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PAPER

A one-pot synthesis of 7-phenylindolo[3,2-*a*]carbazoles from indoles and β-nitrostyrenes, *via* an unprecedented reaction sequence†‡

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A six-step one-pot reaction was designed for synthesizing homodimeric 7-phenylindolo[3,2-*a*]carbazoles from 1*H*-indoles and β-nitrostyrenes, in the presence of $SnCl_2 \cdot 2H_2O$. The reactions proceeded under very mild conditions and the desired heterocycles were obtained in moderate to good yields. An unprecedented mechanism involving sequential indole dimerization, regioselective nucleophilic conjugate addition of the resulting 2,3′-biindole to β-nitrostyrene and formal intramolecular [4 + 2]-cycloaddition is proposed.

Introduction

In contrast to extensive studies on the indolo[2,3-*a*]carbazole ring system **1**, the chemistry of the isomeric indolo[3,2-*a*]carbazole skeleton **2** has received only little attention to date (Fig. 1). This is undoubtedly due to the existence of biologically active natural indolo[2,3-*a*]carbazole alkaloids such as rebeccamycin or staurosporine, whose structure–activity relationships have been thoroughly investigated.[1,2] Instead, ancorinazole **3** is the only indolo[3,2-*a*]carbazole reported from a natural source, namely the marine sponge *Ancorina* sp.[3] On the other hand, in recent times, there has been a growing interest in the use of indolocarbazoles, particularly indolo[3,2-*b*]carbazoles, in the field of materials chemistry. Indeed, such compounds could serve as hosts for organic electroluminescent (EL) devices (organic light emitting diodes or OLEDs).[4] For this purpose, preparation of EL devices based on 7-phenylindolo[3,2-*a*]carbazoles are currently under investigation (an example of such a carbazole is given in Fig. 1).[5]

To the best of our knowledge, only a limited number of methods (less than ten) allowing access to indolo[3,2-*a*]carbazoles have been reported. They generally take place under rather drastic conditions, particularly by heating in high boiling solvents and/or require numerous steps.[6] However, particular efforts have been devoted to the synthesis of arcyriaflavin A analogues in this series (**4**).[6a,6b]

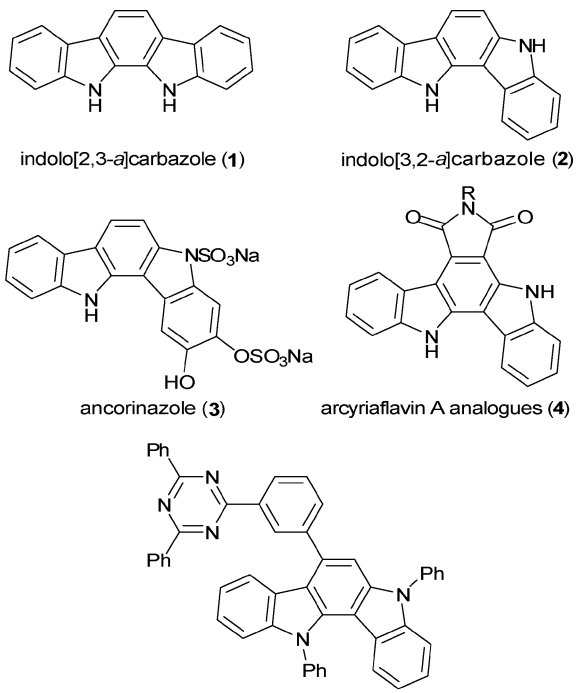

Fig. 1 Structures of indolo[*a*]-annulated carbazole skeletons. Structural examples of natural and synthetic indolo[3,2-*a*]carbazoles.

Such compounds have been synthesized by means of a one-pot synthesis starting from 1*H*-indole and different maleimides (R = H or alkyl substituent), heated in acetic acid.[6a] In a further study, the same authors also reported that direct heating of *N*-ethylmaleimide with 2,3′-biindole **5**, resulted in the formation of the corresponding indolo[3,2-*a*]carbazole through a formal [4 + 2] cycloaddition. This reaction has been successfully carried out with

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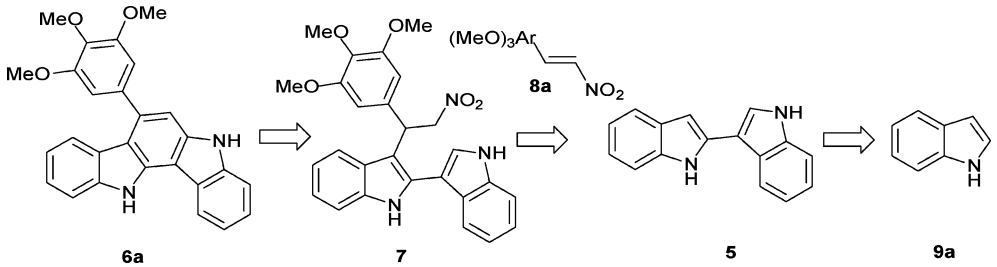
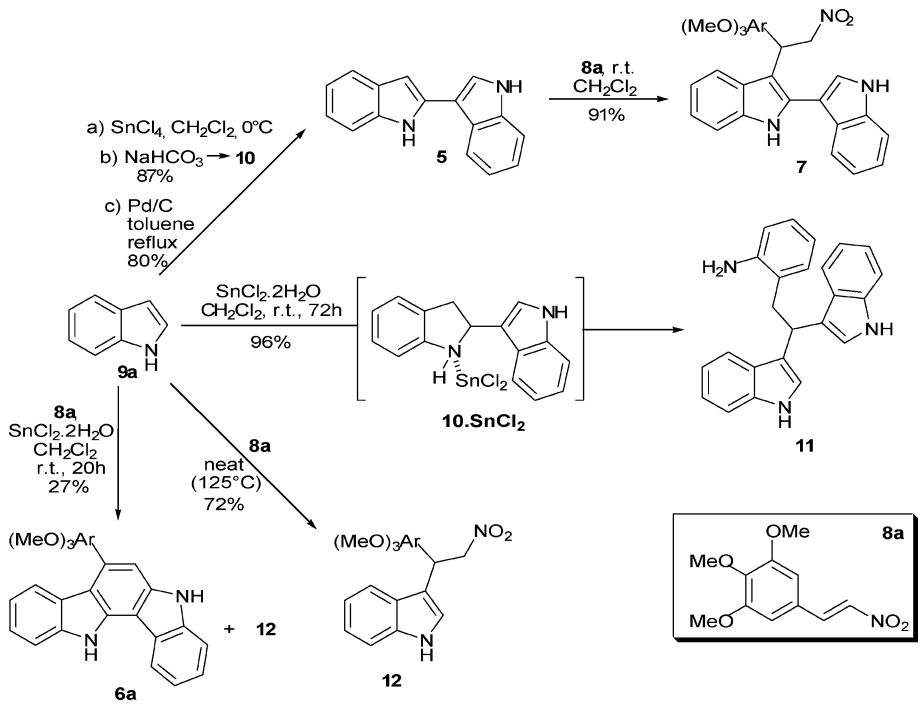
† This paper is dedicated to the memory of the late Professor François Tillequin.

‡ Electronic supplementary information (ESI) available: ^1H and ^{13}C NMR spectra of all new compounds, COSY and NOESY spectra of compound **6a**. Crystallographic data for compound **6g**. CCDC reference number 825605. For ESI and crystallographic data in CIF or other electronic format see DOI: 10.1039/c1ob06108a



Scheme 1 Retrosynthesis of the 7-phenylindolo[3,2-*a*]carbazole **6a**.



Scheme 2 Preliminary studies toward the synthesis of the indolo[3,2-*a*]carbazole **6a**.

a small number of other dienophiles, including dialkyl acetylene dicarboxylates.[6b] Finally, a one-pot method for the synthesis of 6,7-diphenylindolo[3,2-*a*]carbazoles starting from 1*H*-indoles and symmetrical diaryl 1,2-diones has been recently published.[6d]

None of the aforementioned methods allowed an efficient access to 7-phenylindolo[3,2-*a*]carbazoles. In view of the increasing interest in these compounds, particularly in the field of materials chemistry, and in continuation of our own interest in ring-fused carbazoles,[7] we report herein an expeditious one-pot sequential synthesis of such compounds through an unusual reaction involving both a β-nitrostyrene and an indole unit.

Results and discussion

The retrosynthetic analysis is outlined in Scheme 1 and is exemplified for the synthesis of **6a** from 1*H*-indole **9a**. 7-(3,4,5-Trimethoxyphenyl)indolo[3,2-*a*]carbazole **6a** was chosen as the initial target because of the relative simplicity of its ^{1}H NMR spectrum. The key intermediate nitroalkane, **7**, would be prepared by a regioselective nucleophilic conjugate addition of homodimer 2,3′-biindole **5** to 3,4,5-trimethoxy-β-nitrostyrene **8a**. It might be expected that after oxidation into the corresponding nitroalkene, this compound would undergo subsequent cyclization upon heating. Finally, 2,3′-biindole **5** would be directly obtained from 1*H*-indole **9a**.

To test the feasibility of this retrosynthetic strategy, we first focused on the preparation of the intermediate **7** from 2,3′-biindole **5** (Scheme 2). First of all, the latter compound **5** was synthesized in two steps from 1*H*-indole **9a**. The dimerization of 1*H*-indole[8] was thus achieved by treatment with one equivalent of $SnCl_4$ in CH_2Cl_2. Basic treatment of the resulting tin salt precipitate afforded 3-(indolin-2-yl)-1*H*-indole **10** in 87% yield. This procedure constitutes a convenient alternative to those previously reported in the literature which involve the precipitation of **10** as the HCl salt, avoiding therefore problems associated with the handling of gaseous HCl.[9] Thereafter, aromatization of **10** to the desired **5** was performed in 80% yield according to a literature procedure using Pd/C.[9b]

Secondly, we decided to investigate the reactivity of **5** toward the β-nitrostyrene **8a**. Michael-type Friedel–Crafts alkylation of indoles with a β-nitrostyrene always proceeds sluggishly without a catalyst.[10,11] We were therefore surprised to observe that, probably due to the higher nucleophilicity of the dimer **5**, a spontaneous reaction occurred at room temperature and without a catalyst

between **5** and **8a**, resulting in conversion to the desired adduct **7** in 91% yield. As expected, reaction of 1*H*-indole **9a** with **8a** under similar conditions failed to afford the corresponding nitroalkane **12**. Finally, this compound could be prepared in 72% yield under thermal conditions[12] (neat, 125 °C).

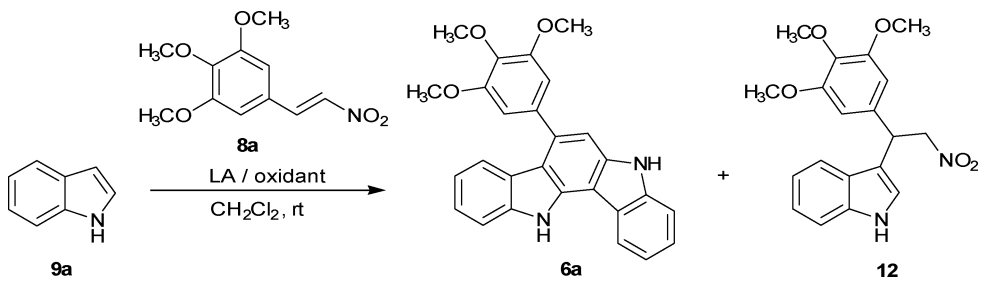
During studies directed toward the synthesis of adduct **7**, we also found that treatment of 1*H*-indole **9a** with one equivalent of $SnCl_2{\cdot}2H_2O$ in CH_2Cl_2 resulted in the formation of the well known trimer **11** in quantitative yield.[13] According to the generally accepted mechanism, compound **11** is supposed to be derived from the intermediate 3-(indolin-2-yl)-1*H*-indole **10**.[9c,15] We therefore postulated that although the weak and heterogeneous Lewis acid $SnCl_2{\cdot}2H_2O$ enables indole dimerization into **10**, this reaction may proceed without any concomitant precipitation of the corresponding tin salts in CH_2Cl_2, thereby allowing further polymerization of **10** into **11**.

These observations prompted us to investigate the possibility of a one-pot synthesis of **7** from **9a**, *via* a tandem dimerization–oxidation–addition reaction. Thus, we hypothesized that, if the dimer **5** could be conveniently formed *in situ* from 1*H*-indole **9a**, it would be subsequently trapped by the β-nitrostyrene **8a**.

We therefore decided to attempt the reaction using the reagent combination $SnCl_2{\cdot}2H_2O$/oxidant/**8a**. We initially tried the reaction in CH_2Cl_2 at room temperature, with stoichiometric amounts of both **8a** and $SnCl_2{\cdot}2H_2O$ and air as the oxidant. We were surprised to find that neither the desired compound **7** nor the trimer **11** could be isolated from the reaction mixture. Instead, a blue fluorescent compound was formed as the major product in 27% yield, which was unambiguously identified by NMR spectroscopy and mass spectrometry as the target carbazole **6a** and probably arising from the cyclization of **7** (See ESI).‡[16] The formation of **6a** was also accompanied by a trace amount[17] of the monoindole adduct **12**. This pleasant result was totally unexpected in regard to the previous syntheses of the indolo[3,2-*a*]carbazole skeleton always achieved under drastic conditions. Furthermore, the isolated yield of this one-pot reaction was acceptable considering the number of steps necessary to convert 1*H*-indole **9a** into a complex pentacyclic compound. Therefore, we decided to optimize the reaction conditions before further exploration of its scope.

A number of conditions, including appropriate molar ratios of reactants, different solvents and oxidants, were screened to optimize the reaction and especially to limit the formation of Michael adduct **12**. The pertinent results are summarized in Table 1.[18] More polar solvents such as CH_3CN and EtOAc were not suitable and no conversion was observed, most probably because they complex preferentially to the Lewis acid. Increasing the amount of **8a** to 2 equiv led only to traces of Michael adduct **12** and slightly decreased the yield of **6a** to 20% (Table 1, entry 4). If the reaction was carried out with a catalytic amount (10 mol%) of $SnCl_2{\cdot}2H_2O$ (Table 1, entry 5),[19,20] the yield was similar (28%) albeit a longer reaction time was required. However, the reaction was cleaner, thus allowing facile separation of a non-negligible amount of **12** (52% yield). We were surprised to observe that the yield of this reaction decreased significantly to 12% when anhydrous $SnCl_2$ was used as the Lewis acid (Table 1, entry 6). Combinations of catalytic $SnCl_2{\cdot}2H_2O$ with other oxidants were also attempted without success (Table 1, entries 7 and 8). Finally, the best yields (41–59%) were obtained by employing equimolar amounts of $SnCl_2{\cdot}2H_2O$, **8a** and **9a**, and by replacing air (Table 1, entry 4) with either an oxygen atmosphere in the presence of catalytic amount of salcomine[21] (Table 1, entry 11) or the heterogeneous oxidant MnO_2[21,22] (1 equiv or excess) (Table 1, entries 9 and 10), which are both versatile reagents often used

Table 1 Optimization of one-pot indolo[3,2-*a*]carbazole **6a** formation[a]



Entry	Lewis acid (equiv)	Oxidant (equiv)	Reaction time (h)	Yield **6a** (%)[b]	Yield **12** (%)[b]
1	/	/	48	0	0
2	/	/	4[c]	0	72
3	A (1.0)	(air)	48	27	NI[d]
4	A (1.0)	(air)	20[e]	20[f]	Traces
5	A (0.1)	(air)	72	28	52
6	B (0.1)	(air)	72	12	NI[d]
7	A (0.1)	O_2[g]	72	27	23
8	A (0.1)	MnO_2 (1.0)	72	17	29
9	A (1.0)	MnO_2 (1.0)	48	59	10
10	A (1.0)	MnO_2 (3.0)	48	53	16
11	A (1.0)	O_2[g]+Salc.[h]	48	41	NI[d]
12	/	MnO_2 (1.0)	48	0	0

[a] Reaction conditions: **9a** (0.43 mmol, 1.0 equiv), **8a** (0.43 mmol, 1.0 equiv), DCM (10 mL), room temperature. [b] Isolated yield based on indole. [c] Without solvent, temperature: 125 °C. [d] Not isolated (inseparable mixture of several products). [e] **8a** (0.86 mmol, 2.0 equiv). [f] 62% of **8a** is recovered. [g] O_2 atmosphere. [h] Salcomine (0.1 equiv). LA: $SnCl_2{\cdot}2H_2O$ (A), $SnCl_2$ (B).

for oxidation of indolines into indoles. The best conditions found were, therefore, employing one equivalent of MnO_2 as oxidant (Table 1, entry 9). In this case the yield of **6a** was increased from 27 to 59% (it is also interesting to note that MnO_2 alone did not induce any observable reaction (Table 1, entry 12). From these results, MnO_2 (1 equiv) emerged as the reagent of choice.

To illustrate the scope of this reaction, other 1*H*-indoles (**9b–9i**) were tested under the same reaction conditions optimized above (equimolar amounts of $SnCl_2{\cdot}2H_2O$, MnO_2 and **8a**) (Table 2, entries 2–9). We next examined the scope of this reaction with a variety of β-nitrostyrenes (**8b–8e**) under the same conditions, but using **9a** as the reaction partner (Table 2, entries 10–14). The reaction generally proceeded in modest to good yields (18–66%), depending both on the nature of the substituents and on the solubility of the corresponding carbazole in common solvents. However, both reactions of **8a** with poor electron nitroindoles **9h** and **9i** failed to afford the desired products (Table 2, entries 8 and 9), and starting indoles were recovered unchanged. Furthermore, the 5,6-dimethoxy-1*H*-indole (**9e**) seems to be sensitive to the reaction conditions since its quantitative conversion into 5,6-dimethoxy-anthranilic acid[23] was observed (Table 2, entry 5).

Compounds **6b–k** were characterized on the basis of their spectroscopic data. Particularly, in the ^{1}H NMR spectra of these compounds, besides the two D_2O-exchangeable NH signals (except for **6b** which bears two *N*-methyl groups) the most deshielded proton always appears in the range of 8.10–8.70 ppm, depending both on substituents and NMR solvent. This signal was assigned to H1. Additionally, the structure of **6g** was confirmed by single crystal X-ray analysis (Fig. 2) (ESI).‡

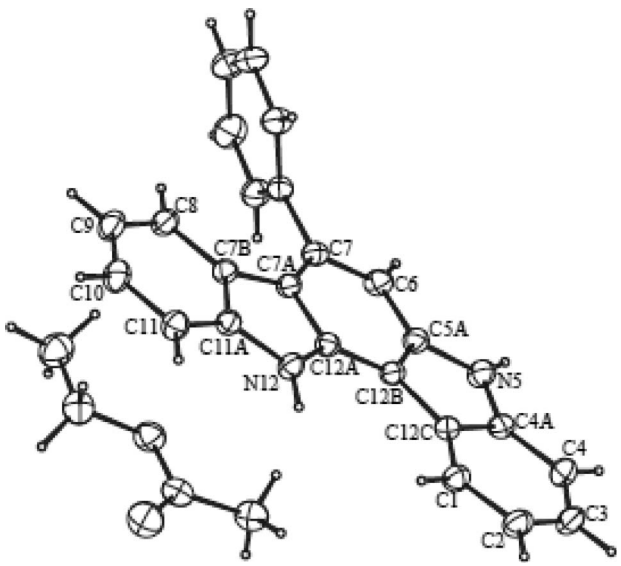
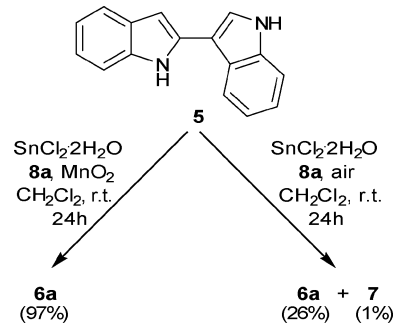


Fig. 2 SHELXTL Plot of X-ray crystal structure of **6g** (Atomic displacement parameters at 50% probability levels) with lattice ethyl acetate molecule included.

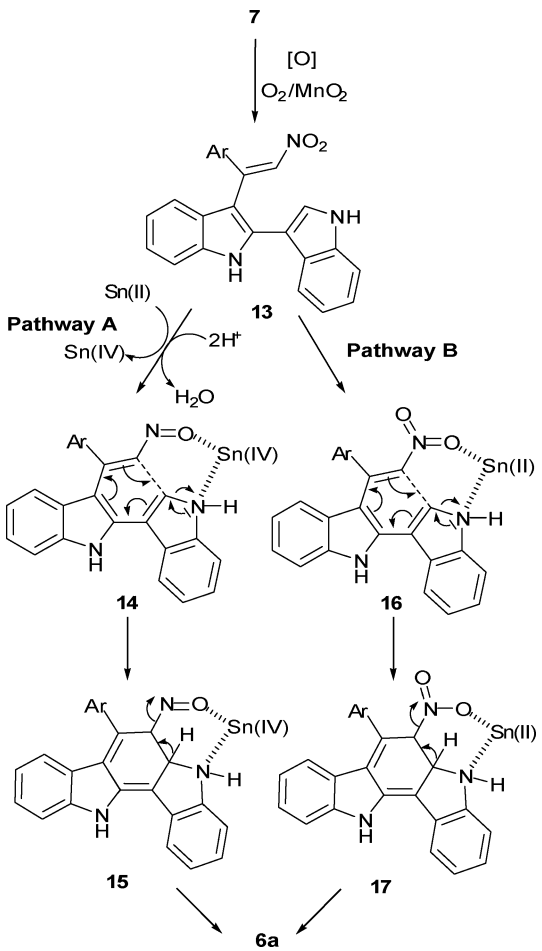
Mechanism

Evidence for the formation of the key intermediate **7** proposed in our retrosynthetic analysis for compound **6a** (Scheme 1) was provided by the following experiment (Scheme 3).[24] Direct treatment of 2,3′-biindole **5** with **8a** under the aforementioned optimized conditions afforded the carbazole **6a** in near quantitative yield. Examination of the reaction course by TLC monitoring showed the rapid formation and subsequent total disappearance of **7**. Interestingly, the use of $SnCl_2{\cdot}2H_2O$/air combination led to a decreased yield of 27% and a small amount (in about 1% yield) of **7** was also isolated.



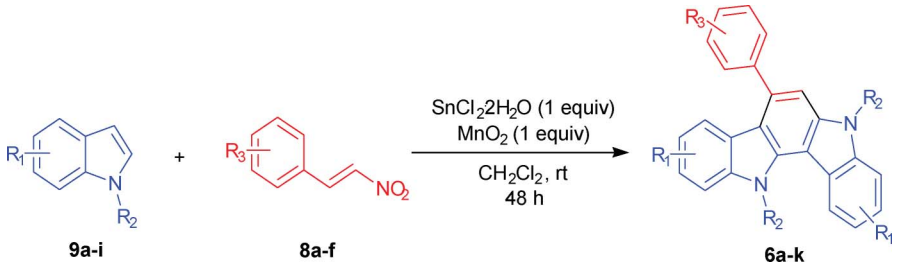
Scheme 3 Reaction of 2,3′-biindole **5** with **8a**.

A proposed mechanism to account for the unexpected smooth cyclization of **7** to **6a** is shown in Scheme 4. Heterogeneous oxidation of **7** with MnO_2 into the corresponding nitroalkene **13**, followed by tin(II) mediated two-electron reduction afford a highly reactive nitrosoalkene[25] **14** that undergoes further formal intramolecular [4 + 2]-cycloaddition (Scheme 4, pathway A).[26,27]



Scheme 4 Plausible mechanism accounting for the cyclization of **7** to **6a**.

Table 2 Synthesis of indolo[3,2-*a*]carbazoles from various substituted indoles



9a-i **8a-f** **6a-k**

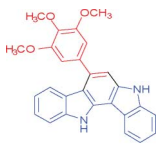
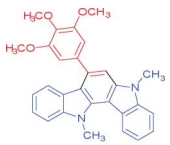
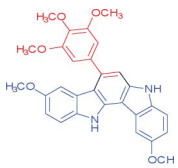
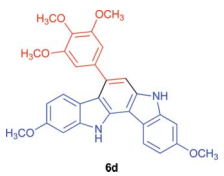
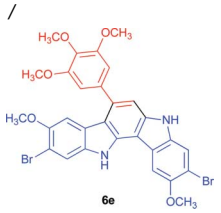
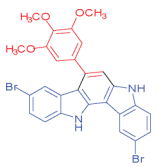
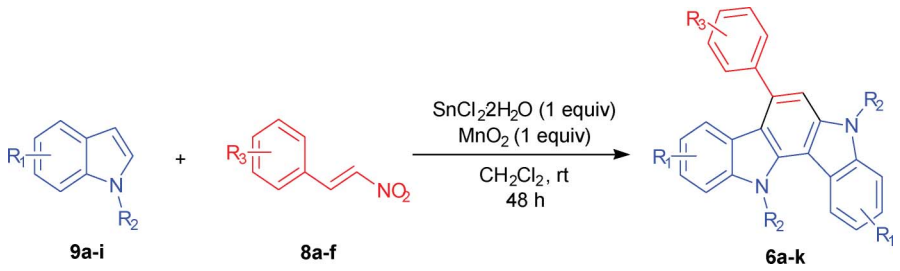
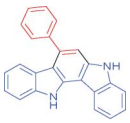
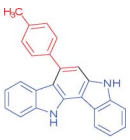
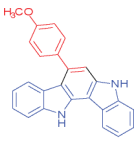
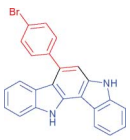
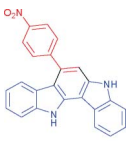
Entry	R^1, R^2	R^3	Product	Yield[a] (%)
1	$R^1 = R^2 = H$ **9a**	3,4,5- trimethoxy **8a**	 **6a**	59
2	$R^1 = H$, $R^2 = Me$ **9b**	3,4,5- trimethoxy **8a**	 **6b**	30[b]
3	$R^1 = 5\text{-OMe}$, $R^2 = H$ **9c**	3,4,5- trimethoxy **8a**	 **6c**	41
4	$R^1 = 6\text{-OMe}$, $R^2 = H$ **9d**	3,4,5- trimethoxy **8a**	 **6d**	52
5	$R^1 = 5,6\text{-OMe}$, $R^2 = H$ **9e**	3,4,5- trimethoxy **8a**	/	0[c]
6	$R^1 = 5\text{-OMe, 6-Br}$, $R^2 = H$ **9f**	3,4,5- trimethoxy **8a**	 **6e**	66
7	$R^1 = 5\text{-Br}$, $R^2 = H$ **9g**	3,4,5- trimethoxy **8a**	 **6f**	18[c]
8	$R^1 = 5\text{-NO}_2$, $R^2 = H$ **9h**	3,4,5- trimethoxy **8a**	/	0
9	$R^1 = 6\text{-NO}_2$, $R^2 = H$ **9i**	3,4,5- trimethoxy **8a**	/	0

Table 2 (*Contd.*)



Entry	R^1, R^2	R^3	Product	Yield[a] (%)
10	$R^1 = R^2 =$ H **9a**	H **8b**	 **6g**	53
11	$R^1 = R^2 =$ H **9a**	4-Me **8c**	 **6h**	31
12	$R^1 = R^2 =$ H **9a**	4-OMe **8d**	 **6i**	40
13	$R^1 = R^2 =$ H **9a**	4-Br **8e**	 **6j**	33
14	$R^1 = R^2 =$ H **9a**	4-NO_2 **8f**	 **6k**	20[d]

[a] Isolated yields. [b] Compound with a poor solubility in many solvents. [c] Indole non-stable in the reaction conditions. [d] Difficult purification.

An alternative mechanism, involving a direct Lewis-acid promoted cyclization of **16** cannot be discarded since the one-pot reaction also succeeds with a catalytic amount of $SnCl_2{\cdot}2H_2O$ (Scheme 4, pathway B). However, in both pathways, coordination of the Lewis acid to the oxygen of the nitroso or nitro group, as well as to the lone pair of the nitrogen atom N(1) likely favours the cycloaddition. Finally, the cycloadduct may undergo aromatization through the formal loss of HNO or HNO_2.

Conclusions

In summary, we have developed an efficient and expeditious synthesis of homodimeric 7-phenylindolo[3,2-*a*]carbazoles from 1*H*-indoles and β-nitrostyrenes, *via* a six-step one-pot reaction. In contrast to previous indolo[3,2-*a*]carbazole syntheses, our reaction proceeds under very mild conditions. Moreover, although the nucleophilic conjugate addition of indoles to nitroolefins in the presence of Lewis acid catalysts has received considerable attention, to the best of our knowledge, this is the first report of such a reaction. In this context, our results underline the crucial role of $SnCl_2{\cdot}2H_2O$ in nonpolar solvents such as CH_2Cl_2, in this one-pot reaction.

Furthermore, the first step of the mechanism for the formation of indolo[3,2-*a*]carbazoles involves indole dimerization. The efficiency of this dimerization depends on indole reactivity, which limits the scope of the method. However, independent syntheses of 2,3′-biindoles may well overcome this limitation. Further studies on the synthetic applications of this one-pot reaction, for example

in the preparation of electroactive carbazoles, are currently under investigation in our laboratory.

Experimental

General methods

All reagents were used as purchased without further treatment unless otherwise stated. All solvents were dried according to standard procedures. β-Nitrostyrenes **8a–8f** were readily prepared according to literature procedures. Reactions were monitored by thin layer chromatography (TLC) using Merck Kieselgel 60 F254 silica gel; zones were detected visually under ultraviolet irradiation (254 and 366 nm) and by spraying with sulfuric vanillin followed by heating. All indolo[3,2-*a*]carbazoles exhibited brilliant fluorescence (from blue to yellow, depending on the substitution pattern) under UV light (366 nm). Flash column chromatography was performed with silica gel (SDS 60 ACC 35–70 μM). NMR spectra were recorded at 300 or 400 MHz (^{1}H) and at 75 or 100 MHz (^{13}C) with AC 300 and Avance 400 BRUKER spectrometers. Chemical shifts are given in parts per million (ppm, δ) relative to solvent peaks as internal standards (δ: $CDCl_3$: 7.27 ppm (^{1}H), 77.0 ppm (^{13}C); DMSO-d_6: 2.50 ppm (^{1}H), 40.6 ppm (^{13}C); acetone-d_6: 2.05 ppm (^{1}H), 29.8 and 206.0 ppm (^{13}C); DMF-d_7: 2.05 ppm (^{1}H), 29.8 and 206.0 ppm (^{13}C)); coupling constants are given in hertz (Hz, *J*). IR spectra were recorded on a NICOLET 500 FT-IR spectrophotometer. The UV spectrum of **6a** was recorded on a BECKMAN DU 640 spectrophotometer. Melting points were measured on a LEICA VM microscope equipped with a heating stage and are uncorrected. Mass spectra (MS) were measured with a Nermag R10-10C mass spectrometer (CI/NH_3) or with a ZQ 2000 Waters mass spectrometer (ESI). High-resolution mass spectrometry (HRMS) spectra were performed at the Laboratoire de Spectrométrie de Masse (I.C.S.N./C.N.R.S., Gif sur Yvette, France).

Typical procedure for the synthesis of indolocarbazoles 6 from 1*H*-indoles 9. To a solution of indolic compound (**9**, 50 or 100 mg) and β-nitrostyrene (**8**, 1.0 equiv) in anhydrous DCM (10 or 20 mL) was added equimolar amounts of $SnCl_2{\cdot}2H_2O$ and MnO_2. After 48 h of stirring at room temperature, the reaction mixture was filtered through a Celite pad and the residue was washed thoroughly with ethyl acetate. Solvents were evaporated under reduced pressure and the residue was then purified by chromatography on silica gel.

7-(3′,4′,5′-Trimethoxyphenyl)-5*H*,12*H*-indolo[3,2-*a*]carbazole (6a). The title compound **6a** was prepared according to the typical procedure using indole **9a** (50 mg, 0.43 mmol) and β-nitrostyrene **8a**. Purification was carried out by flash chromatography (cyclohexane/ethyl acetate 8 : 2) to afford **6a** (53 mg, 59%) as a colorless solid. Mp 272–274 °C (from dichloromethane/methanol 9 : 1). UV ($CDCl_3$) λ_{max} (nm) 209 (logε = 4.54); 212 (logε = 4.55); 241 (logε = 4.51); 269 (logε = 4.51); 283 (logε = 4.55); 352 (logε = 4.01). IR (NaCl film) ν' (cm^{-1}) 2932, 1631, 1580, 1455, 1429, 1413, 1375, 1305, 1266, 1227, 1123. ^{1}H NMR ($CDCl_3$) δ 3.88 (s, 6H, $^{3'-5'}OCH_3$), 4.03 (s, 3H, $^{4'}OCH_3$), 6.93 (s, 2H, $H_{2'-6'}$), 7.08 (td, *J* = 7.6 Hz, *J* = 1.0 Hz, 1H, H_9), 7.24 (s, 1H, H_6), 7.37 (td, *J* = 8.0 Hz, *J* = 1.0 Hz, 1H, H_{10}), 7.39 (td, *J* = 7.3 Hz, *J* = 1.0 Hz, 1H, H_2), 7.49 (td, *J* = 7.5 Hz, *J* = 1.0 Hz, 1H, H_3), 7.55 (d, *J* = 7.8 Hz, 1H, H_8), 7.57 (d, *J* = 8.0 Hz, 1H, H_4), 7.61 (d, *J* = 8.0 Hz, 1H, H_{11}), 8.22 (d, *J* = 7.7 Hz, 1H, H_1), 8.37 (br s, D_2O exch., 1H, NH_5), 8.78 (br s, D_2O exch., 1H, NH_{12}). ^{13}C NMR ($CDCl_3$) δ 56.2 ($^{3'-5'}OCH_3$), 61.1 ($^{4'}OCH_3$), 104.9 (C_6), 106.3 (C_{12b}), 106.6 ($C_{2'-6'}$), 110.6 (C_{11}), 110.8 (C_4), 113.9 (C_{7a}), 119.6 (C_9), 119.9 (C_2), 120.5 (C_1), 121.5 (C_8), 122.0 (C_{12c}), 123.8 (C_{7b}), 124.0 (C_{10}), 124.7 (C_3), 134.5 (C_{12a}), 136.4 ($C_{1'}$), 137.2 (C_{5a}), 137.6 ($C_{4'}$), 138.8 (C_7), 139.0 (C_{4a}), 139.2 (C_{11a}), 153.2 ($C_{3'-5'}$). MS (ZQ2000/ESI+) *m*/*z* 445 [M + Na]$^+$; Anal. ($C_{27}H_{22}N_2O_3$). Found: C, 68.26%; H, 5.08%; N, 5.11%; Calc: C, 68.29%; H, 5.05%; N, 5.13%.

5,12-Dimethyl-7-(3′,4′,5′-trimethoxyphenyl)-5*H*,12*H*-indolo[3,2-*a*]carbazole (6b). The title compound **6b** was prepared according to the typical procedure using indole **9b** (50 mg, 0.38 mmol) and β-nitrostyrene **8a**. Purification was carried out by chromatography with 20–45 μm silica gel (cyclohexane/diethyl ether 9 : 1) to afford **6b** (25 mg, 29%) as a colorless solid. Mp: 272–273 °C (from acetone). IR (KBr) ν' (cm^{-1}) 3042, 2949, 2932, 2827, 1654, 1618, 1581, 1560, 1508, 1460, 1429, 1406, 1355, 1327, 1230, 1127, 1095, 1024, 1007, 974, 835, 723, 742. ^{1}H NMR ($CDCl_3$) δ 3.90 (s, 6H, $OCH_3 \times 2$), 3.99 (s, 3H, NCH_3), 4.04 (s, 3H, OCH_3), 4.58 (s, 3H, NCH_3), 6.92 (s, 2H), 7.07 (dd, *J* = 7.2 Hz, *J* = 1.0 Hz, 1H), 7.22 (s, 1H), 7.34 (ddd, *J* = 8.2 Hz, *J* = 5.5 Hz, *J* = 2.7 Hz, 1H), 7.39–7.45 (m, 2H), 7.50–7.57 (m, 3H), 8.64 (dl, *J* = 8.1 Hz, 1H). ^{13}C NMR ($CDCl_3$) δ 29.6 (NCH_3), 35.0 (NCH_3), 56.2 ($OCH_3 \times 2$), 61.2 (OCH_3), 103.0 (CH), 106.0 (Cq), 106.4 (CH), 108.8 (CH), 114.0 (Cq), 119.1 (CH), 119.2 (CH), 121.1 (Cq), 121.3 (CH), 122.7 (CH), 123.8 (CH), 124.3 (CH), 136.2 (Cq), 137.4 (Cq), 138.0 (Cq), 140.7 (Cq), 141.1 (Cq), 141.4 (Cq), 153.2 (Cq × 2). MS (ZQ2000/ES+) *m*/*z* 923 [2M + Na]$^+$, 473 [M + Na]$^+$. HRMS (QTOF/ESI+) calcd for $C_{29}H_{27}N_2O_3$, *m*/*z* 451.2022, found 451.2032.

2,9-Dimethoxy-7-(3′,4′,5′-trimethoxyphenyl)-5*H*,12*H*-indolo[3,2-*a*]carbazole (6c). The title compound **6c** was prepared according to the typical procedure using indole **9c** (50 mg, 0.34 mmol) and β-nitrostyrene **8a**. Purification was carried out by chromatography with 20–45 μm silica gel (cyclohexane/ethyl acetate 7 : 3) to afford **6c** (33 mg, 41%) as a colorless solid. Mp: 281–283 °C (from acetone). IR (NaCl film) ν' (cm^{-1}) 3378, 2936, 1695, 1634, 1583, 1557, 1510, 1487, 1357, 1291, 1219, 1125, 1158, 1033. ^{1}H NMR (acetone-d_6) δ 3.64 (OCH_3), 3.81 (OCH_3), 3.89 (s, 6H, $OCH_3 \times 2$), 3.95 (s, 3H, OCH_3), 6.92 (dd, *J* = 8.6 Hz, *J* = 2.5 Hz, 1H), 6.95 (s, 2H), 6.97 (d, *J* = 2.5 Hz, 1H), 7.09 (dd, *J* = 8.8 Hz, *J* = 2.5 Hz, 1H), 7.24 (s, 1H), 7.47 (dd, *J* = 8.6 Hz, *J* = 0.5 Hz, 1H), 7.53 (dd, *J* = 8.7 Hz, *J* = 0.4 Hz, 1H), 8.10 (d, *J* = 2.5 Hz, 1H), 10.48 (br s, D_2O exch., 1H, NH), 10.93 (br s, D_2O exch., 1H, NH). ^{13}C NMR (acetone-d_6) δ 54.7 (OCH_3), 55.5 (OCH_3), 55.7 ($OCH_3 \times 2$), 59.9 (OCH_3), 103.8 (CH), 104.2 (CH), 104.5 (CH), 106.3 (Cq), 106.8 (CH × 2), 111.2 (CH), 111.3 (CH), 112.1 (CH), 112.8 (Cq), 113.3 (CH), 122.3 (Cq), 124.3 (Cq), 134.3 (Cq), 135.3 (Cq), 136.1 (Cq), 137.5 (Cq), 137.8 (Cq), 140.1 (Cq), 153.4 (Cq × 2), 153.5 (Cq), 154.3 (Cq). MS (ZQ2000/ES+) *m*/*z* 505 [M + Na]$^+$. HRMS (QTOF/ESI+) calcd for $C_{29}H_{26}N_2O_5Na$, *m*/*z* 505.1739, found 505.1736.

3,10-Dimethoxy-7-(3′,4′,5′-trimethoxyphenyl)-5*H*,12*H*-indolo-[3,2-*a*]carbazole (6d). The title compound **6d** was prepared according to the typical procedure using indole **9d** (50 mg, 0.34 mmol) and β-nitrostyrene **8a**. Purification was carried out by chromatography with 20–45 μm silica gel (cyclohexane/ethyl acetate 7 : 3) to afford **6d** (43 mg, 52%) as a white solid. Mp:

162–163 °C (from acetone). IR (NaCl film) ν' (cm^{-1}) 3385, 2933, 1620, 1580, 1503, 1452, 1366, 1234, 1198, 1161, 1125, 822. ^1H NMR (acetone-d_6) δ 3.85 (OCH_3), 3.86 (OCH_3), 3.87 (s, 6H, $OCH_3 \times 2$), 3.91 (s, 3H, OCH_3), 6.66 (dd, J = 8.8 Hz, J = 2.4 Hz, 1H), 6.93 (dd, J = 8.6 Hz, J = 2.3 Hz, 1H), 6.95 (s, 2H); 7.14 (d, J = 2.5 Hz, 1H), 7.15 (d, J = 2.5 Hz, 1H), 7.22 (s, 1H), 7.43 (d, J = 8.7 Hz, 1H), 8.39 (d, J = 8.6 Hz, 1H), 10.44 (br s, D_2O exch., 1H, NH), 10.84 (br s, D_2O exch., 1H, NH). ^{13}C NMR (acetone-d_6) δ 54.7 (OCH_3), 54.9 (OCH_3), 55.6 ($OCH_3 \times 2$), 59.9 (OCH_3), 94.7 (CH), 94.9 (CH), 104.6 (CH), 106.8 (CH × 2), 107.2 (CH), 108.0 (CH), 113.3 (Cq), 115.7 (Cq), 117.6 (Cq), 121.3 (CH), 121.6 (CH), 133.8 (Cq), 133.9 (Cq), 137.6 (Cq), 137.7 (Cq), 138.8 (Cq), 141.0 (Cq), 141.2 (Cq), 153.4 (Cq × 2), 157.6 (Cq), 158.3 (Cq). MS (ZQ2000/ES+) m/z 505 $[M + Na]^+$. HRMS (QTOF/ESI+) calcd for $C_{29}H_{26}N_2O_5Na$, m/z 505.1739, found 505.1737.

3,10-Dibromo-2,9-dimethoxy-7-(3′,4′,5′-trimethoxyphenyl)-5*H*,12*H*-indolo[3,2-*a*]carbazole (6e). The title compound **6e** was prepared according to the typical procedure using indole **9f** (100 mg, 0.44 mmol) and β-nitrostyrene **8a**. Purification was carried-out by flash chromatography (cyclohexane/ethyl acetate 7 : 3) to afford **6e** (93 mg, 66%) as a colorless solid. Mp: 142–144 °C (from acetone). IR (NaCl film) ν' (cm^{-1}) 2924, 1592, 1560, 1508, 1459, 1425, 1381, 1359, 1322, 1237, 1205, 1158, 1127, 999. ^1H NMR (DMSO-d_6) δ 3.58 (OCH_3), 3.77 (OCH_3), 3.82 (s, 6H, $OCH_3 \times 2$), 4.08 (s, 3H, OCH_3), 6.88 (s, 1H), 6.91 (s, 2H), 7.22 (s, 1H), 7.79 (s, 1H), 7.80 (s, 1H), 8.29 (s, 1H), 11.52 (br s, D_2O exch., 1H, NH), 11.91 (br s, D_2O exch., 1H, NH). ^{13}C NMR (DMSO-d_6) δ 56.2 (OCH_3), 56.5 ($OCH_3 \times 2$), 57.7 (OCH_3), 60.6 (OCH_3), 104.0, 104.9, 105.4, 105.9, 106.9 (CH × 2), 107.1, 108.6, 112.3, 115.1 (CH), 115.3 (CH), 121.4, 123.5 (CH/q), 134.6 (Cq), 134.9 (Cq), 135.0 (Cq), 136.2 (Cq), 136.9 (Cq), 137.4 (Cq), 140.4 (Cq), 148.9 (Cq), 149.8 (Cq), 153.3 (Cq × 2). MS (ZQ2000/ESI+) m/z 665 $[C_{29}H_{24}{}^{81}Br_2N_2O_5Na]^+$, 663 $[C_{29}H_{24}{}^{79}Br^{81}BrN_2O_5Na]^+$, 661 $[C_{29}H_{24}{}^{79}Br_2N_2O_5Na]^+$. HRMS (QTOF/ESI+) calcd for $C_{29}H_{24}{}^{79}Br^{81}Br\ N_2O_5Na$, m/z 662.9929, found 662.9925.

2,9-Dibromo-7-(3′,4′,5′-trimethoxyphenyl)-5*H*,12*H*-indolo[3,2-*a*]carbazole (6f). The title compound **6f** was prepared according to the typical procedure using indole **9g** (100 mg, 0.86 mmol) and β-nitrostyrene **8a**. Purification was carried out by flash chromatography (cyclohexane/ethyl acetate 8 : 2) to afford **6f** (26 mg, 18%) as a colorless solid. Mp: >350 °C (from acetone). IR (KBr) ν' (cm^{-1}) 3442, 3384, 2999, 2960, 2933, 2834, 1638, 1577, 1509, 1457, 1413, 1372, 1368, 1310, 1284, 1235, 1121, 1083, 1053, 1003, 901, 850, 797, 760, 736, 685, 658, 571, 434. ^1H NMR (acetone-d_6) δ 3.89 (s, 3H, OCH_3), 3.92 (s, 6H, $OCH_3 \times 2$), 6.99 (s, 2H), 7.37 (s, 1H), 7.43 (dd, J = 8.5 Hz, J = 2.0 Hz, 1H), 7.56 (dd, J = 8.6 Hz, J = 1.8 Hz, 1H), 7.59–7.66 (m, 2H), 7.70 (d, J = 2.0 Hz, 1H), 8.70 (d, J = 1.8 Hz, 1H), 10.96 (br s, D_2O exch., 1H, NH), 11.38 (br s, D_2O exch., 1H, NH). ^{13}C NMR (acetone-d_6) δ 55.7 ($OCH_3 \times 2$), 59.9 (OCH_3), 105.5 (CH), 106.8 (CH × 2), 111.3 (Cq), 111.7 (Cq), 112.4 (Cq), 112.7 (CH × 2), 123.1 (CH), 123.4 (Cq), 123.5 (CH), 125.5 (Cq), 126.0 (CH), 127.0 (CH), 134.9 (Cq), 136.6 (Cq), 137.1 (Cq), 138.2 (Cq), 138.6 (Cq), 140.3 (Cq), 153.6 (Cq × 2). MS (ZQ2000/ES+) m/z 605 $[C_{27}H_{20}{}^{81}Br_2N_2O_3Na]^+$, 603 $[C_{27}H_{20}{}^{79}Br^{81}BrN_2O_3Na]^+$, 601 $[C_{27}H_{20}{}^{79}Br_2N_2O_3Na]^+$. HRMS (QTOF/ESI+) calcd for $C_{27}H_{20}Br_2N_2O_3Na$, m/z 602.9718, found 602.9706.

7-Phenyl-5*H*,12*H*-indolo[3,2-*a*]carbazole (6g). The title compound **6g** was prepared according to the typical procedure using indole **9a** (100 mg, 0.86 mmol) and β-nitrostyrene **8b**. Purification was carried out by flash chromatography (cyclohexane/ethyl acetate 8 : 1) to afford **6g** (76 mg, 53%) as a colorless solid. Mp: 230–232 °C (colorless prisms from ethyl acetate). IR (KBr) ν' (cm^{-1}) 3373, 3334, 3046, 2999, 2960, 2935, 1638, 1584, 1512, 1459, 1416, 1322, 1270, 1122, 1039, 836, 732. ^1H NMR ($CDCl_3$) δ 7.05 (ddd, J = 7.9 Hz, J = 7.2 Hz, J = 1.0 Hz, 1H), 7.19 (s, 1H), 7.33–7.44 (m, 3H), 7.49 (ddd, J = 7.4 Hz, J = 6.9 Hz, J = 1.0 Hz, 1H), 7.53–7.61 (m, 5H), 7.71 (dd, J = 8.0 Hz, J = 1.8 Hz, 1H), 8.21 (d, J = 7.7 Hz, 1H), 8.29 (br s, D_2O exch., 1H, NH), 8.74 (br s, D_2O exch., 1H, NH). ^{13}C NMR ($CDCl_3$) δ 105.2 (CH), 106.2 (Cq), 110.6 (CH), 110.8 (CH), 114.0 (Cq), 119.5 (CH), 119.9 (CH), 120.5 (CH), 121.4 (CH), 122.0 (Cq), 123.9 (Cq, CH), 124.6 (CH), 127.5 (CH), 128.4 (CH × 2), 129.5 (CH × 2), 134.4 (Cq), 136.5 (Cq × 2), 138.8 (CH), 138.9 (Cq), 139.2 (Cq), 141.7 (Cq). MS (ZQ2000/ESI+) m/z 355 $[M+Na]^+$. HRMS (QTOF/ESI+) calcd for $C_{24}H_{16}N_2Na$ ($[M + Na]^+$), m/z 355.1211, found 355.1220.

7-(4′-Methyl)-5*H*,12*H*-indolo[3,2-*a*]carbazole (6h). The title compound **6h** was prepared according to the typical procedure using indole **9a** (50 mg, 0.43 mmol) and β-nitrostyrene **8c**. Purification was carried out by flash chromatography (cyclohexane/ethyl acetate 9 : 1) to afford **6h** (23 mg, 31%) as a colorless solid. Mp: 256–258 °C (from acetone). IR (KBr) ν' (cm^{-1}) 3461, 3378, 3016, 2916, 1637, 1611, 1758, 1518, 1455, 1374, 1353, 1263, 1180, 1155, 1020, 821, 802, 747. ^1H NMR (acetone-d_6) δ 2.50 (s, 3H, CH_3), 6.96 (ddd, J = 7.5 Hz, J = 1.1 Hz, 1H), 7.25 (s, 1H), 7.31 (ddd, J = 7.5 Hz, J = 1.1 Hz, 2H), 7.38–7.47 (m, 4H), 7.58 (d, J = 9.0 Hz, 2H), 7.63 (dd, J = 9.0 Hz, J = 3.0 Hz, 2H), 8.57 (dd, J = 9.0 Hz, J = 3.0 Hz, 1H, H_1), 10.65 (br s, D_2O exch., 1H, NH), 11.04 (br s, D_2O exch., 1H, NH). ^{13}C NMR (acetone-d_6) δ 20.5 (CH_3), 105.0 (CH), 106.0 (Cq), 110.8 (CH), 110.9 (CH), 113.2 (Cq), 118.7 (CH), 119.1 (CH), 120.7 (CH), 120.8 (CH), 121.9 (Cq), 123.3 (CH), 123.9 (Cq), 124.2 (CH), 128.9 (CH × 2), 129.2 (CH × 2), 134.6 (Cq), 136.2 (Cq), 136.9 (Cq), 139.3 (Cq), 139.5 (Cq × 2), 139.9 (Cq). MS (ZQ2000/ESI+) m/z 369 $[M + Na]^+$, 347 $[M + H]^+$. HRMS (QTOF/ESI+) calcd for $C_{25}H_{19}N_2$ ($[M + H]^+$), m/z 347.1524, found 347.1531.

7-(4′-Methoxyphenyl)-5*H*,12*H*-indolo[3,2-*a*]carbazole (6i). The title compound **6i** was prepared according to the typical procedure using indole **9a** (50 mg, 0.43 mmol) and β-nitrostyrene **8d**. Purification was carried out by flash chromatography (cyclohexane/dichloromethane 7 : 3) to afford **6i** (31 mg, 40%) as a colorless solid. Mp: 314–316 °C (from dichloromethane/acetone 9 : 1). IR (KBr) ν' (cm^{-1}) 3417, 3011, 2918, 1708, 1642, 1607, 1516, 1456, 1378, 1321, 1285, 1266, 1182, 1149, 1126, 1023, 841, 819, 749, 734. ^1H NMR (acetone-d_6) δ 3.98 (s, 3H, OCH_3), 6.97 (dd, J = 7.5 Hz, 1H), 7.16 (d, J = 8.6 Hz, 1H) 7.24 (s, 1H), 7.25–7.33 (m, 2H), 7.40–7.46 (m, 2H), 7.60–7.65 (m, 4H), 8.56 (d, J = 7.7 Hz, 1H), 10.65 (br s, D_2O exch., 1H, NH), 11.01 (br s, D_2O exch., 1H, NH). ^{13}C NMR (acetone-d_6, 75 MHz) δ 54,7 (OCH_3), 105.0 (CH), 105.9 (Cq), 110.7 (CH), 110.8 (CH), 113.3 (Cq), 113.7 (CH × 2), 118.7 (CH), 119.1 (CH), 120.7 (CH), 120.8 (CH), 121.9 (Cq), 123.2 (CH), 123.9 (Cq), 124.1 (CH), 130.4 (CH × 2), 134.4 (Cq), 134.5 (Cq), 135.9 (Cq), 139.4 (Cq), 139.5 (Cq), 139.9 (Cq), 159.3 (Cq). MS (ZQ2000/ESI-) m/z 361 $[M - H]^-$. HRMS

(QTOF/ESI-) calcd for $C_{25}H_{17}N_2O$ ([M − H]$^-$), *m/z* 361.1341, found 361.1357.

7-(4′-Bromophenyl)-5*H*,12*H*-indolo[3,2-*a*]carbazole (6j). The title compound **6j** was prepared according to the typical procedure using indole **9a** (50 mg, 0.43 mmol) and β-nitrostyrene **8e**. Purification was carried out by flash chromatography (cyclohexane/dichloromethane 7 : 3) to afford **6j** (29 mg, 33%) as a colorless solid. Mp: 304–306 °C (from dichloromethane/acetone 9 : 1). IR (KBr) *ν′* (cm^{-1}) 3350, 3280, 3065, 2995, 1697, 1636, 1456, 1355, 1268, 827, 752, 735. ^{1}H NMR (acetone-d_6) δ 7.00 (dd, J = 8,3 Hz, J' = 7.5 Hz, 1H), 7.28 (s, 1H), 7.29–7.33 (m, 2H), 7.39 (br d, J = 8.0 Hz, 1H), 7.45 (dd, J = 8.3 Hz, J' = 7.5 Hz, 1H), 7.63–7.68 (m, 4H), 7.79 (br d, J = 8.3 Hz, 2H), 8.58 (br d, J = 7.9 Hz, 1H), 10.71 (br s, D_2O exch., 1H, NH), 11.09 (br s, D_2O exch., 1H, NH). ^{13}C NMR (acetone-d_6) δ 105.0 (CH), 106.4 (Cq), 110.8 (CH), 111.0 (CH), 112.8 (Cq), 118.9 (CH), 119.2 (CH), 120.5 (CH), 120.8 (CH), 121.0 (Cq), 121.8 (Cq), 123.5 (CH + Cq), 124.4 (CH), 131.4 (CH × 4), 134.5 (Cq), 134.6 (Cq), 139.4 (Cq), 139.5 (Cq), 139.9 (Cq), 141.5 (Cq). MS (ZQ2000/ESI-) *m/z* 411 [M − H]$^-$. HRMS (QTOF/ESI-) calcd for $C_{24}H_{14}{}^{79}BrN_2$ ([M − H]$^-$), *m/z* 409.0340, found 409.0343.

7-(4′-Nitrophenyl)-5*H*,12*H*-indolo[3,2-*a*]carbazole (6k). The title compound **6k** was prepared according to the typical procedure using indole **9a** (50 mg, 0.43 mmol) and β-nitrostyrene **8f**. Purification was carried out by successive flash chromatographies (cyclohexane/ethyl acetate 8 : 2) to afford **6k** (16 mg, 20%) as a yellow solid. Mp: 246–248 °C (from ethyl acetate). IR (KBr) *ν′* (cm^{-1}) 3395, 3048, 2961, 2917, 1637, 1610, 1591, 1514, 1458, 1380, 1340, 1267, 1153, 1099, 833, 747, 733, 705, 699. ^{1}H NMR (acetone-d_6) δ 6.96 (dd, J = 8.4 Hz, J' = 7.4 Hz, 1H), 7.28–7.34 (m, 3H including a singlet (1H) at 7.34 ppm), 7.39 (br d, J = 8.2 Hz, 1H), 7.45 (dd, J = 8.3 Hz, J' = 7,1 Hz, 1H), 7.65 (br d, J = 8.2 Hz, 1H), 7.99 (br d, J = 8.8 Hz, 2H), 8.47 (br d, J = 8.8 Hz, 2H), 8.58 (d, J = 7.7 Hz, 1H), 10.78 (br s, D_2O exch., 1H, NH), 11.15 (br s, D_2O exch., 1H, NH). ^{13}C NMR (acetone-d_6) δ 106.2 (CH), 107.9 (Cq), 111.9 (CH), 112.0 (CH), 113.3 (Cq), 119.9 (CH), 120.3 (CH), 121.4 (CH), 121.9 (CH), 122.5 (Cq), 124.0 (Cq), 124.5 (CH × 2), 124.7 (CH), 125.6 (CH), 131.5 (CH × 2), 134.3 (Cq), 135.6 (Cq), 140.2 (Cq), 140.6 (Cq), 140.9 (Cq), 148.3 (Cq), 150.0 (Cq). MS (QTOF/ESI-) *m/z* 376 [M − H]$^-$. HRMS (QTOF/ESI-) calcd for $C_{24}H_{14}N_3O_2$ ([M − H]$^-$), *m/z* 376.1086, found 376.1085.

3-(Indolin-2-yl)-1*H*-indole (10). To a stirred solution of 1*H*-indole **9a** (1.0 g, 8.5 mmol) in anhydrous DCM (200 mL), $SnCl_4$ (4.25 mL, 0.5 eq) was added dropwise at 0 °C under argon. After stirring at 0 °C for 6 h, the mixture was allowed to reach room temperature and stirred for another 8 h. The subsequent precipitate was filtered on a Büchner funnel and washed three times with DCM (10 mL), then was taken-up in deionized water (10 mL). After adjustment of pH to 11–12 with a saturated solution of $NaHCO_3$, the aqueous layer was extracted four times with ethyl acetate (60 mL). Combined organic layers were dried on $MgSO_4$, filtered and evaporated under reduced pressure. The title compound **10** was obtained as an amorphous white powder in 87% yield (867 mg) and engaged in the next step without further purification. ^{1}H NMR ($CDCl_3$) (lit.,[9c]) δ 3.23 (dd, ^2J = 15.6 Hz, $J_{3'-2'}$ = 8.3 Hz, 1H, $H_{3'b}$), 3.47 (dd, ^2J = 15.6 Hz, $J_{3'a-2'}$ = 9.1 Hz, 1H, $H_{3'a}$), 5.26 (dd, $J_{3'a-2'}$ = 9.1 Hz, $J_{3'b-2'}$ = 8.3 Hz, 1H, $H_{2'}$), 6.68 (d, J = 7.72 Hz, 1H, $H_{7'}$), 6.76 (d, J = 7.22 Hz, J' = 7.36 Hz, 1H, $H_{5'}$), 7.09 (m, 1H, H_5), 7.08 (m, 1H, $H_{6'}$), 7.15 (d, J = 7.22 Hz, 1H, $H_{4'}$), 7.19 (br s, 1H, H_2), 7.21 (t, J = 7.81 Hz, J' = 7.72 Hz, 1H, H_6), 7.38 (d, J = 8.12 Hz, 1H, H_7), 7.60 (d, J = 7.96 Hz, 1H, H_4), 8.02 (br s, D_2O exch., 1H, NH_1). ^{13}C NMR ($CDCl_3$) δ 37.7 ($C_{3'}$), 56.4 ($C_{2'}$), 109.2 ($C_{7'}$), 111.3 (C_7), 118.7 ($C_{5'}$), 119.5 (Cq), 119.5 (C_4), 119.6 ($C_{6'}$), 121.1 (C_2), 122.3 (C_5), 124.7 (C_6), 125.8 (Cq), 127.4 ($C_{4'}$), 128.9 (Cq), 136.76 (C_{7a}, $C_{7'a}$). MS (DIC/NH_3) *m/z* 235 [M + H]$^+$, 118.

3-(1*H*-Indol-2-yl)-1*H*-indole (5)[9b]. To a solution of 3-(indolin-2-yl)-1*H*-indole **10** (170 mg, 0.7 mmol) in toluene (30 mL) was added 10% Pd/C (30 mg) under argon atmosphere. The mixture was refluxed for 10 h and filtered on a Celite pad. The suspension was washed with warm ethyl acetate (50 mL). The subsequent browny filtrate was evaporated under reduced pressure. Crude product was purified by flash chromatography on silica gel (cyclohexane/ethyl acetate 8 : 2) affording the title compound **5** as a white powder in 80% yield (135 mg). ^{1}H NMR (dmso-d_6) (lit.,[29]) δ 6.76 (br s, 1H, H_3), 6.96 (t, J = 7.89 Hz, J' = 6.99 Hz, 1H, H_5), 7.03 (t, J = 7.69 Hz, J' = 7.57 Hz, 1H, H_6), 7.15 (m, 1H, $H_{5'}$), 7.19 (m, 1H, H_6'), 7.35 (d, J = 7.69 Hz, 1H, H_7), 7.47 (d, J = 8.37 Hz, 1H, $H_{7'}$), 7.50 (d, J = 7.89 Hz, 1H, H_4), 7.86 (d, 1H, $H_{2'}$), 8.00 (d, J = 6.97 Hz, 1H, $H_{4'}$), 11.21 (br s, D_2O exch., 1H, NH_1), 11.40 (br s, D_2O exch., 1H, $NH_{1'}$). ^{13}C NMR (75 MHz, dmso-d_6) (lit.[29]) δ 97.3 (C_3), 110.9 ($C_{3'}$), 112.4 ($C_{7'}$), 119.3 (C5), 119.5 (C_4), 120.1 ($C_{4'}$), 120.3 ($C_{5'}$), 120.8 (C_6), 122.2 ($C_{6'}$), 123.6 ($C_{2'}$), 125.1 ($C_{3'a}$), 129.7 (C_{3a}), 134.6 (C_2), 136.4 (C_{7a}), 137.1($C_{7'a}$).

Procedure for synthesis of indolocarbazole 6a from 2,3′-biindole 5. To a solution of 2,3′-biindole (**5**, 20 mg, 0.086 mmol, 1.0 equiv) and *trans*-nitrostyrene (**8a**, 21 mg, 0.086 mmol, 1.0 equiv) in anhydrous dichloromethane (10 mL) was added $SnCl_2{\cdot}2H_2O$ (19.4 mg, 0.086 mmol, 1 equiv) and MnO_2 (7.5 mg, 0.086 mmol, 1.0 equiv). After 24 h of stirring at room temperature, the reaction mixture was filtered and the precipitate washed with ethyl acetate. Solvents were evaporated under reduced pressure and the residue was purified by flash chromatography on silica gel (cyclohexane/ethyl acetate 8 : 2 to 7 : 3) affording the indolocarbazole derivative **6a** in a pure state in 97% yield (35 mg).

3-[1-(3′,4′,5′-Trimethoxyphenyl)-2″-nitroethyl]-1*H*-indole (12). A mixture of 1*H*-indole **9a** (50 mg, 0.43 mmol) and 3,4,5-trimethoxynitrostyrene **8a** (102.1 mg, 0.43 mmol) was heated for 4 h at 125 °C. Crude product was purified by flash chromatography on silica gel (cyclohexane/ethyl acetate 6 : 4) affording the title compound **12** as a colorless amorphous powder in 72% (110 mg). Mp: 136–138 °C (from ethyl acetate). IR (NaCl) *ν′* (cm-1) 3056, 2994, 2963, 2939, 2838, 1593, 1551, 1506, 1460, 1423, 1379, 1332, 1236, 1184, 1126, 1000, 910, 835, 744. ^{1}H NMR ($CDCl_3$) δ 3.80 (s, 6H, $^{3'-5'}OCH_3$), 3.84 (s, 3H, $^{4'}OCH_3$), 4.94 (dd, J_{a-b} = 12,4 Hz, $J_{a-1''}$ = 8,5 Hz, 1H, Ha), 5.06 (dd, J_{b-a} = 12,4 Hz, $J_{b-1''}$ = 7,5 Hz, 1H, Hb), 5.15 (dd, $J_{1''-a}$ = 8,5 Hz, $J_{1''-b}$ = 7,5 Hz, 1H, $H_{1''}$), 6.58 (s, 2H, $H_{2'-6'}$), 7.02 (s, 1H, H_2), 7.11 (t, J = 7,5 Hz, 1H, H_5), 7.21 (t, J = 7,5 Hz, 1H, H_6), 7.35 (d, J = 8 Hz, 1H, H_7), 7.52 (d, J = 7,9 Hz, 1H, H_4), 8.22 (br s, D_2O exch., 1H, NH). ^{13}C NMR ($CDCl_3$) δ 42.0 ($C_{1''}$), 56.2 ($^{3'-5'}OCH_3$), 60.9 ($^{4'}OCH_3$), 79.6 ($C_{2''}$), 105.0 ($C_{2'-6'}$), 111.6 (C_7), 114.4 (C_3), 119.0 (C_4), 120.1 (C_5), 121.8 (C_2), 122.9 (C_6), 126.2 (C_{3a}), 135.0 ($C_{1'}$), 136.6 (C_{7a}), 137.4 ($C_{4'}$), 153.6 ($C_{3'-5'}$). MS (ZQ2000/ES+) *m/z* 379 [M + Na]$^+$; Anal. ($C_{19}H_{20}N_2O_5$). Found:

C, 63.65%; H, 5.82%; N, 7.59%; Calc: C, 63.84; H, 5.76%; N, 7.76%.

2-(1*H*-Indol-3-yl)-3-(1-(3,4,5-trimethoxyphenyl)-2-nitroethyl)-1*H*-indole (7). A mixture of 3-(1*H*-indol-2-yl)-1*H*-indole **5** (179 mg, 0.77 mmol) and 3,4,5-trimethoxynitrostyrene **8a** (185 mg, 0.77 mmol) in dichloromethane (25 mL) was stirred for 24 h at room temperature. Solvent was evaporated under reduced pressure and the residue was then purified by flash chromatography on silica gel (cyclohexane/ethyl acetate 7 : 3) affording the title compound **7** in 91% yield (331 mg). Mp: 211–213 °C (from dichloromethane). IR (KBr) ν' (cm^{-1}) 3385, 3351, 3055, 2971, 2938, 2839, 1702, 1594, 1551, 1508, 1459, 1425, 1378, 1332, 1232, 1124, 1010, 993, 826, 770, 725. ^{1}H NMR ($CDCl_3$) δ 3.67 (s, 6H, $OCH_3 \times 2$), 3.81 (s, 3H, OCH_3), 5.10–5.21 (m, 2H), 5.27 (dd, J = 15.8 Hz, J = 7.8 Hz, 1H), 6.53 (s, 2H), 7.13–7.31 (m, 5H), 7.42 (d, J = 8.0 Hz, 1H), 7.46 (d, J = 8.2 Hz, 1H), 7.58 (d, J = 7.8 Hz, 1H), 7.64 (d, J = 7.8 Hz, 1H), 8.34 (br s, D_2O exch., 1H, NH), 8.54 (br s, D_2O exch., 1H, NH). ^{13}C NMR ($CDCl_3$) δ 41.5 (CH), 56.2 ($OCH_3 \times 2$), 60.8 (OCH_3), 79.3 (CH_2), 104.7 (CH × 2), 107.6 (Cq), 110.0 (Cq), 111.3 (CH), 111.7 (CH), 119.2 (CH), 119.4 (CH), 120.0 (CH), 120.7 (CH), 122.0 (CH), 123.0 (CH), 124.4 (CH), 126.9 (Cq), 127.0 (Cq), 131.1 (Cq), 135.9 (Cq), 136.0 (Cq), 136.1 (Cq), 136.7 (Cq), 153.2 (Cq × 2). MS (ZQ2000/ESI+) m/z 494 $[M + Na]^+$, 965 $[2M + Na]^+$. HRMS (QTOF/ESI+) calcd for $C_{27}H_{25}N_3O_5Na$ ($[M + Na]^+$) m/z 494.1692, found 494.1694.

2-(2,2-Di(1*H*-indol-3-yl)ethyl)benzenamine (the 3,3′-trimer) (11). To a solution of 1*H*-indole **9a** (1 g, 8.55 mmol) in CH_2Cl_2 (15 mL), $SnCl_2{\cdot}2H_2O$ (1.93 g, 8.55 mmol) was added and the reaction mixture was stirred at room temperature for 72 h. The organic layer was washed with water and brine, dried over $MgSO_4$, and concentrated *in vacuo*. Crude product was purified by flash chromatography on silica gel (cyclohexane/ethyl acetate 1 : 1) affording the title compound **11** as a lacquer in 96% yield (0.96 g). IR (KBr) ν' (cm^{-1}) 3385, 3351, 3055, 2971, 2938, 2839, 1702, 1594, 1551, 1508, 1459, 1425, 1378, 1332, 1232, 1124, 1010, 993, 826, 770, 725. ^{1}H NMR ($CDCl_3$)[13] δ 3.44 (d, J = 7.2 Hz, 2H, CH_2), 4,87 (t, J = 7,2 Hz, 1H, CH), 5.30 (br s, D_2O exch., 2H, NH_2), 6.55 (d, J = 8.0 Hz, 1H), 6.62 (m, 1H), 6.95–7.05 (m, 6H), 7.14 (m, 2H), 7.32 (d, J = 8.0 Hz, 2H), 7.49 (d, J = 7.9 Hz, 2H), 7.84 (br s, D_2O exch., 2H, NH × 2). ^{13}C NMR ($CDCl_3$)[13] δ 34.3 (CH), 37.0 (CH_2), 111.1 (CH × 2), 115.7 ($C_{3'}$), 118.8, 119.0 (CH × 2), 119.3 (CH), 119.5 (CH × 2), 121.7 (CH × 2), 121.9 (CH × 2), 126.0, 126.8 (CH), 130.2 (CH), 136.5 (Cq × 2), 144.6 (Cq). MS (ZQ2000/ESI+) m/z 390 $[M + K]^+$, 374 $[M + Na]^+$.

2-Amino-4,5-dimethoxybenzoic acid. Orange crystals. Mp: 175–177 °C (from ethanol) (lit.[30] 172 °C). IR (KBr) ν' (cm^{-1}) 3453, 3326, 1648, 1593, 1509, 1397, 1236, 850. ^{1}H NMR (dmso-d_6) δ 3.72 (s, 3H, OCH_3), 3.80 (s, 3H, OCH_3), 6.51 (s, 1H, H_3), 7.32 (s, 1H, H_6), 7.48 (br s, D_2O exch., 2H), 7.32 (s, 1H). ^{13}C NMR ($CDCl_3$) δ 56.3 ($OCH_3 \times 2$), 99.0 ($C_1 + C_3$), 106.5 (C_6), 141.5 (C_5), 142.5 (C_2), 156.8 (C_4), 169.1 (CO_2H). MS (ZQ2000/ESI-) m/z 197 $[M - H]^-$.

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19 A recent report described the use of catalytic amounts (10 mol%) of metal halide hydrates such as $SnCl_2{\cdot}2H_2O$ and $MnCl_2{\cdot}4H_2O$ in the conjugated Friedel–Crafts reaction between 1*H*-indole **9a** and nitrostyrene **8b**. Reactions were carried out either at room temperature in various solvents or in refluxing dichloromethane and always failed to proceed. These findings are consistent with our own observations. The best results were achieved either in polar protic solvents under refluxing conditions or under solventless conditions at 100 °C. However, under these conditions, the use of $SnCl_2{\cdot}2H_2O$ led to poor yields of conversion (54 and 57%, respectively). In our hands, treatment at room temperature of a dichloromethane solution of equimolar amounts of both **9a** and **8a** with catalytic or stoichiometric amount of $MnCl_2{\cdot}4H_2O$ gave no reaction (See ref. 20).
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