A Synthesis of Arcyriacyanin A, an Unsymmetrically Substituted Indole Pigment of the Slime Mould by Palladium Catalyzed Cross-Coupling Reaction

Masayuki MURASE, Kazuhiro WATANABE, Takayuki KURIHARA, and Seisho TOBINAGA*

Showa College of Pharmaceutical Sciences, Machida, Tokyo 194–8543, Japan.
Received October 8, 1997; accepted February 16, 1998

The slime mould alkaloid of *Arcyria obvelata* Onsberg, arcyriacyanin A, was synthesized by the palladium catalyzed cross-coupling reaction with the indolylborate and 4-iodoindole derivatives, which provides an unsymmetrically substituted indole pigment.

Key words slime mould; indole pigment; palladium catalyzed; cross-coupling reaction; indolylborate; iodoindole

Slime moulds have various colors and which are constituted of unique indole pigments, bisindolylmaleimides.[1,2] Considerable attention has recently been focused on this type of metabolite families isolated from *Streptomyces* and *Actinomycetes*, staurosporin[3] and rebeccamycin[4] according to their anticancer activity[5] and the potent inhibitory activity of protein kinase C.[2]

This paper describes the synthesis of arcyriacyanin A (**1**), a green-blue pigment of the slime mould *Arcyria obvelata* Onsberg (*Arcyria nutans* Grev.). The foregoing review articles[2] introduced a total synthesis of arcyriacyanin A (**1**) by M. Brenner and W. Steglich, as an unpublished work, but it described only a synthetic route, and we find no other paper corresponding to their detailed synthetic pathway and physical data. Compound **1** may be derived biogenetically[1] from arcyriarubin A (**2**) by unsymmetrical coupling reaction between two indole nuclei at C-2 and C-4′. The present synthesis of **1** is achieved by palladium catalyzed cross-coupling reaction with the indolylborate **7** and 4-iodoindole **5b** to give 2,4′-bisindole **8b**, which was transformed to **3** followed by reaction with *N*-magnesioindole **9** prepared from **3** and dibromomaleimide **10**.

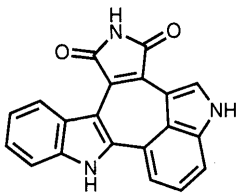
4-Iodoindole **5b** was prepared from 4-nitroindole *via* 4-iodo-1-tosylindole **5a** according to the known method[6] with some modifications. The protecting group of **5b** was selected to be *tert*-butyldimethylsilyl chloride (TBS-chloride) because of its steric effect. Reaction of **5b** with TBS-chloride gave 1-*tert*-butyldimethylsilyl-4-iodoindole **5c** in 85% yield.

Terashima and Ishikura reported[7] the utility of trialkyl-(1-methylindole-2-yl)borate for the synthesis of 2-substituted indoles involving the palladium catalyzed cross-coupling reaction with aromatic halides. Thus, we selected triethyl-(1-methoxyindole-2-yl)borate (**7**)[7b] as a synthon for the construction of **1**.

According to the previous report[7a] on the reaction with **7** and iodobenzene in the presence of a Pd(0) catalyst, the reaction with **7** and **5** afforded the unsymmetrically substituted bisindole **8a**—**c** in yields of 46%, 38%, and 51% respectively (yield of **8b**, **8c** was transformed to **8b** without purification). Deprotection of **8c** was performed by the treatment of tetra-*n*-butylammonium fluoride (TBAF) to afford 2,4′-bisindole derivative **8b** in quantitative yield.

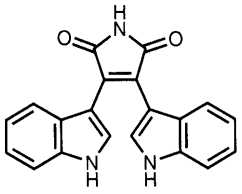
The structure of **8b** was assigned by analyses of the ^{1}H- and ^{13}C-NMR spectra, ^{1}H–^{13}C shift correlation spectroscopy (^{1}H–^{13}C COSY), and ^{1}H–^{13}C long-range coupling in ^{1}H detected heteronuclear multiple bond connectivity (HMBC) experiments.

(i) In the HMBC spectrum, the proton at δ 6.72 (C_3-H) showed long-range correlation with the carbons at δ 134.5 (C-2), 125.61 (C-3a), 121.52 (C-4) and 123.07 (C-4′); the proton at δ 7.52 ($C_{5'}$-H) showed long-range correlation with the carbons at δ 134.5 (C-2) and 112.53 (C-7′); the proton at δ 7.26 ($C_{6'}$-H) showed long-range correlation with the carbons at δ 120.58 (C-5′), 123.07 (C-4′), 137.69 (C-7′a), and 134.50 (C-2); the proton at δ 6.80 ($C_{3'}$-H) showed long-range correlation with the carbons at δ 126.37 (C-2′). (ii) ^{1}H-NMR spectrum of **8b** showed the presence of one NH proton [δ 10.47], three OCH_3 protons [δ 3.68], one indole α proton [δ 7.45 (t, J=2.75 Hz)], and two indole β protons [δ 6.72 (d, J=0.61 Hz), δ 6.80 (dd, J=2.75, 0.91 Hz)]. (iii) The ^{13}C-NMR spectrum showed the pres-



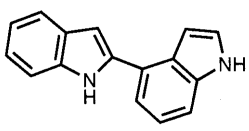
arcyriacyanin

1



arcyriarubin

2



3

Chart 1

* To whom correspondence should be addressed.

© 1998 Pharmaceutical Society of Japan

NII-Electronic Library Service

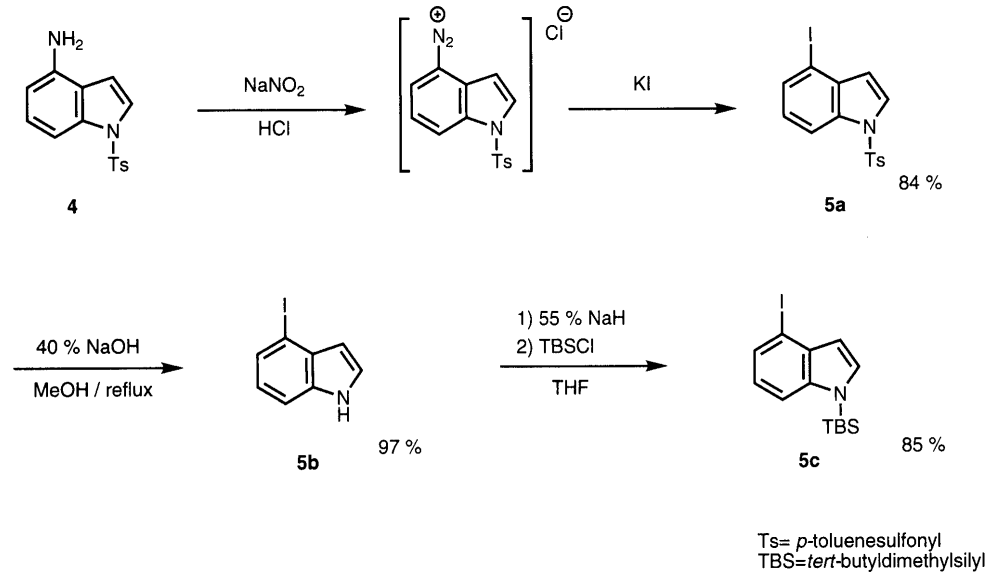


Chart 2

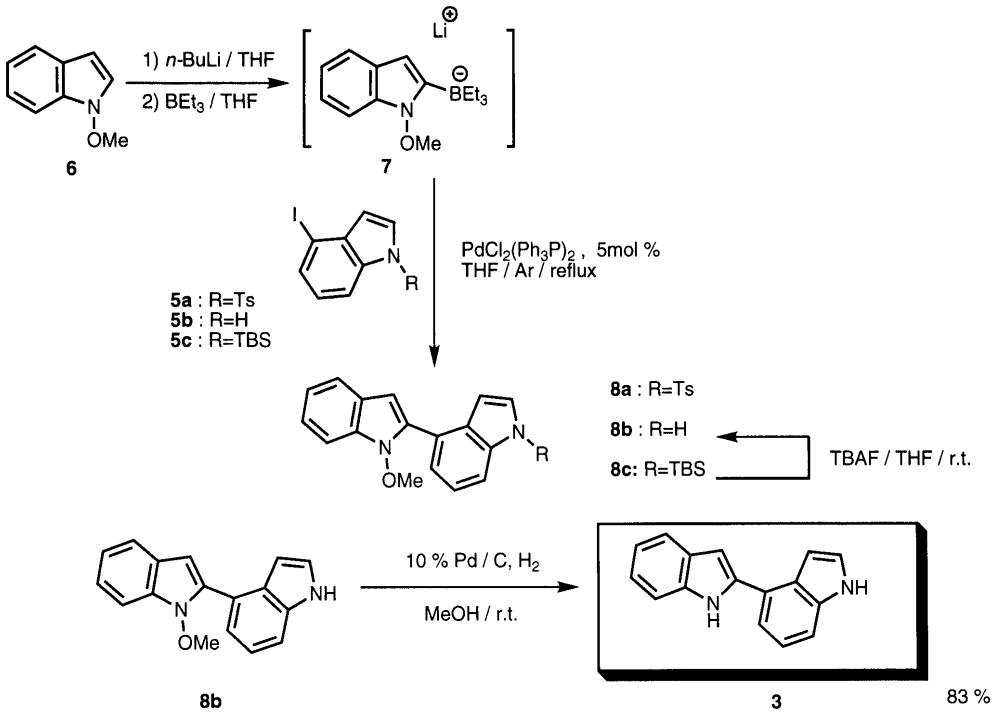


Chart 3

ence of 6 quaternary carbons and 10 tertiary carbons. (iv) The molecular ion peak at m/z 262 (M^+) was observed in the mass spectrum (MS), and the molecular formula was determined by high-resolution MS (HR-MS) to be $C_{17}H_{14}N_2O$. Furthermore, the ^1H–^1H and ^1H–^{13}C COSY data substantiated the structure of **8b**. Consequently, this structure was assigned to be an unsymmetrical 2,4′-bisindole derivative.

Catalytic hydrogenation[8] of **8b** in the presence of 10% Pd/C in MeOH gave 2,4′-bis-1*H*-indole **3**.

The final stage for the synthesis of pigment **1** was carried out by the reaction with *N*-protected dibromomaleimide **10** with the Grignard reagent prepared from bisindole **3** previously developed by Steglich.[2]

The reaction of **3** with 2 eq of methylmagnesium bromide in absolute ether gave the bisindolyl-MgBr **9**. The condensation of **9** with *N*-TBS-2,3-dibromomaleimide **10** in benzene gave *N*-TBA-arcyriacyanin A **11** as green-blue powder in a yield of 16%. Solvent using toluene instead of benzene, however, afforded arcyriacyanin A (**1**) directly as green-blue powder in a yield of 46%.

Removal of the TBS group in product **11** was performed by the treatment with TBAF in tetrahydrofuran (THF) to give **1** in quantitative yield. The structure of **1** was confirmed by comparison with the melting point and UV spectrum data in the literature[1b] and by analyses of its ^1H-NMR, ^{13}C-NMR, IR and HR-MS.

Thus, an unsymmetrical slime mould pigment arcyriacyanin A (**1**) was synthesized in 7 steps from 1-methoxyindole (**6**) in an overall yield of 19.5%.

NII-Electronic Library Service

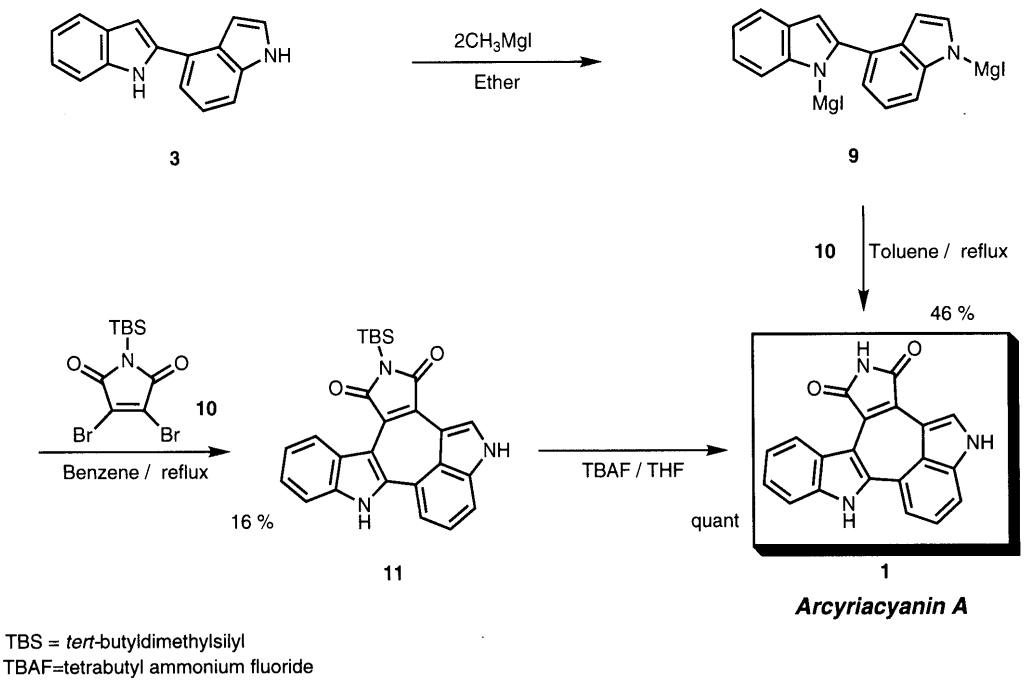


Chart 4

We are currently examining the synthesis of arcyriacyanin A (**1**) using a new methodology mimicking the biosynthesis of the indole pigment in nature.

Experimental

All melting points (mp) were determined on a Yanagimoto micromelting point apparatus and are uncorrected. IR spectra were recorded with a JASCO IR-700 spectrometer, ^{1}H- and ^{13}C-NMR spectra were obtained on JEOL JNM-EX90, JNM-GX270 and JNM-α 500 spectrometers. The chemical shifts are given in ppm (δ) values with tetramethylsilane as an internal standard (acetone-d_6, $CDCl_3$ and dimethyl sulfoxide (DMSO)-d_6 solution). Mass spectra were recorded on JEOL JMS-D300, JMS-HX110 and Shimadzu QP-5000 spectrometers. Ultraviolet (UV) spectra were recorded on Hitachi U-3200 and U-2000 spectrophotometers. Wako silica gel C-200 (200 mesh), and Fuji Silysia silica gel BW-127 ZH were used for column chromatography. Thin-layer chromatography (TLC) used Merck Kieselgel $60F_{254}$, and spots were detected by ultraviolet (UV) illumination and by spraying 1% $Ce(SO_4)_4$ in 10% H_2SO_4 followed by heating. The organic extract was dried over Na_2SO_4. THF was distilled from sodium/benzophenone under a nitrogen atmosphere before use. Commercial aq. titanium(III) chloride (aq. $TiCl_3$ 20%, d=1.5, from Kanto Chemical Co., Inc.) was used.

4-Iodo-1-*p*-toluenesulfonylindole (5a) A solution of $NaNO_2$ (1.52 g, 22 mmol) in H_2O (50 ml) was added to an ice-cooled suspension of **2** (2.87 g, 10 mmol) in H_2O (50 ml) and 10% HCl (50 ml) with stirring, maintaining the temperature below 5 °C . After being stirred for 30 min, the reaction mixture was added to a cold solution of KI (42.7 g) in H_2O (100 ml) with stirring. After 1.5 h, the solution was heated in a water bath (85 °C) for 10 min, then cooled and extracted with AcOEt. The organic layer was washed with brine, dried and concentrated *in vacuo*. The residue was subjected to silica gel column chromatography. The eluate with Et_2O–*n*-hexane (1 : 3, v/v) gave 3.34 g (84%) of **5a** as colorless prisms (Et_2O–*n*-hexane), mp 91.0—92.5 °C [*Rf* 0.79 (Et_2O/*n*-hexane 1 : 2)].

5a: IR (KBr) cm^{-1}: 1592, 1460, 1409, 1367, 1163, 1130, 810, 744, 671, 570. ^{1}H-NMR (acetone-d_6, 270 MHz) δ: 2.36 (3H, s, –Me), 6.67 (1H, d, J=3.66 Hz, H-3), 7.15 (1H, t, J=7.94 Hz, H-6), 7.39 (2H, t, J=8.55 Hz, Ar-H), 7.68 (1H, d, J=8.24 Hz, H-7), 7.87 (1H, d, J=3.66 Hz, H-2), 7.90 (2H, d, J=8.55 Hz, Ar-H), 8.05 (1H, d, J=8.24 Hz, H-5). EI-MS *m/z* (rel. int.%): 397 (M^+, 100), 242 (53), 156 (69). HR-MS Calcd for $C_{15}H_{12}INO_2S$: 396.9632. Found: 396.9646.

4-Iodoindole (5b) A solution of **5a** (3.97 g, 10 mmol) in methanol (150 ml) and 40% aq. NaOH (150 ml) was refluxed for 18 h. The reaction mixture was poured into ice-water and extracted with $CHCl_3$. The organic layer was washed with brine, then dried and concentrated. The residue was recrystallized from *n*-hexane to give **5b** (2.35 g, 97%) as colorless needles, mp 98.5—99.0 °C [*Rf* 0.45 (Et_2O/*n*-hexane 1 : 2)].

5b: IR (KBr) cm^{-1}: 3388, 1608, 1552, 1409, 1329, 1172, 878, 769, 739. ^{1}H-NMR ($CDCl_3$, 270 MHz) δ: 6.35 (1H, ddd, J=3.2, 3.2, 0.8 Hz, H-3), 6.78 (1H, dd, J=8.0, 7.2 Hz, Ar-H), 7.10 (1H, t, J=3.2 Hz, H-2), 7.22 (1H, d, J=8.0 Hz, Ar-H), 7.41 (1H, dd, J=7.2, 0.8 Hz, Ar-H), 8.12 (1H, br s, NH). EI-MS *m/z* (rel. int.%): 243 (M^+, 100), 116 (52). HR-MS Calcd for C_8H_6IN: 242.9544. Found: 242.9541.

1-(*tert*-Butyldimethylsilyl)-4-iodoindole (5c) A solution of **5b** (972 mg, 4 mmol) in THF (20 ml) was slowly added to a suspension of 55% NaH (192 mg, 4.4 mmol) in THF (3 ml) at 0 °C with stirring under a nitrogen atmosphere. After 5 min, a solution of TBS-chloride (906 mg, 6 mmol) in THF (5 ml) was added, and the mixture was stirred for 1 h. The reaction mixture was poured into purified water and extracted with Et_2O. The organic layer was washed with brine, then dried and concentrated. The residue was recrystallized from *n*-hexane to give **5c** (1.21 g, 85%) as colorless needles, mp 72.5—73.5 °C [*Rf* 0.67 (Et_2O/*n*-hexane 1 : 4)].

5c: IR (KBr) cm^{-1}: 2932, 2852, 1464, 1415, 1258, 1156, 984, 840, 782, 736. ^{1}H-NMR ($CDCl_3$, 90 MHz) δ: 0.60 (6H, s, Si-Me_2), 0.92 (9H, s, C-Me_3), 6.55 (1H, dd, J=3.29, 0.88 Hz, H-3), 6.87 (1H, t, J=7.3 Hz, Ar-H), 7.22 (1H, d, J=3.29 Hz, H-2), 7.41—7.55 (2H, m). EI-MS *m/z* (rel. int.%): 357 (M^+, 95), 300 (100), 173 (72). HR-MS Calcd for $C_{14}H_{20}INSi$: 357.0410. Found: 357.0418.

General Procedure for the Cross-Coupling Reaction between Halide 5a, 5b and Triethyl(1-methoxyindol-2-yl)borate (7) A mixture of **6** (90 mg, 0.6 mmol) and *n*-BuLi (1.5 M sol., in THF, 0.72 mmol, 0.5 ml) in THF (10 ml) was stirred at −20 °C for 15 min under argon atmosphere. Triethylboran (1.0 M sol., in *n*-hexane, 0.72 mmol, 0.72 ml) was added at −20 °C and the reaction mixture was stirred for 30 min. Thereafter, $PdCl_2(Ph_3P)_2$ (5 mol%, 21 mg), and a halide (0.9 mmol) in THF (5 ml) was added immediately. The reaction mixture was refluxed for 4 h under argon atmosphere; after cooling, it was treated with 10% NaOH (4 ml) and 30% H_2O_2 aqueous (1 ml) at 0 °C and diluted with AcOEt. The organic layer was washed with brine, then dried and concentrated *in vacuo*.

The residue was purified by silica gel column chromatography with Et_2O–*n*-hexane (1 : 8, v/v) (for iodobenzene), THF–*n*-hexane (1 : 9, v/v) (for **5a**), acetone–*n*-hexane (1 : 6, v/v) (for **5b**).

1-Methoxy-2-(1′-tosylindol-4′-yl)indole (**8a**): The foregoing procedure applied to **6** and **5a** gave 114 mg (46%) of **8a** as colorless needles ($CHCl_3$–*n*-hexane), mp 128—129 °C [*Rf* 0.48 (AcOEt/*n*-hexane 1 : 2)].

8a: IR (KBr) cm^{-1}: 3406, 2926, 1594, 1415, 1370, 1177, 1127, 752. ^{1}H-NMR ($CDCl_3$, 500 MHz) δ: 2.16 (3H, s, –Me), 3.59 (3H, s, –OMe),

NII-Electronic Library Service

6.56 (1H, s, H-3), 6.96 (1H, d, J=3.66 Hz, H-3'), 7.15 (1H, t, J=7.94 Hz, Ar-H), 7.23—7.29 (3H, m), 7.40 (1H, t, J=7.94 Hz, Ar-H), 7.49 (1H, d, J=8.24 Hz, Ar-H), 7.60 (2H, d, J=8.55 Hz, Ar-H), 7.64 (1H, d, J=3.66 Hz, H-2'), 7.81 (2H, d, J=8.55 Hz, Ar-H), 8.03 (1H, d, J=8.24 Hz, Ar-H). ^{13}C-NMR ($CDCl_3$, 125 MHz) δ: 21.5, 64.3, 100.1, 108.87, 108.89, 113.3, 120.7, 120.9, 122.7, 123.6, 123.8, 124.3, 124.5, 126.6, 126.9, 129.2, 129.9, 133.5, 134.6, 135.1, 135.3, 145.0. EI-MS m/z 416 (M^+, 11), 229 (83), 203 (100). HR-MS Calcd for $C_{24}H_{20}N_2O_3S$: 416.1194. Found: 416.1190.

1-Methoxy-2-(1'*H*-indol-4'-yl)indole (**8b**): The foregoing procedure applied to **6** and **5b** gave 100 mg (38%) of **8b** as colorless needles ($CHCl_3$–*n*-hexane), mp 154—156 °C [*Rf* 0.30 (acetone/*n*-hexane 1 : 4)]. **8b**: IR (KBr) cm^{-1}: 3386, 1448, 1336, 750, 725. ^{1}H-NMR (acetone-d_6, 500 MHz) δ: 3.68 (3H, s, –OMe), 6.72 (1H, d, J=0.61 Hz, H-3), 6.80 (1H, dd, J=2.75, 0.91 Hz, H-3'), 7.12 (1H, td, J=7.94, 0.92 Hz, H-5), 7.23—7.27 (2H, m, H-6, 6'), 7.45 (1H, t, J=2.75 Hz, H-2'), 7.46—7.61 (3H, m, H-5', H-7, 7'), 7.62 (1H, d, J=7.94 Hz, H-4), 10.47 (1H, br, NH). ^{13}C-NMR (acetone-d_6, 125 MHz) δ: 64.5 (–OMe), 100.3 (C-3), 102.5 (C-3'), 109.5 (C-7), 112.5 (C-7'), 120.6 (C-5'), 121.3 (C-5), 121.5 (C-4), 122.1 (C-6'), 123.05 (C-6), 123.07 (C-4'), 125.6 (C-3a), 126.4 (C-2'), 127.5 (C-3a'), 134.5 (C-2), 137.2 (C-7a), 137.7 (C-7a'). EI-MS m/z 263 (M^++1, 9), 262 (M^+, 47), 231 (100), 204 (45) 115 (52). HR-MS Calcd for $C_{17}H_{14}N_2O$: 262.1102. Found: 262.1075.

1-Methoxy-2-(1'*H*-indol-4'-yl)indole (8b) The foregoing procedure applied to **6** and **5c** gave **8c** which was used for the next reaction without further purification. A solution of solid residue in THF (10 ml) was added to a solution of TBAF (1.0 M sol., in THF, 2 ml), and the whole was stirred at room temperature for 2 h. The reaction mixture was poured into ice-water and sat. NH_4Cl solution was added. The mixture was then extracted with AcOEt; the organic layer was washed with brine, dried and concentrated. The residue was recrystallized from $CHCl_3$–*n*-hexane to give **8b** (135 mg, 51%) as colorless needles, mp 154—156 °C [*Rf* 0.30 (acetone/*n*-hexane 1 : 4)].

2,4'-Bis-1*H*-indole (3) A mixture of **8b** (150 mg, 0.57 mmol) and 10% palladium on carbon (70 mg) in methanol (50 ml) was vigorously stirred for 2 h under a hydrogen atmosphere. The catalyst was filtered off, and the filtrate was evaporated to give a crude oil, which was purified by recrystallization from $CHCl_3$–*n*-hexane to give **3** (110 mg, 83%) as colorless needles, 199—202 °C [*Rf* 0.34 (acetone/*n*-hexane 1 : 2)].

3: IR (KBr) cm^{+1}: 3376, 1430, 1342, 770, 738. ^{1}H-NMR (acetone-d_6, 500 MHz) δ: 6.98 (1H, dd J=2.31, 0.61 Hz, H-3), 6.80 (1H, td, J=2.13, 0.91 Hz, H-3'), 7.12 (1H, dd, J=7.94, 8.24 Hz, H-5), 7.21 (1H, dd, J=8.24, 1.22 Hz, H-6), 7.45—7.49 (4H, m), 7.61 (1H, d, J=7.94 Hz, H-4), 10.48 (1H, br, NH), 10.56 (1H, br, NH) . ^{13}C-NMR (acetone-d_6, 125 MHz) δ: 101.6, 102.2, 111.9, 112.0, 118.3, 120.2, 120.9, 122.2, 122.3, 125.8, 126.2, 126.4, 130.4, 137.9, 139.3. EI-MS m/z 232 (M^+, 100), 231 (39), 115 (51). HR-MS Calcd for $C_{16}H_{12}N_2$: 232.1014. Found: 232.0979.

1-(*tert*-Butyldimethylsilyl)-3,4-dibromo-2,5-dihydro-1*H*-pyrrol-2,5-dione (10) A solution of 3,4-dibromomaleimide (5.5 g, 21.6 mmol) in THF (150 ml) was slowly added to a suspension of 55% NaH (1.056 g, 22 mmol) in THF (30 ml) at 0 °C with stirring under a nitrogen atmosphere. After 15 min, a solution of TBS-chloride (3.262 g, 21.6 mmol) in THF (10 ml) was added, and the mixture was stirred for 1 h. The solvent was removed *in vacuo*, followed by the addition of $CHCl_3$ (100 ml). The $CHCl_3$ layer was filtered off, and then filtrate was evaporated under reduced pressure, affording a yellow solid residue, which was purified by recrystallization from petroleum ether to give **10** (4.82 g, 61%), mp 120—122 °C.

10: IR (KBr) cm^{-1}: 1792, 1334, 1090. ^{13}C-NMR ($CDCl_3$, 22.5 MHz) δ: −4.6 (Si–Me_2), 18.9 (C–Me_3), 26.1 (C–Me_3), 131.6 (C–Br×2), 168.7 (C=O×2). CI-MS m/z (rel. int.%): 370 (M^++1, 100), 368 (67).

***N*-(*tert*-Butyldimethylsilyl)arcyriacyanin A (11)** A solution of 2,4'-Bis-1*H*-indole (**3**) (100 mg, 0.43 mmol) in dry benzene (15 ml) was added to a solution of methylmagnesium iodide [from iodomethane (185 mg, 1.3 mmol) and magnesium turnings (42 mg, 1.3 mmol)] at room temperature over 30 min. The mixture was warmed to 45 °C and stirred for 30 min, then cooled to room temperature. A solution of **10** (318 mg, 0.86 mmol) in dry benzene (20 ml) was added dropwise to the mixture at this temperature over 30 min. The mixture was refluxed for 6 h, decomposed with sat. aq. NH_4Cl and extracted with AcOEt. The organic layer was washed with brine, dried and concentrated *in vacuo*. The residue was subjected to silica gel column chromatography. The eluate with Et_2O–*n*-hexane (1 : 2, v/v) gave 25 mg (16%) of **11** as green-blue powder ($CHCl_3$–*n*-hexane), mp >300 °C [*Rf* 0.46 (Et_2O/benzene 4 : 1)].

11: IR (KBr) cm^{-1}: 3338, 1752, 1682, 1520, 1440, 1338, 1215, 749. ^{1}H-NMR (acetone-d_6, 500 MHz) δ: 0.53 (6H, s, Si–Me_2), 1.04 (9H, s, C–Me_3), 6.96 (1H, dd, J=7.94 , 8.24 Hz, H-6'), 7.02 (1H, td, J=7.63, 1.22 Hz, H-5), 7.08—7.13 (3H, m, H-5', 6, 7'), 7.32 (1H, d, J=7.94 Hz, H-7), 7.98 (1H, d, J=2.75 Hz, H-2), 8.36 (1H, d, J=8.24 Hz, H-4), 10.72 (1H, br s, NH) , 10.93 (1H, br s, NH). ^{13}C-NMR (acetone-d_6, 125 MHz) δ: −3.97, 19.6, 26.9, 108.5, 111.8, 111.9, 114.5, 121.7, 124.0, 124.2, 125.0, 125.7, 128.1, 128.4, 130.6, 131.7, 132.9, 138.3, 138.9, 139.8, 175.9, 176.7. EI-MS m/z (rel. int.%): 439 (M^+, 75), 382 (34), 280 (100). HR-MS Calcd for $C_{26}H_{25}N_3O_2Si$: 439.1702, Found: 439.1716.

Arcyriacyanin A (1) *via* 9 A solution of 2,4'-bis-1*H*-indole (**3**) (50 mg, 0.22 mmol) in THF (15 ml) was added to a solution of methylmagnesium iodide [from iodomethane (93 mg, 0.6 mmol) and magnesium turnings (21 mg, 0.6 mmol)] at room temperature over 30 min. The mixture was warmed to 45 °C and stirred for 30 min, then cooled to room temperature. A solution of **10** (301 mg, 0.815 mmol) in dry toluene (20 ml) was added dropwise to the mixture at this temperature over 30 min. The mixture was refluxed for 6 h, and decomposed with sat. aq. NH_4Cl. The reaction mixture was extracted with AcOEt. The organic layer was washed with brine, dried and concentrated *in vacuo*. The residue was subjected to silica gel column chromatography. The eluate with Et_2O–*n*-hexane (2 : 1, v/v) gave 32 mg (46%) of **1** as green-blue powder ($CHCl_3$–*n*-hexane), mp >300 °C [*Rf* 0.48 (Et_2O/*n*-hexane 4 : 1)]. IR (KBr) cm^{-1}: 3402, 3216, 1745, 1689, 1610, 1512, 1445, 1348, 1331, 732. ^{1}H-NMR (acetone-d_6, 500 MHz) δ: 6.95 (1H, dd, J=7.94 , 8.24 Hz, H-6'), 7.02 (1H, td, J=7.63, 1.22 Hz H-5), 7.08—7.11 (3H, m, H-5', 6, 7'), 7.31 (1H, d, J=7.94 Hz, H-7), 7.96 (1H, d, J=2.74 Hz, H-2), 8.47 (1H, d, J=8.55 Hz, H-4), 9.56 (1H, br s, NH), 10.71 (1H, br s, NH) , 10.94 (1H, br s, NH). ^{13}C-NMR (acetone-d_6, 125 MHz) δ: 108.56, 111.86, 112.05, 112.87, 114.42, 121.78, 123.80, 123.96, 125.07, 125.71, 128.07, 128.47, 131.61, 131.76, 138.38, 138.81, 139.81, 171.59, 172.52. EI-MS m/z (rel. int.%): 326 (M^++1, 26), 325 (M^+, 100), 324 (15), 254 (17), 253 (12). HR-MS Calcd for $C_{20}H_{11}N_3O_2$: 325.0851, Found: 325.0832. UV λ_{max} (MeOH) nm (log ε): 224 (4.06), 243 (4.11), 264 (sh, 3.83), 360 (3.70), 625 (2.49).

Arcyriacyanin A (1) from 11 A solution of **11** (3 mg, 0.032 mmol) in THF (10 ml) was added to a solution of TBAF (1.0 M sol., 0.05 ml), and the whole was stirred at room temperature for 2 h. The reaction mixture was poured into ice-water and sat.NH_4Cl solution was added. The mixture was extracted with AcOEt. The organic layer was washed with brine, then dried and concentrated. The residue was recrystallized from acetone–*n*-hexane to give **1** (1.45 mg, quant).

References

1) *a*) Bergman J., "Studies in Natural Products Chemistry," Vol. 1, Elsevier Science Publishers, New York, 1988, pp. 3—30 and references cited therein.; *b*) Gill M., Steglich W., *Progress in the Chemistry of Organic Natural Products*, **51**, 216—226 (1987); *c*) Steglich W., *Pure & Appl. Chem.*, **61**, 281—288 (1989).
2) Gribble G., Berthel S., "Studies in Natural Products Chemistry," Vol. 12, Elsevier Science Publishers, New York, 1993, pp. 365—409 and references cited therein.
3) *a*) Ômura S., Iwai Y., Hirano A., Nakagawa A., Awaya J., Tsuchiya H., Takahashi Y., Masuma R., *J. Antibiot.*, **30**, 275—282 (1977); *b*) Furusaki A., Hashiba N., Matsumoto T., *J. Chem. Soc., Chem. Commun.*, **1978**, 800—801; *c*) Furusaki A., Hashiba N., Matsumoto T., Hirano A., Iwai Y., Ômura S., *Bull. Chem. Soc. Jpn.*, **55**, 3681—3685 (1982).
4) Nettleton D. E., Doyle T. W., Krishnan B., Matsumoto G. K., Clardy J., *Tetrahedron Lett.*, **26**, 4011—4014 (1985).
5) Yamashita Y., Fujii N., Murakata C., Ashizawa T., Okabe M., Nakano H., *Biochemistry*, **31**, 12069—12075 (1992).
6) Somei M., Tsuchiya M., *Chem. Pharm Bull.*, **29**, 3145—3157 (1981).
7) *a*) Ishikura M., Terashima M., *J. Chem. Soc., Chem. Commun.*, **1989**, 135—136; *b*) Ishikura M., Agata I., *Heterocycles*, **41**, 2437—2440 (1995).
8) Kawasaki T., Kodama A., Nishida T., Shimizu K., Somei M., *Heterocycles*, **32**, 221—227 (1991).

NII-Electronic Library Service