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TETRAHEDRON

Syntheses of 6,12-Disubstituted 5,11-Dihydroindolo[3,2-*b*]carbazoles, Including 5,11-Dihydroindolo[3,2-*b*]carbazole-6,12-dicarbaldehyde, an Extremely Efficient Ligand for the TCDD (Ah) Receptor

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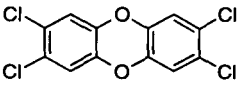
Abstract:

Symmetrically and unsymmetrically 6,12-disubstituted 5,11-dihydroindolo[3,2-*b*]carbazoles have been synthesized *via* a range of methods: a) double Fischer indolization of the *bis*-phenylhydrazone of 2,5-dimethyl-1,4-cyclohexanedione, b) condensation of indole with aliphatic aldehydes, and c) Pd-mediated cyclization of a diphenyl phenylenediamine derivative. Most notably, 5,11-dihydroindolo[3,2-*b*]carbazole-6,12-dicarbaldehyde has been synthesized, whereby a previously assigned structure has been confirmed. This compound is an extremely efficient ligand for the TCDD (Ah) receptor.

Keywords: polycyclic heterocyclic compounds, dimerisation, indoles, indolisation

1. Introduction

The TCDD (2,3,7,8-tetrachlorodibenzo-*p*-dioxin **1**) receptor is a ubiquitous intracellular protein in virtually all rodent tissues or human cells examined.[1] Another name for the same receptor commonly used in the literature is the aryl hydrocarbon (Ah) receptor protein.



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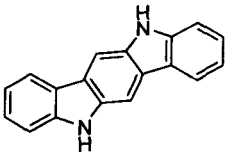

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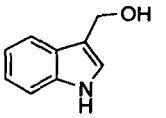

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Upon binding to a proper ligand the resulting receptor-ligand complex is translocated to the nucleus where activation of transcription of several genes will take place. These genes encode

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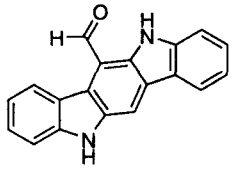
proteins involved in metabolism of xenobiotica and in cell growth and differentiation. Most notably, cytochrome P-4501A1 (CYP1A1), considered to play a major role in the activation of procarcinogens, is induced by TCDD-like substances.[1a,b,2] The hitherto known ligands of the receptor include polychlorinated aromatic hydrocarbons (*e.g.* **1**), polycyclic aromatic hydrocarbons, and 5,11-dihydroindolo[3,2-*b*]carbazole **2**.[3] Since it was shown in 1970 that **2** could be formed from indole-3-carbinol[4] **3** and thereby have dietary origin[5] (**3** is prevalent in cruciferous vegetables such as cabbage and brussels sprouts), it has been the subject of a number of papers. More recently it has been demonstrated that **3** can be transformed into **2** also in *in vivo* systems.[6]

The importance of the signal pathways involving the TCDD receptor in mammals, including man, can hardly be overestimated. Recent data appear to favour a physiological role for the TCDD receptor in addition to its function in xenobiotic metabolism:[7] TCDD receptor deficient mice have a low survival rate and show impaired development of the liver and the immune system.[7] A physiological ligand of the receptor has not yet been found, but the search is on. Studies in rats have indicated that UV light induces CYP1A1 in the skin[8] and in the liver.[9] Of the UV-absorbing amino acids, tryptophan is among the most strong-absorbing.[10] Two of the many products formed when UV-irradiating an aqueous solution of tryptophan possess extremely high affinity for the TCDD receptor.[11] The compounds were assigned[12] the structures **4** and **5** and the identity of the former has recently been confirmed by an independent synthesis.[13] Compound **4** is especially intriguing as it binds 5-8 times as strong to the receptor (K_d 7×10^{-11}) as TCDD itself. The synthesis of **4** has now made animal studies possible, aiming at further investigating receptor function and if **4** could in fact be an endogenous ligand to the receptor.



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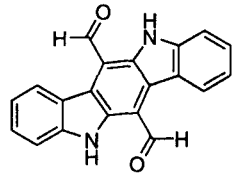
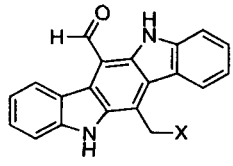
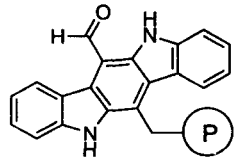


5

So, is **4** an endogenous ligand to the TCDD receptor? To test that hypothesis we were interested in creating antibodies to **4** for detecting minute quantities of it (and probably **5**) in biological systems. In this article we want to describe some work regarding our attempts to synthesize the dialdehyde **5** and at this stage the perhaps more important unsymmetrical **6** or a protected version thereof. The assigned structure of compound **5** still needs to be confirmed, and the unsymmetrical **6** could potentially be coupled to a solid phase to give **7** and as such be used as hapten for the creation of antibodies to the monoaldehyde derivative **4**.



6) X = OH, Hal



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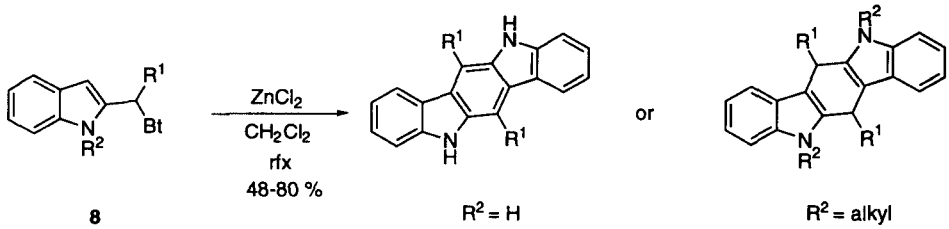
2. Results and discussion

2.1 Dimerization of indol-2-ylmethanols

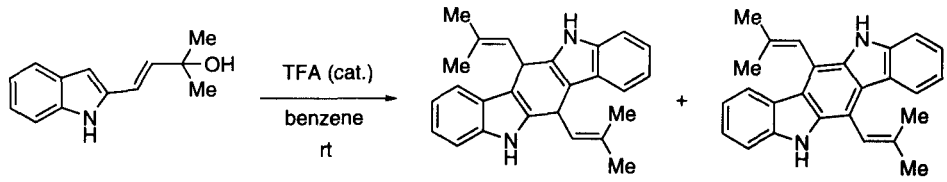
Among the syntheses of 6,12-disubstituted indolo[3,2-*b*]carbazoles in the literature,[14] Katritzky's dimerization of 2-(benzotriazol-1-ylalkyl)indoles **8** to various 6,12-disubstituted indolo[3,2-*b*]carbazoles under Lewis acidic conditions[14a] is notable (Scheme 1).



8 R^2 = H R^2 = alkyl

Scheme 1

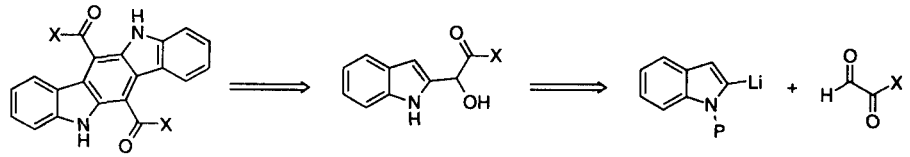
Cheng has similarly dimerized **9** to give indolo[3,2-*b*]carbazoles **10** and **11** in fair total yields[14b] (Scheme 2).



9 **10** (31 %) **11** (25 %)

Scheme 2

Compound **11** can be considered as a precursor to the desired dialdehyde **5**, requiring oxidative cleavage of the alkene side chains, but the multi-step route to **9** was not very attractive from our point of view, so this approach was not considered further. However, the dimerization principle in the examples above seemed to be a very appealing way of synthesizing symmetrical indolo[3,2-*b*]carbazoles and we therefore decided to try a variant of it (Scheme 3).



5) X = H
14) X = OR

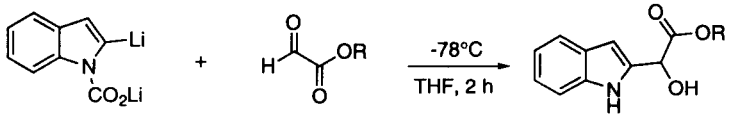
12) X = H
13) X = OR

Scheme 3

It must be pointed out that the dimerization in this case will not be as favoured as in the examples shown above: the developing cation can no longer be stabilized by an extra electron-donating group (Bt, alkyl respectively). Nevertheless, we decided to try it as the reaction would give us a big advantage by directly establishing carbonyl groups in the desired 6- and 12-positions.

The hydroxy aldehyde **12** (X = H) seemed hard to obtain, but hydroxy esters **13** (X = OR) might be produced by the addition of 2-lithiated indole (a well-known nucleophile) to a suitable glyoxylate; it should then be possible to transform the resulting indolocarbazole diester **14** into the required dialdehyde **5**. Furthermore, the diester **14** is itself of interest for ligand studies.

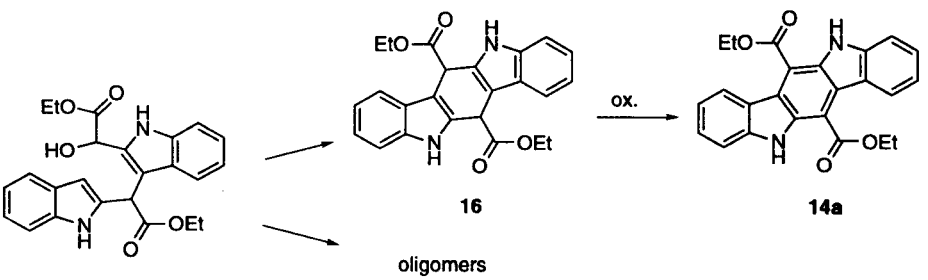
For the glyoxylate addition we chose to use the excellent Katritzky protocol[15] where CO_2 is used as a readily removed protecting/directing group which essentially makes it possible to perform protection-addition-deprotection in one pot. As can be seen in Scheme 4, such additions gave good yields of hydroxy esters **13** which are difficult to obtain by other methods.



13a R = Et (61 %)
b R = Menthyl (58 %)

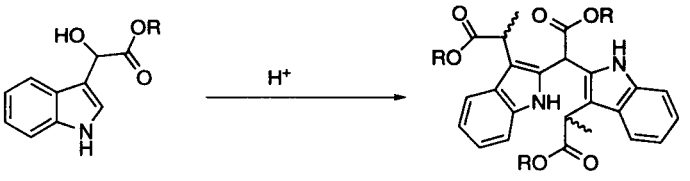
Scheme 4

For the dimerization experiments we chose to use the ethyl ester which should give simpler NMR spectra. However, despite extensive experimentation trying a wide range of conditions, not more than minor amounts (3-4 %) of the desired diester **14a** could occasionally be found (apart from the established procedures mentioned above, *p*-TsOH, $Yb(OTf)_3$, CH_3CN, iso-PrCN, dioxane, toluene, and various temperatures were used in a multitude of combinations). When monitoring the attempted dimerization reactions (TLC), it was found that in all cases approximately the same temperature (50°C) was needed to start the reaction. Indications are (unpublished results) that the coupling product **15** is formed, but to a very small extent undergoes cyclization to tetrahydroindolo[3,2-*b*]carbazole **16** despite its favoured character, *6-Exo-Tet* according to the Baldwin classification.[16] Instead oligomers seemed to be formed as a result of intermolecular reactions (Scheme 5).



Scheme 5

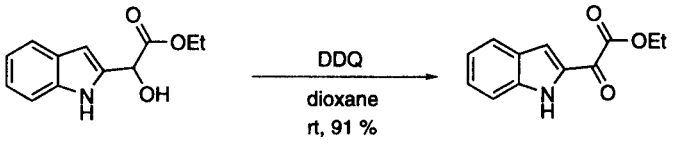
This would be consistent with the reported[17] oligomerization of hydroxy ester **17**, a regioisomer of **13**, to give the polymeric pigment **18**, which is claimed to give urine its colour (Scheme 6).



17 **18**

Scheme 6

Under two conditions, (1) refluxing iso-PrCN with *p*-TsOH as catalyst (2) dioxane with $Yb(OTf)_3$ as catalyst at 50°C, we obtained somewhat larger yields (≈ 20-25 %) of a compound that we first thought was the dimer tetrahydroindolo[3,2-*b*]carbazole **16** or possibly the corresponding trimer[18] of **13a**. However, a mass spectrum of the product revealed that the α-keto ester **19**[19] had been formed, something which could be confirmed by DDQ-oxidation of the hydroxy ester **13a** (Scheme 7).



13a **19**

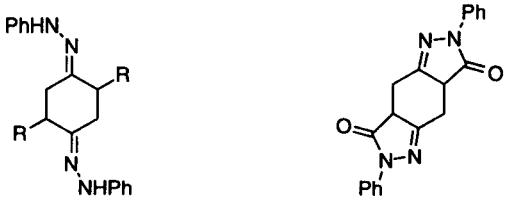
Scheme 7

In control experiments in the absence of acid no α-keto ester **19** was formed from the hydroxy ester **13a**, implying that the oxidation is acid-mediated.

The difficulties encountered made us turn to another strategy.

2.2 Double Fischer indolization of bis-phenylhydrazones of 1,4-cyclohexanediones

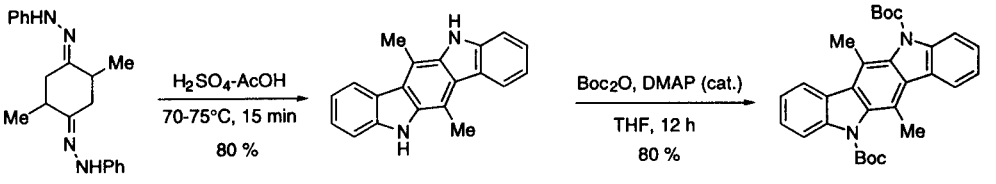
The classical method for synthesizing the parent 5,11-dihydroindolo[3,2-*b*]carbazole **2** is by a double Fischer indolization of the *bis*-phenylhydrazone of cyclohexane-1,4-dione.[20] Unfortunately, synthesis of the dialdehyde **5** from the *bis*-phenylhydrazone dialdehyde **20** using the same approach is not an option. Compound **20** is not only difficult to prepare, but it would also undergo the same fate as *bis*-phenylhydrazone **21**, namely intramolecular ring closure: the formation of imidazolones (to *bis*-imidazolone **22** in the case of **21**) when reacting β-keto esters with phenylhydrazines is well known.[21]



20) R = CHO
21) R = COOEt

22

Therefore, we reasoned that it should be more sensible to run a Fischer indolization with the dimethyl-*bis*-phenylhydrazone **23** (easily prepared from 2,5-dimethylcyclohexane-1,4-dione[22]) as substrate with the aim of preparing the unfunctionalized dimethylindolocarbazole **24**: double benzylic oxidation of this molecule might then give us the desired dialdehyde **5**. So, the dimethyl-*bis*-phenylhydrazone **23** was prepared and underwent cyclization under appropriate acidic conditions[20] to **24** (Scheme 8).



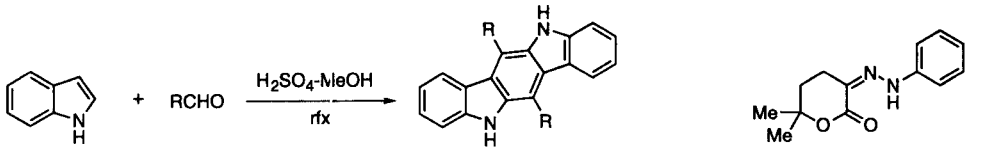
23 **24** **25**

Scheme 8

The extreme insolubility of **24** made it difficult to perform further synthetic transformations, but we nevertheless made some attempts. For example, oxidation with CAN gave a plethora of products as indicated by the ^{1}H NMR spectrum of the crude product. It is not hard to imagine that the amine hydrogens of the molecule can take part in the reaction – the oxidation of indolocarbazole **2** to corresponding azaquinone is known[23] – so it seemed reasonable to find a suitable protecting group for this functionality. Such a protecting group would preferably also be a bulky one, disrupting the stacking of **24** and thereby conferring some solubility to the molecule: this would hopefully give us greater flexibility in the choice of reaction conditions for the oxidation. After much experimentation, it was found that the Boc group seemed to to fulfil the requirements (Scheme 8).[24] The Boc groups made the dihydroindolo[3,2-*b*]carbazole system more soluble in CH_2Cl_2 (somewhat) and THF (readily), and also demonstrated reasonable stability towards silica gel, which could be of importance for column chromatography. However, all our attempts to transform the methyl groups of **25** into formyl groups (CAN, NBS-bromination followed by hydrolysis *etc.*) have so far failed.

2.3 Acid-catalyzed condensation of indole with aliphatic aldehydes

In the context of this work we also re-investigated condensations of indole with aldehydes induced by sulfuric acid in hot methanol.[18] By this route large amounts of *e.g.* indolo[3,2-*b*]carbazole **26a** can be prepared[18] (Scheme 9). This reaction has not yet been extended to aliphatic aldehydes (except formaldehyde[4,18]), probably because all potential explorers have foreseen problems with self-condensations (which certainly is true for acetaldehyde: not even a trace of the desired dimethylindolocarbazole **24** was produced). However, with the relatively hindered iso-butyraldehyde, an excellent yield (80 %) of **26b** could quickly be obtained. Likewise, condensation of indole with pentanal readily gave **26c** in high yield. As a comparison, it can mentioned that compound **26b** has been prepared before *via* a lengthy route involving Fischer indolization (and decarboxylation) of the relatively sophisticated precursor **27**,[25] and compound **26c** from a 2-(benzotriazol-1-ylmethyl)indole[14a] (*vide supra*).

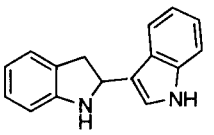


26a) R = Ph (37 %)
b) R = iso-Pr (80 %)
c) R = n-Bu (72 %)

27

Scheme 9

These results spurred us to investigate whether it might be possible to condense indole with aldehydes such as ethyl glyoxylate, glycolic aldehyde, chloroacetaldehyde, or glyoxal to obtain 6,12-*difunctionalized* indolo[3,2-*b*]carbazoles. However, these experiments have been a complete disappointment: we have just obtained complex mixtures which are probably due to trapping reactions of the indole dimer **28** formed under the strongly acidic conditions. In this context it should be mentioned that Hasselström[26] has reported the condensation of indole with glyoxal under acidic conditions and claimed the isolation of tetraindolylethylene **29**. We have not been able to reproduce this preparation and any dialdehyde **5** could, as previously mentioned, not be detected.



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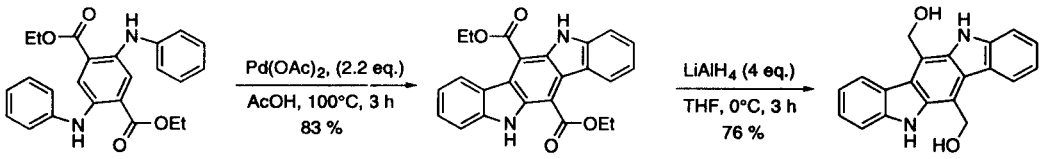
29) R = 1*H*-indol-3-yl

2.4 Pd-mediated cyclization of an ester-substituted diphenyl phenylenediamine

Pd-mediated cyclizations of diphenylamines to carbazoles[27] are known, but (to the best of our knowledge) no attempts to synthesize indolocarbazoles in this fashion have been reported. The precursor in our case would preferably be the diester **30** (aldehydes are usually decarbonylated by Pd), which has been known since 1914.[28] This diester turned out to be an excellent substrate for the Pd-mediated cyclization,[27a] giving **14a** in 83 % yield (Scheme 10).

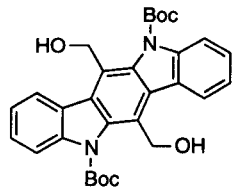


30 **14a** **31**

Scheme 10

A direct conversion of the diester **14a** into the dialdehyde **5** failed: reduction with DIBAL could not be stopped at the aldehyde stage but proceeded to the dialcohol (at ca. –50°C). Therefore, we decided to try to reach the target *via* the dialcohol. So, the diester **14a** was conveniently reduced with LAH to give the dialcohol **31** in 76 % yield. We soon discovered that this dialcohol was very difficult to dissolve in most solvents (warm dioxane and DMSO being exceptions), severely limiting the options available for oxidation. In this context the use of the pyridine-SO_3 complex[29] seemed to be an attractive alternative. This is a very mild Swern-type method sometimes used in syntheses of natural products.[30] However, this type of transformation did not succeed, but gave intractable mixtures.

As a solution to the solubility problem we considered protecting the nitrogens of the diester **14a** and selectively reducing the ester groups to obtain the indolocarbazole **32**: our experience told us that **32** might be relatively soluble in CH_2Cl_2 or THF, common solvents for many types of oxidations.



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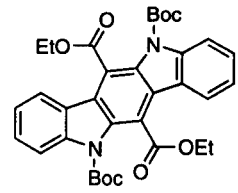
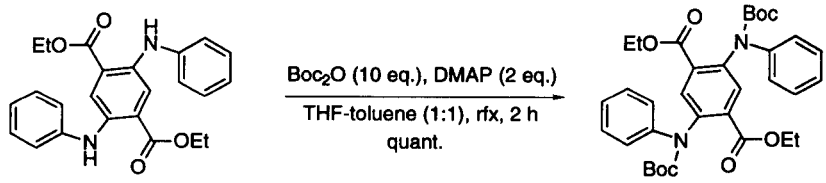


33

So, the diester **14a** was protected with Boc-groups to give **33** in 94 % yield using the standard conditions (see Experimental section). It is worth mentioning that the nucleophilicity of the sterically hindered nitrogens in **14a** was somewhat surprising considering that complete Boc-ylation of the diphenyl phenylenediamine **30** to **34** required 10 equivalents of Boc_2O and a stoichiometric amount of DMAP at reflux temperature (toluene-THF) (Scheme 11).

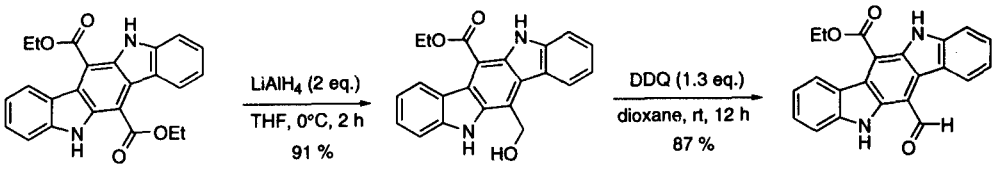


30 **34**

Scheme 11

We now tried various ways to reduce the esters of the indolocarbazole **33** selectively to produce the dialcohol **32**, but the results were consistently all or nothing. DIBAL – under appropriate conditions[31] known to reduce esters, but not carbamates – did not affect the diester **33** at all, even at reflux temperatures. In contrast, $LiAlH_4$ gave a completely unselective reduction/de-protection already at 0°C. Different tactics were apparently needed.

During the course of the LAH-reduction of the diester **14a** we had found that it was possible to stop the reduction at an intermediate stage, and the monoalcohol **35** could be isolated in a 91 % yield (Scheme 12).



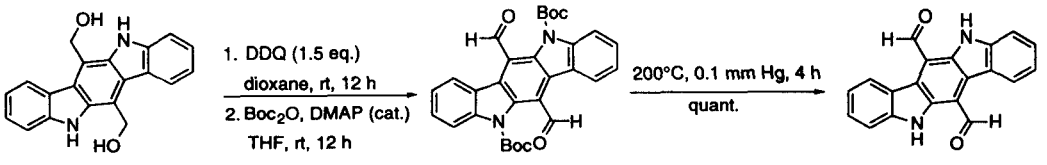
14a 35 36

Scheme 12

The monoalcohol **35**, in contrast to the dialcohol **31**, was relatively soluble in organic solvents, so we decided to use it as a model for further oxidation experiments. We found that DDQ was an excellent reagent for oxidation of **35** giving the aldehyde **36** in 87 % yield. The selective monoreduction also gave us good access to a type of unsymmetrically 6,12-substituted dihydroindolo[3,2-*b*]carbazoles which we had planned to use for antibody-creation (see Introduction). Suitable transformations of **35** before or after attachment to the solid phase should give us the type of hapten **7** we need. At this stage we at least had a potential model system to work with: **37** (coupling of **35** to a proper solid phase) might be used to create antibodies, which then can be tested against both the diester **14a** and the previously made monoester **38**.[13b]

37 38

Compound **36** once again showed the importance of bulkier groups for conferring solubility to 5,11-dihydroindolo[3,2-*b*]carbazoles: the monoaldehyde **36** had much more limited solubility than, for example, the monoalcohol **35** or the diester **14a**. Nevertheless, the dialcohol **31** was now given the same DDQ-treatment as the monoalcohol **35** in order to produce the dialdehyde **5**. After suitable work-up, the raw product was derivatized with Boc-groups (this has been used to our advantage before[13b]) and the desired dialdehyde could be isolated as its di-Boc derivative **39** in a 65 % yield in 2 steps (Scheme 13). The Boc-groups of **39** could be removed quantitatively in a final step by heating at reduced pressure[13b] to leave the pure dialdehyde **5**.



31 39 5

Scheme 13

The analytical data of the obtained compound were in all aspects identical to those of the authentic sample,[12] whose assigned structure thus could be confirmed. Furthermore, this method allows the preparation of sufficient amounts of the dialdehyde **5** for further probing the TCDD receptor.

We are currently seeking ways to make the synthesis of the diester **14a** catalytic in Pd, making this entry into the indolo[3,2-*b*]carbazole field more attractive. Work on coupling of unsymmetrical indolo[3,2-*b*]carbazoles (such as the monoalcohol **35**) to a proper solid phase for antibody-creation is also in progress.

3. Conclusions

In summary, we have synthesized various 6,12-substituted 5,11-dihydroindolo[3,2-*b*]carbazoles, most notably 5,11-dihydroindolo[3,2-*b*]carbazole-6,12-dicarbaldehyde **5**, an extremely efficient ligand for the TCDD receptor. We have also synthesized the unsymmetrical ethyl 12-(hydroxymethyl)-5,11-dihydroindolo[3,2-*b*]carbazole-6-carboxylate **35** and ethyl 12-formyl-5,11-dihydroindolo[3,2-*b*]carbazole-6-carboxylate **36**, both intriguing starting points for coupling to a solid phase with the aim of creating antibodies against 5,11-dihydroindolo[3,2-*b*]carbazole-6-carbaldehyde **4**. The precursor of these 6,12-substituted 5,11-dihydroindolo[3,2-*b*]carbazoles was diethyl 5,11-dihydroindolo[3,2-*b*]carbazole-6,12-dicarboxylate **14a**, produced by a Pd-mediated coupling of diethyl 2,5-dianilinoterephthalate **30**. Efficient syntheses of symmetrically 6,12-dialkylsubstituted 5,11-dihydroindolo[3,2-*b*]carbazoles by condensation of indole with aldehydes (alkyl = iso-Pr, n-Bu) and by a double Fischer indolization (alkyl = Me) have also been developed.

4. Experimental section

With the following exceptions all reagents and solvents were purchased from commercial suppliers and used without further purification: ethyl and menthyl glyoxylate were kindly donated by Hoechst (France). Ethyl glyoxylate was delivered as a solution in toluene (50 % w/w) and was refluxed for 3 h before use to effect depolymerization; menthyl glyoxylate was delivered as a white solid (crystallized as a hydrate) and was therefore refluxed for 3 h in toluene in a Dean-Stark apparatus to remove the crystal water. Toluene was thereafter evaporated and the white, solid residue was used for the reaction; 2,5-dimethylcyclohexane-1,4-dione[22] and diethyl 1,4-cyclohexanedione-2,5-dicarboxylate[32] were synthesized according to known procedures; THF was distilled from Na/benzophenone, and distilled solvents were used for flash chromatography. The petroleum ether used for chromatography had the boiling point range 60-80°C. Silica gel (230-400 mesh) for column chromatography and TLC plates were purchased from Merck. Experiments involving dry solvents were performed under N_2 using oven-dried glassware. The expression "evaporation of solvent(s)" refers to the use of a rotatory evaporator at 30°C at reduced pressure. NMR experiments were performed on a Bruker DPX300 instrument. IR spectra were recorded on a Perkin-Elmer FT-IR 1600 spectrophotometer. Melting points (uncorrected) were determined on an Electrothermal IA9020 digital melting point apparatus and occasionally on a Kofler Hotbench (Leica VM HB) when appropriate. The microanalyses were performed by H. Kolbe Mikroanalytisches Laboratorium, Mülheim an der Ruhr, Germany. High resolution mass spectroscopy (HRMS) experiments were performed by Sveriges Lantbruksuniversitet (SLU), Uppsala, Sweden.

Ethyl 2-hydroxy-2-(1*H*-2-indolyl)acetate (13a)

Indole (1.172 g, 10 mmol) was dissolved in dry THF (20 mL) under N_2. The solution was cooled to -78 °C and *n*-BuLi (12.5 mmol, 5.0 mL, 2.5 M in hexane) was added dropwise during 10 min. The lithium salt precipitated within 5-10 min. 1.5 h after the last drop of n-BuLi had been added the solution was protected with a drying tube and CO_2 was bubbled through the mixture during 20 min. A clear solution was obtained almost immediately, whereupon the solution was allowed to stir for 30 min to let most of the dissolved CO_2 evaporate. A vacuum pump was now connected to the system to remove the solvent (to ensure complete removal of CO_2). After pumping for 30 min at -78 °C the CO_2-EtOH-bath was replaced with an ordinary ice-bath to remove the solvent completely. Freshly distilled THF (20 mL) was added to dissolve the solid residue and the solution was once again cooled to -78 °C. *t*-BuLi (12.5 mmol, 7.4 mL, 1.7 M in hexane) was added dropwise during 10 min to the stirred solution, with a colour change from yellow to deep orange. 1 h after the addition of *t*-BuLi ethyl glyoxylate (3.063 g, 15 mmol, 50% w/w in toluene) was added in one portion and then stirred for 2 h at -78°C before quenching with saturated, aqueous NH_4Cl (1 mL). The solution was then warmed to room temperature and diluted with CH_2Cl_2 (100 mL). The organic phase was washed consecutively with water (30 mL) and brine (40 mL) before drying ($MgSO_4$). After filtering off $MgSO_4$, the solvents were evaporated and the residue was purified by column chromatography (ethyl acetate-petroleum ether gradient, 0-50 %) to give a yellowish sticky solid **13a** (1.342 g, 61 %). An analytical sample was obtained as shiny, white crystals by recrystallization from toluene-petroleum ether (50 %), mp 84.5-85.5°C.
^{1}H NMR ($CDCl_3$, 300 MHz) δ 8.63 (br s, 1H, N*H*), 7.61 (d, 1H, J = 7.8 Hz), 7.35 (d, 1H, J = 8.0 Hz), 7.21 (dd, 1H, J = 7.7, 7.7 Hz), 7.13 (dd, 1H, J = 7.7, 7.7 Hz)), 6.56 (s, 1H), 5.44 (s, 1H), 4.41 (m, 2H), 3.70 (br s, 1H, O*H*), 1.32 (t, 3H, J = 7.1 Hz).
^{13}C NMR ($CDCl_3$, 75 MHz) δ 172.4 (s), 136.2 (s), 134.5 (s), 128.3 (s), 122.6 (d), 120.9 (d), 120.2 (d), 111.3 (d), 101.1 (d), 68.0 (d), 62.9 (t), 14.3 (q).
IR (KBr) 3422, 3370, 1732, 1455, 1292, 1217, 1081, 737 cm^{-1}.
Anal. calcd. for $C_{12}H_{13}NO_3$: C: 65.74; H: 5.98; N: 6.39. Found: C: 65.71; H: 5.89; N: 6.32.

Menthyl 2-hydroxy-2-(1*H*-2-indolyl)acetate (13b)

The same procedure was used as for **13a**. In this case menthyl glyoxylate (2.65 g, 12.5 mmol) was the electrophile and **13b** (1.916 g 58 %) was isolated as a yellowish sticky solid (mixture of two diastereomers:≈ 1:1 according to ^{1}H NMR). An analytical sample was obtained as a shiny, white, fibrous solid by recrystallization from toluene-petroleum ether (50 %), mp 149.5-154.5°C.
^{1}H NMR ($CDCl_3$, 300 MHz) δ 8.46 (br s, 0.5H, N*H*), 8.39 (br s, 0.5H, N*H*), 7.60 (d, 0.5H, J= 8.1 Hz), 7.58 (d, 0.5H, J = 7.9 Hz), 7.37 (d, 0.5H, J = 8.9 Hz), 7.34 (d, 0.5H, J = 8.9 Hz), 7.23-7.07 (m, 2H), 6.54 (br s, 1H), 5.41 (s, 0.5H), 5.38 (s, 0.5H), 4.93-4.74 (m, 1H), 3.46 (br s, 1H, O*H*), 2.13-0.72 (m, 15H), 0.61 (d, 1.5H, J = 6.9 Hz), 0.50 (d, 1.5H, J = 6.8 Hz).
IR (KBr) 3445, 3411, 2955, 2868, 1721, 1456, 1289, 1213, 1200, 1080 cm^{-1}.
Anal. calcd. for $C_{20}H_{27}NO_3$: C: 72.92; H: 8.26; N: 4.25. Found: C: 72.79; H: 8.36; N: 4.21.

Ethyl 2-(1*H*-2-indolyl)-2-oxoacetate (19)

Ethyl 2-hydroxy-2-(1*H*-2-indolyl)acetate **13a** (99 mg, 0.45 mmol) was dissolved in dioxane (2 mL) at room temperature. DDQ (112 mg, 0.495 mmol) dissolved in dioxane (5 mL) was added

dropwise during 5 min. Initially, the solution darkened, but with time a sand-colured precipitate was formed. After 1 h the reaction was complete as judged by TLC (CH_2Cl_2). The solvent was evaporated and the residue purified by column chromatography to give pure **19** (90 mg, 92 %) as a bright-yellow powder, mp 79.5-80.5°C.
^{1}H NMR (DMSO-d_6, 300 MHz) δ 12.17 (br s, 1H, N*H*), 7.76 (d, 1H, J = 8.1 Hz), 7.58 (s, 1H), 7.48 (d, 1H, J = 8.4 Hz), 7.37 (dd, 1H, J = 8.2, 8.2 Hz), 7.12 (dd, 1H, J = 8.2, 8.2 Hz), 4.41 (q, 2H, J = 7.1 Hz), 1.36 (t, 3H, J = 7.1 Hz).
^{13}C NMR (DMSO-d_6, 75 MHz) δ 176.3 (s), 162.3 (s), 139.1 (s), 131.8 (s), 127.3 (d), 126.9 (s), 123.5 (d), 121.0 (d), 114.9 (d), 113.0 (d), 62.2 (t), 13.9 (q).
IR (KBr) 3394, 1728, 1645, 1618, 1523, 1339, 1281, 1219, 1156, 1140, 1047, 756, 742, 649 cm^{-1}.
HRMS (EI+), calcd for $C_{12}H_{11}NO_3$: 217.0739. Found: 217.0738.

2,5-Dimethylcyclohexane-1,4-dione *bis*-phenylhydrazone (23)

Phenylhydrazine (2.14 g, 19.8 mmol) was dissolved in EtOH (20 mL). 2,5-Dimethylcyclohexane-1,4-dione[22] (1.24 g, 9.0 mmol) was added followed by 3 drops of AcOH. The orange solution was then warmed to reflux and a thick yellow precipitate was soon formed. The suspension was refluxed for 2-3 min before being allowed cool. Pure **23** (2.70 g, 94 %) was filtered off as a light-yellow powder, mp 169-185°C (a mixture of isomers).
IR (KBr) 3352, 2975, 2960, 2924, 1597, 1502, 1308, 1251, 1132, 1087, 1062, 751, 693 cm^{-1}.

6,12-Dimethyl-5,11-dihydroindolo[3,2-*b*]carbazole (24)

2,5-Dimethylcyclohexane-1,4-dione *bis*-phenylhydrazone **23** (4.50 g, 14.0 mmol) was added in portions to a solution of conc. H_2SO_4 (8 mL) in AcOH (20 mL) at 30°C. The red solution obtained was allowed to reach 60°C in 10 min, whereupon a precipitate started to form. The solution was now warmed towards 80°C and at 60°C a thick beige precipitate began to form. The mixture was now stirred at 70-75°C for 15 min and then allowed to cool. After 24 h ethanol (20 mL) and water (10 mL) were added and the precipitate was collected, washed with ethanol and dried to give **24** (3.20 g, 80 %) as a greyish powder. An analytical sample was obtained as light-yellow, shiny flakes by sublimation, mp 296-298°C.
^{1}H NMR (DMSO-d_6, 300 MHz) δ 10.83 (s, 2H), 8.25 (d, 2H, J = 7.8 Hz), 7.52 (d, 2H, J = 8.0 Hz), 7.38 (dd, 2H, J = 7.7, 7.7 Hz), 7.14 (dd, 2H, J = 7.7, 7.7 Hz), 3.21 (s, 6H).
^{13}C NMR (DMSO-d_6, 75 MHz) δ 141.2 (s), 134.4 (s), 124.4 (d), 123.5 (s), 121.9 (d), 120.2 (s), 117.4 (d), 110.2 (d), 109.5 (s), 14.1 (q).
IR (KBr) 3421, 1614, 1540, 1459, 1376, 1336, 1324, 1302, 1258, 1108, 1020, 741 cm^{-1}.
Anal. calcd. for $C_{20}H_{16}N_2$: C: 84.48; H: 5.67; N: 9.85. Found: C: 84.52; H: 5.58; N: 9.95.

Di(*tert*-butyl) 6,12-dimethyl-5,11-dihydroindolo[3,2-*b*]carbazole 5,11-dicarboxylate (25)

6,12-Dimethyl-5,11-dihydroindolo[3,2-*b*]carbazole **24** (0.284 g, 1.00 mmol) was suspended in dry THF (20 mL) under N_2. Boc_2O (0.655 g, 3.00 mmol) was added followed by DMAP (27 mg, 0.22 mmol). The suspension gradually became thinner as starting material was consumed and product went into solution. After 24 h the reaction was complete as judged by TLC (10 % ethyl acetate-petroleum ether) and the solvent was evaporated. The residue was purified by column chromatography (CH_2Cl_2-petroleum ether, 0-50 %) which gave pure **25** (0.388 g, 80%) as shiny off-white crystals, mp 231°C (de-Boc-ylation; this process is gradual, so the melting

point given was determined on a Kofler Hotbench in such a way that the crystals were rapidly moved towards ever-higher temperatures until a complete, immediate melt was observed).
^{1}H NMR ($CDCl_3$, 400 MHz) δ 8.20 (2×d, 4H, J = 7.9 Hz), 7.47 (dd, 2H, J = 7.8, 7.8 Hz), 7.39 (dd, 2H, J = 7.8, 7.8 Hz), 2.89 (s, 6H), 1.71 (s, 18H).
^{13}C NMR ($CDCl_3$, 100 MHz) δ 151.5 (s), 141.6 (s), 136.9 (s), 127.7 (s), 126.3 (d), 126.0 (s), 123.0 (d), 122.8 (d), 118.5 (s), 115.3 (d), 83.7 (s), 28.3 (q), 19.2 (q).
IR (KBr) 2977, 1729, 1442, 1368, 1354, 1283, 1266, 1251, 1222, 1149, 1079, 766, 744 cm^{-1}.
HRMS (EI+), calcd for $C_{30}H_{32}N_2O_4$: 484.2362. Found: 484.2342.

6,12-Diisopropyl-5,11-dihydroindolo[3,2-*b*]carbazole (26b)

To a solution of indole (11.72 g, 0.1 mol) and iso-butyraldehyde (7.21 g, 0.1 mol) dissolved in methanol (400 mL) concentrated sulfuric acid (10 mL) was carefully added. The mixture was heated at reflux for 4 h and then allowed to cool. The mixture was now concentrated to appoximately 100 mL and a greyish solid (15.35 g) was collected. The filtate was poured into water (400 mL) to give an additional solid, which was washed consecutively with 5 % aqueous Na_2CO_3 and water before being dried. This solid crystallized from CH_3CN to give **26b** (2.95 g). The less pure first solid was now given the same treatment as the second and the pure material already obtained were used as seed crystals. A total of 13.50 g (80 %) of **26b** was finally obtained, mp 330-333°C (Lit.[25] 340 °C).
The spectral data were identical with those already reported[25] except that the signal from the N*H* in the ^{1}H NMR spectrum appeared at δ 10.5 rather than at δ 9.2.

6,12-Dibutyl-5,11-dihydroindolo[3,2-*b*]carbazole (26c)

The same procedure as for **26b** was used to give **26c** (72 %) as white crystals, mp 290-291°C (Lit.[14a] 287-290 °C).
The spectral data were identical with those already reported.[14a]

Diethyl 2,5-dianilinoterephthalate (30)

A modification of the method of Liebermann[28] was used. Diethyl 1,4-cyclohexanedione-2,5-dicarboxylate[32] (1.025 g, 4 mmol) was suspended in AcOH (12 mL) in a wide-necked flask without a reflux condenser (to give access to air) and aniline (0.894 g, 9.6 mmol) was added. The suspension was heated to 100°C whereupon a red solution was obtained and after about an hour red crystals started to precipitate. The mixture was kept at 100°C during 12 h to assure that the dihydro intermediate was completely oxidized to the target compound. After cooling the mixture was filtered to give pure **30** (1.40 g, 87 %) as dark-red crystals, mp 146-147.5°C (Lit. 143 °C[28], 144-146 °C[33]).
^{1}H NMR ($CDCl_3$, 300 MHz) δ 8.81 (br s, 2H, N*H*), 8.06 (s, 2H), 7.33 (dd, 4H, J = 8.0 Hz), 7.20 (d, 4H, J = 8.5 Hz), 7.01 (t, 2H, J = 7.3 Hz), 4.34 (q, 4H, J = 7.1 Hz), 1.36 (t, 6H, J = 7.1 Hz).
^{13}C NMR ($CDCl_3$, 75 MHz) δ 167.7 (s), 142.4 (s), 137.9 (s), 129.6 (d), 122.0 (d), 119.6 (d), 119.5 (s), 119.0 (d), 61.5 (t), 14.4 (q).
IR (KBr) 3354, 2972, 1687, 1600, 1586, 1541, 1497, 1434, 1410, 1255, 1216, 1100, 1024, 782, 733, 690 cm^{-1}.

Diethyl 5,11-dihydroindolo[3,2-*b*]carbazole-6,12-dicarboxylate (14a)

Diethyl 2,5-dianilinoterephthalate **30** (0.405 g, 1 mmol) was suspended in AcOH (20 mL) and $Pd(OAc)_2$ (0.494 g, 2.2 mmol) was added. The mixture was heated to 100 °C and kept at that temperature for 3 h before all starting material was consumed as judged by TLC (CH_2Cl_2). The choice of temperature is essential: at reflux (116-117 °C) acylation of the product takes place and the yield deteriorates rapidly. After cooling of the mixture the solvent was evaporated and the residue was subjected to column chromatography (CH_2Cl_2-petroeum ether, 0-100 %) to give pure **14a** (0.334 g, 83 %) as a bright, yellow powder. An analytical sample was obtained as bright, yellow crystals by recrystallization from toluene, mp 201.5-204 °C.
^1H NMR (DMSO-d_6, 300 MHz) δ 11.28 (s, 2H, N*H*), 8.45 (d, 2H, J = 8.1 Hz), 7.72 (d, 2H, J = 8.1 Hz), 7.48 (dd, 2H, J = 7.9, 7.9 Hz), 7.22 (dd, 2H, J = 7.9, 7.9 Hz), 4.71 (q, 4H, J = 7.1 Hz), 1.50 (t, 6H, J = 7.1 Hz).
^{13}C NMR (DMSO-d_6, 75 MHz) δ 166.8 (s), 141.8 (s), 134.2 (s), 126.9 (d), 123.7 (d), 120.4 (s), 120.2 (s), 118.6 (d), 111.6 (d), 109.8 (s), 61.6 (t), 14.2 (q).
IR (KBr) 3445, 1701, 1615, 1513, 1462, 1453, 1417, 1316, 1302, 1204, 1177, 1153, 1122, 1025, 749 cm^{-1}.
Anal. calcd. for $C_{24}H_{20}N_2O_4$: C: 71.99; H: 5.03; N: 7.00. Found: C: 71.82; H: 5.05; N: 6.88.

6,12-Di(hydroxymethyl)-5,11-dihydroindolo[3,2-*b*]carbazole (31)

Diethyl 5,11-dihydroindolo[3,2-*b*]carbazole-6,12-dicarboxylate **14a** (310 mg, 0.774 mmol) was dissolved in dry THF (20 mL) under N_2 and cooled to 0°C. $LiAlH_4$ (95 %) (247 mg, 6.19 mmol) was added in portions under gas evolution. The bright yellow solution transformed into a red-brown slurry. After 2 h the reaction was complete as judged by TLC (50 % ethyl acetate-petroleum ether) and was carefully quenched with a saturated solution of Rochelle's salt. The mixture was filtered through Celite® and the filter-cake was washed with THF (40 mL) and CH_2Cl_2 (120 mL). The filtrate was washed with water (2×40 mL) and then dried with $MgSO_4$. After filtering off the solid material the solvents were evaporated to give pure **31** (187 mg, 76 %) as a light-brown powder. An analytical sample was obtained as a light-yellow powder by recrystallization from dioxane, mp > 400 °C (upper limit of the melting point apparatus).
^1H NMR (DMSO-d_6, 300 MHz) δ 11.02 (s, 2H, N*H*), 8.31 (d, 2H, J = 7.9 Hz), 7.54 (d, 2H, J = 8.0 Hz), 7.38 (dd, 2H, J = 7.9, 7.9 Hz), 7.13 (dd, 2H, J = 7.9, 7.9 Hz), 5.43 (s, 4H), 5.35 (br s, 2H, O*H*).
^{13}C NMR (DMSO-d_6, 75 MHz) δ 141.2 (s), 134.2 (s), 125.0 (d), 123.3 (d), 122.4 (s), 120.7 (s), 117.6 (d), 115.6 (s), 110.4 (d), 57.6 (t).
IR (KBr) 3522, 3294, 2961, 1613, 1534, 1459, 1324, 1300, 1261, 1024, 989, 803, 745 cm^{-1}.
HRMS (EI+), calcd for $C_{20}H_{16}N_2O_2$: 316.1186. Found: 316.1212.

5,11-Di(*tert*-butyl) 6,12-diethyl 5,11-dihydroindolo[3,2-*b*]carbazole-5,6-11,12-tetracarboxylate (33)

Diethyl 5,11-dihydroindolo[3,2-*b*]carbazole-6,12-dicarboxylate **14a** (0.252 g, 0.630 mmol) was dissolved in dry THF (15 mL) under N_2. Boc_2O (0.345 g, 1.58 mmol) was added followed by DMAP (15 mg, 0.13 mmol). After 2 h the consumption of starting material was complete as judged by TLC (CH_2Cl_2) and the solvent was evaporated. The residue was purified by column chromatography (CH_2Cl_2-petroleum ether, 50-100 %) to give pure **33** (0.356 g, 94 %) as a light-yellow powder. An analytical sample was obtained as light-yellow crystals by

recrystallization from H_2O-CH_3CN (1:9), mp 196-198°C [de-Boc-ylation; this process started earlier (≈175°C), but at the given melting point a complete melt was obtained].
^1H NMR ($CDCl_3$, 300 MHz) δ 8.33 (d, 2H, J = 7.7 Hz), 8.17 (d, 2H, J = 8.4 Hz), 7.52 (dd, 2H, J = 8.1, 8.1 Hz), 7.36 (dd, 2H, J = 8.1, 8.1 Hz), 4.59 (q, 4H, J = 7.2 Hz), 1.46 (t, 6H, J = 7.2 Hz).
^{13}C NMR ($CDCl_3$, 75 MHz) δ 166.8 (s), 151.6 (s), 140.6 (s), 133.9 (s), 128.2 (d), 124.5 (s), 124.2 (s), 123.4 (d), 123.3 (d), 117.4 (s), 115.9 (d), 85.2 (s), 61.8 (t), 28.5 (q), 14.4 (q).
IR (KBr) 2984, 1724, 1503, 1476, 1448, 1372, 1356, 1330. 1287, 1257, 1221, 1184, 1149, 1128, 1103, 1068, 1021, 762, 740 cm^{-1}.
Anal. calcd. for $C_{34}H_{36}N_2O_8$: C: 67.99; H: 6.04; N: 4.66. Found: C: 68.13; H: 6.08; N: 4.75.

Diethyl 2,5-[(*N-tert*-butoxycarbonyl)anilino]terephthalate (34)

Diethyl 2,5-dianilinoterephthalate **30** (0.809 g, 2.00 mmol) was dissolved in a mixture of dry THF (24 mL) and dry toluene (24 mL) under N_2. Boc_2O (8.730 g, 40 mmol) and DMAP (0.538 g, 4.4 mmol) was added and the mixture was heated to reflux. After 2 h at reflux the consumption of starting material was complete as judged by TLC (20 % ethyl acetate-petroleum ether) and the solution was cooled to room temperature. The solvents were evaporated and the residue was purified by column chromatography (ethyl acetate-petroleum ether, 1-5 %) to give pure **34** (1.209 g, 100 %) as a white powder. An analytical sample was obtained as shiny, white crystals by recrystallization from H_2O-CH_3CN (1:9), mp 162.5-164°C.
^1H NMR ($CDCl_3$, 300 MHz) δ 7.61 (br s, 2H), 7.39-7.28 (m, 8H), 7.26-7.11 (m, 2H), 4.27 (q, 4H, J = 7.1 Hz), 1.26 (t, 6H, J = 7.1 Hz).
^1H NMR (DMSO-d_6, 300 MHz, 80°C) δ 7.56 (s, 2H), 7.38-7.27 (m, 8H), 7.20 (t, 2H, J = 8.4 Hz), 4.22 (q, 4H, J = 7.1 Hz), 1.21 (t, 6H, J = 7.1 Hz).
^{13}C NMR (DMSO-d_6, 75 MHz, 80°C) δ 163.9 (s), 151.8 (s), 141.7 (s), 139.2 (s), 132.7 (s)130.6 (d), 128.2 (d), 125.7 (d), 125.2 (d), 80.6 (s), 60.9 (t), 27.3 (q), 13.3 (t). At room temperature the peaks in the ^{13}C spektrum were very broad.
IR (KBr) 2979, 1716, 1596, 1497, 1464, 1456, 1412, 1391, 1367, 1328, 1292, 1268, 1251, 1227, 1159, 1121, 1060, 1007, 921, 844, 768, 756, 742, 696 cm^{-1}.
Anal. calcd. for $C_{34}H_{40}N_2O_8$: C: 67.53; H: 6.67; N: 4.63. Found: C: 67.51; H: 6.73; N: 4.78.

Ethyl 12-(hydroxymethyl)-5,11-dihydroindolo[3,2-*b*]carbazole-6-carboxylate (35)

Diethyl 5,11-dihydroindolo[3,2-*b*]carbazole-6,12-dicarboxylate **14a** (0.324 g, 0.809 mmol) was dissolved in dry THF (20 mL) in a flask equipped with a drying tube and cooled to 0°C. Lithium aluminium hydride (65 mg, 1.62 mmol, 95 %) was added in one portion under gas evolution and change of colour (yellow solution to brown suspension). After 30 min the reaction was complete as judged by TLC (ethyl acetate-petroleum ether, 50 %) and quenched with a saturated solution of Rochelle's salt. The suspension was filtered through Celite® with the help of THF (20 mL) and CH_2Cl_2 (100 mL). The filtrate was then washed with water (2×30 mL) and dried ($MgSO_4$). After filtering off $MgSO_4$ the solvents were evaporated and the residue subjected to column chromatography (ethyl acetate-CH_2Cl_2, 0-16 %) to give pure **35** (0.263 g, 91 %) as an orange powder. An analytical sample was obtained as dark-orange crystals by recrystallization from toluene, mp, 172-174°C.

^{1}H NMR (DMSO-d_6, 300 MHz) δ 11.51 (s, 1H, N*H*), 11.00 (s, 1H, N*H*), 8.69 (d, 1H, J = 8.1 Hz), 8.36 (d, 1H, J = 7.9 Hz), 7.73 (d, 1H, J = 8.0 Hz), 7.63 (d, 1H, J = 8.1 Hz), 7.48-7.41 (m, 2H), 7.22 (dd, 1H, J = 7.9, 7.9 Hz), 7.15 (dd, 1H, J = 7.9, 7.9 Hz), 5.70 (br s, 1H, O*H*), 5.50 (s, 2H), 4.69 (q, 2H, J = 7.1 Hz), 1.53 (t, 3H, J = 7.1 Hz).
^{13}C NMR (DMSO-d_6, 75 MHz) δ 167.3 (s), 141.7 (s), 141.2 (s), 135.9 (s), 134.1 (s), 126.1 (d), 125.7 (d), 124.7 (d), 123.4 (d), 122.6 (s), 121.5 (s), 121.3 (s), 121.1 (s), 120.1 (s), 118.6 (d), 117.6 (d), 111.3 (d), 111.0 (d), 104.2 (s), 60.8 (t), 57.5 (t), 14.5 (q).
IR (KBr) 3533, 3370, 3317, 1654, 1614, 1518, 1459, 1321, 1303, 1244, 1206, 1081, 741 cm^{-1}.
Anal. calcd. for $C_{22}H_{18}N_2O_3$: C: 73.73; H: 5.06; N: 7.82. Found: C: 73.82; H: 4.95; N: 7.78.

Ethyl 12-formyl-5,11-dihydroindolo[3,2-*b*]carbazole-6-carboxylate (36)

Ethyl 12-(hydroxymethyl)-5,11-dihydroindolo[3,2-*b*]carbazole-6-carboxylate **35** (299 mg, 0.834 mmol) was dissolved in dioxane (15 mL) and a solution of DDQ (246 mg, 1.084 mmol) dissolved in dioxane (6 mL) was added dropwise during 5 min. After 2 h the reaction was complete as judged by TLC (CH_2Cl_2), so the solvent was evaporated and the residue was purified by column chromatography (CH_2Cl_2-petroleum ether, 0-100 %) to give pure **36** (260 mg, 87 %) as red powder. An analytical sample was obtained as a bright-red, fibrous solid by recrystallization from toluene, mp 232.5-234°C.
^{1}H NMR (DMSO-d_6, 300 MHz) δ 12.00 (br s, 1H, N*H*), 11.44 (s, 1H), 11.42 (br s, 1H, N*H*), 8.59 (d, 1H, J = 8.1 Hz), 8.38 (d, 1H, J = 8.1 Hz), 7.83 (d, 1H, J = 8.1 Hz), 7.76 (d, 1H, J = 8.1 Hz), 7.57-7.46 (m, 2H), 7.28 (m, 2H), 4.73 (q, 2H, J = 7.1 Hz), 1.51 (t, 3H, J = 7.1 Hz).
^{13}C NMR (DMSO-d_6, 75 MHz) δ 190.7 (d), 166.6 (s), 142.3 (s), 141.9 (s), 134.8 (s), 133.5 (s), 127.3 (d), 126.9 (d), 124.8 (d), 123.3 (d), 122.9 (s), 120.5 (s), 120.2 (s), 119.7 (s), 119.5 (d), 119.3 (d), 114.3 (s), 113.3 (s), 112.3 (d), 112.1 (d), 62.0 (t), 14.2 (q).
IR (KBr) 3408, 3317, 1685, 1649, 1612, 1508, 1463, 1456, 1319, 1302, 1251, 1221, 1204, 1126, 1072, 740 cm^{-1}.
Anal. calcd. for $C_{22}H_{16}N_2O_3$: C: 74.15; H: 4.53; N: 7.86. Found: C: 74.04; H: 4.62; N: 7.92.

Di(*tert*-butyl) 6,12-diformyl-5,11-dihydroindolo[3,2-*b*]carbazole-5,11-dicarboxylate (39)

6,12-Di(hydroxymethyl)-5,11-dihydroindolo[3,2-*b*]carbazole **31** (188 mg, 0.594 mmol) was dissolved in dioxane (15 mL) with warming. After cooling to room temperature DDQ (405 mg, 1.78 mmol) in dioxane (10 mL) was added dropwise to the solution during 5 min. The solution gradually darkened and a precipitate soon fell out. The consumption of starting material was complete within an hour as judged by TLC (50 % ethyl acetate-petroleum ether), but the stirring was continued for 24 h to assure that oxidation of both hydroxymethyl groups would take place: the mono-oxidized product is most probably rather insoluble in the reaction medium, so by this procedure we hoped to maximize the amount of desired product. After 24 h most of the solvent was evaporated and a 2 M solution of NaOH (40 mL) was added dropwise under stirring to destroy the unreacted DDQ and transfer the DDQ-H_2 to the aqueous phase. Gas evolution soon started and the suspension was stirred for 4 h whereupon the remaining solid was filtered off, thoroughly washed with water, and dried in a desiccator to give crude indolo[3,2-*b*]carbazole-6,12-dicarbaldehyde **5** (183 mg) as a red-brown powder.
Approximately half of the crude material (90 mg, 0.29 mmol) was suspended in dry THF (8 mL) under a nitrogen atmosphere. Boc_2O (377 mg, 1.73 mmol) was added followed by DMAP (21 mg, 0.17 mmol). The suspension gradually became thinner and finally a clear, yellow solution was obtained. After stirring for 12 h the solution was diluted with CH_2Cl_2 (25 mL)

and washed consecutively with 2 M aqueous HCl (10 mL), saturated, aqueous $NaHCO_3$ (10 mL), water (10 mL), and brine (10 mL) before being dried ($MgSO_4$). After filtering off the solid material the solvents were evaporated and the residue subjected to column chromatography to give pure, di-Boc-protected indolo[3,2-*b*]carbazole-6,12-dicarbaldehyde **39** (97 mg, 66 %) as a yellow solid. The other half of the crude dialdehyde **5** was transformed into **39** in the same way as described above, and the yield was this time 64 %. An analytical sample was obtained as a yellow powder by recrystallization from iso-PrCN. The compound never melted as **39**: it gradually lost its Boc-groups and melted as **5**. The temperature at which the de-Boc-ylation started was highly dependent upon the rate at which the temperature was increased, but **39** was stable up to at least 150°C.
^{1}H NMR ($CDCl_3$, 300 MHz) δ 10.85 (s, 2H), 8.62 (d, 2H, J = 7.9 Hz), 8.24 (d, 2H, J = 8.3 Hz), 7.59 (dd, 2H, J = 7.9, 7.9 Hz), 7.45 (dd, 2H, J = 7.9, 7.9 Hz), 1.71 (s, 18H).
^{13}C NMR ($CDCl_3$, 75 MHz) δ 188.8 (d), 151.6 (s), 141.3 (s), 136.0 (s), 128.9 (d), 125.1 (d), 124.9 (s), 124.7 (s), 124.2 (d), 122.9 (s), 116.2 (d), 86.3 (s), 28.3 (q).
IR (KBr) 2979, 2837, 1714, 1698, 1445, 1392, 1373, 1356, 1294, 1256, 1222, 1154, 1111, 1083, 764, 748 cm^{-1}.
Anal. calcd. for $C_{30}H_{28}N_2O_6$: C: 70.30; H: 5.51; N: 5.47. Found: C: 70.21; H: 5.61; N: 5.48.

5,11-Dihydroindolo[3,2-*b*]carbazole-6,12-dicarbaldehyde (5)

Di(*tert*-butyl) 6,12-diformyl-5,11-dihydroindolo[3,2-*b*]carbazole-5,11-dicarboxylate **39** was heated at 200°C under reduced pressure (0.1 mm Hg) for 4 h to remove the Boc groups (-CO_2, -iso-butene) and give pure 5,11-dihydroindolo[3,2-*b*]carbazole-6,12-dicarbaldehyde **5** (100 %) as a brick-red powder, mp 390°C. The compound has an extremely low solubility in all solvents tested.
^{1}H NMR (DMSO-d_6, 300 MHz) δ 12.11 (s, 2H, N*H*), 11.48 (s, 2H), 8.61 (d, 2H, J = 8.1 Hz), 7.88 (d, 2H, J = 8.1 Hz), 7.54 (dd, 2H, J = 8.0, 8.0 Hz), 7.27 (dd, 2H, J = 8.0, 8.0 Hz).
^{13}C NMR (DMSO-d_6, 75 MHz) δ 191.2 (d), 142.5 (s), 134.3 (s), 127.3 (d), 124.8 (d), 123.3 (s), 119.9 (d), 119.8 (s), 116.8 (s), 112.8 (d).
IR (KBr) 3380, 1649, 1459, 1322, 1298, 1227 cm^{-1}.
HRMS (EI+), calcd for $C_{20}H_{12}N_2O_2$: 312.0899. Found: 312.0899.

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