol). The product was purified by flash column chromatography using gradient light petroleum–ethyl acetate as eluent (ratio 1:2); yield 60% (220 mg), mp 180–183 °C (from ethanol). Several purification methods were used. In all cases the compound included ethanol in a non-stoichiometric ratio. Therefore the results of elemental analysis are given with the inclusion of ethanol (0.2 mol) (Found: C, 73.32; H, 4.89; N, 7.51. $C_{45}H_{36}N_4O_6$ requires C, 73.27; H, 4.88; N, 7.59%); δ_H(600 MHz; acetone) 2.73 (6H, s, 2 × CH_3), 3.03–3.07 (2H, dd, ^2J 15.98 and ^3J 8.4, 2 × 10-Hβ), 3.25–3.29 (2H, dd, ^2J 15.95 and ^3J 3.7, 2 × 10-Hα), 3.39–3.43 (2H, dd, ^2J 15.86 and ^3J 8.06, 2 × 4-Hβ), 3.59–3.63 (2H, ddd, ^3J 8.5, 2 × 10a-H), 3.69–3.72 (2H, ddd, ^3J 8.15, 2 × 3a-H), 3.82–3.86 (2H, dd, ^2J 17.11 and ^3J 3.20, 2 × 4-Hα), 3.94 (2H, s, ArCH_2Ar), 7.02–7.04 (4H, d, ^3J 8.52, 2 × 2H-phenyl), 7.19–7.21 (4H, d, ^3J 8.85, 2 × 2H-phenyl), 7.21–7.24 (2H, ^3J 7.4, ddd, 2 × 8-H), 7.24–7.27 (2H, ddd, ^3J 7.6, 2 × 7-H), 7.51–7.52 (2H, d, ^3J 7.13, 2 × 9-H), 8.07–8.08 (2H, d, ^3J 7.66, 2 × 6-H) ethanol 1.20 (3H, t, CH_3), 2.10 (1H, s, OH) and 3.53 (2H, q, CH_2); δ_C(150.9 MHz; $CDCl_3$) 20.60 (2 × C-10), 24.03 (2 × C-4), 27.22 (2 × CH_3), 38.70 (2 × C-10a), 40.06 (2 × C-3a), 41.00 (ArCH_2Ar), 115.19 (2 × C-6), 115.70 (2 × C-9b), 118.02 (2 × C-9), 123.29 (2 × C-8), 124.57 (2 × C-7), 126.21 (2 × 2 × C_t-phenyl), 128.80 (2 × C-9a), 129.52 (2 × 2 × C_t-phenyl), 130.02 (2 × C_q), 133.03 (2 × C_q), 135.98 (2 × C_q), 140.79 (2 × C_q), 169.58 (2 × C=O, Ac), 178.04 (2 × C-1) and 178.36 (2 × C-3); *m/z* (FD) 728 (M^+, 100%), 691 (40) and 647 (21).

***meso*-*N*,*N*′-Sulfonyldi-*p*-phenylenebis(5-benzoyl-1,2,3,3a,4,5,10,10a-octahydropyrrolo[3,4-*b*]carbazole-1,3-dione) 9d**

This compound was obtained from *in situ* generated *N*-benzoylindole-2,3-quinodimethane **3a** from *N*-benzoyl-2,3-bis(bromomethyl)indole **8a** (1000 mg, 2.45 mmol) as the starting educt and the bismaleimide **4b** (500 mg, 1.22 mmol). The product was purified by flash column chromatography using gradient light petroleum–ethyl acetate as eluent (ratio 1:2); yield 80% (1.76 g), mp 175–180 °C (from ethanol) (Found: C, 71.38; H, 4.16; N, 6.00; S, 4.61. $C_{54}H_{38}N_4O_8S$ requires C, 71.85; H, 4.21; N, 6.20; S, 3.55%); δ_H(400 MHz; $CDCl_3$) 3.03–3.09 (4H, dd, ^2J 15.65 and ^3J 8.53, 2 × 10-Hβ, 2 × 4-Hβ), 3.31–3.43 (4H, m, 2 × 10-Hα, 2 × 4-Hα), 3.43–3.55 (4H, m, ^3J 8.2, 2 × 10a-H, ^3J 8.16, 2 × 3a-H), 7.06–7.10 (2H, d, 2 × 9-H), 7.16–7.23 (4H, m, 2H-phenyl), 7.32–7.38 (4H, m, 2 × 2H-phenyl), 7.43–7.59 (6H, m, 2 × 8-H, 2 × 7-H, 2 × 6-H), 7.6–7.65 (6H, m,

2 × 3′-H, 2 × 5′-H and 2 × 4′-H) and 7.86–7.96 (4H, d, 2 × 2′-H and 2 × 6′-H); δ_C(100.6 MHz; $CDCl_3$) 20.75 (2 × C-10), 23.57 (2 × C-4), 39.18 (2 × C-10a), 40.12 (2 × C-3a), 114.79 (2 × C-6), 115.24 (2 × C-9b), 117.9 (2 × C-9), 123.08 (2 × C-8), 124.04 (2 × C-7), 126.58 (2 × 2 × C_t-phenyl), 128.30 (2 × C-9a), 128.50 (2 × 2 × C_t-phenyl), 128.9 (2 × 2 × C_t-phenyl), 129.44 (2 × 2 × C_t-phenyl), 132.92 (2 × C_t), 133.25 (2 × C_q), 135.25 (2 × C_q), 136.27 (2 × C_q), 136.8 (2 × C_q), 140.58 (2 × C_q), 168.78 (2 × C=O, COPh), 177.08 (2 × C-1) and 177.61 (2 × C-3); *m/z* (FD) 902 (M^+, 100%), 798 (7), 657 (5), 617 (6) and 451 (4).

meso-*N*,*N*′-Sulfonyldi-*p*-phenylenebis(5-phenylsulfonyl-1,2,3,3a,4,5,10,10a-octahydropyrrolo[3,4-*b*]carbazole-1,3-dione) 9e

This compound was obtained from *in situ* generated *N*-phenylsulfonylindole-2,3-quinodimethane **3b** from *N*-phenylsulfonyl-2,3-bis(bromomethyl)indole **8b** (200 mg, 0.45 mmol) as starting educt and the bismaleimide **4b** (92 mg, 0.22 mmol). The product was purified by flash column chromatography using gradient light petroleum–ethyl acetate as eluent (ratio 1:2); yield 80% (350 mg), mp 176–180 °C (from ethanol) (Found: C, 63.97; H, 3.99; N, 5.67; S, 9.93. $C_{52}H_{38}N_4O_{10}S_3$ requires C, 64.07; H, 3.89; N, 5.74; S, 9.86%); δ_H(200 MHz; DMSO) 2.93–3.05 (2H, m, ^2J 15.9 and ^3J 8.32, 2 × 10-Hβ), 3.1–3.2 (2H, m, ^2J 16.2 and ^3J 3.48, 2 × 4-Hβ), 3.34–3.46 (2H, m, 2 × 10-Hα), 3.55–3.77 (6H, m, 2 × 10a-H, 2 × 3a-H and 2 × 4-Hα), 7.22–7.55 (16H, m, 2 × 9-H, 2 × 2H-phenyl, 2 × 2H-phenyl, 2 × 8-H, 2 × 7-H, 2 × 6-H), 7.77–7.81 (4H, d, 2 × 3′-H, 2 × 5′-H) and 7.86–7.96 (6H, m, 2 × 2′-H, 2 × 6′-H and 2 × 4′-H); δ_C(50.3 MHz; DMSO) 19.67 (2 × C-10), 21.81 (2 × C-4), 37.96 (2 × C-10a), 38.86 (2 × C-3a), 113.90 (2 × C-6), 116.90 (2 × C-9b), 118.49 (2 × C-9), 123.63 (2 × C-8), 124.52 (2 × C-7), 125.98 (2 × 2 × C_t-phenyl), 127.48 (2 × 2 × C_t-phenyl), 128.08 (2 × 2 × C_t-phenyl), 128.54 (2 × C-9a), 129.60 (2 × 2 × C_t-phenyl), 132.61 (2 × C_t), 134.28 (2 × C_q), 135.41 (2 × C_q), 136.53 (2 × C_q), 137.26 (2 × C_q), 139.95 (2 × C_q), 177.81 (2 × C-1), 177.95 (2 × C-3); *m/z* (FD) 974 (M^+, 100%), 830 (16) and 487 (15).

meso-*N*,*N*′-Sulfonyldi-*p*-phenylenebis(5-acetyl-1,2,3,3a,4,5,10,10a-octahydropyrrolo[3,4-*b*]carbazole-1,3-dione) 9f

This compound was obtained from *in situ* generated *N*-acetylindole-2,3-quinodimethane **3c** from *N*-acetyl-2,3-bis(bromomethyl)indole **8c** (1000 mg, 2.9 mmol) as the starting educt and the bismaleimide **4b** (590 mg, 1.45 mmol). The product was purified by flash column chromatography using gradient light petroleum–ethyl acetate as eluent (ratio 1:2); yield 70% (1.5 g), mp 173–177 °C (from ethanol) (Found: C, 67.24; H, 4.45; N, 7.09; S, 4.11. $C_{44}H_{34}N_4O_8S$ requires C, 67.88; H, 4.36; N, 7.19; S, 4.11); δ_H(400 MHz; acetone) 2.72 (6H, s, 2 × CH_3), 3.03–3.06 (2H, m, ^2J 15.98 and ^3J 8.4, 2 × 10-Hβ), 3.07–3.1 (2H, dd, ^2J 15.95 and ^3J 3.7, 2 × 10-Hα), 3.23–3.47 (2H, m, 2 × 4-Hβ), 3.63–3.68 (2H, ddd, 2 × 10a-H), 3.73–3.85 (4H, m, 2 × 3a-H and 2 × 4-Hα), 7.2–7.28 (4H, m, 2 × 2H-phenyl), 7.44–7.51 (6H, m, 2 × 2H-phenyl and 2 × 8-H), 7.69–7.99 (4H, d, 2 × 7-H and 2 × 9-H) and 8.04–8.06 (2H, d, ^2J 6.96, 2 × 6-H); δ_C(100.6 MHz; $CDCl_3$) 20.44 (2 × C-10), 23.93 (2 × C-4), 27.2 (2 × CH_3 Ac), 38.71 (2 × C-10a), 40.02 (2 × C-3a), 115.03 (2 × C-6), 115.45 (2 × C-9b), 118.02 (2 × C-9), 123.28 (2 × C-8), 124.6 (2 × C-7), 126.51 (2 × 2 × C_t-phenyl), 128.40 (2 × 2 × C_t-phenyl), 128.67 (2 × C-9a), 132.92 (2 × C_q), 135.82 (2 × C_q), 136.21 (2 × C_q), 140.44 (2 × C_q), 169.57 (2 × C=O, Ac), 177.32 (2 × C-1), 177.59 (2 × C-3); *m/z* (FD) 778 (M^+, 100%), 744 (73), 700 (46) and 388 (8).

meso-*N*,*N*′-Carbonyldi-*p*-phenylenebis(5-benzoyl-1,2,3,3a,4,5,10,10a-octahydropyrrolo[3,4-*b*]carbazole-1,3-dione) 9g

This compound was obtained from *in situ* generated *N*-benzoylindole-2,3-quinodimethane **3a** from *N*-benzoyl-2,3-bis(bromomethyl)indole **8a** (1.0 g, 2.45 mmol) as the starting educt and the bismaleimide **4c** (450 mg, 1.22 mmol). The product was purified by flash column chromatography using gradient light petroleum–ethyl acetate as eluent (ratio 1:2); yield 60% (1.27 g), mp 148–153 °C (from ethanol) (Found: C, 76.41; H, 4.21; N, 6.34. $C_{55}H_{38}N_4O_7$ requires C, 76.23; H, 4.38; N, 6.46%); δ_H(400 MHz; $CDCl_3$) 3.04–3.14 (4H, m, 2 × 10-Hβ, 2 × 4-Hβ), 3.33–3.45 (4H, m, 2 × 10-Hα and 2 × 4-Hα), 3.46–3.59 (4H, m, 2 × 10a-H and 2 × 3a-H), 7.08–7.13 (2H, d, 2 × 9-H), 7.18–7.25 (4H, m, 2 × 2H-phenyl), 7.26–7.32 (4H, m, 2 × 2H-phenyl), 7.45–7.52 (6H, m, 2 × 8-H, 2 × 7-H, 2 × 6-H), 7.59–7.7 (6H, m, 2 × 3′-H, 2 × 5′-H and 2 × 4′-H) and 7.74–7.8 (4H, d, 2 × 2′-H and 2 × 6′-H); δ_C(100.6 MHz; $CDCl_3$) 20.74 (2 × C-10), 23.59 (2 × C-4), 39.21 (2 × C-10a), 40.13 (2 × C-3a), 114.79 (2 × C-6), 115.31 (2 × C-9b), 117.9 (2 × C-9), 123.07 (2 × C-8), 124.01 (2 × C-7), 125.89 (2 × 2 × C_t-phenyl), 128.36 (2 × C-9a), 128.86 (2 × 2 × C_t-phenyl), 129.44 (2 × 2 × C_t-phenyl), 130.57 (2 × 2 × C_t-phenyl), 132.9 (2 × C_t), 133.33 (2 × C_q), 135.28 (2 × C_q), 135.48 (2 × C_q), 136.8 (2 × C_q), 168.8 (2 × C=O, COPh), 177.43 (2 × C-1), 177.69 (2 × C-3) and 194.18 (C=O); *m/z* (FD) 866 (M^+, 100%), 863 (8), 758 (5) and 433 (3).

meso-*N*,*N*′-Carbonyldi-*p*-phenylenebis(5-phenylsulfonyl-1,2,3,3a,4,5,10,10a-octahydropyrrolo[3,4-*b*]carbazole-1,3-dione) 9h

This compound was obtained from *in situ* generated *N*-phenylsulfonylindole-2,3-quinodimethane **3b** from *N*-phenylsulfonyl-2,3-bis(bromomethyl)indole **8b** (200 mg, 0.45 mmol) as the starting educt and the bismaleimide **4c** (83.73 mg, 0.22 mmol). The product was purified by flash column chromatography using gradient light petroleum–ethyl acetate as eluent (ratio 1:2); yield 60% (253 mg), mp 158–161 °C (from ethanol). Several purification methods were used. In all cases the compound included ethanol in a non-stoichiometric ratio. Therefore the results of elemental analysis are given with the inclusion of ethanol (0.2 mol) (Found: C, 67.06; H, 4.24; N, 5.86; S, 6.45. $C_{53}H_{38}N_4O_9S_2$ requires C, 67.17; H, 4.04; N, 5.90; S, 6.76%); δ_H(200 MHz; $CDCl_3$) 2.85–2.98 (2H, m, ^2J 15.8, 2 × 10-Hβ), 3.02–3.48 (4H, m, 2 × 4-Hβ and 2 × 10-Hα), 3.52–3.65 (4H, m, 2 × 10a-H and 2 × 3a-H), 4.06–4.14 (2H, d, 2 × 4-Hα), 7.09–7.13 (4H, d, 2 × 2H-phenyl), 7.2–7.48 (12H, m, 2 × 2H-phenyl, 2 × 9-H, 2 × 8-H, 2 × 7-H and 2 × 6-H), 7.61–7.8 (4H, d, 2 × 3′-H and 2 × 5′-H), 7.84–7.98 (4H, d, 2 × 2′-H and 2 × 6′-H), 8.14–8.18 (2H, d, 2 × 4′-H) ethanol 1.18 (3H, t, CH_3), 2.09 (1H, s, OH) and 3.50 (2H, q, CH_2); δ_C(50.3 MHz; $CDCl_3$) 20.74 (2 × C-10), 22.6 (2 × C-4), 38.62 (2 × C-10a), 39.79 (2 × C-3a), 114.57 (2 × C-6), 116.38 (2 × C-9b), 118.26 (2 × C-9), 123.69 (2 × C-8), 124.91 (2 × C-7), 125.94 (2 × 2 × C_t-phenyl), 126.52 (2 × 2 × C_t-phenyl), 128.58 (2 × C-9a), 129.32 (2 × 2 × C_t-phenyl), 130.47 (2 × 2 × C_t-phenyl), 132.05 (2 × C_q), 133.75 (2 × C_t), 135.42 (2 × C_q), 136.36 (2 × C_q), 136.78 (2 × C_q), 138.58 (2 × C_q), 177.42 (2 × C-1), 177.8 (2 × C-3) and 194.16 (C=O); *m/z* (FD) 938 (M^+, 100%), 806 (38), 653 (36) and 469 (13).

meso-*N*,*N*′-Carbonyldi-*p*-phenylenebis(5-acetyl-1,2,3,3a,4,5,10,10a-octahydropyrrolo[3,4-*b*]carbazole-1,3-dione) 9i

This compound was obtained from *in situ* generated *N*-acetylindole-2,3-quinodimethane **3c** from *N*-acetyl-2,3-bis(bromomethyl)indole **8c** (1.0 g, 2.9 mmol) as the starting educt and bismaleimide **4c** (540 mg, 1.45 mmol). The product was purified by flash column chromatography using gradient light petroleum–ethyl acetate as eluent (ratio 1:2); yield 70% (1.5 g), mp 222–226 °C (from ethanol). Several purification methods were used. In all cases the compound included ethanol in a non-stoichiometric ratio. Therefore the results of elemental analysis are given with the inclusion of ethanol (0.2 mol) (Found: C, 71.80; H, 4.68; N, 7.35. $C_{45}H_{34}N_4O_7$ requires C, 71.92; H, 4.52; N, 7.45%); δ_H(200 MHz; $CDCl_3$) 2.73 (6H, s, 2 × CH_3, Ac), 3.02–3.08 (2H, dd, ^2J 15.9, 2 × 10-Hβ), 3.33–

3.41 (4H, m, ^2J 16.7, 2 × 4-Hβ and 2 × 10-Hα), 3.52–3.61 (4H, m, ^3J 8.8, 2 × 10a-H and 2 × 3a-H), 3.95–4.00 (2H, d, 2 × 4-Hα), 7.23–7.33 (8H, m, 4 × 2H-phenyl), 7.45–7.47 (2H, d, 2 × 9-H), 7.74–7.79 (4H, d, 2 × 8-H, 2 × 7-H), 7.88–7.9 (2H, d, 2 × 6-H) ethanol 1.18 (3H, t, CH_3), 2.09 (1H, s, OH), 3.50 (2H, q, CH_2); δ_C(50.3 MHz; $CDCl_3$) 19.47 (2 × C-10), 23.43 (2 × C-4), 26.92 (2 × C-10a), 38.87 (2 × C-3a), 115.11 (2 × C-9b), 115.27 (2 × C-6), 117.76 (2 × C-9), 122.86 (2 × C-8), 124.02 (2 × C-7), 126.61 (2 × 2 × C_t-phenyl), 128.38 (2 × C-9a), 130.04 (2 × 2 × C_t-phenyl), 133.16 (2 × C_q), 135.42 (2 × C_q), 135.82 (2 × C_q), 136.10 (2 × C_q), 170.00 (2 × C=O, Ac), 178.17 (2 × C-1), 178.28 (2 × C-3) and 194.01 (C=O); *m/z* (FD) 742 (M^+, 100%), 700 (36), 658 (14), 519 (5) and 371 (11).

General procedure for the preparation of compounds 10–12

To a solution of the appropriate vinylindole **6** (1.78 mmol) in $CHCl_3$ (20 ml), a solution of the bismaleimide **4a** (0.89 mmol) in $CHCl_3$ (30 ml) was added dropwise. The reaction mixture was stirred at room temperature, for 6 days, in the case of the dienes **6a** and **6b**, and refluxed for 4 days for the vinylindole **6c**. The solution was concentrated under reduced pressure and the residue was purified by flash column chromatography using light petroleum–ethyl acetate as eluent.

meso-*N*,*N*′-Methylenedi-*p*-phenylenebis(5-methyl-10-phenylsulfonyl-1,2,3,3aβ,4,10,10aβ,10bβ-octahydropyrrolo[3,4-*a*]carbazole-1,3-dione) 10a and 2-{4-[4-(2,5-dioxo-2,5-dihydro-1*H*-pyrrol-1-yl)benzyl]phenyl}-5-methyl-10-phenylsulfonyl-1,2,3,3aβ,4,10,10aβ,10bβ-octahydropyrrolo[3,4-*a*]carbazole-1,3-dione 11a

The mixture of the two compounds was obtained from 3-vinylindole **6a** (528 mg, 1.78 mmol) and the bismaleimide **4a** (320 mg, 0.89 mmol). The products were separated and purified by flash column chromatography using light petroleum–ethyl acetate as eluent (ratio 2:1).

Compound 10a. Yield 31% (263 mg), mp 200–202 °C (from methanol) (Found: C, 68.99; H, 4.75; N, 5.63; S, 6.76. $C_{55}H_{44}N_4O_8S_2$ requires C, 69.31; H, 4.65; N, 5.87, S, 6.72%); δ_H(200 MHz; $CDCl_3$) 2.07 (6H, s, 2 × 5-CH_3), 2.34 (2H, dd, ^2J 15.0 and ^3J 6, 2 × 4-Hα), 2.87 (2H, dd, ^2J 15.0 and ^3J 1.7, 2 × 4-Hβ), 3.28 (2H, pt, ^3J 7.3, 2 × 3a-Hβ), 3.84 (2H, s, ArCH_2Ar), 4.09 (2H, dd, ^3J 8.9 and ^3J 6, 2 × 10b-Hβ), 4.57 (2H, br s, 2 × 10a-Hβ), 6.84 (4H, d, ^3J 7.8, ArH), 6.94–7.06 (6H, m, ArH), 7.13–7.23 (4H, m, ArH), 7.37–7.53 (6H, m, ArH), 7.63 (2H, d, ^3J 7.8, 2 × 6-H) and 7.88 (4H, d, ^3J 8.2, 2 × 2-H and 2 × 6-H of $PhSO_2$); δ_C(50.3 MHz; $CDCl_3$) 20.2 (q, 2 × 5-CH_3), 33.9 (t), 37.3 (d), 40.9 (t, ArCH_2Ar), 43.4 (d), 62.5 (d), 115.2 (d), 123.5 (d), 123.9 (d), 126.2 (d), 126.4 (s), 127.3 (d), 127.5 (s), 129.0 (s + d), 129.1 (d), 129.5 (d), 129.9 (s), 133.4 (d), 137.7 (s), 140.7 (s), 144.6 (s), 173.2 (s, 2 × C=O) and 177.5 (s, 2 × C=O); *m/z* (FD) 952 (M^+, 100%), 655 (26) and 297 (17).

Compound 11a. Yield 55% (320 mg), mp 155–160 °C (from light petroleum) (Found: C, 69.49; H, 4.68; N, 6.15. $C_{38}H_{29}N_3O_6S$ requires C, 69.60; H, 4.45; N, 6.40%); δ_H(400 MHz; $CDCl_3$) 2.11 (3H, s, 5-CH_3), 2.39 (1H, dd, ^2J 15.0 and ^3J 6.0, 4-Hα), 2.90 (1H, dd, ^2J 15.0 and ^3J 1.7, 4-Hβ), 3.32 (1H, pt, 3a-Hβ), 3.94 (2H, s, ArCH_2Ar), 4.13 (1H, dd, ^3J 8.8 and ^3J 5.9, 10b-Hβ), 4.62 (1H, br s, 10a-Hβ), 6.81 (2H, s, olefinic H of maleimide), 6.87 (2H, d, ^3J 7.6, ArH), 6.97 (1H, t, ^3J 7.6, ArH), 7.11 (2H, d, ^3J 7.9, ArH), 7.15–7.23 (5H, m, ArH), 7.40–7.50 (3H, m, ArH), 7.54 (1H, t, ^3J 7, 7-H or 8-H), 7.65 (1H, d, ^3J 8.2, 6-H) and 7.90 (2H, d, ^3J 7.5, 2-H and 6-H of $PhSO_2$); δ_C(100.6 MHz; $CDCl_3$) 20.2 (q, 5-CH_3), 33.8 (t), 37.2 (d), 41.0 (t, ArCH_2Ar), 43.4 (d), 62.5 (d), 115.2 (d), 123.5 (d), 123.9 (d), 126.1 (d), 126.3 (2 × d), 127.3 (d), 127.4 (s), 129.0 (d), 129.2 (d), 129.3 (s), 129.5 (d), 129.7 (d), 129.8 (s), 133.4 (s), 134.1 (d), 137.4 (s), 140.2 (s), 140.8 (s), 144.5 (s), 169.5 (s, 2 × C=O), 173.3 (s, C=O) and 177.7 (s, C=O); *m/z* (FD) 655 (M^+, 100%).

meso-*N*,*N*′-Methylenedi-*p*-phenylenebis(4-methoxy-10-phenylsulfonyl-1,2,3,3aβ,4,10,10aβ,10bβ-octahydropyrrolo[3,4-*a*]carbazole-1,3-dione) 10b and 2-{4-[4-(2,5-dioxo-2,5-dihydro-1*H*-pyrrol-1-yl)benzyl]phenyl}-4-methoxy-10-phenylsulfonyl-1,2,3,3aβ,4,10,10aβ,10bβ-octahydropyrrolo[3,4-*a*]carbazole-1,3-dione 11b

A mixture of the two compounds was obtained from 3-vinylindole **6b** (560 mg, 1.78 mmol) and the bismaleimide **4a** (320 mg, 0.89 mmol). The products were separated and purified by flash column chromatography using gradient light petroleum–ethyl acetate as eluent (ratio 2:1 then 1:1).

Compound 10b. Yield 4% (35 mg), mp 200–203 °C (from light petroleum–ethyl acetate) (Found: C, 67.22; H, 4.70; N, 5.60; S, 6.66. $C_{55}H_{44}N_4O_{10}S_2$ requires C, 67.05; H, 4.50; N, 5.68; S, 6.51%); δ_H(200 MHz; $CDCl_3$) 3.63 (6H, s, 2 × OCH_3), 3.67 (2H, pt, ^3J 7.9, 2 × 3a-Hβ), 3.82 (2H, s, ArCH_2Ar), 4.05–4.12 (4H, m, 2 × 10b-Hβ and 2 × 4-Hβ), 4.57 (2H, dd, ^3J 4.8 and ^4J 2.7, 2 × 10a-Hβ), 6.11 (2H, br s, 5-H), 6.92–7.08 (6H, m, ArH), 7.17–7.24 (4H, m, ArH), 7.44–7.61 (12H, m, ArH) and 7.90 (4H, d, ^3J 7, 2 × 2-H and 2 × 6-H of $PhSO_2$); δ_C(50.3 MHz; $CDCl_3$) 39.7 (d), 40.9 (t, ArCH_2Ar), 41.0 (d), 42.7 (d), 58.0 (q, 2 × OCH_3), 60.8 (d), 115.3 (d), 116.1 (d), 121.2 (d), 124.1 (d), 125.8 (s), 126.2 (d), 127.3 (d), 129.1 (s), 129.2 (d), 129.4 (d), 129.5 (s), 129.7 (s), 130.8 (d), 133.5 (d), 135.6 (s), 145.3 (s), 172.2 (s, 2 × C=O) and 172.6 (s, 2 × C=O); *m/z* (FD) 984 (M^+, 3%), 810 (10), 636 (100) and 313 (1).

Compound 11b. Yield 16% (95 mg), mp 157–160 °C (from light petroleum–ethyl acetate) (Found: C, 68.24; H, 4.31; N, 5.95. $C_{38}H_{29}N_3O_7S$ requires C, 67.94; H, 4.35; N, 6.25); δ_H(400 MHz; $CDCl_3$) 3.63 (3H, s, OCH_3), 3.67 (1H, pt, ^3J 7.9, 3a-Hβ), 3.91 (2H, s, ArCH_2Ar), 4.08–4.17 (2H, m, 10b-Hβ and 4-Hβ), 4.58 (1H, dd, ^3J 4.8 and ^4J 2.7, 10a-Hβ), 6.11 (1H, dd, ^3J 5.8 and ^4J 2.9, 5-H), 6.79 (2H, s, olefinic H of maleimide), 6.95–7.00 (3H, m, ArH), 7.10 (2H, d, ^3J 8.2, ArH), 7.22–7.30 (6H, m, ArH), 7.43 (2H, m, ArH), 7.54 (1H, t, ^3J 7, 7-H or 8-H), 7.61 (1H, d, ^3J 8.1, 6-H) and 7.89 (2H, d, ^3J 7.8, 2-H and 6-H of $PhSO_2$); δ_C(100.6 MHz; $CDCl_3$) 39.7 (d), 41.0 (d), 41.1 (t, ArCH_2Ar), 42.8 (d), 58.0 (q, OCH_3), 60.8 (d), 115.3 (d), 116.2 (d), 121.2 (d), 124.1 (d), 125.8 (s), 126.1 (2 × d), 126.3 (d), 127.3 (d), 129.3 (d), 129.4 (d), 129.6 (d), 129.8 (s), 130.8 (d), 133.6 (s), 134.1 (d), 135.5 (s), 137.5 (s), 140.3 (s), 140.7 (s), 145.2 (s), 169.5 (s, 2 × C=O), 172.3 (s, C=O) and 172.7 (s, C=O); *m/z* (FD) 671 (M^+, 22%), 506 (13), 493 (20), 464 (54), 450 (100), 436 (61), 422 (47), 408 (62), 380 (25) and 312 (9).

meso-*N*,*N*′-Methylenedi-*p*-phenylenebis(4-methoxycarbonyl-10-methyl-1,2,3,3aβ,4β,5,10aβ,10bβ-octahydropyrrolo[3,4-*a*]-carbazole-1,3-dione) 12

This compound was obtained from 3-vinylindole **6c** (383 mg, 1.78 mmol) and the bismaleimide **4a** (320 mg, 0.89 mmol). The product was purified by flash column chromatography using gradient light petroleum–ethyl acetate as eluent (ratio 2:1 then 1:1); yield 27% (189 mg), mp 185 °C (from methanol) (Found: C, 71.38; H, 5.24; N, 7.19. $C_{47}H_{40}N_4O_8$ requires C, 71.56; H, 5.11; N, 7.10%); δ_H(200 MHz; $CDCl_3$) 2.86–3.05 (4H, sa, 2 × 5-Hα and 2 × 5-Hβ), 3.26–3.31 (2H, m, 2 × 4-Hβ), 3.83 (6H, s, 2 × NCH_3 or 2 × OCH_3), 3.93 (8H, br s, ArCH_2Ar and 2 × NCH_3 or 2 × OCH_3), 4.28 (2H, dd, ^3J 8.2 and ^3J 4, 2 × 3a-Hβ), 4.53 (2H, d, ^3J 8.2, 2 × 10b-Hβ), 7.10–7.29 (14H, m, ArH) and 7.54 (2H, d, ^3J 7.5, 2 × 6-H); δ_C(50.3 MHz; $CDCl_3$) 29.6 (t), 31.0 (q, 2 × NCH_3), 39.6 (d), 40.6 (d), 40.9 (t, ArCH_2Ar), 43.1 (d), 52.3 (q, 2 × OCH_3), 109.4 (d), 110.3 (s), 118.5 (d), 119.5 (d), 122.5 (d), 125.9 (s), 126.3 (d), 127.4 (s), 129.6 (d), 134.1 (s), 138.1 (s), 140.9 (s), 172.4 (s, C=O), 173.9 (s, C=O) and 175.2 (s, C=O); *m/z* (FD) 788 (M^+, 100%), 519 (45) and 394 (16).

Computational methods

Input geometries of compounds **9a** and **10a** for semiempirical quantum chemistry calculations were derived from SYBYL 6.03[17] using the option BUILD MOLECULE and the TRIPOS

force field MAXIMIN2 for minimizing on a VAX station 4000/90. These conformations were then quantum mechanically minimized by using the keyword XYZ, and furthermore with VECT PRECISE, using a dec8400 5/300 (Zentrum für Datenverarbeitung, University of Mainz). The AM1 hamiltonians in the MOPAC version 6.0 were used.[18] The quality and precision of the application of the AM1 method to anellated carbazole heterocycles has been documented by us.[19]

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References

1 M. L. Kopka and T. A. Larsen, in *Nucleic Acid Targeted Drug Design*, eds. C. L. Probst, T. J. Perun, Marcel Dekker, New York, 1992, pp. 303–374.
2 S. Neidle, L. H. Pearl and J. V. Skelly, *Biochem. J.*, 1987, **243**, 1.
3 U. Pindur and G. Fischer, *Curr. Medicinal Chem.*, 1996, **2**, 325.
4 F. Acarmone, S. Penco, P. Orezzi, V. Nicolella and A. Pirelli, *Nature*, 1964, **203**, 1064.
5 D. L. Boger, D. S. Johnson, W. Yun and C. M. Tarby, *Bioorg. Med. Chem.*, 1994, **2**, 115.
6 U. Pindur, *Cycloaddition Reactions of Indole Derivatives*, in *Advances in Nitrogen Heterocycles*, ed. C. J. Moody, JAI Press, Greenwich, 1995, vol. 1, pp. 121–172.
7 L. Pfeuffer and U. Pindur, *Helv. Chim. Acta*, 1988, **71**, 467.
8 U. Pindur, E. Gonzalez and D. Schollmeyer, *J. Chem. Soc., Perkin Trans. 1*, 1996, 1767.
9 U. Pindur and H. Erfanian-Abdoust, *Chem. Rev.*, 1989, **89**, 1681.
10 M. Haber and U. Pindur, *Tetrahedron*, 1991, **47**, 1925.
11 U. Pindur and M. Haber, *J. Prakt. Chem., Chem.-Ztg.*, 1993, **335**, 12.
12 W. E. Noland, M. J. Walhstrom, M. J. Konkel, M. E. Brigham, A. G. Trowbridge, L. M. C. Konkel, R. P. Gourneau, C. A. Scholten, N. H. Lee, J. J. Condoluci, T. S. Gac, M. M. Pour and P. M. Radford, *J. Heterocycl. Chem.*, 1993, **30**, 81.
13 L. Pfeuffer and U. Pindur, *Helv. Chim. Acta*, 1987, **70**, 1419.
14 U. Pindur, L. Pfeuffer, M. Eitel, M. Rogge and M. Haber, *Monatsh. Chem.*, 1991, **122**, 291.
15 U. Pindur, M.-H. Kim, M. Rogge, W. Massa and M. Molinier, *J. Org. Chem.*, 1992, **57**, 910.
16 C. A. G. Haasnot, F. A. A. M. De Leeuew and C. Altona, *Tetrahedron*, 1980, **36**, 2783.
17 SYBYL version 6.03, 1993, program packet from TRIPOS Associates, Inc., St. Louis, Missouri, USA.
18 For details to the MOPAC 6.0 program (QCPE-455) 1990 see: M. J. S. Dewar, E. G. Zoebisch, E. F. Healy and J. J. P. Stewart, *J. Am. Chem. Soc.*, 1985, **107**, 3902; J. J. P. Stewart, *J. Comp. Chem.*, 1989, **10**, 209.
19 U. Pindur, M. Rogge, C. Rehn, W. Massa and B. Peschel, *J. Heterocycl. Chem.*, 1994, **341**, 981; M. Eitel and U. Pindur, *J. Org. Chem.*, 1990, **55**, 5368.
20 RACCOON program was used, a variant of LAOCOON-program; H. Günther, NMR-Spektroskopie, Thieme Verlag, Stuttgart, 1992, pp. 181.
21 D. P. Chakraborty and S. Roy, *Fortschr. Chem. Org. Naturst.*, 1991, **57**, 71.
22 M. Rogge, G. Fischer and U. Pindur, *Monatsh. Chem.*, 1996, **127**, 97.
23 C. Rehn and U. Pindur, *Monatsh. Chem.*, 1996, **127**, 631; 645.

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