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Received February 24, 1995

The paper describes a convenient synthesis of hydroxy- $\beta$ -carbolines from commercial anisidines based on key steps such as metalation, cross-coupling and cyclization. The first total synthesis of a major cytotoxic constituent of a marine bryozoan is also reported, the 8-hydroxy-1-vinyl- $\beta$ -carboline.

*J. Heterocyclic Chem.*, **32**, 1171 (1995).

### Introduction.

Numerous alkaloids of the  $\beta$ -carboline series bearing various substituents on the benzene ring display interesting biological properties [1]. Among these substituents, hydroxyl is one of the most important and widely found in nature [2]. Most syntheses of such hydroxylated molecules are based on condensation reactions between the appropriate tryptophan or tryptamine derivatives and aldehydes [3]. Some related compounds are prepared from available  $\beta$ -carboline reagents through specific reactions [4]. 5-Hydroxy- $\beta$ -carbolines are found in nature in *canthinone* structures [10]. 6- and 7-Hydroxy- $\beta$ -carbolines are widely present in nature like *eudistomins* [11a] as well as in 9-hydroxycanthin-6-one [11b]. 8-Hydroxy- $\beta$ -carbolines are found in *picrasidines* [12] and some bis-carbolines [13].

We have previously described [5] a general and convergent route to carbolines based on metalation [6] and cross-coupling [7] reactions, as well as a convenient synthesis of 6-hydroxyharmane [8]. We wish to report here an extension of this fruitful method to the total synthesis of the 4 parent hydroxy- $\beta$ -carbolines **1-4** and to the first total synthesis of 8-hydroxy-1-vinyl- $\beta$ -carboline **5**. This alkaloid has been isolated in 1991 by Munro *et al.* [9] from *cribricellina criberia* and characterized as the major cytotoxic constituent of this New Zealand marine bryozoan (Scheme I).

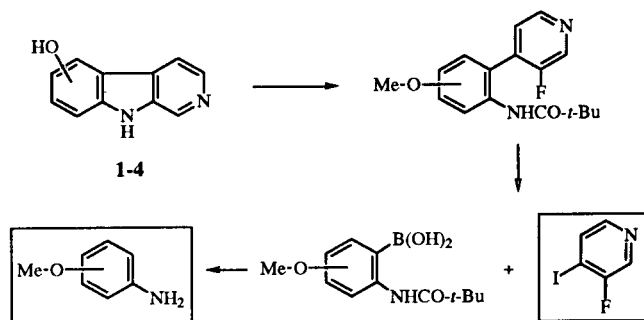
Scheme I



### Retrosynthesis.

From a retrosynthetic analysis (Scheme II), hydroxy- $\beta$ -carbolines **1-4** could be prepared by cyclization of conve-

Scheme II



niently functionalized methoxyphenylpyridines. These phenylpyridines could be obtained by a cross-coupling reaction between the required anisidine building blocks and 3-fluoro-4-iodopyridine.

### Results and Discussion.

Arylboronic acids **11-13** were prepared by metalation-boronation [5a] of the corresponding anisidines protected as a pivaloyl in 50-52% yields (Scheme III and Table I). Compound **10** was prepared in a similar way from the carboxylated compound **7**. The carboxylic group was used as a protective group of the 2-position of compound **6** and

Scheme III

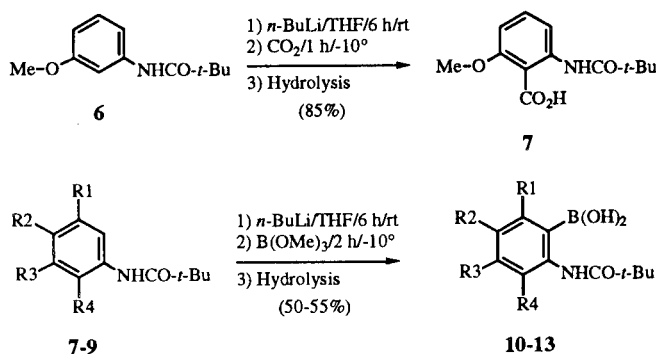


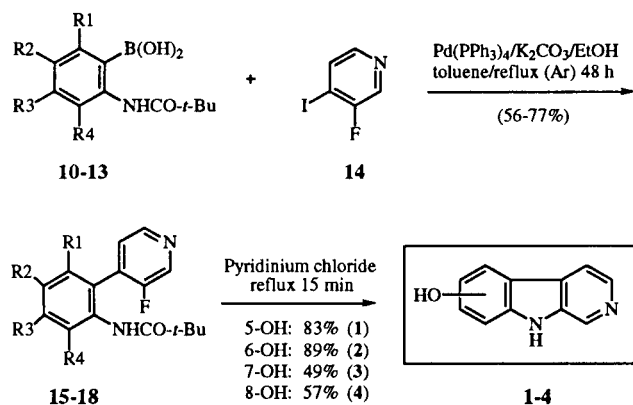
Table I

Product	R1	R2	R3	R4	Yield (%)
<b>11</b>	OMe	H	H	H	52
<b>12</b>	H	OMe	H	H	51
<b>10</b>	H	H	OMe	COOH	55
<b>13</b>	H	H	H	OMe	50

will be removed in the final cyclization step.

The palladium catalyzed cross-coupling reaction between phenylboronic acids **10-13** and 3-fluoro-4-iodopyridine **14** using the Suzuki conditions gave the corresponding heterobiaryls **15-18** in good yields (Scheme IV and Table II). The phenylpyridines **15-18** were cyclized by treatment with boiling pyridinium chloride (215°). Hydrolysis and basic workup yielded the corresponding hydroxy- $\beta$ -carbolines **1-4** in good yields. Under these conditions, the expected hydrolysis of methoxy groups (compounds **15-18**) as well as a decarboxylation (compound **17**) were observed (Scheme IV).

Scheme IV

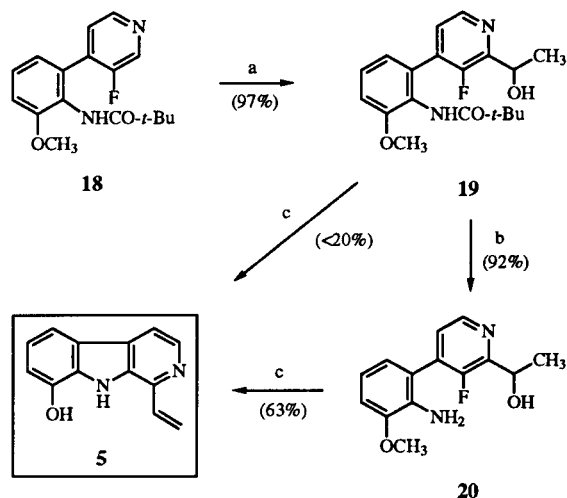


Based on our previously reported synthesis of pavettine [5b], **5** was obtained in two steps from the biaryl **18**. Regioselective metalation of **18** with *n*-butyllithium in tetrahydrofuran at low temperature and reaction of the resulting lithioderivative with acetaldehyde afforded the corresponding phenylpyridine **19** in 97% yield. Hydrolysis of **19** to amine **20** was carried out in 20% sulfuric acid (92% yield). Cyclization of **20** to 8-hydroxy-1-

Table II

Product	R1	R2	R3	R4	Yield (%)
<b>15</b>	OMe	H	H	H	77
<b>16</b>	H	OMe	H	H	70
<b>17</b>	H	H	OMe	COOH	56
<b>18</b>	H	H	H	OMe	63

Scheme V



a: 1) BuLi/THF/-75°/1.5 h 2) CH<sub>3</sub>CHO/-75°/1 h 3) H<sub>2</sub>O  
b: 20% H<sub>2</sub>SO<sub>4</sub>/100°/1.5 h  
c: Pyridinium chloride/180°/15 min

vinyl- $\beta$ -carboline **5** was best achieved by treatment with pyridinium chloride at 180° followed by basic workup. In these conditions, cyclization of **20** occurs simultaneously with dehydration of the hydroxyethyl group and hydrolysis of the methoxy group to give the expected  $\beta$ -carboline **5** (Scheme V). It can be noted that the one-step cyclization of **19** to **5** is also possible but in low yield (<20%).

## Conclusion.

The reported syntheses of the 4-parent hydroxy- $\beta$ -carbolines **1-4** relies on key steps such as metalation, cross-coupling and cyclization. The strategy is fully convergent, regioselective and allows interesting 15-33% overall yield in 3 or 4 steps. The methodology was successfully applied for the first total synthesis of the natural alkaloid **5** in a 18% overall yield (5 steps). The present work is currently being extended to the preparation of more complex related carbolines.

## EXPERIMENTAL

### General Data.

The <sup>1</sup>H nmr spectra were obtained on a Varian T60 spectrometer (60 MHz) spectrometer (and were recorded in ppm downfield from internal standard, TMS in deuteriochloroform, or HMDS in DMSO-d<sub>6</sub>) or on a 200 MHz Brüker spectrometer. The ir spectra were taken on a Beckman IR 4250 spectrometer, and main absorption frequencies (NH, CH, C=O, C=C, C=N) are given in cm<sup>-1</sup>. Mass spectra were obtained on a JEOL D700 instrument, and elemental analyses were performed on a Carlo Erba CHN apparatus.

Tetrahydrofuran was distilled from benzophenone/sodium. The water content of the solvent was estimated lower than 45 ppm by the modified Karl-Fischer method [15]. Commercial diisopropylamine was distilled from calcium hydride and stored over calcium hydride under a dry argon atmosphere. 3-Fluoro-4-iodopyridine (**15**) was prepared [5a] by metalation-iodination of the corresponding fluoropyridine. Methoxypivaloylamino-benzenes **6**, **8** and **9** were prepared from commercial anisidines according to a procedure described in a previous paper [5a] in very good yields (92-97%). Commercial 2.5M solution of *n*-butyllithium in hexane was stored and transferred under a dehydrated and deoxygenated argon atmosphere.

#### 6-Methoxy-2-(pivaloylamino)phenylcarboxylic Acid (**7**).

*n*-Butyllithium (60 ml, 0.15 mole) was slowly added to a cold (-25°) solution of 2,2-dimethyl-*N*-(3-methoxyphenyl)propanamide (**6**) (10.36 g, 0.05 mole) in anhydrous tetrahydrofuran (100 ml). The resulting solution was stirred 6 hours at room temperature and a creamy precipitate appeared. The mixture was cooled to -20°, and a large excess of solid carbon dioxide (~20 g) was added. Stirring was continued for 1 hour at -10° before hydrolysis at -15°. After decantation and extraction with methylene chloride, the aqueous layer was acidified with 1/5 hydrochloric acid (pH = 1) to isolate the orange precipitate which was purified by flash chromatography on silica (ethyl acetate) to yield 10.68 g (85%) of **7**, mp 114-116°; <sup>1</sup>H nmr (deuteriochloroform):  $\delta$  1.26 (s, 9H, *t*-Bu), 3.72 (s, 3H, OCH<sub>3</sub>), 6.62 (d, 1H, 5-H, *J* = 8.5 Hz), 7.38 (t, 1H, 4-H, *J* = 8.5 Hz), 8.47 (d, 1H, 3-H, *J* = 8.5 Hz), 9.50 (s, 1H, NH), 12.80 (s, 1H, COOH); ir (potassium bromide):  $\nu$  3450, 3252, 2969, 1698, 1583, 1472 cm<sup>-1</sup>.

*Anal.* Calcd. for C<sub>13</sub>H<sub>17</sub>NO<sub>4</sub>: C, 62.14; H, 6.82; N, 5.57. Found: C, 61.93; H, 6.98; N, 5.39.

#### General Procedure A: Synthesis of Arylboronic Acids.

*n*-Butyllithium (60 ml, 0.15 mole) was slowly added to a cold (-25°) solution of the corresponding protected anisidine (0.05 mole) in anhydrous tetrahydrofuran (100 ml). The resulting solution was stirred 6 hours at room temperature and a creamy precipitate appeared. The mixture was cooled to -20°, and trimethylborate (17 ml, 0.15 mole) was slowly added. Stirring was continued for 2 hours at -15° before hydrolysis at 0°. After filtration and extraction by methylene chloride, the aqueous layer was acidified with hydrochloric acid 1/5. The medium was immediately extracted with methylene chloride (3 x 50 ml). Drying over magnesium sulfate and solvent removal afforded the corresponding boronic acid.

#### 3-Carboxy-4-methoxy-2-(pivaloylamino)phenylboronic Acid (**10**).

The general procedure A applied to **7** using 0.20 mole of *n*-butyllithium, gave 8.12 g (55%) of **10** (unstable and moisture sensitive); <sup>1</sup>H nmr (DMSO-*d*<sub>6</sub>):  $\delta$  1.20 (s, 9H, *t*-Bu), 3.60 (m, 2H, B(OH)<sub>2</sub>), 3.77 (s, 3H, OCH<sub>3</sub>), 6.80 (d, 1H, 5-H, *J* = 8.0 Hz), 7.55 (d, 1H, 6-H, *J* = Hz), 9.59 (s, 1H, NH), 13.50 (s, 1H, COOH); ir (potassium bromide):  $\nu$  3450, 3208, 2967, 1706, 1608, 1585, 1467 cm<sup>-1</sup>.

#### 6-Methoxy-2-(pivaloylamino)phenylboronic Acid (**11**).

The general procedure A applied to **6** gave 6.53 g (52%) of **11**, mp 168-170°; <sup>1</sup>H nmr (DMSO-*d*<sub>6</sub>):  $\delta$  1.10 (s, 9H, *t*-Bu), 3.16 (m, 2H, B(OH)<sub>2</sub>), 3.61 (s, 3H, OCH<sub>3</sub>), 6.62 (d, 1H, 5-H, *J* = 8.1

Hz), 7.09 (t, 1H, 4-H, *J* = 8.1 Hz), 7.36 (d, 1H, 3-H, *J* = 8.1 Hz), 10.80 (s, 1H, NH); ir (potassium bromide):  $\nu$  3284, 2966, 1612, 1579, 1553, 1463 cm<sup>-1</sup>.

*Anal.* Calcd. for C<sub>12</sub>H<sub>18</sub>BNO<sub>4</sub>: C, 57.40; H, 7.23; N, 5.58. Found: C, 57.13; H, 7.30; N, 5.25.

#### 5-Methoxy-2-(pivaloylamino)phenylboronic Acid (**12**).

The general procedure A, applied to **8**, gave 6.40 g (51%) of **12**, mp >260°; <sup>1</sup>H nmr (DMSO-*d*<sub>6</sub>):  $\delta$  1.10 (s, 9H, *t*-Bu), 3.18 (m, 2H, B(OH)<sub>2</sub>), 3.62 (s, 3H, OCH<sub>3</sub>), 6.83 (comp, 1H, 4-H), 7.56-7.75 (m, 3H, 2H<sub>arom</sub> + NH); ir (potassium bromide):  $\nu$  3323, 2967, 1654, 1602, 1534, 1490 cm<sup>-1</sup>.

*Anal.* Calcd. for C<sub>12</sub>H<sub>18</sub>BNO<sub>4</sub>: C, 57.40; H, 7.23; N, 5.58. Found: C, 57.05; H, 7.18; N, 5.33.

#### 3-Methoxy-2-(pivaloylamino)phenylboronic Acid (**13**).

The general procedure A, applied to **9**, gave 6.28 g (50%) of **13**, mp 137-139°; <sup>1</sup>H nmr (DMSO-*d*<sub>6</sub>):  $\delta$  1.10 (s, 9H, *t*-Bu), 3.10 (m, 2H, B(OH)<sub>2</sub>), 3.75 (s, 3H, OCH<sub>3</sub>), 6.80-7.05 (m, 3H, 4-H + 5-H + 6-H), 9.40 (s, 1H, NH); ir (potassium bromide):  $\nu$  3427, 2966, 1684, 1626, 1545, 1466 cm<sup>-1</sup>.

*Anal.* Calcd. for C<sub>12</sub>H<sub>18</sub>BNO<sub>4</sub>: C, 57.40; H, 7.23; N, 5.58. Found: C, 57.19; H, 6.85; N, 5.38.

#### General Procedure B: Cross-coupling Reaction Between 3-Fluoro-4-iodopyridine and Benzenboronic Acids.

The required arylboronic acid (2.0 mmoles) and 3-fluoro-4-iodopyridine (**14**) (2.0 mmoles) were added to an aqueous solution of potassium carbonate (2M, 2.0 ml) and ethanol (1.0 ml) in deoxygenated toluene (20 ml). The resulting mixture was stirred for 30 minutes under an argon atmosphere. Tetrakis(triphenylphosphine)-palladium(0) (70 mg, 0.060 mmole) was added, and the reaction mixture was refluxed for 48 hours. Cooling, filtration, extraction with toluene, drying over magnesium sulfate, and solvent removal afforded a crude oil which was purified by flash chromatography on silica (eluent).

#### 2,2-Dimethyl-*N*-(3-methoxy-2-(3-fluoro-4-pyridyl)phenyl)propanamide (**15**).

The general procedure B, applied to **11**, gave 0.466 g (77%) of **15** (hexane/ethyl acetate: 1/1), mp 141-143°; <sup>1</sup>H nmr (deuteriochloroform):  $\delta$  1.10 (s, 9H, *t*-Bu), 3.79 (s, 3H, OCH<sub>3</sub>), 6.83 (d, 1H, 4-H, *J* = 8.8 Hz), 7.03 (s, 1H, NH), 7.29 (d, 1H, 5'-H, *J* = 4.9 Hz), 7.43 (t, 1H, 5-H, *J* = 8.2 Hz), 7.80 (d, 1H, 6-H, *J* = 8.2 Hz), 8.53 (d, 1H, 6'-H, *J* = 4.9 Hz), 8.63 (s, 1H, 2'-H); ir (potassium bromide):  $\nu$  3348, 2957, 1685, 1609, 1587, 1469 cm<sup>-1</sup>.

*Anal.* Calcd. for C<sub>17</sub>H<sub>19</sub>FN<sub>2</sub>O<sub>2</sub>: C, 67.53; H, 6.33; N, 9.27. Found: C, 67.38; H, 6.12; N, 9.03.

#### 2,2-Dimethyl-*N*-(4-methoxy-2-(3-fluoro-4-pyridyl)phenyl)propanamide (**16**).

The general procedure B, applied to **12**, gave 0.423 g (70%) of **16** (hexane/ethyl acetate: 1/1), mp 184-186°; <sup>1</sup>H nmr (deuteriochloroform):  $\delta$  1.33 (s, 9H, *t*-Bu), 3.82 (s, 3H, OCH<sub>3</sub>), 6.98 (d, 1H, *J* = 8.9 Hz), 7.31 (comp, 1H, 6-H), 7.45-7.58 (m, 3H, 2H<sub>arom</sub> + NH), 8.43 (d, 1H, 6'-H, *J* = 4.9 Hz), 8.50 (s, 1H, 2'-H); ir (potassium bromide):  $\nu$  3280, 1670, 1601 cm<sup>-1</sup>.

*Anal.* Calcd. for C<sub>17</sub>H<sub>19</sub>FN<sub>2</sub>O<sub>2</sub>: C, 67.53; H, 6.33; N, 9.27. Found: C, 67.86; H, 6.50; N, 9.25.

#### 6-Methoxy-2-pivaloylamino-3-(3-fluoro-4-pyridyl)phenylcarboxylic Acid (**17**).

The general procedure B, applied to **10** (after extraction with

toluene, the clear aqueous layer was acidified (2*M* hydrochloric acid) to pH = 1 and extracted again with methylene chloride), gave 0.388 g (56%) of **17** (hexane/ethyl acetate: 1/1), mp 90–92°; <sup>1</sup>H nmr (deuteriochloroform): δ 1.10 (s, 9H, *t*-Bu), 6.50 (d, 1H, 5-H, *J* = 8.0 Hz), 7.05–7.32 (m, 2H), 8.30 (m, 1H), 8.90 (s, 1H, NH), 13.20 (s, 1H, COOH); ir (potassium bromide): ν 3192, 2960, 1702, 1585, 1472 cm<sup>-1</sup>.

*Anal.* Calcd. for C<sub>18</sub>H<sub>19</sub>FN<sub>2</sub>O<sub>4</sub>: C, 62.42; H, 5.53; N, 8.09. Found: C, 62.64; H, 5.85; N, 8.36.

2,2-Dimethyl-*N*-(6-methoxy-2-(3-fluoro-4-pyridyl)phenyl)propanamide (**18**).

The general procedure B, applied to **13**, gave 0.381 g (63%) of **18** (hexane/ethyl acetate: 1/1), mp 176–178°; <sup>1</sup>H nmr (deuteriochloroform): δ 0.95 (s, 9H, *t*-Bu), 3.79 (s, 3H, OCH<sub>3</sub>), 6.95 (dd, 1H, *J* = 6.4, 1.3 Hz), 7.16 (dd, 1H, *J* = 8.4, 1.3 Hz), 7.27 (m, 3H, 2H + NH), 8.38 (dd, 1H, *J* = 4.9, 1.1 Hz), 8.56 (d, 1H, *J* = 1.9 Hz), 8.65 (s, 1H, 2'-H); ir (potassium bromide): ν 3281, 2971, 1666, 1585, 1506, 1466 cm<sup>-1</sup>.

*Anal.* Calcd. for C<sub>17</sub>H<sub>19</sub>FN<sub>2</sub>O<sub>2</sub>: C, 67.53; H, 6.33; N, 9.27. Found: C, 67.84; H, 6.57; N, 9.21.

2,2-Dimethyl-*N*-(6-methoxy-2-(3-fluoro-1-hydroxyethyl-4-pyridyl)phenyl)propanamide (**19**).

*n*-Butyllithium (3.0 mmoles) was slowly added to a cold (-75°) solution of **17** (0.302 g, 1.0 mmole) in anhydrous tetrahydrofuran (25 ml). The resulting solution was reacted for 1 hour and 30 minutes at -75°. Three equivalents of acetaldehyde (0.132 g in 5 ml of tetrahydrofuran) was added. Stirring was continued for 1 hour at -75°, before hydrolysis at 0°. Extraction with ethyl acetate, drying over magnesium sulfate and solvent removal afforded a crude product, which was purified by flash chromatography on silica (ethyl acetate/hexane: 1/1) to yield 0.336 g (97%) of **19** (oil); <sup>1</sup>H nmr (deuteriochloroform): δ 0.96 (s, 9H, *t*-Bu), 1.06 (m, 3H, CH<sub>3</sub>), 3.79 (s, 3H, OCH<sub>3</sub>), 4.70 (m, 1H, CH), 5.20 (comp, OH), 6.95 (d, 1H, *J* = 7.6 Hz), 7.15 (d, 1H, *J* = 8.4 Hz), 7.25–7.40 (m, 2H<sub>arom</sub>), 8.30 (d, 1H, 6'-H, *J* = 4.8 Hz), 8.70 (s, 1H, NH); ir (potassium bromide): ν 3322, 2978, 1675, 1586, 1503, 1424 cm<sup>-1</sup>.

*Anal.* Calcd. for C<sub>19</sub>H<sub>23</sub>FN<sub>2</sub>O<sub>3</sub>: C, 65.88; H, 6.69; N, 8.09. Found: C, 66.15; H, 6.87; N, 7.87.

1-(3-Fluoro-4-(2-amino-3-methoxy-1-phenyl)pyrid-1-yl)ethanol (**20**).

Compound **19** (1.0 mmole) was added to a 20% solution of sulfuric acid (10 ml) and refluxed 2 hours. The resulting cold solution was diluted with water (20 ml). Extraction with ethyl acetate removed pivalic acid. Basification at 0° with ammonia to pH = 6–7 followed by several extraction with ethyl acetate (5 x 10 ml), and drying over magnesium sulfate afforded the crude amine **20** which was purified by flash chromatography on silica (ethyl acetate) to yield 0.224 g (92%) of **20** (oil); <sup>1</sup>H nmr (deuteriochloroform): δ 1.51 (t, 3H, CH<sub>3</sub>), 3.90 (s, 2H, NH<sub>2</sub>), 3.95 (s, 3H, OCH<sub>3</sub>), 4.50 (dd, 1H, CH, *J* = Hz), 5.20 (comp, OH), 6.80–7.10 (m, 2H<sub>arom</sub>), 7.30–7.40 (m, 2H, 1H<sub>arom</sub> + NH), 8.42 (dd, 1H, 6'-H, *J* = Hz); ir (potassium bromide): ν 3343, 1675 cm<sup>-1</sup>.

*Anal.* Calcd. for C<sub>14</sub>H<sub>15</sub>FN<sub>2</sub>O<sub>2</sub>: C, 64.11; H, 5.76; N, 10.68. Found: C, 64.32; H, 5.92; N, 10.55.

General Procedure C: Synthesis of Hydroxy-β-carbolines.

Anhydrous boiling (215°) pyridinium chloride (10 g) was added to the required phenylpyridines (1.0 mmole), and the

resulting mixture was refluxed for 15 minutes. The resulting hot solution was poured onto a mixture of ice and concentrated ammonia. Filtration of the precipitate, washing with water, and drying gave a first crop of the corresponding carboline. Extraction of the aqueous layer by ethyl acetate, drying over magnesium sulfate, solvent removal, and crystallization from toluene (or acetone) gave an additional crop.

5-Hydroxy-9*H*-pyrido[3,4-*b*]indole or 5-Hydroxy-β-carboline (**1**).

The general procedure C, applied to **15**, gave 0.153 g (83%) of **1**, mp 164–165°; <sup>1</sup>H nmr (DMSO-*d*<sub>6</sub>): δ 6.60 (d, 1H, 6-H, *J* = 7.5 Hz), 6.98 (d, 1H, 8-H, *J* = 8.0 Hz), 7.30 (dd, 1H, 7-H, *J* = 7.5, 8.0 Hz), 8.01 (dd, 1H, 4-H, *J* = 0.7, 5.1 Hz), 8.27 (d, 1H, 3-H, *J* = 5.1 Hz), 8.79 (d, 1H, 1-H, *J* = 0.7 Hz), 10.35 (s, 1H, OH), 11.45 (s, 1H, NH); ir (potassium bromide): ν 3100, 2962, 1591, 1449 cm<sup>-1</sup>.

*Anal.* Calcd. for C<sub>11</sub>H<sub>8</sub>N<sub>2</sub>O: C, 71.73; H, 4.38; N, 15.21. Found: C, 71.97; H, 4.49; N, 15.06.

6-Hydroxy-9*H*-pyrido[3,4-*b*]indole or 6-hydroxy-β-carboline (**2**).

The general procedure C, applied to **16**, gave 0.164 g (89%) of **2**, mp 189–190°; <sup>1</sup>H nmr (DMSO-*d*<sub>6</sub>): δ 7.03 (d, 1H, 8-H, *J* = 7.6 Hz), 7.40 (dd, 1H, 7-H, *J* = 7.6, 2.2 Hz), 7.50 (d, 1H, 5-H, *J* = 2.2 Hz), 7.98 (d, 1H, 4-H, *J* = 5.1 Hz), 8.25 (d, 1H, 3-H, *J* = 5.1 Hz), 8.80 (s, 1H, 1-H), 9.12 (s, 1H, OH), 11.25 (s, 1H, NH); ir (potassium bromide): ν 3275, 3049, 2966, 2567, 1580, 1458 cm<sup>-1</sup>.

*Anal.* Calcd. for C<sub>11</sub>H<sub>8</sub>N<sub>2</sub>O: C, 71.73; H, 4.38; N, 15.21. Found: C, 71.61; H, 4.47; N, 15.33.

7-Hydroxy-9*H*-pyrido[3,4-*b*]indole or 7-Hydroxy-β-carboline (**3**).

The general procedure C, applied to **17**, gave 0.090 g (49%) of **3**, mp >260°; <sup>1</sup>H nmr (DMSO-*d*<sub>6</sub>): δ 6.69 (dd, 1H, 6-H, *J* = 2.0, 8.5 Hz), 6.86 (d, 1H, 8-H, *J* = 2.0 Hz), 7.89 (d, 1H, 4-H, *J* = 5.1 Hz), 7.97 (d, 1H, 5-H, *J* = 8.5 Hz), 8.22 (d, 1H, 3-H, *J* = 5.1 Hz), 8.72 (s, 1H, 1-H), 9.75 (s, 1H, OH), 11.27 (s, 1H, NH); ir (potassium bromide): ν 3278, 1560, 1458 cm<sup>-1</sup>.

*Anal.* Calcd. for C<sub>11</sub>H<sub>8</sub>N<sub>2</sub>O: C, 71.73; H, 4.38; N, 15.21. Found: C, 71.91; H, 4.60; N, 15.05.

8-Hydroxy-9*H*-pyrido[3,4-*b*]indole or 8-Hydroxy-β-carboline (**4**).

The general procedure C, applied to **18**, gave 0.105 g (57%) of **4**, mp 250° dec; <sup>1</sup>H nmr (DMSO-*d*<sub>6</sub>): δ 6.92–7.09 (m, 2H, 5-H + 6-H), 7.65 (d, 1H, 7-H, *J* = 7.5 Hz), 8.02 (d, 1H, 4-H, *J* = 5.2 Hz), 8.28 (d, 1H, 3-H, *J* = 5.2 Hz), 8.82 (s, 1H, 1-H), 10.10 (s, 1H, OH), 11.40 (s, 1H, NH); ir (potassium bromide): ν 3060, 1508, 1450 cm<sup>-1</sup>.

*Anal.* Calcd. for C<sub>11</sub>H<sub>8</sub>N<sub>2</sub>O: C, 71.73; H, 4.38; N, 15.21. Found: C, 71.90; H, 4.24; N, 15.43.

8-Hydroxy-1-vinyl-9*H*-pyrido[3,4-*b*]indole or 8-Hydroxy-1-vinyl-β-carboline (**5**).

The general procedure C, applied to **20**, gave 0.132 g (63%) of **5**, mp 158–160° (lit [9], oil); <sup>1</sup>H nmr (DMSO-*d*<sub>6</sub>): δ 5.52 (dd, 1H, 2'-Hb (vinyl), *J* = 10.6, 2.5 Hz), 6.49 (dd, 1H, 2'-Ha (vinyl), *J* = 16.9, 2.5 Hz), 6.96–7.15 (m, 3H, 5-H + 6-H + 1'-H (vinyl)), 7.64 (d, 1H, 7-H, *J* = 7.7 Hz), 7.94 (d, 1H, 4-H, *J* = 5.1 Hz), 8.28 (d, 1H, 3-H, *J* = 5.1 Hz), 10.09 (s, 1H, OH), 11.37 (s, 1H, NH);

ir (potassium bromide):  $\nu$  3205, 2966, 1586, 1430  $\text{cm}^{-1}$ .

Anal. Calcd. for  $\text{C}_{13}\text{H}_{10}\text{N}_2\text{O}$ : C, 74.27; H, 4.79; N, 13.32. Found: C, 74.53; H, 4.53; N, 13.21.

#### Acknowledgment.

Financial support to this research by the National Universities Commission of Nigeria is gratefully acknowledged.

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