

**A PHOTOCHEMICAL APPROACH TO SPIRANIC 2,3-INDOLINES,
USEFUL INTERMEDIATES IN PENTACYCLIC INDOLE
ALKALOID SYNTHESIS.**

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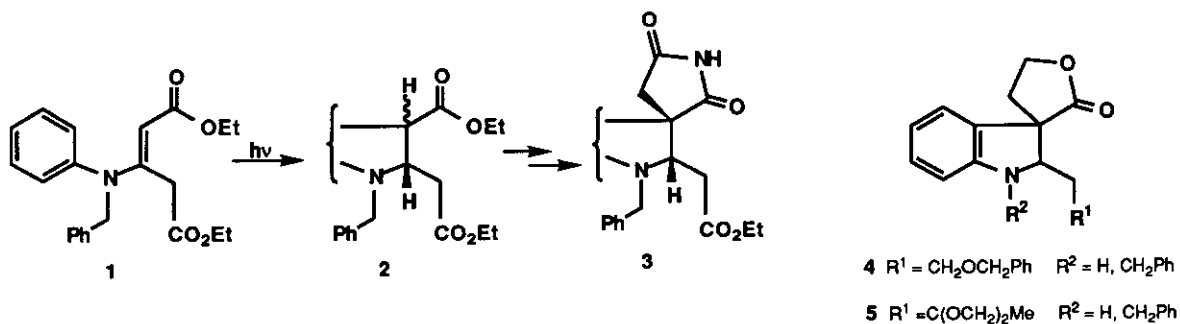
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Abstract - Spirolactones (4) and (5) were obtained by photocyclization of arylenaminolactones (8) and (9). The stereochemistry of the ring junction in tricyclic spiranic compounds was determined by NOE difference spectroscopy.

INTRODUCTION

2,3-Dihydroindole (2,3-indoline) is a key structural element often present in natural products.¹ Its synthesis is not easy due to elimination-aromatization, which leads invariably to indoles. During the past decade, much work has been devoted to this structure² and to its use in natural product synthesis.³

In a previous paper⁴ we reported a stereoselective approach to indolines based on the photoconversion of enaminoesters (1) into substituted indolines (2), which then gave the spirostructure (3) with the required ring junction (Scheme 1).

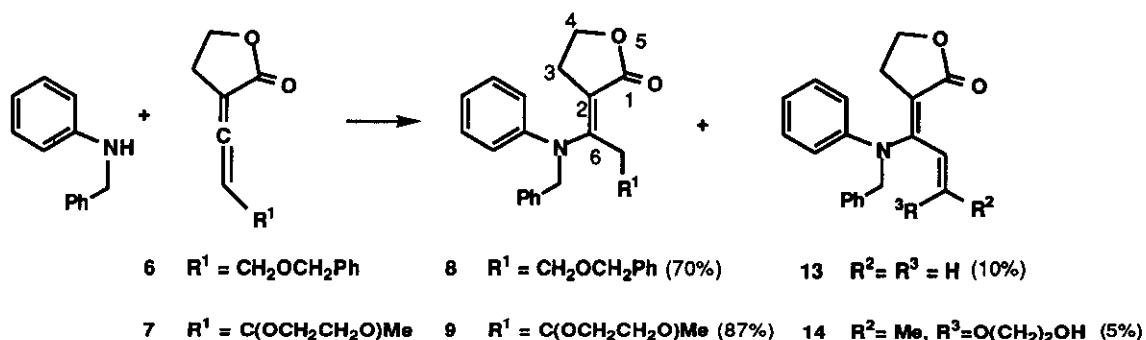


Scheme 1

In continuation of our work on the preparation of this spiroindoline structure, we describe a synthesis and the complete ¹H, and ¹³C-nmr spectral assignments of lactones (4) and (5) (Scheme 1).

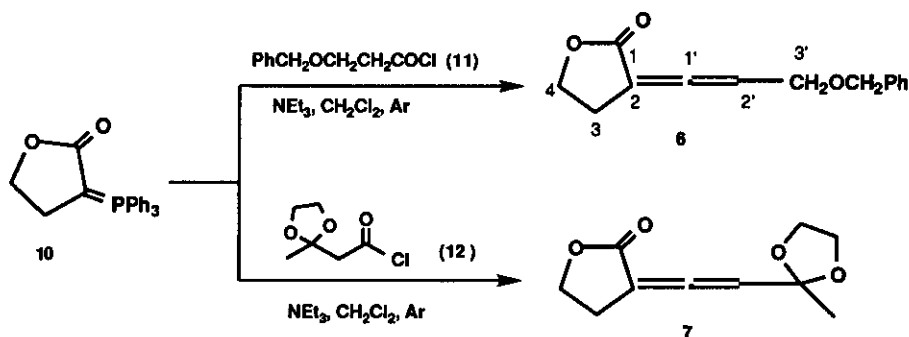
RESULTS AND DISCUSSION

In accordance with our strategy, enaminolactones (**8**) and (**9**) were employed as key precursors. Preparation of **8** and **9** (Scheme 2) was envisaged through condensation⁵ of *N*-benzylaniline with the appropriate allenic lactones (**6**) and (**7**), the synthesis of which is outlined in Scheme 3.



Scheme 2

Compound (**6**) was obtained in 74% yield by a Wittig-type reaction⁶ between triphenyl-(2-oxotetrahydrofuran-3-ylidene)phosphorane (**10**)⁷ with 3-benzyloxypropionyl chloride (**11**).⁸ Similarly, reaction of **10** with 3,3-ethylenedioxybutanoyl chloride (**12**)⁹ gave compound (**7**) in 82% yield (Scheme 3). The formation of compounds (**6**) and (**7**)¹⁰ was confirmed by spectroscopic data especially by the presence of two bands at 1971 and 1769 cm⁻¹ for **6**, and 1976 and 1764 cm⁻¹ for **7** in the ir spectra corresponding to allenic and carbonyl groups, respectively. The observed downfield shift of the C-1' in the ¹³C-nmr spectra (δ 205.6 in **6**; δ 203.9 in **7**) also agrees with the proposed structure.

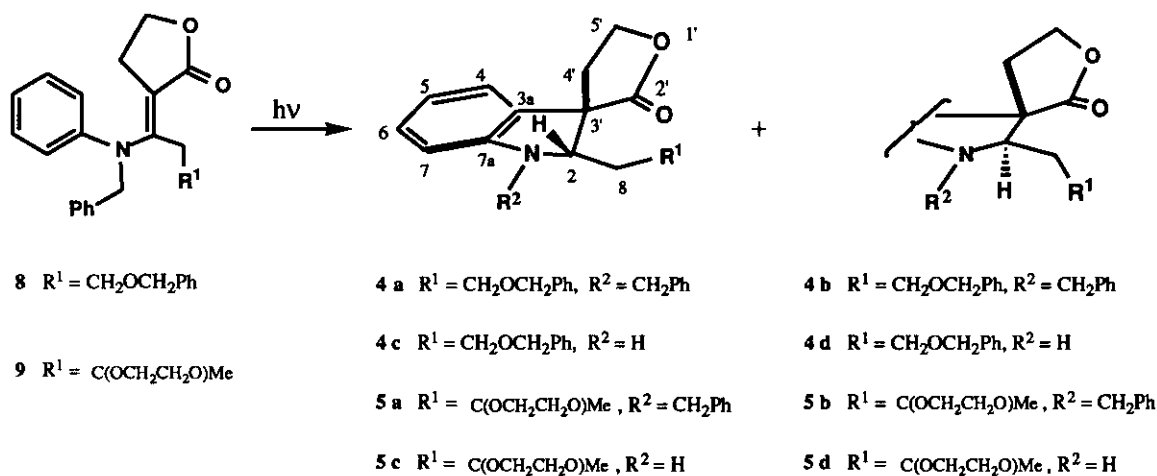


Scheme 3

Condensation of *N*-benzylaniline with **6** or **7** in refluxing benzene under argon led to the desired enaminolactones (**8**) and (**9**) together with small amounts of by-products (**13**) and (**14**) (Scheme 2). Compound (**13**) results from

elimination of benzyl alcohol, and compound (14) from ring opening of the acetal. All the enaminolactones were characterized by both spectroscopic and microelemental analytical data, and were obtained only as E isomer.⁵ Moreover, no NOE was observed between the protons of the CH₂R¹ lateral chain and H-3 in compound (8) and (9). On the other hand, NOEs of 5% and 3% were observed between H-3 and respectively the *ortho* and the *meta* proton of the aromatic moiety of the enaminolactones. Supplementary double bond in 14 has a *Z* configuration as indicated in Scheme 2. This attribution is based upon the chemical shift of the methyl group (17.8 ppm).¹¹

Enaminolactone (8) was exposed to irradiation with a high pressure mercury lamp through a Pyrex filter in stirred deoxygenated benzene-methanol mixture (1:1). Two photocyclized five-membered lactones (4a) and (4b) were obtained in 25% and 38% yields respectively (63% overall yield) after separation by flash chromatography (Scheme 4).



Scheme 4

The product (4b) was characterized as a stereoisomer of 4a. The mass spectra (ms) of compounds (4a) and (4b) exhibited a molecular ion peak at m/z 413. Ir spectra of 4a and 4b exhibited a band at 1780 cm⁻¹ due to a five-membered lactone group. The complete assignments of ¹H- and ¹³C-nmr spectra of compounds (4a) and (4b) are given in Table 1. The attribution of all chemical shifts were deduced unambiguously by ¹H-¹H and ¹H-¹³C-COSY experiments.

Table 1- ¹H- and ¹³C-nmr data of compounds (4-5)

Compd	¹ H-nmr(a) (CDCl ₃ ; 400 MHz)	¹³ C-nmr (CDCl ₃ ; 100 MHz)
(4a)	2.15-2.20 (m, H-8)	29.8 (C-8)
	2.30-2.40 (m, H-8)	37.4 (C-4')
	2.38-2.47 (m, H _B -4')	51.2 (N-CH ₂ Ph)
	2.50-2.57(m, H _A -4')	54.3 (C-3)

3.55-3.60 (m, CH ₂ CH ₂ OCH ₂ Ph)	65.4 (C-5')
3.95 (dd, <i>J</i> = 5 and 8, H-2)	66.9 (CH ₂ CH ₂ OCH ₂ Ph)
4.10-4.20 (m, H _B -5')	69.2 (C-2)
4.35-4.45 (m, H _A -5')	72.9 (OCH ₂ Ph)
4.45 (AB spectrum, <i>J</i> = 16, Δ <i>v</i> = 98.7, N-CH ₂ Ph)	107.8 (C-7)
4.50 (s, OCH ₂ Ph)	118.3 (C-5)
6.45 (d, <i>J</i> = 8, H-7)	122.7 (C-4)
6.75 (t, <i>J</i> = 7, H-5)	129.3 (C-6)
7.08 (d, <i>J</i> = 7, H-4)	130.4 (C-3a)
7.15 (t, <i>J</i> = 8, H-6)	137.8 (C- <i>ipso</i> N-CH ₂ Ph)
7.20-7.50 (m, H aromatic)	138.1 (C- <i>ipso</i> O-CH ₂ Ph)
	151.3 (C-7a)
	176.7 (C-2')

(4b)	1.90-1.95 (m, H _B -4')	28.8 (C-8)
	2.10-2.15 (m, H-8)	30.9 (C-4)
	2.95-3.05 (m, H _A -4')	51.9 (N-CH ₂ Ph)
	3.40-3.45 (m, CH ₂ CH ₂ OCH ₂ Ph)	54.5 (C-3)
	3.61-3.65 (m, CH ₂ CH ₂ OCH ₂ Ph)	65.3 (C-5')
	4.10 (dd, <i>J</i> = 7 and 6, H-2)	67.8 (CH ₂ CH ₂ OCH ₂ Ph)
	4.10-4.20 (m, H _B -5')	69.8 (C-2)
	4.38-4.42 (m, H _A -5')	73.1 (OCH ₂ Ph)
	4.40 (AB spectrum, <i>J</i> = 16, Δ <i>v</i> = 87.2, N-CH ₂ Ph)	108.5 (C-7)
	4.45 (AB spectrum, <i>J</i> = 10, Δ <i>v</i> = 69.5, O-CH ₂ Ph)	118.7 (C-5)
	6.50 (d, <i>J</i> = 7.9, H-7)	121.7 (C-4)
	6.75 (t, <i>J</i> = 7.9, H-5)	128.9 (C-6)
	7.05 (d, <i>J</i> = 7.9, H-4)	131.9 (C-3a)
	7.15 (t, <i>J</i> = 7.9, H-6)	137.9 (C- <i>ipso</i> N-CH ₂ Ph)
	7.25-7.45 (m, H aromatic)	138.7 (C- <i>ipso</i> O-CH ₂ Ph)
		150.7 (C-7a)
		178.4 (C-2')

(4c)	1.80-1.90 (m, H-8)	31.3* (C-8)
	2.10-2.20 (m, H-8)	36.5* (C-4)
	2.45-2.55 (m, H _B -4')	55.4 (C-3)
	2.65-2.72 (m, H _A -4')	65.6 (C-5')
	3.65-3.75 (m, CH ₂ CH ₂ OCH ₂ Ph)	66.8 (C-2)
	4.05 (dd, <i>J</i> = 3 and 10.5, H-2)	68.1 (CH ₂ CH ₂ OCH ₂ Ph)
	4.20-4.30 (m, NH)	73.1 (OCH ₂ Ph)
	4.35-4.45 (m, H _B -5')	110.3 (C-7)
	4.45-4.52 (m, H _A -5')	119.4 (C-5)

	4.55 (AB spectrum, $J = 12$, $\Delta\nu = 13.4$, O-CH ₂ Ph)	123.2 (C-4)
	6.65 (d, $J = 8$, H-7)	129.3 (C-6)
	6.80 (t, $J = 8$, H-5)	129.6 (C-3a)
	7.10 (d, $J = 8$, H-4)	138.0 (C-ipso)
	7.15 (t, $J = 8$, H-6)	150.5 (C-7a)
	7.35-7.45 (m, H aromatic)	176.2 (C-2)
(4d)	1.95-2.2 (m, H-8)	30.7 (C-8)
	2.00-2.05 (m, H _B -4')	30.7 (C-4)
	2.65-2.80 (m, H _A -4')	55.1 (C-3)
	3.55-3.72(m, CH ₂ CH ₂ OCH ₂ Ph)	64.7 (C-5)
	4.35 (dd, $J = 7.6$ and 3, H-2)	65.7 (C-2)
	4.25-4.3 (m, H _B -5' and NH)	68.6 (CH ₂ CH ₂ OCH ₂ Ph)
	4.40-4.47 (m, H _A -5')	73.2 (OCH ₂ Ph)
	4.55 (AB spectrum, $J = 12$, $\Delta\nu = 18.8$, OCH ₂ Ph)	110.1 (C-7)
	6.67 (d, $J = 8.2$, H-7)	119.4 (C-5)
	6.70 (t, $J = 8.2$, H-5)	122.4 (C-4)
	7.05 (d, $J = 8.2$, H-4)	129.1 (C-6)
	7.15 (t, $J = 8.2$, H-6)	131.4 (C-3a)
	7.30-7.45 (m, H aromatic)	138.0 (C-ipso)
		149.3(C-7a)
		178.6 (C-2')
(5a)	1.32 (s, CH ₃)	24.3 (CH ₃)
	2.40 [AB, Part of ABX, 2.65 (A part, dd, 1H, $J_{AB} = 15.2$ and $J_{AX} = 8.9$), 2.15 (B part, dd, 1H, $J_{AB} = 15.2$ and $J_{BX} = 2.4$)	32.1 (C-8)
	, 3.84 (X part, dd, $J = 2.4$ and 9, H-2)]	37.0 (C-4')
	2.52-2.73 (m, 2H, H-4')	50.2 (N-CH ₂ Ph)
	3.87-4.00 (m, acetal)	54.4 (C-3)
	4.39 (AB spectrum, $J = 16.5$, $\Delta\nu = 143$, N-CH ₂ Ph)	64.5 and 64.7 (OCH ₂ CH ₂ O)
	4.40-4.55 (m, 2H, H-5')	65.7 (C-5')
	6.37 (d, $J = 8$, H-7)	68.2 (C-2)
	6.70 (t, $J = 8$, H-5)	107.8 (C-7)
	7.05 (m, H-4 and H-6)	108.3 (C-(OCH ₂ CH ₂ O))
	7.20-7.40 (m, H aromatic)	118.3 (C-5)
		122.6 (C-4)
		129.0 (C-6)
		131.2 (C-3a)
		138.3 (C-ipso)
		151.1 (C-7a)
		176.6 (C-2)
(5b)	1.30 (s, CH ₃)	24.6 (CH ₃)

	2.00-2.08 (m, H _B -4')	31.4 (C-8)
	2.27 [AB, part of ABX, 2.40 (A part, dd, 1H, $J_{AB} = 15.2$ and $J_{AX} = 1.9$), 2.22 (B part, dd, 1H, $J_{AB} = 15.2$ and $J_{BX} = 11$), 4.18 (X part, dd, $J = 2$ and 10.5, H-2)]	37.6 (C-4') 52.6 (N-CH ₂ Ph) 54.6 (C-3)
	2.90-3.0 (m, H _A -4')	63.6 and 64.5 (OCH ₂ CH ₂ O)
	3.75-4.00 (m, OCH ₂ CH ₂ O)	65.6 (C-5')
	4.35 (AB spectra, $J = 15$, $\Delta\nu = 107.6$, N-CH ₂ Ph)	65.9 (C-2)
	4.48-4.55 (m, 2H, H-5')	108.1 (C-(OCH ₂ CH ₂ O))
	6.35 (d, $J = 8$, H-7)	108.6 (C-7)
	6.70 (t, $J = 8$, H-5)	118.7 (C-5)
	7.05 (m, $J = 8$, H-4 and H-6)	122.0 (C-4)
	7.25-7.45 (m, H aromatic)	129.0 (C-6) 132.0 (C-3a) 139.0 (C-ipso) 150.9 (C-7a) 179.0 (C-2')
(5c)	1.35 (s, CH ₃)	24.4 (CH ₃)
	2.10 [AB, part of ABX, 1.92 (B part, dd, 1H $J_{AB} = 15.4$ and $J_{BX} = 1.90$), 2.26 (A part, dd, 1H, $J_{AB} = 15.4$ and $J_{AX} = 10.4$), 4.03 (X part, dd, $J = 1.9$ and 9.8, H-2)]	36.4 (C-4') 39.9 (C-8) 55.4 (C-3)
	2.40-2.50 (m, H _B -4')	64.1 (C-2)
	2.55-2.65 (m, H _A -4')	64.56 and 64.63 (OCH ₂ CH ₂ O)
	4.00 (m, OCH ₂ CH ₂ O and H-2)	65.6 (C-5')
	4.35-4.45 (m, H _B -5')	109.6 (C-(OCH ₂ CH ₂ O))
	4.47-4.52 (m, H _A -5')	110.0 (C-7)
	6.68 (d, $J = 7.5$, H-7)	119.1(C-5)
	6.75 (t, $J = 7.5$, H-5)	123.5 (C-4)
	7.05 (d, $J = 7.5$, H-4)	129.2 (C-3a)
	7.12 (t, $J = 7.5$, H-6)	129.3 (C-6) 150.7 (C-7a) 176.1 (C-2')
(5d)	1.35 (s, CH ₃)	24.3 (CH ₃)
	2.00-2.10 (m, 3H, H-CH ₂ C-acetal and H _B -4')	30.7* (C-8)
	2.65-2.72 (m, H _A -4')	39.6* (C-4')
	3.90-4.05 (m, 5H, H-2 and OCH ₂ CH ₂ O)	55.1 (C-3)
	4.30-4.40 (m, H _B -5')	61.4 (C-2)
	4.45-4.50 (m, H _A -5')	64.4 and 64.5 (OCH ₂ CH ₂ O)
	6.68 (d, $J = 7.5$, H-7)	66.0 (C-5')
	6.75 (t, $J = 7.5$, H-5)	109.0 (C-(OCH ₂ CH ₂ O))

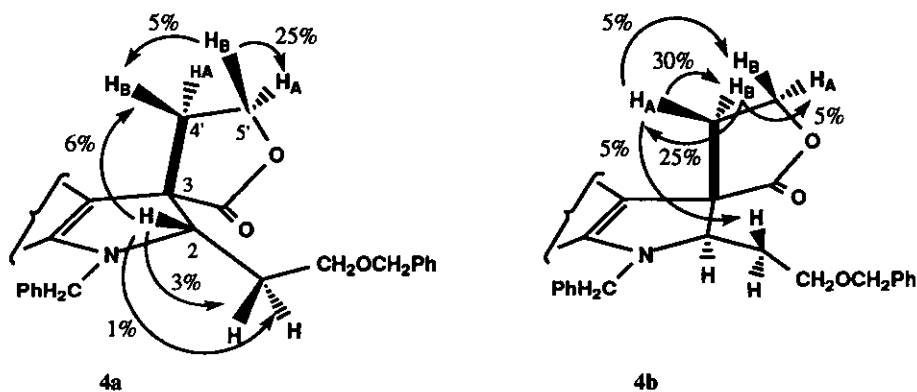
7.05 (d, $J = 7.5$, H-4)	110.3 (C-7)
7.12 (t, $J = 7.5$, H-6)	119.7 (C-5)
7.20-7.30 (m, NH)	122.6 (C-4)
	125.8 (C-6)
	131.6 (C-3a)
	148.8 (C-7a)
	178.6 (C-2')

(s) = singlet, d = doublet, t = triplet, m = multiplet

Apparent coupling constants 3J and 2J are given in Hz, chemical shifts in ppm. For geminal hydrogens, the proton at lower field is noted A.

Knowing the exact stereochemistry of ring junction in compounds (4) is important because the *cis*-relationship is the configuration observed in natural products. The most reliable approach to determine this stereochemistry is through nuclear Overhauser effects¹² (Scheme 5).

Observed NOEs in compounds (4a) and (4b).



Scheme 5

From the following spectral data, the major product (4b) is the lactone with the *trans* stereochemistry. In this case, irradiation of H_B-4' at δ 1.90-1.95 gave enhancement of H_A-4' (δ 2.95-3.05) and of H_A-5' (δ 4.38-4.42). Irradiation of H_A-4' at δ 2.95-3.05 produced NOEs at H_B-4' (δ 1.90-1.95), H_B-5' (δ 4.10-4.20) and at the methylene group of the side chain. No NOEs were observed between H-4' and H-2. These results confirm a *trans* relationship between H-2 and the CH₂CH₂ moiety of the butyrolactone. The NOE experimental results are presented in Scheme 5.

In compound (4a) the NOEs at H_B-4' (δ 2.38-2.47) upon irradiation at H-2 (δ 3.95), and at H_A-5' (δ 4.35-4.45) and H_B-4' (δ 2.38-2.47) upon irradiation at H_B-5' (δ 4.10-4.20) gave a *cis* relationship between H_B-5' and H_B-4', H-2 and H_B-4'. NOEs were also observed at the protons of the side chain (δ 2.15-2.20 and 2.30-2.40) upon irradiation at H-2 (Scheme 5).

The same photocyclization reaction was carried out on enamminolactone (**9**) and gave a mixture of compounds (**5a**) and (**5b**) in 45% and 50% yield respectively (Scheme 4). Structures of **5a** and **5b** were elucidated by nmr experiments similar to those described for **4a** and **4b**.

The ^{13}C -nmr spectra of both *cis* - and *trans*-series are similar except for the C-3a, C-7 and C-2' signals which appear at a lower field in the *trans*-derivatives. Also, the C-8 of the side chain appears at higher field in the *trans*-series. The signals of H-4' and H-2 in the ^1H -nmr spectra were also significant. In the *trans*-series each of the two H-4' appears as a multiplet separated by about 1 ppm; they are identical in the *cis*-series. (Table 1)

To improve the yield of five-membered spiroactones (**4a**) and (**5a**), we investigated the solvent effect in the photocyclization step. The results are given in Table 2. When the reaction was conducted in dry acetonitrile, the cyclization proceeded more rapidly to give the lactams with a *cis* ring junction as main products. Also, in neutral aprotic solvents such as benzene, we observed the formation of *N*-debenzylated spiroactones (**4c**) and (**5c**) together with the *N*-benzylspiroindolines. Irradiation of pure **4a**, **4b**, **5a** and **5b** in acetonitrile for a short time¹³ gave respectively **4c**, **4d**, **5c** and **5d** in nearly quantitative yield. The mechanism of this debenzylation reaction is under investigation.

Table 2 - Irradiation of enamminolactones (**8**) and (**9**)

Starting Material	Solvent	Time (h)	Yield (%)	Compound (%)		
8				4a	4b	4c
	C ₆ H ₆	1	80	12	45	23
	Et ₂ O	0.5	49		28	21
	C ₆ H ₆ /MeOH(1/1)	2	63	25	38	
	MeOH	1	85	42.5	42.5	
	MeCN	0.75	92	79	5	8
9				5a	5b	5c
	C ₆ H ₆	0.75	85	30	25	30
	C ₆ H ₆ /MeOH(1/1)	0.5	95	45	50	
	MeCN	0.75	90	82.5	7.5	

The results obtained in this work illustrate the application of photochemical cyclization of enamminolactones to the synthesis of 2,3-indolines. The ratio of *cis/trans* isomers depends on the solvent used and may result from competition between *cis/trans* isomerization of the double bond of enamminolactones and the cyclization process.¹⁴ This method proved highly stereoselective and gave as the major product the *cis* isomer in high yield using dry acetonitrile as solvent. Stereochemistry of the spiroindolines synthesized was unambiguously proved by combined nmr methods.

EXPERIMENTAL

^1H - and ^{13}C -nmr spectra were recorded on BRUKER AC 400 (400.13 MHz for ^1H and 100.61 MHz for ^{13}C) BRUKER AC 200 (200.13 MHz for ^1H and 50.32 MHz for ^{13}C) NMR spectrometers. NOE difference spectra were obtained by subtracting alternatively right-off resonance-free induction decays (FIDs) from right-on resonance-induced FIDs. ^1H - and ^{13}C -nmr measurements were made at room temperature and NOE difference measurements at 30°C . Ir spectra were recorded on a Perkin-Elmer 377 spectrophotometer in CCl_4 solution. Low resolution (70 eV) and high resolution mass spectra were recorded on a Varian CH5 instrument. Microanalysis was performed by the analytical service of the Service Central d'Analyses du CNRS, Solaize (France). Merck silica gel 60 (40-63 μ and 63-200 μ) was used for column chromatography. Tlc was performed on Kieselgel 60 F 254 plates and developed with the solvent described in each case for flash chromatography. The spots were monitored by uv light and *p*-methoxybenzaldehyde reagent. All extracts were dried over anhydrous MgSO_4 powder prior to concentration under reduced pressure.

General procedure for the preparation of allenic lactones (6) and (7).

Triethylamine (1.42 g; 14.00 mmol) in dry methylene chloride (7.5 ml) was added to a solution of triphenyl-(2-oxotetrahydrofuran-3-ylidene) phosphorane (**10**; 2.99 g; 7.00 mmol) in dry methylene chloride (6 ml) followed after 10 min by a solution of acid chloride (**11** or **12**) (7.00 mmol). The resulting mixture was stirred under argon at room temperature for an additional 2 h. Water was added and the reaction mixture was extracted with methylene chloride (40 ml). The extract was treated as usual. Flash chromatography purification of the residue (5:5, AcOEt-hexane) gave the allenic lactones as an oil.

(6): Yield 70%; oil; ir (CCl_4) 1769 (C=O) and 1971 cm^{-1} (C=C=C); ^1H -nmr (200 MHz, CDCl_3) 2.95 (m, 2H, H-3), 4.10 (m, 2H, H-4), 4.25 (t, $J = 7\text{ Hz}$, H-3'), 4.5 (s, 2H, CH_2Ph), 5.7-5.9 (m, 1H, H-2'), 7.1-7.4 (m, 5H, H aromatic); ^{13}C -nmr (50 MHz, CDCl_3) 26.5 (C-3), 65.5 (C-3)*, 65.9 (C-4)*, 71.6 (CH_2Ph), 94.9 (C-2), 96.0 (C-2'), 138.3 (C-*ipso*), 168.6 (C-1), 205.6 (C-1'); ms (m/z , %) 230 (M^+ , 3), 105 (4), 91 (100), 77 (4), 65 (5), 63 (3), 51 (4), 39 (5), 27 (4). Calcd for $\text{C}_{14}\text{H}_{14}\text{O}_3$: 230.0942; Found: 230.0943. Anal. Calcd for $\text{C}_{14}\text{H}_{14}\text{O}_3$: C 73.01, H 6.13; Found: C 72.41, H 6.19.

(7): Yield 82%; unstable oil; ir (CCl_4) 1764 (C=O) and 1976 cm^{-1} (C=C=C); ^1H -nmr (200 MHz, CDCl_3), 1.55 (s, 3H, CH_3), 3.05 (m, 2H, H-3), 3.9-4.0 (m, 2H, $\text{OCH}_2\text{CH}_2\text{O}$), 3.95-4.05 (m, 2H, $\text{OCH}_2\text{CH}_2\text{O}$), 4.40 (m, 2H, H-4), 6.72 (m, H-2'); ^{13}C -nmr (50 MHz, CDCl_3) 25.5 (CH_3), 26.4 (C-3), 64.4 ($\text{OCH}_2\text{CH}_2\text{O}$), 65.0 (C-4)*, 66.0 ($\text{OCH}_2\text{CH}_2\text{O}$)*, 96.0 (C-2), 101.6 (C-2'), 106.3 (C-3'), 169.7 (C-1), 203.9 (C-1').

General procedure for condensation of *N*-benzylaniline with allenic lactones (6) and (7).

To a solution of allenic lactones (3.26 mmol) in dry benzene (3 ml) under argon was added a solution of *N*-benzylaniline (0.537 g; 2.93 mmol) in dry benzene (15 ml). After refluxing for 4 h, the solvent was evaporated and the crude mixture was flash chromatographed (1:9, AcOEt-hexane).

(8): Yield 70%; oil; ir (CCl_4) 1738 cm^{-1} (C=O); ^1H -nmr (200 MHz, CDCl_3), 2.17 (m, 2H, H-3), 3.37* (t, $J = 6\text{ Hz}$, 2H, $\text{CH}_2\text{CH}_2\text{OCH}_2\text{Ph}$), 3.60* (t, $J = 6\text{ Hz}$, 2H, $\text{CH}_2\text{CH}_2\text{OCH}_2\text{Ph}$), 4.03 (m, 2H, H-4), 4.53 (s, 2H, OCH_2Ph), 5.02 (s, 2H, NCH_2Ph), 6.9-7.3 (m, 15H, H aromatic); ^{13}C -nmr (50 MHz, CDCl_3) 28.8 (C-3), 29.7 ($\text{CH}_2\text{CH}_2\text{OCH}_2\text{Ph}$), 55.1 (NCH_2Ph), 64.2 (C-4), 69.4 ($\text{CH}_2\text{CH}_2\text{OCH}_2\text{Ph}$), 72.8 (OCH_2Ph), 104.1 (C-

2), 138.3 (C-*ipso*), 138.9 (C-*ipso*), 147.0 (C-*ipso*), 155.6 (C-6), 172.7 (C-1); ms (*m/z*, %) 413 (M^+ , 40), 322 (5), 183 (16), 91 (100), 77 (12), 65 (8). Calcd for $C_{27}H_{27}NO_3$: 413.1990. Found : 413.1986. Anal. Calcd for $C_{27}H_{27}NO_3$: C 78.41, H 6.58, N 3.39 ; Found : C 77.92, H 6.72, N 3.15 ; uv (EtOH): λ_{max} 325.5 nm (16100).

(13): Yield 10% ; oil ; ir (CCl₄) 1742 cm^{-1} (C=O) ; 1H -nmr (400 MHz, CDCl₃), 2.45 (m, 2H, H-3), 4.15 (m, 2H, H-4), 4.85 (s, 2H, CH₂Ph), 5.57 (d, $J = 11$ Hz, 1H, CH=CH₂), 5.7 (d, $J = 17$ Hz, 1H, CH=CH₂), 6.8-6.9 (m, 3H, H aromatic), 7.2-7.4 (m, 7H, H aromatic), 7.6 (dd, $J = 11$ and 17 Hz, CH=CH₂) ; ^{13}C -nmr (100 MHz, CDCl₃) 28.9 (C-3), 54.4 (CH₂Ph), 64.8 (C-4), 117.5 (C-2), 122.4 (CH=CH₂), 130.2 (CH=CH₂), 138.8 (C-*ipso*), 146.5 (C-*ipso*), 151.9 (C-6), 171.1 (C-1) ; ms (*m/z*, %) 305 (M^+ , 62), 304 (12), 276 (3), 260 (7), 246 (7), 228 (7), 214 (12), 181 (13), 182 (39), 167 (4), 144 (11), 130 (16), 128 (5), 105 (7), 91 (100), 77 (22), 65 (12). Calcd for $C_{20}H_{19}NO_2$: 305.1415. Found : 305.1407. Anal. Calcd for $C_{20}H_{19}NO_2$: C 78.65, H 6.28, N 4.59 ; Found : C 77.98, H 6.27, N 4.64 ; uv (EtOH) : λ_{max} 249.5 nm (16800).

(9): Yield 87% ; mp : 113-114°C (ether) ; ir (CCl₄) 1738 cm^{-1} (C=O) ; 1H -nmr (400 MHz, CDCl₃), 1.55 (s, 3H, CH₃), 2.30 (m, 2H, H-3), 3.60 (s, 2H, CH₂-C-acetal), 4.00 (s, 4H, OCH₂CH₂O), 4.12 (m, 2H, H-4), 5.15 (s, 2H, CH₂Ph), 6.95-7.1 (m, 3H, H aromatic), 7.2-7.4 (m, 7H, H aromatic) ; ^{13}C -nmr (100 MHz, CDCl₃) 24.9 (CH₃), 30.5 (C-3), 35.2 (CH₂-C acetal), 55.4 (NCH₂Ph), 64.1 (C-4), 64.5 (OCH₂CH₂O), 108.4 (C-2), 109.7 (C-acetal), 139.5 (C-*ipso*), 147.9 (C-*ipso*), 152.3 (C-6), 172.6 (C-1) ; ms (*m/z*, %) 379 (M^+ , 3), 318 (3), 292 (1), 218 (2), 183 (2), 182 (2), 91 (21), 87 (100), 77 (4). Calcd for $C_{23}H_{25}NO_4$: 379.1783 ; Found : 379.1775. Anal. Calcd for $C_{23}H_{25}NO_4$: C 72.79, H 6.65, N 3.69 ; Found : C 72.17, H 6.48, N 3.61 ; uv (EtOH) : λ_{max} 333.6 nm (15300).

(14): Yield 5% ; oil ; ir (CCl₄) 1734 cm^{-1} (C=O) ; 1H -nmr (400 MHz, CDCl₃), 1.95 (s, 3H, CH₃), 2.27 (m, 2H, H-3), 3.9-4.0 (m, 2H, CH₂OH), 4.0-4.1 (m, 2H, OCH₂CH₂OH), 4.05-4.15 (m, 2H, H-4), 4.90 (s, 2H, NCH₂Ph), 5.90 (s, 1H, H ethylenic), 6.95-7.05 (m, 3H, H aromatic), 7.25-7.40 (m, 7H, H aromatic) ; ^{13}C -nmr (100 MHz, CDCl₃) 17.8 (CH₃), 29.8 (C-3), 55.4 (NCH₂Ph), 61.5 (CH₂OH), 64.5 and 64.7 (OCH₂CH₂OH), 69.9 (C-4), 95.2 (CH=CH₂), 106.6 (C-2), 139.9 (C-*ipso*), 146.2 (C-*ipso*), 151.1 (C-6), 160.9 (CH=C-), 172.6 (C-1).

General procedure for the irradiation of enamminolactones (8) and (9).

A solution of enamminolactones (1.21 mmol) in 150 ml of dry solvents was irradiated under argon in a Pyrex reactor with a 400-W medium pressure uv lamp. After removal of the solvent under reduced pressure, the residue was flash chromatographed (2:8, AcOEt-hexane). The yields of **4a,b,c** and **5a,b,c** were listed in table 2. Compounds **4d** and **5d** were obtained in quantitative yield by irradiation of **4b** and **5b** respectively.

(4a): oil ; ir (CCl₄) 1780 cm^{-1} (C=O) ; 1H -nmr : see Table 1 ; ^{13}C -nmr : see Table 1 ; ms (*m/z*, %) 413 (M^+ , 9), 278 (7), 234 (8), 117 (12), 91 (47), 84 (72), 49 (100), 45 (66), 28 (45). Calcd for $C_{27}H_{27}NO_3$: 413.1984. Found : 413.1991. Anal. Calcd for $C_{27}H_{27}NO_3$: C 78.41, H 6.59, N 3.39 ; Found : C 77.92, H 6.20, N 3.23.

(4b): oil ; ir (CCl₄) 1780 cm^{-1} (C=O) ; 1H -nmr : see Table 1 ; ^{13}C -nmr : see Table 1 ; ms (*m/z*, %) 413 (M^+ , 13), 278 (13), 234 (16), 220 (3), 91 (100), 65 (8), 39 (3). Calcd for $C_{27}H_{27}NO_3$: 413.1984. Found : 413.1991. Anal. Calcd for $C_{27}H_{27}NO_3$: C 78.41, H 6.59, N 3.39 ; Found : C 77.71, H 6.81, N 3.91.

(4c): oil ; ir (CCl₄) 3371 (NH) and 1781 cm^{-1} (C=O) ; 1H -nmr : see Table 1 ; ^{13}C -nmr : see Table 1 ; ms (*m/z*, %) 323 (M^+ , 47), 278 (3), 234 (6), 217 (8), 188 (22), 174 (12), 144 (72), 130 (39), 115 (7), 91 (100), 77

(16), 65 (12), 49 (100), 44 (6). Calcd for $C_{20}H_{21}NO_3$: 323.1516. Found : 323.1518. Anal. Calcd for $C_{20}H_{21}NO_3$: C 74.27, H 6.55, N 4.33 ; Found : C 73.73, H 6.63, N 4.37.

(4d): mp : 111-112°C (ether) ; ir (CCl₄) 3397 (NH) and 1783 cm^{-1} (C=O) ; ¹H-nmr : see Table 1 ; ¹³C-nmr : see Table 1 ; ms (m/z, %) 323 (M⁺, 29), 278 (2), 265 (2), 251 (2), 232 (11), 217 (6), 188 (24), 174 (26), 156 (12), 144 (88), 130 (56), 117 (12), 91 (100), 77 (15), 65 (13). Calcd for $C_{20}H_{21}NO_3$: 323.1516. Found : 323.1515.

(5a): oil ; ir (CCl₄) 1774 cm^{-1} (C=O) ; ¹H-nmr : see Table 1 ; ¹³C-nmr : see Table 1 ; ms (m/z, %) 379 (M⁺, 66), 334 (6), 317 (3), 292 (3), 278 (7), 258 (2), 246 (2), 234 (6), 220 (2), 195 (2), 180 (7), 165 (3), 144 (6), 129 (3), 105 (5), 91 (59), 87 (100), 77 (3). Calcd for $C_{23}H_{25}NO_4$: 379.1783. Found : 379.1775. Anal. Calcd for $C_{23}H_{25}NO_4$: C 72.79, H 6.65, N 3.69 ; Found : C 72.32, H 6.71, N 3.58.

(5b): mp : 80-81°C (ether) ; ir (CCl₄) 1780 cm^{-1} (C=O) ; ¹H-nmr : see Table 1 ; ¹³C-nmr : see Table 1 ; ms (m/z, %) 379 (M⁺, 91), 334 (7), 278 (4), 279 (4), 234 (5), 181 (10), 165 (4), 144 (5), 107 (6), 103 (4), 91 (52), 87 (100), 77 (3). Calcd for $C_{23}H_{25}NO_4$: 379.1783. Found : 379.1568. Anal. Calcd for $C_{23}H_{25}NO_4$: C 72.79, H 6.65, N 3.69 ; Found : C 72.43, H 6.50, N 3.32.

(5c): oil ; ir (CCl₄) 3378 (NH) and 1782 cm^{-1} (C=O) ; ¹H-nmr : see Table 1 ; ¹³C-nmr : see Table 1 ; ms (m/z, %) 289 (M⁺, 12), 244 (2), 200 (1), 188 (7), 158 (2), 144 (29), 130 (5), 88 (4), 87 (100), 59 (16). Calcd for $C_{16}H_{19}NO_4$: 289.1314. Found : 289.1309. Anal. Calcd for $C_{16}H_{19}NO_4$: C 66.42, H 6.62, N 4.84 ; Found : C 66.62, H 6.45, N 4.55.

(5d): oil ; ir (CCl₄) 3400 (NH) and 1784 cm^{-1} (C=O) ; ¹H-nmr : see Table 1 ; ¹³C-nmr : see Table 1 ; ms (m/z, %) (M⁺, 13), 244 (5), 188 (9), 187 (3), 158 (5), 144 (46), 143 (11), 130 (12), 128 (3), 117 (5), 107 (4), 91 (17), 88 (5), 87 (100), 84 (4), 71 (7), 59 (13). Calcd. for $C_{16}H_{19}NO_4$: 289.1314. Found : 289.1311

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