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Synthesis of arcyriarubine regioisomers by Pd(0)-catalysis or via lithiated indole derivatives – conformational analysis by semiempirical and X-ray methods

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Regioisomers of arcyriarubines were synthesized by the reaction of *N*-protected indoles with dibromomaleimide either in the presence of a Pd(0)-catalyst or *n*-BuLi. Methods for *N*-alkylation of these bisindolylmaleimides and deprotection of the indole-N are described. The structure of the bisindolylmaleimide **11** was studied by semiempiric quantum-chemical calculations, the structure of its derivative **14b** was ascertained by X-ray analysis.

1. Introduction

The indolo[2,3-*a*]carbazole alkaloid ring system is part of several biologically active molecules, such as arcyriaflavines and the potent antitumor agent rebeccamycin [1], isolated from Nocardia aerocoligenes in 1985 [2, 3]. Together with the closely related arcyriarubines this structurally rare class of compounds represents new leading structures for the synthesis of biologically active substances.

For arcyriaflavine derivatives, e.g., antimicrobacterial activity against *Bacillus cereus* [4], activity against P_{388} leukemia cells [4] and inhibitor effects against protein kinase A (PKA), protein kinase C (PKC) [4–6], the topoisomerases I and II [4] and tyrosine and serine kinases were reported [5]. Analogs of arcyriaflavine are currently evaluated in clinical trials as new anti-cancer drugs [1].

The arcyriarubines [7–10], isolated from the fruiting bodies of the slime mould *Arcyria denundata* [11], just as the arcyriaflavines and related compounds also show remarkable biological activities. Effects on protein kinases A and C and on protein tyrosine kinase (PTK) are described and emerge more and more frequently from the patent literature [8, 12–15].

Compounds **1a–c** (arcyriaflavines) have a flat structure, whereas bisindolylmaleimides (arcyriarubines; **1d–f**) are non-planar molecules [16]. Computer assisted calculations, NMR studies and X-ray structure analysis of arcyriarubine A (**1d**) have revealed three conformations [16]: (I) both indole systems and the maleimide ring are co-planar, (II) one indole moiety is rotated by 180° into the plane of the other indole- and maleimide group, (III) both indole increments are twisted by 37.6° against the maleimide ring (Fig. 1). The folded conformations are energetically favored over the planar conformations. On the basis of energy calculations, conformation II is the local minimum, whereas conformation III represents the global minimum.

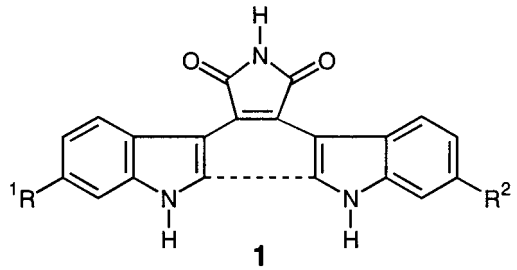
As indicated by X-ray structure analysis, arcyriarubine A (**1d**) exists in the folded conformation II; according to NMR studies this conformation prevails also in solution [9].

As a variation of the structure of the bisindolylmaleimides mentioned above, we have synthesized the regioisomeres with the basic structure **2**, which differs from previously described bisindolylmaleimides because the indole groups are attached via their 2-position to the maleimide ring.

2. Investigations, results and discussion

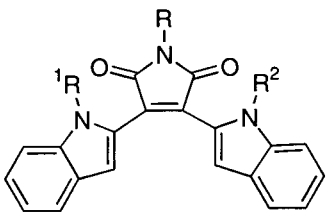
2.1. Chemistry

Among the several approaches available for the synthesis of the bisindolylmaleimides, we have found two methods in the literature to be efficient and straightforward for the synthesis of our target molecule 3,4-bisindol-2-ylmaleimide (**11**). In the first method, 2-tributylstannyl-*N*-(trimethylsilylethoxymethyl)indole (**5**) [17], which was prepared from *N*-(trimethylsilyl-ethoxymethyl)indole (**4**) [18]



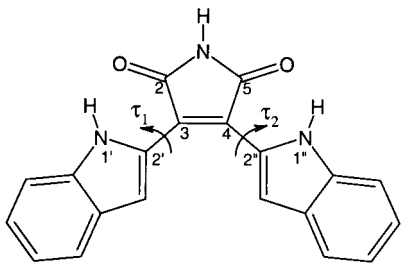
1

Compound	R^1	R^2	–
Arcyriaflavine A (**1a**)	H	H	single bond
Arcyriaflavine B (**1b**)	H	OH	single bond
Arcyriaflavine C (**1c**)	OH	OH	single bond
Arcyriarubine A (**1d**)	H	H	no bond
Arcyriarubine A (**1e**)	H	OH	no bond
Arcyriarubine A (**1f**)	OH	OH	no bond



R^1, R^2 = SO_2Ph, H
R = H, Alkyl-, Aminoalkyl-, Arylgroup

2



11

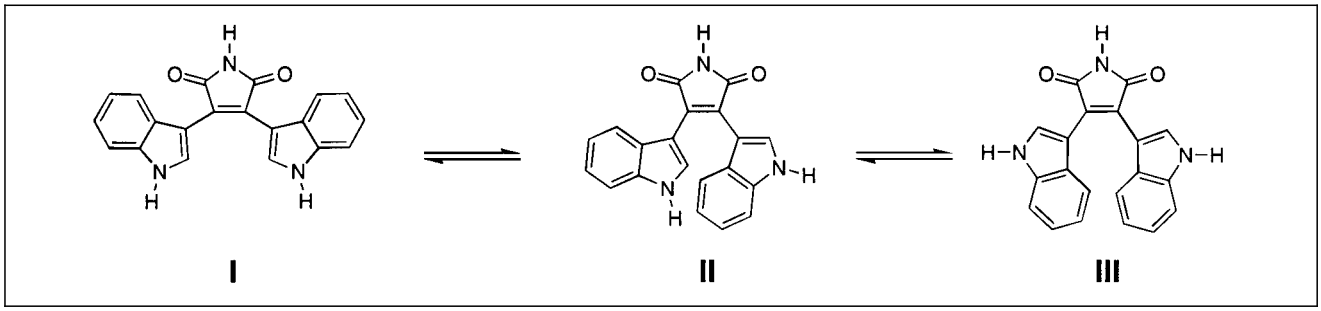


Fig. 1: Conformations of arcyriarubin A (**1d**)

by reaction with *n*-BuLi and tributylstannyl chloride, was coupled with dibromomaleimide (**3**) in the presence of catalytic amounts of tetrakis(triphenylphosphine)palladium(0) to yield compd. **8**, using Stille's procedure [19]. The mono substituted indolylmaleimide **7** was produced as a by-product. Deprotection of **8** with tetrabutylammonium fluoride (TBAF) gave bisindol-2-ylmaleimide **11** (Scheme 1).

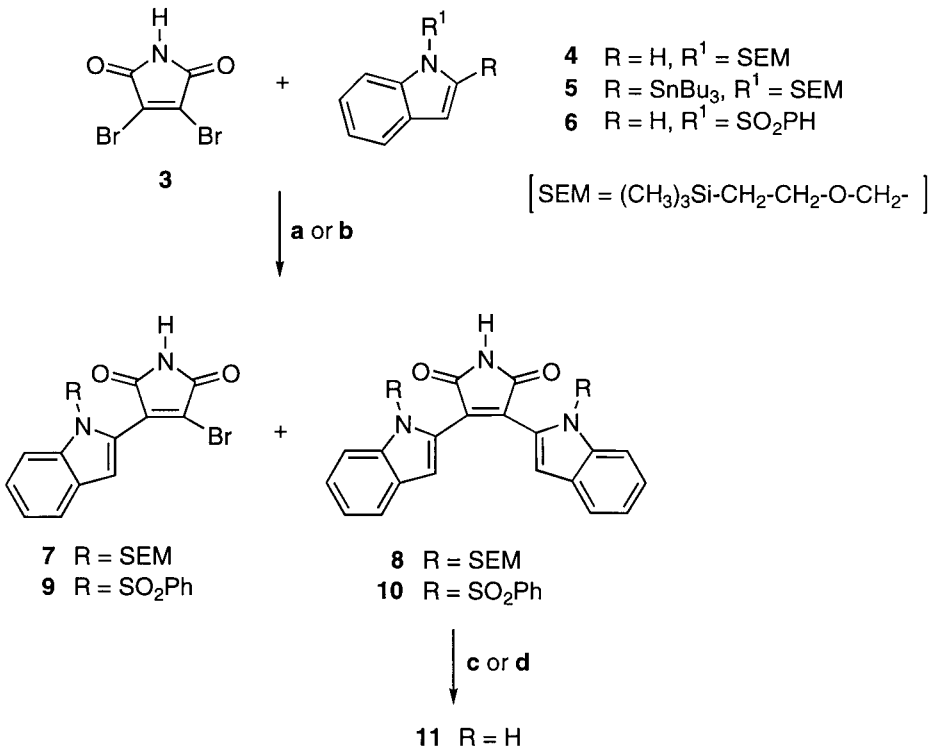
In the second method, *N*-phenylsulfonylindole (**6**) was converted into its 2-lithioderivative using the method described by Saulnier et al. [20], and then subjected to nucleophilic substitution with **3** to get 3,4-bis(*N*-phenylsulfonylindol-2-yl)maleimide (**10**). As in the first method, a small amount of mono substituted indolylmaleimide (**9**) was formed as a by-product. The phenylsulphonyl groups were removed from **10** by NaOH in EtOH (Scheme 1). Contrary to the yellow fluorescence of compounds **8** and **10**, the diamine **11** is red-violet and sensitive to air.

In order to improve the solubility and also to synthesize further derivatives for structure activity relationship studies, the imide nitrogen was substituted with various groups. Compound **10** was selected as a starting material for this purpose, because both indole nitrogens are protected, preventing possible reactions at these positions. In one attempt, **10** was converted to **12a** by treating it with NaH and methyl iodide in DMF (method A). Compound **12a** was then deprotected to **13a** by NaOH in EtOH (method C) or by TBAF in THF (method D, Scheme 2).

Analogously various groups were introduced (**12b**–**k**, **13b**–**g**: Table 1). Treatment of **10** with 1-chloroethyl-dimethylamine and NaH in DMF gave unseparable mixtures. The reaction with a slight excess of KH (method B) resulted in a mixture of two main products, which could not be separated by column chromatography. The MS of this mixture showed that the *N*,*N*-dimethylaminoethyl group had been introduced at the imide nitrogen as expected, but the phenylsulfonyl group at one of the indole nitrogen atoms was removed due to excess KH, affording **14a** (Table 1). Therefore, the resulting mixture of **12b** and **14a** was refluxed with 10% NaOH in EtOH without further separation to yield **13b**.

A bromoethyl group was introduced at the imide nitrogen of **10** by KH and 1,2-dibromoethane. Similar to the previous example, *N*-(1-bromoethyl)-3,4-bis(*N*-phenyl-sulfonylindole-2-yl)maleimide (**12c**) and the monodeprotected by-product **14b** (Table 1) were formed, which could be separated by column chromatography. This suggested that

Scheme 1



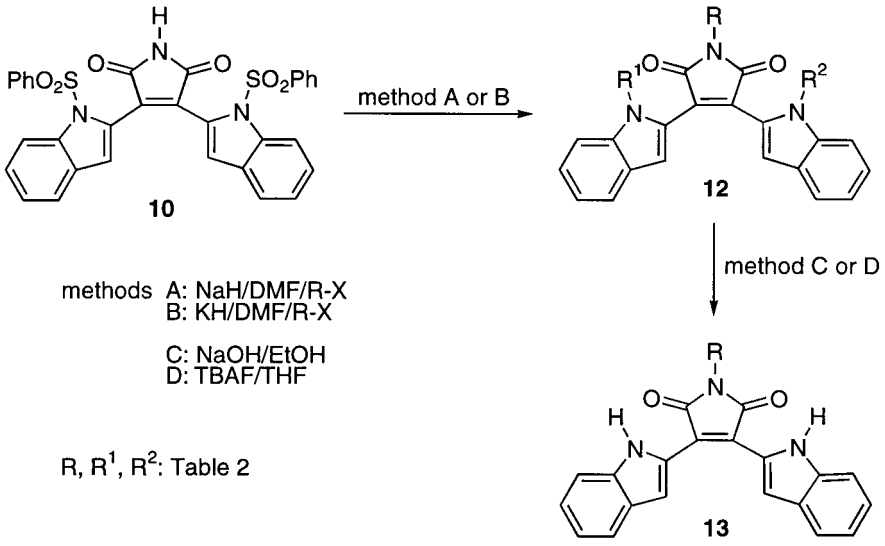
Reagents: (a) for **5**: Pd (tpp)$_4$/DMF/Δ; (b) for **6**: LDA/THF/−78 °C; for **8**: TBAF/THF; (d) for **10**: NaOH/EtOH.

Table 1: *N*-Alkyl-derivatives of 2 (12a–k) and deprotected compounds (13a–g, 14a, 14b)

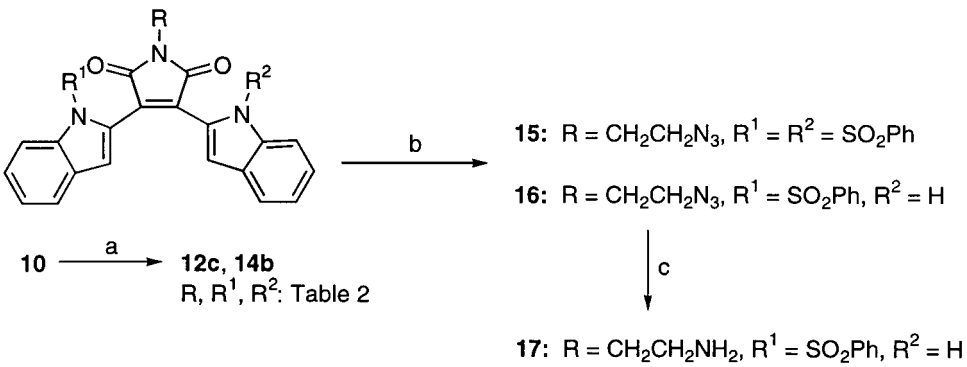
Compd.	Halogenide	Method	R^1	R^2	R
12a	CH_3I	A	SO_2Ph	SO_2Ph	CH_3
12b	$Cl(CH_2)_2N(CH_3)_2$	B	SO_2Ph	SO_2Ph	$(CH_2)_2N(CH_3)_2$
12c	$BrCH_2CH_2Br$	B	SO_2Ph	SO_2Ph	CH_2CH_2Br
12d	CH_3CH_2Br	A	SO_2Ph	SO_2Ph	CH_2CH_3
12e	$Br(CH_2)_6Br$	A	SO_2Ph	SO_2Ph	$(CH_2)_6Br$
12f	$PhCH_2Br$	A	SO_2Ph	SO_2Ph	CH_2Ph
12g	2-cyanobenzyl bromide	A	SO_2Ph	SO_2Ph	2-cyanobenzyl
12h	4-cyanobenzyl bromide	A	SO_2Ph	SO_2Ph	4-cyanobenzyl
12i	2-(N-piperidino)-ethyl chloride	A	SO_2Ph	SO_2Ph	2-(N-piperidino)-ethyl
12k	2-(N-morpholino)-ethyl chloride	A	SO_2Ph	SO_2Ph	2-(N-morpholino)-ethyl
13a		C	H	H	CH_3
13b		C	H	H	$CH_2CH_2N(CH_3)_2$
13c		D	H	H	CH_2CH_3
13d		D	H	H	$(CH_2)_6F$
13e		D	H	H	CH_2Ph
13f		D	H	H	2-(N-piperidino)-ethyl
13g		D	H	H	2-(N-morpholino)-ethyl
14a	$Cl(CH_2)_2N(CH_3)_2$	B	SO_2Ph	H	$(CH_2)_2N(CH_3)_2$
14b	$BrCH_2CH_2Br$	B	SO_2Ph	H	CH_2CH_2Br

the phenylsulfonyl protecting group at the indole nitrogen can also be removed by KH. During the deprotection of **12e** with TBAF in THF the alkyl-Br was completely replaced by F (**13d**, Table 1). Therefore, this method could not be used to deprotect halogen containing derivates. The reactions of **12c** and **14b** with sodium azide in DMF gave **15** and **16**. Compound **16** was hydrogenated to the amine **17** (Scheme 3).

Scheme 2



Scheme 3



Reagents: (a): KH/DMF/$BrCH_2CH_2Br$; (b): NaN_3/DMF; (c): Pd/C/H_2.

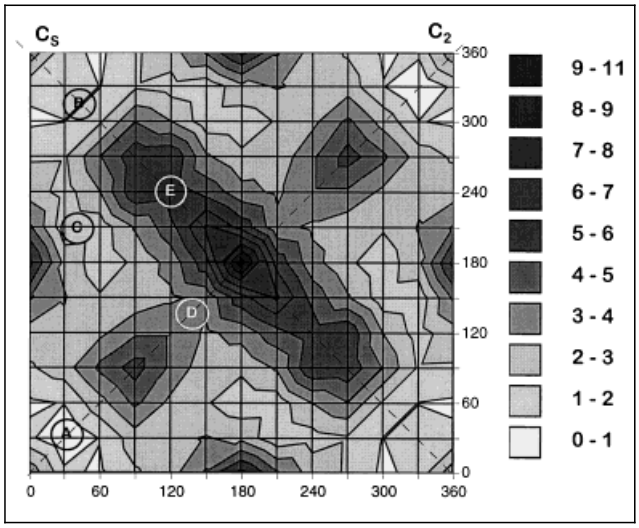


Fig. 2: Potential map of τ_1 (x-axis) and τ_2 (y-axis) as isocontour plot of ΔHF (difference to the global minimum at **A**, [kcal/mol], graduated by a grey scale as shown). For typical conformations **A**–**E**, see Table 2 and Fig. 3 C_2 and C_S denote the diagonals

A lot of the compounds crystallize with solvents which could not be removed in spite of prolonged heating of the ground materials in vacuo. The presence of these solvents was assured by ^{1}H NMR spectra.

In these imide-systems one of the carbonyl groups can be selectively reduced to a hydroxyl group by $LiAlH_4$ [21, 22] or $NaBH_4$ [8]. These hydroxy-substituted compounds are potent inhibitors of PKC [23–25].

The reduction of **11** with $LiAlH_4$ in THF led to compound **18** (Scheme 4). Contrary to **11**, compound **18** is not sensitive to air.

2.2. Structure analysis of 11

The unsubstituted derivative **11** has two degrees of torsional freedom, which can be described by the dihedral angles τ_1 (C2-C3-C2′-N1′) and τ_2 (C5-C4-C2″-N1″). The potential map [heats of formation $HF = f(\tau_1, \tau_2)$] was calculated by the semiempirical quantum-chemical QCPE program MOPAC 6.0 (PM3 Hamiltonian), implemented as interface within the molecular modeling software SYBYL 6.4 (Tripos Ass.) on a Silicon Graphics Indigo^2 solid impact workstation. The GRID algorithm (STEP and POINT keywords, increments of 30°) was used together with other appropriate keywords (gradient norm 0.1, molecular mechanics correction for NHCO groups). Some conformations close to stationary points were additionally minimized without restrictions except for symmetry relations of τ_1 and τ_2 in some cases.

For discussion of the resulting potential map (see Fig. 2), some definitions are necessary. The conformation at the conjugated, rotated bonds (τ_1, τ_2) will be denoted by the *E*–*Z* nomenclature (*trans* or *cis* position of the indole nitrogen with respect to the maleimide CO groups, transition from *E* to *Z* at 90° and 270°). Rotation of the indolyl moieties leads to axial chirality, so that the *aS-aR* nomenclature might be additionally used.

Table 2: Heat of formations (HF) of some typical conformations of compound 11

τ_1	NH–OC configuration	τ_2	NH–OC configuration	HF (kcal/mole)	Conf. in Figs. 2 and 3
0°	*Z*	0°	*Z*	35.899	–
0°	*Z*	180°	*E*	38.541	–
180°	*E*	180°	*E*	42.697	–
90°	*(aS)*	90°	*(aS)*	37.653	–
90°	*(aS)*	270°	*(aR)*	37.939	–
90°	*(aS)*	240°	*E*	38.162	–
31.5°	*Z*	31.5°	*Z*	32.190	**A**
42.8°	*Z*	317.2°	*Z*	32.742	**B**
36.5°	*Z*	216.5°	*E*	33.135	**C**
141.4°	*E*	141.4°	*E*	35.187	**D**
119.2°	*E*	240.8°	*E*	37.729	**E**

[a] The HF values of **A**–**E** are calculated with appropriate symmetry relations of τ_1 and τ_2. Corresponding heats of formations estimated without the SYMMETRY keyword are nearly identical (not more than 0.01 kcal/mol different).

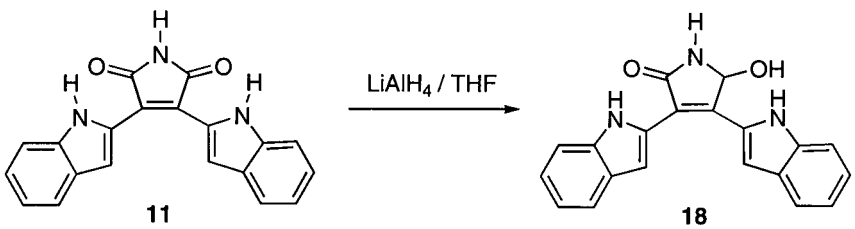
Table 2 contains the heats of formation of some typical conformations. The planar *ZZ* and *EE* structure (C_{2v} point group) are not energy minimum states, but hilltops due to steric repulsion which is especially strong if the indolyl NH groups approach each other. Hilltops are also the "parallel" planar conformations (*ZE* and *EZ*, C_S symmetry) as well as the C_2-symmetric perpendicular structures due to minimum π-orbital overlap. In the case of the *meso*-like *aSaR* and *aRaS* perpendicular conformations, electrostatic NH–NH repulsion additionally enhances the energy barriers, leading to slightly shifted hilltops at, e.g., about 90°/240°.

All nonplanar, propeller-like conformations at the ascending diagonal of the potential map belong to the C_2 point group. This C_2 diagonal may be regarded as mirror or ring interchange and, thus, of *meso*-like pairs of conformations (each structure generated by interchange of the rings can be converted into the original structure by a 180° rotation).

The nonplanar, wing-like conformations at the descending diagonal are achiral (C_S point group). The symmetry plane σ (see Fig. 3, **B**) is perpendicular to the maleimide plane. The C_S diagonal in Fig. 2 also represents a mirror, but in this case of pairs of enantiomeric conformations their interconversion can be described by reflection across σ (note that their reflection across the maleimide plane leads to the ring-interchanged enantiomers).

The twofold global energy minimum, *ZZ* propeller-like conformation (Fig. 3, **A**) is a compromise between favorable conjugation and unfavorable steric effects, additionally stabilized by two intramolecular H bonds (weak due

Scheme 4



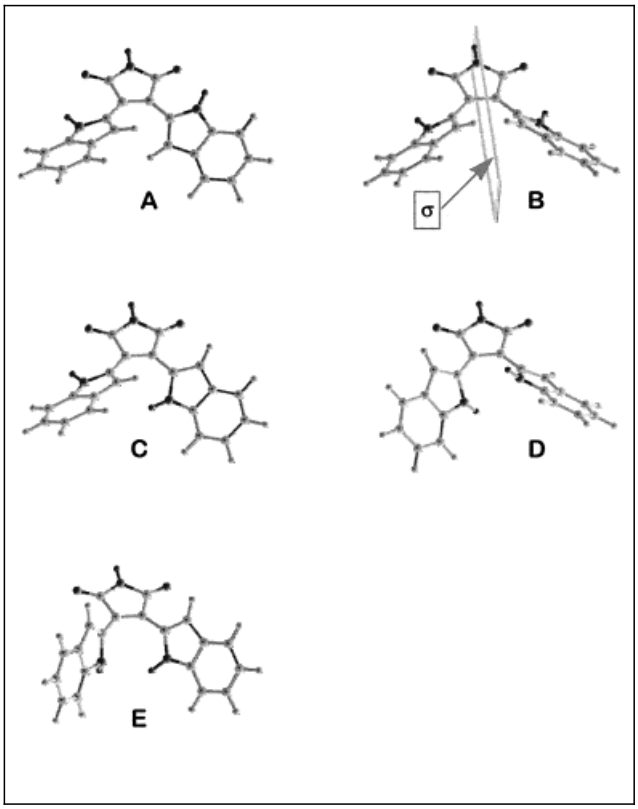


Fig. 3: Typical conformations **A**–**E** of compound **11** as calculated by MOPAC. In conformation **B**, the symmetry plan σ is drawn. NH groups and oxygens are darkened

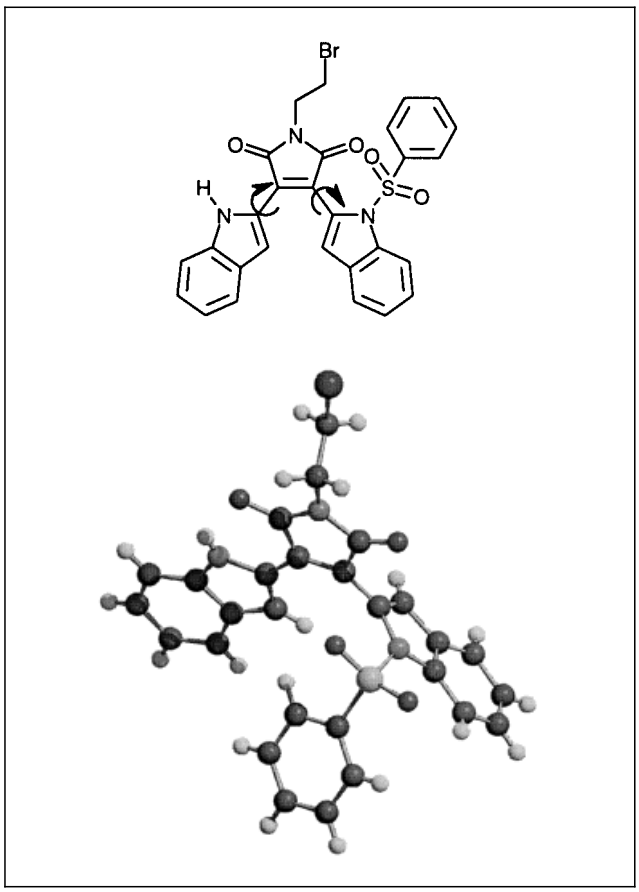


Fig. 4: X-ray crystal structure of **14b**

to bad geometry) and by parallel packing of the indole rings. The second twofold local minimum (Fig. 3, **B**) is rather flat. It belongs to a *ZZ*, wing-shaped conformation, retaining both H bonds, but without ring packing. Compared to **A**, τ_1 and τ_2 are somewhat spread due to steric hindrance, leading to weakened NH−O interactions. The third local minimum (Fig. 3, **C**, see also point C and its three reflections in Fig. 2) is fourfold (ring interchange and enantiomers, respectively) and in a deeper valley than **B**. It shows a *ZE* or *EZ*, packed propeller-like arrangement of the two indole rings, stabilized by one NH−O interaction.

By force analysis, two first-order transition states with *EE* configuration were suggested. The first one (Fig. 3, **D**) is a twofold, propeller-like conformation at the C_2 diagonal, but rather flat. The second one at the C_S diagonal (Fig. 3, **E**) with a wing-shaped structure is twofold only by ring exchange and with steeper flanks.

Parallel calculations with molecular mechanics approaches (Tripos force field with MOPAC PM3 charges, distance-dependent dielectricity function, $\varepsilon = 1$) confirmed the global minimum **A** and the local minimum **C**. However, **B** now becomes a first-order transition state and **D** a local minimum. I.e., the Tripos force field neglects wing-shaped in favor of propeller-like conformations, probably by stronger weighting of intramolecular van der Waals attraction (ring packing).

Fig. 2 suggests possible interconversion pathways. Synchronous rotation of both rings ("*syn*" along 45°, "*anti*" along-45° lines) is unlikely. If one torsional angle is fixed between 30 and 60° or 300 and 330°, the other may widely vary between 30 and 270° without strain. Therefore, energy minimum pathways result from uncorrelated, sequential rotation. Such pathways additionally may cover all local minima found.

2.3. X-ray structure analysis of 14b

Because compound **14b** crystallized better than the other bisindolylmaleimides synthesized in this study, crystals of **14b** were used for X-ray structure analysis. The unsubstituted indole moiety of **14b** and the maleimide ring are nearly coplanar (Fig. 4, angle between both planes of 3°). The hydrogen atom of the unsubstituted indole nitrogen forms a hydrogen bond with a carbonyl oxygen of the maleimide ring. Because of the large phenylsulfonyl substituent, the second indole group deviates by $\tau_1 = 66°$ from the maleimide plane. Together with $\tau_2 \sim 0°$ this corresponds to a point at the potential surface of the unsubstituted compound **11** (see Fig. 3) not more than 2 kcal/mol above the energy minimum. The energetically more unfavorable position of the substituted indolyl moiety is therefore counterbalanced by the most favorable coplanar arrangement of the maleimide ring and the unsubstituted indole with maximal π orbital overlap.

3. Experimental

Melting points were determined on a Büchi 512 device or a Reichert hot-stage microscope and are uncorrected. Fourier-transform IR spectra were recorded on a Nicolet 510 FTIR spectrometer. ^{1}H NMR spectra were recorded on Bruker 250 (250 MHz) or Varian EM 390 (90 MHz). MS were obtained with a Varian MAT 311A, 70 eV. All reactions were carried out under N_2, dried over self-indicating silica gel, concentrated H_2SO_4 and KOH. All the results of elemental analyses were in an acceptable range.

3.1. 3-Bromo-2,5-dihydro-4-(N-trimethylsilyl-ethoxymethylindol-2-yl)-1H-pyrrole-2,5-dione (**7**) *and 2,5-dihydro-3,4-bis(N-trimethylsilyl-ethoxymethylindol-2-yl)-1H-pyrrole-2,5-dione* (**8**)

To a solution of tetrakistriphenylphosphinpalladium (22.65 mg, 0.02 mmol) and **3** (450.0 mg, 1.77 mmol) in 10 ml of absol. DMF was dropped **5** (1.05 g, 1.96 mmol) in 5 ml of absol. DMF, and the mixture was heated

for 1 h at 110 °C. After cooling, 50 ml of H_2O were added, and the mixture was extracted with ether (2 × 50 ml). The etheric phase was washed with 100 ml of H_2O, dried over Na_2SO_4, and the volume was reduced to 10%. Products 7 and 8 were separated by CC (1. SiO_2, CH_2Cl_2/MeOH/hexane 20:1:2; 2. SiO_2, CH_2Cl_2/EtOAc 20:1).

7: yellow wax, yield 20 mg (3%). IR (KBr): 3420 (NH), 3100–2800 (CH), 1780, 1730 (C=O), 1630, 1455 cm^{-1} (C=C). ^1H NMR (90 MHz, $CDCl_3$, δ ppm): 0.02 (s, 9 H, $Si(CH_3)_3$), 0.87 (t, J = 8.8 Hz, 2 H, CH_2Si), 3.32 (t, J = 8.7 Hz, 2 H, CH_2O), 5.81 (s, 2 H, NCH_2O), 6.88–7.97 (m, 5 H, arom.), 8.22 (br s, 1 H, NH). EI-MS [m/z (%)]: 422/420 (18) [$M^{+\bullet}$], 349/347 (33) [M − $Si(CH_3)_3]^+$, 305/303 (15) [M − $O(CH_2)_2Si(CH_3)_3]^+$, 73 (100) $[Si(CH_3)_3]^+$.

8: yellow wax, yield 200 mg (19%). IR (KBr): 3430 (NH), 3100–2800 (CH), 1780, 1720 (C=O), 1625, 1455 cm^{-1} (C=C). ^1H NMR (90 MHz, $CDCl_3$, δ ppm): 0.02 (s, 9 H, $Si(CH_3)_3$), 0.75 (t, J = 8.8 Hz, 2 H, CH_2Si), 3.23 (t, J = 8.7 Hz, 2 H, CH_2O), 5.28 (s, 2 H, NCH_2O), 6.72–8.00 (m, 5 H, arom.), 8.69 (br s, 1 H, NH). EI-MS [m/z (%)]: 587 (72) [$M^{+\cdot}$], 470 (5) [M − $O(CH_2)_2Si(CH_3)_3]^+$, 441 (5), 73 (100) $[Si(CH_3)_3]^+$.

3.2. 3-Bromo-2,5-dihydro-4-(N-phenylsulfonylindol-2-yl)-1 H-pyrrole-2,5-dione (9) *and 2,5-dihydro-3,4-bis(N-phenylsulfonylindol-2-yl)-1 H-pyrrole-2,5-dione* (10)

Lithium diisopropylamide was prepared by mixing diisopropylamine (3.95 ml, 28.1 mmol) and 17.10 ml *n*-BuLi (1.6 M in hexane) in 10 ml of absol. THF at −78 °C under stirring at −78 °C for 10 min and at 0 °C for 30 min. To this freshly prepared solution, at −78 °C was added dropwise a solution of phenylsulfonylindole (**6**) (6.90 g, 39.1 mmol) in 75 ml of absol. THF within 30 min in order to keep the temperature of the reaction mixture at −60 °C. After stirring for 1.5 h at −78 °C und 1 h at 5 °C, the mixture was cooled again to −78 °C, and a solution of **3** (3.10 g, 12.2 mmol) in 15 ml of absol. THF was dropped in rapidly. Stirring was continued for 4 h at −65 °C. Finally, 250 ml of 1% HCl were added, and the organic phase was separated (some ether was added to improve phase separation). The aqueous phase was again extracted with 20 ml of THF and 20 ml of CH_2Cl_2. The combined organic phase was dried over Na_2SO_4 and evaporated in vacuo to give **9** and **10**, which were separated and purified by CC. (SiO_2, CH_2Cl_2/EtOAc 20:1).

9: Yellow crystalls, yield 200 mg (4%); mp. 235–237 °C (EtOAc). IR (KBr): 3250 (NH), 3100–2950 (CH), 1780, 1720 (C=O), 1650, 1455 (C=C), 1370, 1170 cm^{-1} ($PhSO_2$). ^1H NMR (90 MHz, $CDCl_3$, δ ppm): 6.88–8.16 (m, 10 H, arom.), 11.47 (s, 1 H, NH). EI-MS [m/z (%)]: 432/430 (26) [$M^{+\cdot}$], 291/289 (24) [M − $PhSO_2]^+$, 77 (94) $[C_6H_5]^+$.

$C_{18}H_{11}BrN_2O_4S$

10: Yellow crystals, yield 6.1 g (82%); mp. 196–197 °C (dec.) (acetone). IR (KBr): 3200 (NH), 3100–2950 (CH), 1785, 1715 (C=O), 1665, 1455 (C=C), 1370, 1175 cm^{-1} ($PhSO_2$). ^1H NMR (90 MHz, $CDCl_3$, δ ppm): 6.97 (s, 2 H, 3-H and 3′-H), 7.21–8.06 (m, 18 H, arom.), 8.35 (br s, 1 H, NH). EI-MS [m/z (%)]: 607 (6) [$M^{+\cdot}$], 466 (31) [M − $PhSO_2]^+$, 325 (100) [466 − $PhSO_2]^+$, 141 (30) [$PhSO_2]^+$, 77 (94) $[C_6H_5]^+$.

$C_{32}H_{21}N_3O_6S_2$

3.3. 2,5-Dihydro-3,4-bisindol-2-yl-1 H-pyrrole-2,5-dione (11)

3.3.1. By deprotection of **10** *with TBAF in THF*

To a solution of 50.0 mg (0.09 mmol) **8** in 5 ml of absol. THF at 0 °C were added dropwise 268.2 mg (0.1 mmol) dry TBAF in 2 ml of absol. THF. After stirring for 3 h at 0 °C and 16 h at room temperature, 20 ml of H_2O and 20 ml of ether were added, and the etheric phase was separated. The aqueous phase was further extracted by ether (2 × 20 ml), and the combined ether phase was washed with saturated NH_4Cl solution and evaporated in vacuo to give a residue which was purified by CC (SiO_2; CH_2Cl_2/EtOAc 20:1) to yield **11** (6 mg, 20%) as violet crystals; m.p. 197 °C (dec.) (CH_2Cl_2/hexane). IR (KBr): 3200 (NH), 3180–2950 (CH), 1750, 1700 (C=O), 1655, 1455 cm^{-1} (C=C). ^1H-NMR (90 MHz, $CDCl_3$, δ ppm): 6.90–7.62 (m, 10 H, arom.), 7.85 (br s, 2 H, NH-indole), 10.30 (br s, 1 H, NH imide); EI-MS [m/z (%)]: 327 (100) [$M^{+\cdot}$], 326 (74) [M − H]$^+$.

$C_{20}H_{13}N_3O_2$ × 0.25 AcOEt

3.3.2. By deprotection of **10** *with NaOH in EtOH*

Compound **10** (5.57 g, 9.16 mmol) was dissolved in EtOH (200 ml) and 52 ml of 10% NaOH were added. After refluxing for 30 min, the mixture was cooled and extracted by CH_2Cl_2 (2 × 100 ml) after addition of 150 ml of saturated NaCl. The organic phase was dried over Na_2SO_4 and evaporated in vacuo to give a residue, which was crystallized from CH_2Cl_2 to give **11** (2.7 g, 91%).

3.4. N-alkyl-derivatives of imide 10

Method A: The mixture of **10** (3.1 g, 5.1 mmol) in 60 ml of absol. DMF and of 300 mg (10.0 mmol) NaH (80% in paraffin) was stirred for 1 h at room temperature. After adding the halogenide (30 mmol), the mixture was stirred for 70 h. Then 100 ml off ice water were added, and the organic phase was separated. The aqueous phase was extracted with AcOEt (2 × 150 ml). The combined organic phases were dried over Na_2SO_4 and evaporated to give a residue which was purified by CC or recrystallisation.

Method B: KH (270 mg, 6.73 mmol) was carefully added to a stirred solution of **10** (1.60 g, 2.60 mmol) in 30 ml of absol. DMF, and the mixture was stirred for 1 h at room temperature. Then 10 mmol of the halogenide were added, and stirring was continued for 24 h at room temperature. After adding 20 ml of ice water, DMF and H_2O were distilled off under reduced pressure. The resulting residue was dissolved in CH_2Cl_2 and washed with H_2O. The organic phase was dried over Na_2SO_4, evaporated in vacuo and purified by CC.

3.4.1. 2,5-Dihydro-1-methyl-3,4-bis(N-phenylsulfonylindol-2-yl)-1 H-pyrrole-2,5-dione (12a)

According to method A with methyl iodide.
Recrystallisation from CH_2Cl_2 gave **12a** (7.3 g, 71%) as yellow crystals; m.p. 147 ° (ether). IR (KBr): 3070–2960 (CH), 1780, 1750 (C=O), 1560, 1455 (C=C), 1370, 1175 cm^{-1} ($PhSO_2$). ^1H NMR (90 MHz, $CDCl_3$, δ ppm): 3.23 (s, 3 H, CH_3), 7.00 (s, 2 H, 3-H, 3′-H), 7.18–7.97 (m, 18 H, arom.). EI-MS (%)]: 621 (7) [$M^{+\cdot}$], 480 (27) [M − $PhSO_2]^+$, 339 (100) [480 − $PhSO_2]^{+\bullet}$, 256 (23), 254 (62), 141 (28) [$PhSO_2]^+$, 77 (83) $[C_6H_5]^+$.

$C_{33}H_{23}N_3O_6S_2$

3.4.2. 2,5-Dihydro-1-[2-(N,N-dimethylamino)ethyl]-3,4-bis(N-phenylsulfonylindol-2-yl)-1 H-pyrrole-2,5-dione (12b) *and 2,5-dihydro-3-indol-2-yl-1-[2-(N,N-dimethylamino)-ethyl]-4-(N-phenylsulfonylindol-2-yl)-1 H-pyrrole-2,5-dione* (14a)

According to method B with freshly prepared 2-(*N*,*N*-dimethylamino)ethyl chloride. Because **12b** and **14a** could not be separated by CC, the mixture was applied for the further reaction, affording **13b** (see below).

3.4.3. 1-(2-Bromoethyl)-2,5-dihydro-3,4-bis(N-phenylsulfonylindol-2-yl)-1H-pyrrole-2,5-dione (12c) *and 1-(2-bromoethyl)-2,5-dihydro-3-(indol-2-yl)-4-(N-phenylsulfonyl-indol-2-yl)-1 H-pyrrole-2,5-dione* (14b)

According to method B with 1,2-dibromoethane. Separation of **12c** and **14b** by CC (SiO_2, CH_2Cl_2).
12c: Yellow wax, yield 80 mg (4%). IR (KBr): 3435 (NH), 3070–2830 (CH), 1720 (C=O), 1605, 1475 (C=C), 1370, 1175 cm^{-1} ($PhSO_2$). ^1H NMR (250 MHz, $CDCl_3$, δ ppm): 3.65 (t, J = 6.9 Hz, 2 H, NCH_2), 4.16 (t, J = 6.9 Hz, 2 H, CH_2−Br), 6.91–8.02 (m, 20 H, arom.). EI-MS [m/z (%)]: 715/713 (7) [$M^{+\cdot}$], 574/572 (10) [M − $PhSO_2]^+$, 433/431 (54) [574/572 − $PhSO_2]^{+\cdot}$, 77 (100) $[C_6H_5]^+$.
14b: Orange crystals, yield 250 mg (19%); m.p. 238–240 °C (dec.). IR (KBr): 3390 (NH), 3050–2860 (CH), 1710 (C=O), 1630, 1475 (C=C), 1365, 1175 cm^{-1} ($PhSO_2$). ^1H NMR (250 MHz, $CDCl_3$, δ ppm): 3.66 (t, J = 6.7 Hz, 2 H, NCH_2), 4.15 (t, J = 6.7 Hz, 2 H, $BrCH_2$), 6.96–8.25 (m, 20 H, arom.), 10.04 (br s, 1 H, NH). EI-MS [m/z (%)]: 575/573 (12) [$M^{+\cdot}$], 434/432 (49) [M − $PhSO_2]^+$, 352 (12) [432 − HBr]$^+$, 255 (100), 77 (40) $[C_6H_5]^+$.

$C_{28}H_{20}N_3O_4S$

3.4.4. 2,5-Dihydro-3,4-bis(N-phenylsulfonylindol-2-yl)-1-ethyl-1 H-pyrrole-2,5-dione (12d)

According to method A with bromoethane.
CC (SiO_2, CH_2Cl_2) gives **12d** (1.3 g, 41%) as yellow crystals; m.p. 120–121 °C. IR (KBr): 3066–2875 (CH), 1713 (C=O), 1605, 1584, 1560 (C=C), 1373, 1175 cm^{-1} ($PhSO_2$). ^1H NMR (250 MHz, D_6-DMSO, δ ppm): 1.20–1.35 (m, 3 H, CH_3), 3.65–3.75 (m, 2 H, CH_2), 7.05–8.00 (m, 20 H, aromat.). EI-MS [m/z (%)]: 635 (5) [$M^{+\cdot}$], 494 (12) [M − $PhSO_2]^+$, 353 (100) [494 − $PhSO_2]^{+\cdot}$.

$C_{34}H_{25}N_3O_6S_2$ × 0.75 AcOEt

3.4.5. 2,5-Dihydro-3,4-bis(N-phenylsulfonylindol-2-yl)-1-(6-bromohexyl)-1 H-pyrrole-2,5-dione (12e)

According to method A with 1,6-dibromohexane.
CC (SiO_2, CH_2Cl_2) gives **12e** (1.7 g, 45%) as yellow crystals; m.p. 91–93 °C. IR (KBr): 3064–2857 (CH), 1713 (C=O), 1605, 1584, 1560 (C=C), 1368, 1175 cm^{-1} ($PhSO_2$). ^1H NMR (250 MHz, D_6-DMSO, δ ppm): 1.30–1.55 (m, 4 H, CH_2), 1.60–1.85 (m, 4 H, CH_2), 3.35–3.55 (m, 2 H, CH_2), 3.55–3.80 (m, 2 H, CH_2), 7.00–8.03 (m, 20 H, aromat.). PI-FDMS (CH_2Cl_2) [m/z (%)]: 769/771 (85/100) [$M^{+\cdot}$].

$C_{38}H_{32}BrN_3O_6S_2$

3.4.6. 2,5-Dihydro-3,4-bis(N-phenylsulfonylindol-2-yl)-1-benzyl-1 H-pyrrole-2,5-dione (12f)

According to method A with benzyl bromide.
CC (SiO_2, CH_2Cl_2) gives **12f** (2.0 g, 56%) as yellow crystals; m.p. 126–128 °C. IR (KBr): 3065–2927 (CH), 1717 (C=O), 1605, 1585, 1560

(C=C), 1370, 1175 cm^{-1} ($PhSO_2$). ^1H NMR (250 MHz, D_6-DMSO, δ ppm): 4.85–4.95 (m, 2 H, CH_2), 7.05–8.00 (m, 25 H, aromat.). EI-MS [m/z (%)]: 697 (3) $[M^{+\bullet}]$, 556 (7) $[M - PhSO_2]^+$, 415 (100) $[566 - PhSO_2]^{+\bullet}$.
$C_{39}H_{27}N_3O_6S_2 \times 0.75$ AcOEt

3.4.7. 2,5-Dihydro-3,4-bis(N-phenylsulfonylindol-2-yl)-1-(2-cyanobenzyl)-1 H-pyrrole-2,5-dione **(12g)**

According to method A with 2-cyanobenzyl bromide.
CC (SiO_2, CH_2Cl_2) gives **12g** (1.8 g, 49%) as yellow crystals; m.p. 144–145 °C. IR (KBr): 3067–2921 (CH), 2226 (CN), 1713 (C=O), 1601, 1584, 1561 (C=C), 1369, 1171 cm^{-1} ($PhSO_2$). ^1H NMR (250 MHz, D_6-DMSO, δ ppm): 5.05–5.12 (m, 2 H, CH_2), 7.06–7.99 (m, 24 H, aromat.). EI-MS [m/z (%)]: 722 (1) $[M^{+\bullet}]$, 581 (2) $[M - PhSO_2]^+$, 440 (36) $[581 - PhSO_2]^{+\bullet}$.
$C_{40}H_{26}N_4O_6S_2 \times$ AcOEt

3.4.8. 2,5-Dihydro-3,4-bis(N-phenylsulfonylindol-2-yl)-1-(4-cyanobenzyl)-1 H-pyrrole-2,5-dione **(12h)**

According to method A with 4-cyanobenzyl bromide.
CC (SiO_2, CH_2Cl_2) gives **12h** (1.8 g, 52%) as yellow crystals; m.p. 109–111 °C. IR (KBr): 3066–2925 (CH), 2228 (CN), 1717 (C=O), 1609, 1584, 1560 (C=C), 1369, 1173 cm^{-1} ($PhSO_2$). ^1H NMR (250 MHz, D_6-DMSO, δ ppm): 4.94–5.04 (m, 2 H, CH_2), 7.05–7.99 (m, 24 H, aromat.). PI-FDMS (CH_2Cl_2) [m/z (%)]: 722 (100) $[M^{+\bullet}]$.
$C_{40}H_{26}N_4O_6S_2 \times 0.25$ AcOEt

3.4.9. 2,5-Dihydro-3,4-bis(N-phenylsulfonylindol-2-yl)-1-[2-(N-piperidino)ethyl]-1 H-pyrrole-2,5-dione **(12i)**

According to method A with *N*-(2-chloroethyl)piperidine.
CC (SiO_2, AcOEt) gives **12i** (0.8 g, 22%) as yellow crystals; m.p. 130 °C (dec.). IR (KBr): 3116–2803 (CH), 1717 (C=O), 1603, 1586, 1564 (C=C), 1395, 1177 cm^{-1} ($PhSO_2$). ^1H NMR (250 MHz, D_6-DMSO, δ ppm): 1.25–1.55 (m, 6 H, CH_2), 2.35–2.65 (m, 6 H, CH_2), 3.70–3.85 (m, 2 H, CH_2), 7.05–8.00 (m, 25 H, aromat.). EI-MS [m/z (%)]: 697 (3) $[M^{+\bullet}]$, 577 (3) $[M - PhSO_2]^+$, 437 (10) $[577 - PhSO_2]^{+\bullet}$.
$C_{39}H_{34}N_4O_6S_2 \times 0.5$ AcOE

3.4.10. 2,5-Dihydro-3,4-bis(N-phenylsulfonylindol-2-yl)-1-(2-(N-morpholino)ethyl]-1 H-pyrrole-2,5-dione **(12k)**

According to method A with freshly prepared *N*-(2-chloroethyl)morpholine.
CC (SiO_2, AcOEt) gives **12k** (1.5 g, 41%) as yellow crystals; m.p. 100–101 °C. IR (KBr): 3066–2855 (CH), 1713 (C=O), 1605, 1584, 1560 (C=C), 1372, 1175 cm^{-1} ($PhSO_2$). ^1H NMR (250 MHz, D_6-DMSO, δ ppm): 2.39–2.48 (m, 4 H, CH_2), 2.55–2.65 (m, 2 H, CH_2), 3.47–3.57 (m, 4 H, CH_2), 3.72–3.88 (m, 2 H, CH_2), 7.00–8.05 (m, 20 H, aromat.). EI-MS [m/z (%)]: 720 (4) $[M^{+\bullet}]$, 579 (55) $[M - PhSO_2]^+$, 438 (24) $[579 - PhSO_2]^{+\bullet}$.
$C_{38}H_{32}N_4O_7S_2 \times 0.5$ AcOEt

3.5. Deprotection of compounds 12a–k

Method C: To a solution of **12** (11 mmol) in 230 ml of MeOH were added 120 ml of 10% NaOH, and the mixture was refluxed for 1 h. After cooling, 120 ml of saturated NaCl solution were added, and the mixture was extracted with CH_2Cl_2 (2 × 100 ml). The combined organic phase was dried over Na_2SO_4 and evaporated.

Method D: To a solution of 1.0 mmol of **12** in 40 ml of absol. THF were added 1.11 g (3.0 mmol) TBAF × 3 H_2O in 5 ml of absol. THF. After refluxing for 2 h, 120 ml of H_2O and 50 ml of CH_2Cl_2 were added, and the organic phase was separated. The aqueous phase was further extracted by CH_2Cl_2 (2 × 60 ml), and the combined organic phase was dried over Na_2SO_4 and evaporated in vacuo to give a residue which was purified by CC.

3.5.1. 2,5-Dihydro-3,4-bis(indol-2-yl)-1-methyl-1 H-pyrrole-2,5-dione **(13a)**

According to method C from **12a**.
Crystallization of the resulting residue from CH_2Cl_2/hexane gave **13a** (3.2 g, 87%) as dark red crystals, m.p. 247 °C (dec.) (CH_2Cl_2). IR (KBr): 3400 (NH), 3070–2960 (CH), 1750, 1690 (C=O), 1630, 1455 cm^{-1} (C=C). ^1H NMR (90 MHz, D_6-DMSO, δ ppm): 3.17 (s, 3 H, CH_3), 6.97–7.70 (m, 10 H, arom.), 11.23 (s, 2 H, NH, exch.). EI-MS [m/z (%)]: 341 (100) $[M^{+\bullet}]$, 340 (75) $[M - H]^+$, 255 (91).
$C_{21}H_{15}N_3O$

*3.5.2. 2,5-Dihydro-3,4-bis(indol-2-yl)-1-[2-(N,N-dimethylamino)ethyl]-1 H-pyrrole-2,5-dione (***13b***)*

According to method C from **12b** and **14a**.
The crude product was purified by CC (SiO_2, CH_2Cl_2) to get **13b** (151 mg) as black violet wax. IR (KBr): 3390, 3350 (NH), 3070–2820 (CH), 1690 (C=O), 1615, 1450 cm^{-1} (C=C). ^1H NMR (250 MHz, $CDCl_3$, δ ppm): 2.30 (s, 6 H, CH_3), 2.60 (t, J = 6.5 Hz, 2 H, $(CH_3)_2NC\underline{H}_2$), 3.77 (t, J = 6.5 Hz, 2 H, CH_2–N–C=O), 7.11–7.80 (m, 10 H, arom.), 10.06 (br s, 2 H, NH). EI-MS [m/z (%)]: 398 (7) $[M^{+\bullet}]$, 58 (100) $[CH_2{=}N(CH_3)_2]^+$.

3.5.3. 2,5-Dihydro-3,4-bis(indol-2-yl)-1-ethyl-1 H-pyrrole-2,5-dione **(13c)**

According to method D from **12d**.
CC (SiO_2, CH_2Cl_2) gave **13c** (150 mg, 36%) as dark red wax. IR (KBr): 3407, 3350 (NH), 3050–2973 (CH), 1744, 1688 (C=O), 1624, 1615, 1578 cm^{-1} (C=C). ^1H NMR (250 MHz, D_6-DMSO, δ ppm): 1.21 (t, 3 H, CH_3), 3.62 (q, 2 H, CH_2), 7.01–7.63 (m, 10 H, aromat.), 11.30 (s, 2 H, NH). EI-MS [m/z (%)]: 355 (100) $[M^{+\bullet}]$, 255 (32).

3.5.4. 2,5-Dihydro-3,4-bis(indol-2-yl)-1-(6-fluorohexyl)-1 H-pyrrole-2,5-dione **(13d)**

According to method D from **12e**. During the reaction Br was completely replaced by F.
CC (SiO_2, CH_2Cl_2) gave **13d** (150 mg, 36%) as dark red wax. IR (KBr): 3357 (NH), 3062–2863 (CH), 1746, 1694 (C=O), 1626, 1615 cm^{-1} (C=C). ^1H NMR (250 MHz, D_6-DMSO, δ ppm): 1.37 (m, 4 H, CH_2), 1.66 (m, 4 H, CH_2), 3.58 (t, 2 H, N–CH_2), 4.33/4.52 (2t, 2 H, F–CH_2), 7.02–7.64 (m, 10 H, aromat.), 11.30 (s, 2 H, NH). EI-MS [m/z (%)]: 429 (57) $[M^{+\bullet}]$, 409 (100) $[M - HF]^{+\bullet}$, 255 (60).

3.5.5. 2,5-Dihydro-3,4-bis(indol-2-yl)-1-benzyl-1 H-pyrrole-2,5-dione **(13e)**

According to method D from **12f**.
CC (SiO_2, CH_2Cl_2) gave **13e** (150 mg, 36%) as dark red wax. IR (KBr): 3401 (NH), 3058–2960 (CH), 1746, 1686 (C=O), 1615, 1586 cm^{-1} (C=C). ^1H NMR (250 MHz, D_6-DMSO, δ ppm): 4.80 (s, 2 H, CH_2), 7.01–7.64 (m, 15 H, aromat.), 11.35 (s, 2 H, NH). EI-MS [m/z (%)]: 417 (100) $[M^{+\bullet}]$, 326 (17), 270 (25), 256 (70).

3.5.6. 2,5-Dihydro-3,4-bis(indol-2-yl)-1-[2-(N-piperidino)ethyl]-1 H-pyrrole-2,5-dione **(13f)**

According to method D from **12i**.
CC (SiO_2, AcOEt) gave **13f** (150 mg, 36%) as dark red wax. IR (KBr): 3394 (NH), 3058–2851 (CH), 1736, 1690 (C=O), 1615, 1533 cm^{-1} (C=C). ^1H NMR (250 MHz, D_6-DMSO, δ ppm): 1.30–1.50 (m, 6 H, CH_2), 2.4 (m, 6 H, CH_2), 3.70 (m, 2 H, CH_2), 7.05–7.75 (m, 10 H, aromat.), 11.30 (s, 2 H, NH). EI-MS [m/z (%)]: 438 (11) $[M^{+\bullet}]$, 340 (3), 256 (5), 98 (100).

*3.5.7. 2,5-Dihydro-3,4-bis(indol-2-yl)-1-[2-(N-morpholino)ethyl]-1 H-pyrrole-2,5-dione (***13g***)*

According to method D from **12k**.
CC (SiO_2, CH_2Cl_2/AcOEt 10:1) gave **13g** (130 mg, 33%) as dark red wax. IR (KBr): 3403 (NH), 3054–2847 (CH), 1690 (C=O), 1616, 1605 cm^{-1} (C=C). ^1H NMR (250 MHz, D_6-DMSO, δ ppm): 2.39–2.47 (m, 4 H, CH_2), 2.56–2.60 (t, 2 H, CH_2), 3.48–3.58 (m, 4 H, CH_2), 3.67–3.77 (t, 2 H, CH_2), 6.95–7.65 (m, 10 H, aromat.), 10.80–11.50 (br s, 2 H, NH). EI-MS [m/z (%)]: 440 (16) $[M^{+\bullet}]$, 340 (2), 100 (100).

3.6. 1-(2-Azidoethyl)-2,5-dihydro-3,4-bis(N-phenylsulfonylindol-2-yl)-1 H-pyrrole-2,5-dione **(15)**

A solution of **12c** (1.00 g, 1.40 mmol) in 20 ml of absol. DMF was stirred with NaN_3 (450 mg, 6.92 mmol) for 20 h at 60 °C. Then 60 ml of H_2O were added. The resulting crystals were filtered, washed with H_2O, dried, and purified by CC (SiO_2, CH_2Cl_2) to give **15** (600 mg, 63%) as a yellow wax. IR (KBr): 3475 (NH), 3100–2880 (CH), 2105 (N_3), 1715 (C=O), 1605, 1460 (C=C), 1370, 1175 cm^{-1} ($PhSO_2$). ^1H NMR (250 MHz, $CDCl_3$, δ ppm): 3.65 (t, J = 6.6 Hz, 2 H, CH_2N), 3.95 (t, J = 6.6 Hz, 2 H, CH_2N_3), 6.90–8.05 (m, 20 H, arom.). EI-MS [m/z (%)]: 676 (2) $[M^{+\bullet}]$, 535 (3) $[M - PhSO_2]^+$, 394 (4) $[535 - PhSO_2]^{+\bullet}$, 141 (28) $[PhSO_2]^+$, 77 (100) $[C_6H_5]^+$.

3.7. 1-(2-Azidoethyl)-2,5-dihydro-3-indol-2-yl-4-(N-phenylsulfonylindol-2-yl)-1 H-pyrrole-2,5-dione **(16)**

A solution of **14b** (400 mg, 0.70 mmol) in 8 ml of abs. DMF was stirred with NaN_3 (300 mg, 4.63 mmol) for 20 h at 60 °C. Then DMF was evaporated at the oil pump, and the residue was purified by CC (SiO_2, CH_2Cl_2) to give **16** (220 mg, 59%) as an orange wax. IR (KBr): 3400, 3380 (NH), 3070–2850 (CH), 2095 (N_3), 1710 (C=O), 1615, 1460 (C=C), 1370, 1175 cm^{-1} ($PhSO_2$). ^1H NMR (250 MHz, $CDCl_3$, δ ppm): 3.68 (t, J = 6.3 Hz, 2 H, CH_2N), 3.95 (t, J = 6.3 Hz, 2 H, CH_2N_3), 6.95–8.20 (m, 15 H, arom.), 10.05 (br s, 1 H, NH). EI-MS [m/z (%)]: 536 (29) $[M^{+\bullet}]$, 395 (48) $[M - PhSO_2]^+$, 255 (100), 141 (20) $[PhSO_2]^+$, 77 (100) $[C_6H_5]^+$.

3.8. 1-(2-Aminoethyl)-2,5-dihydro-3-indol-2-yl-4-(N-phenylsulfonylindol-2-yl)-1 H-pyrrole-2,5-dione (17)

A mixture of **16** (26 mg, 0.05 mmol) and Pd/C (10 mg) in 5 ml of abs. EtOH was stirred for 24 h at room temperature under a H_2 filled toy balloon. Then 5 ml of H_2O were added, and the solution was extracted with CH_2Cl_2 (2 × 10 ml). The organic phase was dried over Na_2SO_4 and evaporated in vacuto to give a residue which was purified by CC (SiO_2, EtOAc/MeOH 1:1) to get **17** (6 mg, 20%) as yellowish brown wax. IR (KBr): 3390 (NH_2), 3070–2850 (CH), 1705 (C=O), 1610, 1460 (C=C), 1360, 1175 cm^{-1} ($PhSO_2$). ^1H NMR (250 MHz, $CDCl_3$, δ ppm): 2.95 (t, J = 7.3 Hz, 2 H, $C\underline{H}_2NH_2$), 3.75 (t, J = 7.3 Hz, 2 H, CH_2–N–C=O), 4.85 (br s, 2 H, NH_2), 6.40–8.00 (m, 15 H, arom.), 9.35 (br s, 1 H, NH).

3.9. 5-Hydroxy-3,4-bis(2-indolyl)pyrrolin-2-one (18)

At 0 °C to a slurry of 45.4 mg (1.20 mmol) $LiAlH_4$ in 10 ml of absol. THF were added dropwise 159 mg (0.49 mmol) **11** in 10 ml of absol. THF. After stirring for 1 h at 0 °C and 20 h at room temperature, 100 ml of H_2O were added. The mixture was acidified with 5% HCl. The precipitate was separated by filtration and purified by CC. (SiO_2, CH_2Cl_2/MeOH 10:1): **18** (39 mg, 24%), yellow crystals; m.p. 110 °C (dec.). IR (KBr): 3404 (NH), 3055 (CH), 1685 (C=O), 1615, 1580, 1540 cm^{-1} (C=C). ^1H NMR (250 MHz, D_6-DMSO, δ ppm): 5.95 (dd, $J_1 = 9.8$ Hz, $J_2 = 1.5$ Hz; 1 H, 5-H), 6.40 (d, J = 9.5 Hz; 1 H, H/D-exchange, OH), 6.90–7.58 (m, 10 H, aromat.), 8.96 (d, J = 1.5 Hz; 1 H, H/D-exchange, NH aminal), 11.09 (s, 1 H, H/D-exchange, NH indole), 11.21 (s, 1 H, H/D-exchange, NH indole). EI-MS [m/z (%)]: 329 (27) [$M^{+\bullet}$], 117 (100).
$C_{20}H_{14}N_3O_2$

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