

# The first preparation of the unstable 1-hydroxy-2,3-dimethylindole, and structural determination of its air-oxidized product, 3-hydroxy-2,3-dimethyl-3*H*-indole *N*-oxide<sup>1</sup>

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**Dedicated to Professor Keiichiro Fukumoto on his 70<sup>th</sup> birthday**

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## Abstract

1-Hydroxy-2,3-dimethylindole (**1**) has been prepared for the first time. Under atmospheric oxygen, **1** was converted rapidly into 3-hydroxy-2,3-dimethyl-3*H*-indole *N*-oxide (**2**). The structure was deduced, based on its products obtained by the reaction with Ac<sub>2</sub>O in pyridine and confirmed by X-ray single crystallographic analysis.

**Keywords:** 2,3-Dimethylindole, 1-hydroxyindole, 1-hydroxy-2,3-dimethylindole, 3-hydroxy-2,3-dimethyl-3*H*-indole *N*-oxide, 5-acetoxy-2-acetoxymethyl-3-methylindole, 7-acetoxy-2-acetoxymethyl-3-methylindole

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## Introduction

In 1989,<sup>2</sup> we devised a simple and general synthetic method for 1-hydroxyindoles<sup>3</sup> consisting of the following two steps: (1) reduction of indoles to 2,3-dihydroindoles, (2) their oxidation with 30% H<sub>2</sub>O<sub>2</sub> in the presence of a catalytic amount of sodium tungstate or phosphotungstate. Employing the 1-hydroxyindole synthetic method, we have succeeded in preparing novel 3-substituted 1-hydroxyindoles, including 1-hydroxytryptophans and 1-hydroxytryptamines.<sup>4</sup>

In this paper, we report the first preparation of 1-hydroxy-2,3-dimethylindole (**1**) as a representative of 1-hydroxyindoles having an alkyl substituent at both 2- and 3-positions. Compound (**1**) was quite sensitive to air and was converted into a novel 3-hydroxy-2,3-dimethyl-3*H*-indole *N*-oxide (**2**). Treatment of **2** with Ac<sub>2</sub>O in pyridine afforded 5- and 7-acetoxy-2-acetoxymethyl-3-methylindoles together with 3-methylindole-2-carboxaldehyde. On the basis of these chemical results and X-ray analysis, the structure of **2** was determined unequivocally.



On the basis of the above observations, the compound (**B**) was obtained in 64% overall yield from **4** by the sequence of reactions: (1) oxidation of **4** to **1** and work-up, and (2) allowing a  $\text{CHCl}_3$  solution of crude **1** to stand at room temperature under atmospheric oxygen for 22 h, a sufficient time for transforming **1** completely into **B**.

In an attempt to determine the structure of **B** chemically, it was reacted with  $\text{Ac}_2\text{O}$  in pyridine at room temperature, providing a 56% yield of 3-methylindole-2-carboxaldehyde (**8**) together with 5- (**6a**) and 7-acetoxy-2-acetoxymethyl-3-methylindoles (**7a**) in 2 and 3% yields, respectively. The yields of these three products were not affected by reaction temperature or time as can be seen from Table 1.

**Table 1.** The reaction of **2** with  $\text{Ac}_2\text{O}$

Entry	Reaction		Yield (%)		
	Temp. ( $^{\circ}\text{C}$ )	Time (h)	<b>6a</b>	<b>7a</b>	<b>8</b>
1	20	3	2	3	56
2	50	3	2	4	57
3	50	17	2	3	54
4	75	3	1	4	56

The reaction of **B** with trifluoromethanesulfonic anhydride did not produce **6b**, **7b**, and **8** at all, (in contrast to  $\text{Ac}_2\text{O}$ ). With trifluoroacetic anhydride and benzoic anhydride, the expected formation of **6c,d** and **7c,d** was not observed, although the aldehyde (**8**) was obtained in 8–24% yield. The aldehyde (**8**) was identical with the authentic 3-methylindole-2-carboxaldehyde, prepared by Vilsmeier–Haack reaction of 3-methylindole (**9**) by the procedure of Chatterjee *et al.*<sup>6</sup> The structures of **6a** and **7a** were determined by the following observations. Compounds **6a** and **7a** were allowed to react with  $\text{Boc}_2\text{O}$  in  $\text{CH}_2\text{Cl}_2$  in the presence of *N,N*-dimethylaminopyridine (DMAP)<sup>7</sup> to provide 5-acetoxy- (**10**) and 7-acetoxy-2-acetoxymethyl-1-*tert*-butoxycarbonyl-3-methylindole (**11**) in 96 and 82% yields, respectively. Comparison of the  $^1\text{H}$  NMR spectra of **10** with **6a** demonstrates an anisotropy effect of the Boc group on the *ortho*-coupled C(7)-proton ( $\delta$  8.15, d,  $J = 9.0$  Hz) by *ca.* 0.9 ppm, proving these are 5-substituted compounds. In the case of **11**, however, the protons did not shift toward lower magnetic field compared with those of **7a**. This fact confirms that **7a** and **11** are 7-substituted indoles.

There are still other possibilities that **6a** and **7a** are the 3-acetoxymethyl-2-methylindoles, **12a** and **12b**, respectively, as shown in Scheme 2. In order to eliminate these structures, we applied the following series of reactions to **7a**. First, **7a** was converted into 7-hydroxy-3-methylindole-2-methanol (**13**) in 73% yield by the hydrolysis with LiOH in MeOH. Then, selective methylation of the phenolic group of **13** with  $\text{CH}_2\text{N}_2$  provided an 87% yield of 7-methoxy-3-methylindole-2-methanol<sup>8</sup> (**14**). Subsequent oxidation of **14** with active  $\text{MnO}_2$  in  $\text{CHCl}_3$  afforded a formyl compound (**15b**) in 44% yield. By these reactions, **12b** should have been transformed into **15a**. At this stage, comparison of the  $^1\text{H}$  NMR spectrum of **14** with that of

**15b** was made, and no anisotropy effect of the formyl group on the C(4)-proton was observed. Consequently, the formyl group should not be present at the 3-position of the indole nucleus and **15b** is proved to be 7-methoxy-3-methylindole-2-carboxaldehyde.<sup>8</sup>



## Scheme 2

The structure of **6a** was determined by comparing the differences between the  $^1\text{H}$  NMR chemical shifts of the diacetoxy compounds (**6a**, **7a**) and the 1-acyl compounds (**10**, **11**). As shown in Table 2, the  $\Delta\delta$ s observed between protons of **10** and **6a** were almost the same with those observed between protons of **11** and **7a**. These findings confirm that **6a** has a structure similar to **7a**.

**Table 2.**  $^1\text{H}$  NMR data of **6a**, **7a**, **10**, and **11**, and the differences between chemical shifts

Position	<b>6a</b> $\delta_{6a}$	<b>10</b> $\delta_{10}$	$\Delta\delta$ $\delta_{10} - \delta_{6a}$	<b>7a</b> $\delta_{7a}$	<b>11</b> $\delta_{11}$	$\Delta\delta$ $\delta_{11} - \delta_{7a}$
COCH <sub>3</sub>	2.08 (3H, s)	2.06 (3H, s)	-0.02	2.09 (3H, s)	2.05 (3H, s)	-0.04
COCH <sub>3</sub> and 3-CH <sub>3</sub>	2.30 (3H, s)	2.28 (3H, s)	-0.02	2.33 (3H, s)	2.31 (3H, s)	-0.02
	2.31 (3H, s)	2.32 (3H, s)	-0.01	2.40 (3H, s)	2.34 (3H, s)	-0.06
2-CH <sub>2</sub>	5.21 (2H, s)	5.45 (2H, s)	+0.24	5.22 (2H, s)	5.38 (2H, s)	+0.16
4	7.23 (d, 2.2)	7.22 (d, 2.2)	-0.01	7.41 (dd, 7.6, 0.9)	7.40 (dd, 7.8, 1.0)	-0.01
5				7.07 (t, 7.6)	7.23 (t, 7.8)	+0.17
6	6.91 (dd, 8.6, 2.2)	7.04 (dd, 9.0, 2.2)	+0.13	6.99 (dd, 7.6, 0.9)	7.04 (dd, 7.8, 1.0)	+0.05
7	7.27 (d, 8.6)	8.15 (d, 9.0)	+0.88			
1	8.40 (NH)	1.66 (9H, s)		8.30 (NH)	1.62 (9H, s)	

Although the structure (**B**) was deduced to be **2** on the basis of its spectroscopic data and chemical behavior upon reaction with  $\text{Ac}_2\text{O}$  as stated above, we still needed conclusive evidence. Finally, we luckily found a suitable recrystallizing solvent for **B**, providing prisms for X-ray

single crystallographic analysis. The results shown in Figure 1 clearly show a novel 3-hydroxy-2,3-dimethyl-3*H*-indole *N*-oxide (**2**) structure. The atomic parameters are listed in Table 3.

The mechanism for the formation of **6a**, **7a**, and **8** may be explained as shown in Scheme 3. In the reaction of **2** with Ac<sub>2</sub>O, the diacetate (**16**) is formed initially. The following [3,3]-sigmatropic rearrangement of either the 3- (route **a**) or 1-acetoxy groups (route **b**) to the methylene carbon at the 2-position affords **17** or **18**, respectively. In the intermediate (**17**), subsequent [3,5] or [3,3]-sigmatropic rearrangement of the 1-acetoxy group toward the benzene ring results in the formation of **6a** or **7a** (route **c**). On the other hand, **8** would be formed either through the vinylic acetate **19**, a tautomer of **18**, or through the vinylic acetate **20** originating from **17** (route **d**).

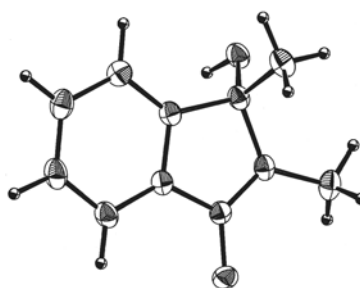
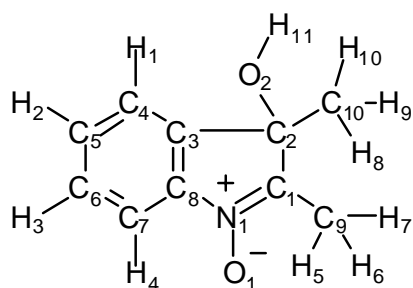
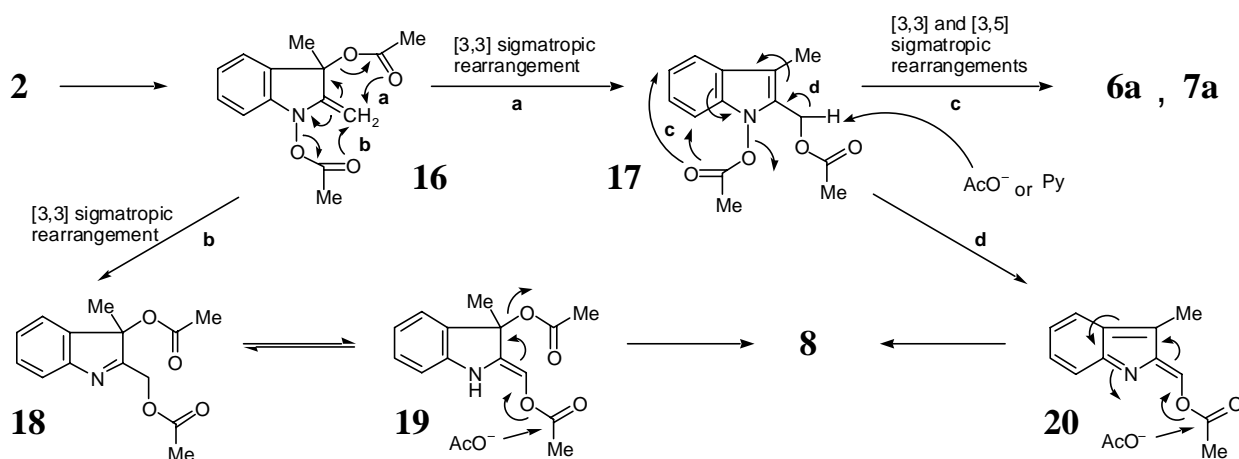


Figure 1

ORTEP Drawing of 2



Scheme 3

In conclusion, we have succeeded in the first preparation of 1-hydroxy-2,3-dimethylindole (**1**), which was an unstable compound and oxidized rapidly into a novel compound, 3-hydroxy-2,3-dimethyl-3*H*-indole *N*-oxide (**2**), on standing at room temperature under atmospheric oxygen. An interesting chemical behavior of **2** upon reaction with Ac<sub>2</sub>O was also demonstrated.

## Experimental Section

**General Procedures.** Melting points were determined on a Yanagimoto micro melting point apparatus and are uncorrected. IR spectra were determined with a HORIBA FT-720 spectrophotometer, and  $^1\text{H}$  NMR spectra with a JEOL GSX-500 spectrometer, with tetramethylsilane as internal standard. MS spectra at 70 eV using electron impact mode were recorded on a JEOL SX-102A or JEOL JMS-GC mate mass spectrometer. Column chromatography was performed on silica gel 60N ( $\text{SiO}_2$ , 70–230 mesh, from Kanto Chemical Co. Inc.) throughout the present study.

**2,3-Dimethylindoline (4).** The procedure of Gribble *et al.*<sup>5</sup> was slightly modified.  $\text{NaBH}_3\text{CN}$  (267.8 mg, 4.27 mmol) was added to a stirred solution of 2,3-dimethylindole (**3**) (305.4 mg, 2.11 mmol) in AcOH/TFA (3:1, 8 mL) at 0 °C and the mixture was stirred at room temperature for 1 h. After evaporation of the solvent under reduced pressure, the whole was made alkaline by adding 8% NaOH under ice cooling and extracted with  $\text{CHCl}_3$ . The extract was washed with brine, dried over  $\text{Na}_2\text{SO}_4$ , and evaporated under reduced pressure to leave an oil, which was column-chromatographed on  $\text{SiO}_2$  with  $\text{CHCl}_3$ /hexane (1:1) to give **4** (287.4 mg, 93%) as a 3:1 mixture of stereoisomers. **4**:  $^1\text{H}$  NMR ( $\text{CDCl}_3$ )  $\delta$ : 1.13 (3/4H, d,  $J = 6.6$  Hz), 1.18 (3/4H, d,  $J = 7.2$  Hz), 1.30 (9/4H, d,  $J = 6.8$  Hz), 1.32 (9/4H, d,  $J = 6.1$  Hz), 2.82 (3/4H, dq,  $J = 9.2, 6.8$  Hz), 3.26 (1/4H, dq,  $J = 8.1, 7.2$  Hz), 3.46 (3/4H, dq,  $J = 9.2, 6.1$  Hz), 3.94 (1/4H, dq,  $J = 8.1, 6.6$  Hz), 6.61 (1H, d,  $J = 7.8$  Hz), 6.72 (1H, t,  $J = 7.8$  Hz), 6.98–7.08 (2H, m). Careful integration of the area between  $\delta$  1.5 and 4.0 disclosed the presence of 1H (NH proton), which disappeared on addition of  $\text{D}_2\text{O}$ . Compound (**4**) was used for the next step without separation of the isomers.

**1-Methoxy-2,3-dimethylindole (5a).** 30%  $\text{H}_2\text{O}_2$  (0.75 mL, 7.28 mmol) was added to a solution of **4** (108.8 mg, 0.74 mmol) and  $\text{Na}_2\text{WO}_4 \cdot 2\text{H}_2\text{O}$  (47.9 mg, 0.036 mmol) in MeOH/ $\text{H}_2\text{O}$  (10:1, 11 mL) at 0 °C, and the mixture was stirred at room temperature for 45 min. To this solution were added  $\text{K}_2\text{CO}_3$  (511.1 mg, 3.70 mmol) and a solution of  $\text{Me}_2\text{SO}_4$  (277.4 mg, 2.20 mmol) in MeOH (1 mL), and the whole was stirred at room temperature for 2 h. After addition of  $\text{H}_2\text{O}$ , the whole was extracted with AcOEt. The extract was washed with brine, dried over  $\text{Na}_2\text{SO}_4$ , and evaporated under reduced pressure to leave an oil, which was column-chromatographed on  $\text{SiO}_2$  with  $\text{CHCl}_3$ /hexane (1:3) to give **5a** (28.2 mg, 22%), as a colorless oil. IR (film): 1458, 1234, 1171, 737  $\text{cm}^{-1}$ .  $^1\text{H}$  NMR ( $\text{CDCl}_3$ )  $\delta$ : 2.20 (3H, s), 2.36 (3H, s), 3.99 (3H, s), 7.07 (1H, ddd,  $J = 7.8, 7.1, 1.0$  Hz), 7.16 (1H, ddd,  $J = 8.1, 7.1, 1.0$  Hz), 7.34 (1H, dd,  $J = 8.1, 1.0$  Hz), 7.45 (1H, br d,  $J = 7.8$  Hz). High-Resolution EI-MS  $m/z$ : Calcd for  $\text{C}_{11}\text{H}_{13}\text{NO}$ : 175.0997. Found: 175.0997.

**1-Acetoxy-2,3-dimethylindole (5b).** 30%  $\text{H}_2\text{O}_2$  (0.73 mL, 7.15 mmol) was added to a solution of **4** (105.2 mg, 0.72 mmol) and  $\text{Na}_2\text{WO}_4 \cdot 2\text{H}_2\text{O}$  (53.0 mg, 0.16 mmol) in MeOH/ $\text{H}_2\text{O}$  (10:1, 11 mL) at 0 °C, and the mixture was stirred at room temperature for 1.5 h. After addition of  $\text{H}_2\text{O}$ , the whole was extracted with  $\text{CHCl}_3$ . The extract was washed with brine, dried over  $\text{Na}_2\text{SO}_4$ , and evaporated under reduced pressure. To the residue, pyridine (2 mL) and  $\text{Ac}_2\text{O}$  (1 mL) were added, and the mixture was stirred at room temperature for 5 h. AcOEt was added and the whole

was washed with saturated  $\text{NH}_4\text{Cl}$ , dried over  $\text{Na}_2\text{SO}_4$ , and evaporated under reduced pressure to leave an oil, which was column-chromatographed on  $\text{SiO}_2$  with AcOEt/hexane (1:3) to give **5b** (91.2 mg, 63%) as a colorless oil. IR (film):  $1801\text{ cm}^{-1}$ .  $^1\text{H NMR}$  ( $\text{DMSO}-d_6$ )  $\delta$ : 2.17 (3H, s), 2.19 (3H, s), 2.43 (3H, s), 7.06 (1H, ddd,  $J = 7.6, 7.1, 1.0\text{ Hz}$ ), 7.11 (1H, ddd,  $J = 8.1, 7.1, 1.0\text{ Hz}$ ), 7.23 (1H, dd,  $J = 8.1, 1.0\text{ Hz}$ ), 7.45 (1H, br d,  $J = 7.6\text{ Hz}$ ). High-Resolution EI-MS  $m/z$ : Calcd for  $\text{C}_{12}\text{H}_{13}\text{NO}_2$ : 203.0947. Found: 203.0950.

**1-Hydroxy-2,3-dimethylindole (1)**. LiOH (16.2 mg, 0.68 mmol) was added to a solution of **5b** (65.0 mg, 0.32 mmol) in MeOH (4 mL) and the mixture was stirred at room temperature for 20 min. After addition of AcOEt, the whole was washed with saturated  $\text{NH}_4\text{Cl}$ , dried over  $\text{Na}_2\text{SO}_4$ , and evaporated under reduced pressure to leave an oil, which was column-chromatographed on  $\text{SiO}_2$  with AcOEt/hexane (1:4) to give **1** (38.4 mg, 67%) as a colorless oil. IR (film): 3159, 1574,  $1456\text{ cm}^{-1}$ .  $^1\text{H NMR}$  ( $\text{CD}_3\text{OD}$ )  $\delta$ : 2.19 (3H, s), 2.33 (3H, s), 6.94 (1H, dd,  $J = 7.8, 7.3\text{ Hz}$ ), 7.04 (1H, dd,  $J = 7.8, 7.3\text{ Hz}$ ), 7.27 (1H, d,  $J = 7.8\text{ Hz}$ ), 7.36 (1H, d,  $J = 7.8\text{ Hz}$ ). High-Resolution EI-MS  $m/z$ : Calcd for  $\text{C}_{10}\text{H}_{11}\text{NO}$ : 161.0841. Found: 161.0843.

**1-Hydroxy-2,3-dimethyl-3H-indole N-oxide (2)**. 30%  $\text{H}_2\text{O}_2$  (4.85 mL, 47.1 mmol) was added to a solution of **4** (698.5 mg, 4.75 mmol) and  $\text{Na}_2\text{WO}_4 \cdot 2\text{H}_2\text{O}$  (316.6 mg, 0.96 mmol) in MeOH/ $\text{H}_2\text{O}$  (10:1, 49.5 mL) at 0 °C and the mixture was stirred at room temperature for 45 min. After addition of  $\text{H}_2\text{O}$ , the whole was extracted with  $\text{CHCl}_3$ . The extract was washed with brine, dried over  $\text{Na}_2\text{SO}_4$ , and evaporated under reduced pressure. To the residue,  $\text{CHCl}_3$  (15 mL) was added and the resultant solution was stirred at room temperature under atmospheric oxygen for 22 h. After evaporation of the solvent under reduced pressure, the residue was column-chromatographed on  $\text{SiO}_2$  with  $\text{CHCl}_3/\text{MeOH}$  (97:3) to give **2** (538.2 mg, 64%). **2**: mp 164–166 °C (colorless prisms, recrystallized from AcOEt). IR (KBr): 3116, 1633, 1577,  $1319\text{ cm}^{-1}$ .  $^1\text{H NMR}$  ( $\text{CD}_3\text{OD}$ )  $\delta$ : 1.60 (3H, s), 2.29 (3H, s), 7.52 (1H, dt,  $J = 1.5, 7.6\text{ Hz}$ ), 7.54 (1H, dt,  $J = 1.7, 7.6\text{ Hz}$ ), 7.59–7.65 (2H, m). EI-MS  $m/z$ : 177 ( $\text{M}^+$ ). Anal. Calcd for  $\text{C}_{10}\text{H}_{11}\text{NO}_2$ : C, 67.78; H, 6.26; N, 7.91. Found: C, 67.69; H, 6.29; N, 7.91%.

**X-Ray crystallographic analysis of 2**. The reflection data were collected on a Rigaku AFC5R diffractometer over the range of  $78.64^\circ < 2\theta < 80.02^\circ$  using  $\text{CuK}\alpha$  radiation ( $\lambda = 1.54178\text{ \AA}$ ) and the  $\omega$ - $2\theta$  scan method at a  $2\theta$  scan speed of  $6^\circ/\text{min}$ . The structure of **2** was solved by the direct method using MITHRIL<sup>9</sup> and refined by the full-matrix least-squares method with anisotropic thermal factors for non-hydrogen atoms and with isotropic ones for hydrogen atoms. The final  $R$ - and  $R_w$ -factors were 0.038 and 0.054 for 1283 observed reflections [ $I > 3.00\sigma(I)$ ], respectively. Crystal data for **2**:  $\text{C}_{10}\text{H}_{11}\text{NO}_2$ ;  $M = 177.20$ ; monoclinic; space group,  $C2/c$  (#15);  $a = 11.344(1)\text{ \AA}$ ,  $b = 12.3639(8)\text{ \AA}$ ,  $c = 13.785(1)\text{ \AA}$ ;  $\beta = 105.391(6)^\circ$ ;  $V = 1864.1(2)\text{ \AA}^3$ ,  $Z = 8$ ,  $D_{\text{calc.}} = 1.263\text{ g/cm}^3$ . Positional parameters and  $B$  (eq) for **2** are summarized in Table 3.

**5-Acetoxy- (6a), 7-acetoxy-2-acetoxymethyl-3-methylindole (7a) and 3-methylindole-2-carboxaldehyde (8)**. **Entry 1**:  $\text{Ac}_2\text{O}$  (1 mL, 10.6 mmol) was added to a solution of **2** (102.3 mg, 0.58 mmol) in pyridine (2 mL) and the mixture was stirred at room temperature for 3 h. After evaporation of the solvent, brine was added and the whole was extracted with  $\text{CHCl}_3/\text{MeOH}$  (95:5). The extract was washed with brine, dried over  $\text{Na}_2\text{SO}_4$ , and evaporated under reduced

pressure to leave an oil, which was column-chromatographed on SiO<sub>2</sub> with AcOEt/hexane (1:3) to give **8** (51.1 mg, 56%) and a mixture of **6a** and **7a** in order of elution. The mixture was subjected to HPLC [column, CPS-223L-1 (i.d., 22 x 100 mm); solvent, AcOEt/hexane (1:5); flow rate, 5.0 mL/min; UV detection, 300 nm]. **6a** (2.5 mg, 2%) and **7a** (3.9 mg, 3%) were obtained in the order of elution. **6a**: mp 70–72 °C (colorless prisms, recrystallized from CHCl<sub>3</sub>/hexane). IR (KBr): 3363, 1739 cm<sup>-1</sup>. High-resolution EI-MS *m/z*: Calcd for C<sub>14</sub>H<sub>15</sub>NO<sub>4</sub>: 261.1001. Found: 261.1001. The <sup>1</sup>H NMR data of **6a** are in Table 2. **7a**: mp 102–103 °C (colorless prisms, recrystallized from CHCl<sub>3</sub>/hexane). IR (KBr): 3350, 1738, 1728 cm<sup>-1</sup>. EI-MS *m/z*: 261 (M<sup>+</sup>). Anal. Calcd for C<sub>14</sub>H<sub>15</sub>NO<sub>4</sub>·0.5CHCl<sub>3</sub>: C, 54.26; H, 4.87; N, 4.36. Found: C, 53.87; H, 4.92; N, 4.38. The <sup>1</sup>H NMR data of **7a** are shown in Table 2. **8**: mp 137–140 °C (lit.<sup>5</sup> mp 138–140 °C) (colorless needles from hexane). IR (KBr): 3307, 1635 cm<sup>-1</sup>. <sup>1</sup>H NMR (CDCl<sub>3</sub>) δ: 2.65 (3H, s), 7.13–7.19 (1H, m), 7.36–7.41 (2H, m), 7.70 (1H, br d, *J* = 8.1 Hz), 8.81 (1H, br s, disappeared on addition of D<sub>2</sub>O), 10.04 (1H, s). EI-MS *m/z*: 159 (M<sup>+</sup>).

**Entry 2:** Ac<sub>2</sub>O (8 mL, 84.6 mmol) was added to a solution of **2** (389.7 mg, 2.20 mmol) in pyridine (16 mL) and the mixture was heated at 50 °C for 3 h with stirring. After the same work-up and purification as described in Entry 1, **8** (200.6 mg, 57%), **6a** (10.8 mg, 2%), and **7a** (22.9 mg, 4%) were obtained (in order of elution).

**5-Acetoxy-2-acetoxymethyl-1-tert-butoxycarbonyl-3-methylindole (10).** Boc<sub>2</sub>O (0.01 mL, 0.04 mmol) was added to a solution of **6a** (5.8 mg, 0.02 mmol) and DMAP (3.2 mg, 0.03 mmol) in CH<sub>2</sub>Cl<sub>2</sub> (1 mL), and the mixture stirred at room temperature for 3 h. After evaporation of the solvent under reduced pressure, the residue was column-chromatographed on SiO<sub>2</sub> with CHCl<sub>3</sub> to give **10** (7.7 mg, 96%). **10**: mp 63–65 °C (colorless prisms, recrystallized from hexane). IR (film): 1757, 1738, 1718 cm<sup>-1</sup>. High-Resolution EI-MS *m/z*: Calcd for C<sub>19</sub>H<sub>23</sub>NO<sub>6</sub>: 361.1525. Found: 361.1528. The <sup>1</sup>H NMR data of **10** are shown in Table 2.

**7-Acetoxy-2-acetoxymethyl-1-tert-butoxycarbonyl-3-methylindole (11).** Boc<sub>2</sub>O (0.01 mL, 0.04 mmol) was added to a solution of **7a** (4.9 mg, 0.02 mmol) and DMAP (2.6 mg, 0.02 mmol) in CH<sub>2</sub>Cl<sub>2</sub> (1 mL), and the mixture was stirred at room temperature for 3 h. After evaporation of the solvent under reduced pressure, the residue was column-chromatographed on SiO<sub>2</sub> with CHCl<sub>3</sub> to give **11** (5.6 mg, 82%). **11**: mp 97–99 °C (colorless prisms, recrystallized from hexane). IR (film): 1753, 1736, 1724 cm<sup>-1</sup>. High-Resolution EI-MS *m/z*: Calcd for C<sub>19</sub>H<sub>23</sub>NO<sub>6</sub>: 361.1525. Found: 361.1526. The <sup>1</sup>H NMR data of **11** are shown in Table 2.

**7-Hydroxy-3-methylindole-2-methanol (13).** LiOH (23.4 mg, 0.98 mmol) was added to a solution of **7a** (28.6 mg, 0.11 mmol) in MeOH (3 mL) and the mixture was stirred at room temperature for 1 h under argon atmosphere. After addition of saturated NH<sub>4</sub>Cl, the whole was extracted with CHCl<sub>3</sub>/MeOH (95:5). The extract was washed with brine, dried over Na<sub>2</sub>SO<sub>4</sub>, and evaporated under reduced pressure to leave a solid, which was column-chromatographed on SiO<sub>2</sub> with CHCl<sub>3</sub>/MeOH (95:5) to give **13** (14.1 mg, 73%). **13**: mp 158–160 °C (dec., colorless prisms, recrystallized from CHCl<sub>3</sub>/hexane). IR (KBr): 3390, 3309, 3140, 1637, 1579, 1321, 1261, 972 cm<sup>-1</sup>. <sup>1</sup>H NMR (CD<sub>3</sub>OD) δ: 2.25 (3H, s), 4.71 (2H, s), 6.50 (1H, dd, *J* = 7.8, 0.7 Hz),



6.80 (1H, t,  $J = 7.8$  Hz), 6.96 (1H, dd,  $J = 7.8, 0.7$  Hz). High-Resolution EI-MS  $m/z$ : Calcd for  $C_{10}H_{11}NO_2$ : 177.0790. Found: 177.0788.

**Table 3.** Positional parameters and  $B$  (eq) of **2**

Atom	$x$	$y$	$z$	$B$ (eq)
O (1)	0.3989 (1)	-0.0311 (1)	0.12803 (8)	4.87 (5)
O (2)	0.7602 (1)	0.0210 (1)	0.05423 (9)	4.67 (5)
N (1)	0.5029 (1)	0.0144 (1)	0.12735 (8)	3.82 (5)
C (1)	0.6083 (1)	-0.0325 (1)	0.1399 (1)	4.00 (6)
C (2)	0.7047 (1)	0.0491 (1)	0.1316 (1)	4.15 (6)
C (3)	0.6301 (1)	0.1524 (1)	0.1111 (1)	3.94 (6)
C (4)	0.6603 (2)	0.2569 (1)	0.0933 (1)	4.80 (7)
C (5)	0.5690 (2)	0.3350 (1)	0.0776 (1)	5.42 (8)
C (6)	0.4516 (2)	0.3089 (2)	0.0809 (1)	5.58 (9)
C (7)	0.4201 (2)	0.2040 (2)	0.0983 (1)	4.86 (7)
C (8)	0.5117 (1)	0.1285 (1)	0.1115 (1)	3.89 (6)
C (9)	0.6257 (2)	-0.1485 (1)	0.1611 (2)	5.30 (8)
C (10)	0.8069 (2)	0.0554 (2)	0.2290 (1)	5.67 (9)
H (1)	0.744 (2)	0.276 (1)	0.089 (1)	5.90 (1)
H (2)	0.589 (2)	0.407 (2)	0.061 (2)	6.73 (1)
H (3)	0.390 (2)	0.367 (2)	0.070 (2)	7.10 (1)
H (4)	0.336 (2)	0.187 (1)	0.099 (1)	5.38 (1)
H (5)	0.636 (3)	-0.163 (2)	0.235 (2)	10.83 (3)
H (6)	0.704 (3)	-0.177 (2)	0.150 (2)	7.94 (2)
H (7)	0.561 (4)	-0.188 (2)	0.126 (2)	12.08 (4)
H (8)	0.773 (2)	0.069 (2)	0.288 (2)	5.55 (1)
H (9)	0.867 (2)	0.111 (2)	0.220 (1)	6.25 (1)
H (10)	0.852 (2)	-0.009 (2)	0.239 (2)	7.01 (1)
H (11)	0.702 (2)	0.026 (1)	-0.008 (2)	6.52 (2)

**7-Methoxy-3-methylindole-2-methanol (14).** An excess of ethereal  $CH_2N_2$  was added to a solution of **13** (6.3 mg, 0.04 mmol) in MeOH (2 mL) and the mixture was stirred at room temperature for 1.5 h. After evaporation of the solvent under reduced pressure, the residue was column-chromatographed on  $SiO_2$  with  $CHCl_3/MeOH$  (97:3) to give **14** (5.9 mg, 87%). **14**: mp 176–178 °C (lit.<sup>8</sup> mp 169–170 °C) (colorless needles, recrystallized from  $CHCl_3$ /hexane). IR (KBr): 3479, 3284, 1628, 1572, 1244, 985  $cm^{-1}$ .  $^1H$  NMR ( $CDCl_3$ )  $\delta$ : 1.61 (1H, br s, disappeared on addition of  $D_2O$ ), 2.27 (3H, s), 3.95 (3H, s), 4.81 (2H, s), 6.64 (1H, d,  $J = 7.8$  Hz), 7.02 (1H, t,  $J = 7.8$  Hz), 7.14 (1H, d,  $J = 7.8$  Hz), 8.35 (1H, br s, disappeared on addition of  $D_2O$ ). High-Resolution EI-MS  $m/z$ : Calcd for  $C_{11}H_{13}NO_2$ : 191.0946. Found: 191.0945.

**7-Methoxy-3-methylindole-2-carboxaldehyde (15b).** Active MnO<sub>2</sub> (56.8 mg, 0.65 mmol) was added to a solution of **14** (6.9 mg, 0.04 mmol) in CHCl<sub>3</sub> (2 mL) and the mixture was stirred at room temperature for 32 h. After evaporation of the solvent under reduced pressure, the residue was column-chromatographed on SiO<sub>2</sub> with CHCl<sub>3</sub> to give **15b** (3.0 mg, 44%). **15b**: mp 132–134 °C (lit.<sup>8</sup> mp 130 °C) (colorless needles, recrystallized from Et<sub>2</sub>O/hexane). IR (KBr): 3288, 1649, 1325, 1259 cm<sup>-1</sup>. <sup>1</sup>H NMR (CDCl<sub>3</sub>) δ: 2.63 (3H, s), 3.96 (3H, s), 6.77 (1H, d, *J* = 7.6 Hz), 7.07 (1H, dd, *J* = 8.1, 7.6 Hz), 7.27 (1H, d, *J* = 8.1 Hz), 8.89 (1H, br s, disappeared on addition of D<sub>2</sub>O), 10.02, (1H, s). High-Resolution EI-MS *m/z*: Calcd for C<sub>11</sub>H<sub>11</sub>NO<sub>2</sub>: 189.0790. Found: 189.0790.

## References and Notes

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