2.5 cm; 230-400 mesh) with 95:5 chloroform-methanol as the eluant. The fractions containing the product [TLC (solvent E) R_f 0.42-0.44] were pooled and concentrated to a solid residue. The residue was recrystallized from chloroform-diethyl ether to give a white solid: 0.17 g (55%); mp 89-91 °C; $[\alpha]^{25}_d$ -57.7° (c 1, MeOH); TLC (solvent E) R_f 0.42 (ninhydrin negative). Anal. ($C_{52}H_{74}N_{10}O_{16}S_2$) C, H, N.

Bis[[[[*N*-[(benzyloxy)carbonyl]-D-seryl]-*N*-methyl-L-alanyl]-L-cysteinyl]-L-valine] Serine Hydroxyl Dilactone Disulfide (13). To a stirred solution of **12** (0.28 g, 0.24 mmol) in methanol (70 mL) was added dropwise a solution of iodine (0.6 g, 4.8 mmol) in methanol (110 mL) in 2 h. The solution was stirred for an additional 4 h and cooled in an ice bath, and 1 N aqueous sodium thiosulfate was added dropwise until the solution became colorless. The reaction mixture was concentrated, and the residue was triturated well with water. The resulting solid was filtered, and the residue was washed with several portions of water and dried in vacuo over P_2O_5. The product was purified on a short column of silica gel (230-400 mesh) with chloroform and chloroform-methanol (97:3 v/v) as the eluant. The fractions containing product [TLC (solvent E) R_f 0.65] were pooled and concentrated to a solid residue. The solid was recrystallized from chloroform-diethyl ether to give a white solid: yield 0.21 g (87.5%); mp 251-253 °C dec; TLC (solvent E) R_f 0.65; NMR ($CDCl_3$, 360 MHz) δ 0.9 (t, 12 H, Val methyl), 1.65 (d, 6 H, Ala methyl), 2.12-2.25 (m, 2 H, Val methine), 2.60-2.65 (m, 2 H, Cys β-methylene), 2.75-2.89 (m, 2 H, Cys β-methylene), 3.2 (s, 3 H, *N*-methyl on Ala), 3.23 (s, 3 H, *N*-methyl on Ala), 3.80 (m, 2 H, α-hydrogen), 4.58 (m, 2 H, Ser β-methylene), 5.85 (t, 2 H, Ser β-methylene), 5.98 (m, 2 H, α-hydrogen), 5.07 (s, 2 H, benzyl), 5.08 (s, 2 H, benzyl), 5.15 (m, 2 H, α-hydrogen), 5.26 (m, 2 H, α-H), 7.35 (s, 10 H, benzyl aromatic), 7.70 (d, 1 H, NH), 7.80 (s, 1 H, NH), 7.95 (d, 2 H, NH), 8.30 (d, 2 H, NH). Anal. ($C_{46}H_{62}N_8O_{14}S_2$) C, H, N.

[MeAla²,MeAla⁶]-Des-*N*-tetramethyltriostin A (3). A solution of **13** (0.11 g, 0.1 mmol) in 32% hydrogen bromide in glacial acetic acid (4 mL) was stirred for 45 min at room temperature. Anhydrous diethyl ether was added, and the precipitated solid was kept in a refrigerator overnight. The solid was filtered in a stream of N_2 and washed well with anhydrous diethyl ether and dried in vacuo over P_2O_5. The solid was recrystallized from methanol-diethyl ether: yield 0.085 g (97.7%); mp 272-276 °C dec.

An ice-cold stirred solution of the above solid (0.085 g, 0.09 mmol) in dry DMF (4 mL) was treated with triethylamine (0.022 g, 0.22 mmol), and the reaction mixture was stirred for 10 min. Another aliquot of triethylamine (0.022 g, 0.22 mmol) was added followed by the dropwise addition of quinoxalyl chloride (0.045 g, 0.23 mmol) in DMF (4 mL). The reaction mixture was stirred at 0 °C for 30 min and at room temperature for 22 h and then treated on a water bath at 50 °C for 2 h. The reaction mixture was concentrated, and the residue was triturated well with ether and filtered. The solid was washed successively with saturated sodium bicarbonate solution, water, ether, and dried in vacuo over P_2O_5. The straw-colored solid was purified by chromatography on a 2 × 25 cm column of silica gel (230-400 mesh) with chloroform-methanol (97:3) as the eluant. The fractions containing the product [TLC (solvent E) R_f 0.62] were pooled and concentrated to a solid residue. After crystallization from chloroform-diethyl ether and drying in vacuo, 0.06 g (61%) of a white solid was obtained: mp 225-228 °C; $[\alpha]^{25}_D$ -3.5° (c 1, $CHCl_3$); TLC (solvent E) R_f 0.62; quinoxaline ($CDCl_3$, 360 MHz) δ 0.96 (t, 12 H, Val methyl), 1.70 (d, 6 H, Ala methyl), 2.14 (m, 2 H, Val methine), 2.80 (s, 6 H, *N*-methyl on Ala), 2.91-3.07 (m, 4 H, Cys β-methylene), 4.09 (m, 2 H, α-hydrogen), 4.72 (m, 2 H, Ser β-methylene), 5.06 (t, 2 H, Ser β-methylene), 5.52 (d, 2 H, α-hydrogen), 5.72 (m, 4 H, α-hydrogen), 7.01 (d, 2 H, NH), 7.92 (m, 4 H, quinoxaline 6-H and 7-H), 8.14 (d, 2 H, quinoxaline), 8.23 (d, 2 H, quinoxaline), 8.38 (d, 2 H, NH), 8.50 (d, 2 H, NH), 9.68 (s, 2 H, qui noxaline 3-H). Anal. ($C_{48}H_{58}N_{12}O_{12}S_2 \cdot H_2O$) C, H, N.

Acknowledgment. Appreciation is expressed to the National Institutes of Health (National Institute of Allergy and Infectious Diseases, Grant No. AI 15759) for support of this research. Acknowledgement is also given to the Colorado State University Regional NMR Center, funded by National Science Foundation Grant No. CHE 78-18581, for providing the 360-MHz spectral data and to Professor G. G. Smith of this department for assistance in obtaining the amino acid racemization analyses.

Registry No. 3, 78186-11-5; **4**, 21691-41-8; **5**, 78166-90-2; **5**·HBr, 78166-91-3; **6**, 78166-92-4; **7**, 78166-93-5; **8**, 78166-94-6; **9**, 78166-95-7; **10**, 78186-12-6; **11**, 78166-96-8; **12**, 78186-13-7; **13**, 78186-14-8; *N*-[(benzyloxy)carbonyl]-D-serine 2,4-dinitrophenyl ester, 5249-65-0; *N*-[(*tert*-butyloxy)carbonyl]-L-valine, 13734-41-3; *N*-[(*tert*-butyloxy)carbonyl]-*S*-(acetamidomethyl)-L-cysteine, 19746-37-3.

Marine Alkaloids. 3.[1] Bromo-Substituted Alkaloids from the Marine Bryozoan *Flustra foliacea*, Flustramine C and Flustraminol A and B

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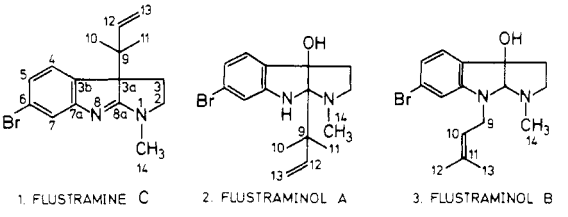
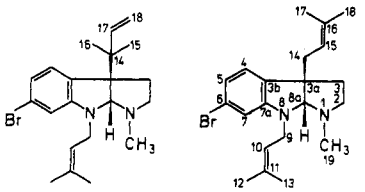
Three new bromo-substituted alkaloids, flustramine C and flustraminol A and B, have been isolated from the marine bryozoan *Flustra foliacea* (L.). The structures have been elucidated by using spectroscopic methods.

In continuation of a study of brominated alkaloids from the marine bryozoan *Flustra foliacea* (L.),[1] we report the isolation and structure elucidation of three new alkaloids, flustramine C (**1**), flustraminol A (**2**), and flustraminol B (**3**). These structures seem, at least formally, closely related to flustramine A (**4**) and flustramine B (**5**). Like flustramine A (**4**) and B (**5**), the structures encompass the basic 6-bromo-substituted physostigmine skeleton; however, in contrast to **4** and **5** they only have one isoprene



(1) J. S. Carlé and C. Christophersen, *J. Am. Chem. Soc.*, **101**, 4012 (1979).

0022-3263/81/1946-3440$01.25/0



4. FLUSTRAMINE A 5. FLUSTRAMINE B

substituent. In the case of **1** and **2** this substituent is the rarely encountered inverted γ,γ-dimethylallyl (2-methyl-3-buten-2-yl) and in **3** the normal γ,γ-dimethylallyl (3-methyl-2-butenyl) substituent. Structures **1–3** all represent a 2-equiv-higher oxidation state than **4** or **5**.

Isolation and Structure Elucidation

A pentane fraction was prepared from the ether-soluble material obtained from dried animals. The basic metabolites were secured by acid (1 N HCl) extraction followed by ether extraction of the neutralized acid fraction. Repeated silica gel column chromatography of this material resulted in pure flustramine C (**1**; 8 mg, 3 ppm, based on animal dry weight). Analogous column chromatographic methods (see Experimental Section) gave pure flustraminol A (**2**; 16 mg, 6 ppm, based on animal dry weight) and flustraminol B (**3**; 2 mg, 0.8 ppm). From high-resolution mass spectroscopic data the elemental composition was determined as follows: **1**, $C_{16}H_{19}BrN_2$ (calcd m/e 318.073, found 318.073); **2**, $C_{16}H_{21}BrN_2O$ (calcd m/e 336.084, found 336.083); **3**, $C_{16}H_{21}BrN_2O$ (calcd m/e 336.084, found 336.087).

Flustramine C was assigned structure **1** [1-methyl-3a-(2-methyl-3-buten-2-yl)-6-bromo-1,2,3,3a-tetrahydropyrrolo[2,3*b*]indole] on the basis of the following data. The presence of the indole subunit was inferred from the fragment ions at m/e 210/208 (6%), representing the brominated analogue of the methylene indole ion,[2] highly characteristic of indole alkaloids. Loss of ^{79}Br and ^{81}Br from the fragment ions m/e 251/249 (100%) generates m/e 170 (49%; metastable ions at m/e 115.1 and 116.1). Presumably m/e 129 (16%) results from m/e 210/208 by a similar reaction. The base peak m/e 251/249 indicated loss of m/e 69, viz., an isoprene unit from the molecular ion. The isoprene substituent must, according to ^1H NMR data (see Table I), be an inverted γ,γ-dimethylallyl system. To demonstrate that this group is situated at C-3a and not at the alternative site N-8, we carried out a series of ^1H–[^1H] NOE difference experiments.[3]

Figure 1a shows the low-field part of the ^1H NMR spectrum of flustramine C. The number above the peaks refers to the carbon atom to which the resonating protons are attached. Signals 4, 5, and 7 are due to the aromatic protons, reflecting only the meta (J = 1.3 Hz) coupling. The single proton at C-12 and the two protons at C-13 are the ABX pattern of the inverse isoprene unit. Figure 1b shows the low-field part of the ^1H–[^1H] nuclear Overhauser enhancement difference spectrum of flustramine C. The resonances here are due to the enhancements only, in this case built up by a sequence of alternate irradiation of the two methyl groups at C-9, resonating at δ 0.99 and 0.88, respectively. The observed enhancements are 6.0% for the proton attached to C-12 and 9.0% for *one* of the protons at C-13 (the proton situated closest the two methyl groups, i.e., the proton which is trans to the C-12 proton). In the aromatic region, observation of 9.6% enhancement of the C-4 (C-5) proton(s) *and* no detectable enhancement of the

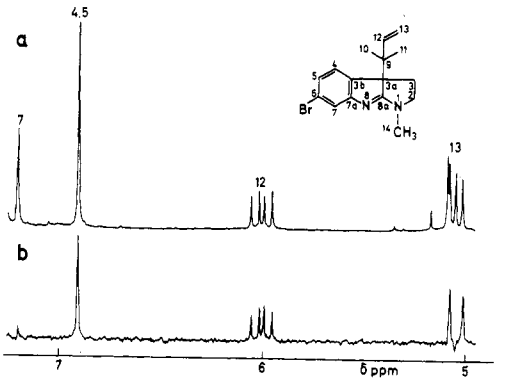
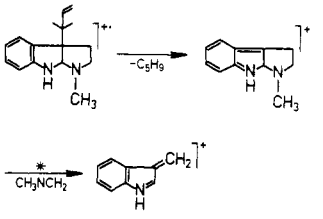


Figure 1. (a) Low-field part of the 270-MHz FT ^1H NMR spectrum of flustramine C ($CDCl_3$, relative to Me_4Si). The number above the peaks refers to the carbon atom to which the resonating protons are attached. (b) ^1H–[^1H] nuclear Overhauser enhancement difference spectrum of the same part of the molecule. The spectrum was built up by a sequence of alternate irradiations of the two methyl groups at C-9 (0.99 and 0.88 ppm, respectively).

proton at C-7 unequivocally place the γ,γ-dimethylallyl group at C-3a.

The presence of an *N*-methyl group was inferred from the ^1H NMR singlet appearing at δ 3.00. This chemical shift value of the *N*-methyl group does not distinguish between the two isomeric possibilities, the one depicted as **1** or the alternative *N*(8)-methyl 1,8a-unsaturated isomer. The *N*-methyl group of 1,3,3-trimethyl-2-(butylimino)indole, for example, has been noted to appear at δ 3.13.[4] The base peak in the mass spectrum of flustramine C, m/e 251/249, is believed to be the dehydro analogue of the base peak in flustramine A and B.[2] The appearance of these ions not only places the bromine atom in the indoline part of the molecule but also locates the *N*-methyl group at N-1.[1,2]

Reduction of flustramine C with lithium aluminium hydride gave, according to ^1H and ^{13}C NMR analyses, debromo-8,8a-dihydroflustramine C. The mass spectrum of the latter compound further substantiates the structural assignment of flustramine C. Base peak m/e 173 represents the debromo analogue to the ions responsible for the base peaks of flustramine A and B. The well-known cyclic collapse of m/e 173 to m/e 130 is supported by a metastable ion. The latter fragment (m/e 130 (44%)) and absence of m/e 144 clearly lends further support to the assignment of the *N*-methyl group to position 1.



Further, in the ^1H–[^1H] nuclear Overhauser enhancement difference spectrum, irradiation of the methyl group at δ 3.00 produced no detectable enhancement (i.e., NOE <0.5%) of the aromatic signals. This result is expected for N-1 substitution while N-8 substitution in analogy with the effect observed in flustramine A and B would be expected to give rise to a substantial enhancement of neighboring H-7. (Irradiation of the C-9 protons of flustramine A and B gave, in both cases, an enhancement of 11% from the C-7 proton.)[2] When these structural features and the information gathered from the investigations

(2) J. S. Carlé and C. Christophersen, *J. Org. Chem.*, **45**, 1586 (1980).
(3) The scope and limitations of the ^1H–[^1H] NOE difference technique are described in ref 2 and references cited herein.
(4) T. Hino, M. Nakagawa, T. Hashizume, N. Yamaji, Y. Miwa, K. Tsuneoka, and S. Akaboshi, *Tetrahedron*, **27**, 775 (1971).

Table I. NMR Data[a] of Flustramine C, Flustraminol A, and Flustraminol B

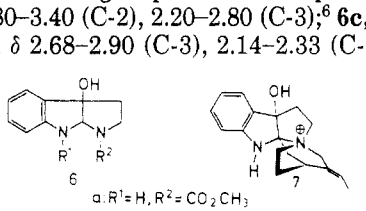
carbon/proton(s) at position	^{13}C NMR, [b] δ			^{1}H NMR, [c] δ		
	flustramine C	flustraminol A	flustraminol B	flustramine C	flustraminol A	flustraminol B
2	59.7 (t)	53.7 (t)	53.1	3.92 (1 H, m), 3.34 (1 H, m)	3.01 (1 H, m), 2.2 (1 H, m)	2.81 (1 H, m), 2.67 (1 H, m)
3	27.9 (t)	38.2 (t)	40.0*	2.33 (1 H, m), 2.04 (1 H, m)	2.2 (2 H, m)	2.30 (1 H, m), 2.16 (1 H, m)
3a	65.7 (s)	89.4° (s)				
3b	137.6 (s)	131.2 (s)				
4	124.3$^{\Delta}$ (d)	124.9$^{\Delta}$ (d)	124.6$^{\Delta}$	6.90 (1 H, d)	7.00 (1 H, d)	7.10 (1 H, d)
5	121.9$^{\Delta}$ (d)	121.2$^{\Delta}$ (d)	119.8$^{\Delta}$	6.90 (1 H, d)	6.80 (1 H, dd)	6.85 (1 H, dd)
6	122.2 (s)	123.5 (s)	123.8			
7	119.1 (d)	111.1 (d)	111.5	7.20 (1 H, t)	6.72 (1 H, d)	6.64 (1 H, d)
7a	163.6 (s)	150.5 (s)				
8						
8a	188.2 (s)	90.5° (s)	95.6			4.38 (1 H, s)
9	42.9 (s)	45.0 (s)	46.6			3.87 (2 H, d)
10	22.8° (q)	22.2† (q)	121.0	0.99 (3 H, s)*	1.19 (3 H, s)*	5.18 (1 H, t)
11	21.6° (q)	24.8† (q)		0.88 (3 H, s)*	1.30 (3 H, s)*	
12	144.4 (d)	146.3 (d)	25.7‡	6.00 (1 H, m)	6.26 (1 H, m)	1.73 (6 H, s)
13	113.6 (t)	112.9 (t)	18.2‡	5.04 (2 H, m)	5.08 (2 H, m)	1.73
14	33.1 (q)	38.5 (q)	38.6*	3.00 (3 H, s)	2.30 (3 H, s)	2.55 (3 H, s)

[a] Assignments for values marked with the same symbols may be interchanged. [b] Spectra measured at 67.89 MHz in $CDCl_3$ with concentrations of 16, 32, and 4.0 mg mL^{-1} for flustramine C, flustraminol A, and flustraminol B, respectively. Chemical shifts are given in parts per million relative to internal Me_4Si. [c] Spectra measured at 270 MHz in $CDCl_3$ with concentrations as in ^{13}C NMR spectra. Chemical shifts are given in parts per million relative to internal Me_4Si. The ^{13}C signal multiplicities as obtained from the off-resonance decoupled spectra are shown in parentheses (s = singlet, d = doublet, t = triplet, q = quartet).

of flustramine A and B[1] (particularly ^{13}C NMR data; compare Table I) are taken into account, only one structure is left for flustramine C, namely, the one depicted as **1**.

To guarantee the physical possibility of the assignments of the spin–spin pattern of the methylene protons in positions 2 (named A and B) and 3 (C and D) in flustramine C, we undertook a computer-assisted simulation.[5] The simulated pattern was superimposable on the one derived from **1** with the following coupling constant values (±0.2 Hz): J_{AB} = −10.0, J_{AC} = 6.2, J_{AD} = 8.5, J_{BC} = 1.0, J_{BD} = 10.0, and J_{CD} = 13.0 Hz, all within accepted limits.

The nature of the oxygen functions in flustraminol A (**2**) and B (**3**) revealed itself as hydroxy groups on exchange with D_2O. The isoprene substituents were identified as an inverted γ,γ-dimethylallyl group in **2** and a γ,γ-dimethylallyl group in **3** (see Table I). Signals at δ 2.30 and 2.55 established the presence of *N*-methyl groups in **2** and **3**, respectively. Chemical shifts of the protons at C-2 and C-3 are within the range reported for comparable systems, e.g.: **6b**, δ 2.80–3.40 (C-2), 2.20–2.80 (C-3);[6] **6c**, δ 2.10–2.90 (C_2–C_3);[7] **6d**, δ 2.68–2.90 (C-3), 2.14–2.33 (C-3).[8]



a: R^1 = H, R^2 = CO_2CH_3
b: R^1 = R^2 = H
c: R^1 = H, R^2 = CH_3
d: R^1 = R^2 = CH_3

In flustraminol A (**2**) two ^{13}C signals at δ 90.5 and 89.4 were shown, by off-resonance techniques, to originate from quaternary carbons, thus defining these as C-3a bearing the hydroxyl group and C-8a carrying the isoprene substituent. This assignment was further supported by the absence of the characteristic signal from the proton at C-8a in the ^{1}H NMR spectrum. On the basis of these observations and comparison with available data for this type of structure, we assign the structure of 1-methyl-3a-hydroxy-6-bromo-8a-(2-methyl-3-buten-2-yl)-1,2,3,3a,8,8a-hexahydropyrrolo[2,3-*b*]indole (**2**) for flustraminol A.

The small amount of flustraminol B (**3**, 2 mg) available did not permit the location of signals originating from quaternary carbons in the ^{13}C NMR spectrum. Neither did this amount suffice for off-resonance experiments to be performed. In spite of this lack of data, inspection of the NMR information (Table I) leaves little doubt that flustraminol B must be formally derived from flustramine A or B by exchange of a 3a-isoprene substituent with a hydroxy group; i.e., flustraminol B has the structure of 1-methyl-3a-hydroxy-6-bromo-8-(3-methyl-2-butenyl)-1,2,3,3a,8,8a-hexahydropyrrolo[2,3-*b*]indole (**3**). The chemical shift of H-8a compares favorably with values reported for H-8a in **6c** (δ 4.38)[7] and **6d** (δ 4.25).[8]

The structural assignment of flustraminol A (**2**) and B (**3**) was further substantiated by additional evidence from UV absorption data. The absorption bands of both compounds underwent the expected hypsochromic shifts of ~10 nm on acidification.[1] The positions of the absorption bands at 256 and 318 nm for flustraminol A and at 256 and 310 nm for flustraminol B compare favorably with reported values for the 3a-hydroxy-substituted 1,2,3,3a,8,8a-hexahydropyrrolo[2,3-*b*]indole chromophore as exemplified with the following: **6a**, 242 and 298 nm;[6] **6b**, 243.5 and 301.5 nm;[6] **6c**, 243 and 302 nm;[7] **6d**, 250 and 303 nm.[8] Furthermore, the skeleton of hunteracine (**7**),[9] exhibiting absorption bands at 234 and 289 nm, is structurally identical with the protonated form of flustraminol A (**2**)

(5) O. H. Manscher, J. P. Jacobsen, and K. Schaumburg, "Mimer", Quantum Chemistry Program Exchange, Bloomington, IN, Program No. 394.

(6) M. Nakagawa, H. Okajima, and T. Hino, *J. Am. Chem. Soc.*, *98*, 635 (1976); M. Nakagawa, H. Okajima, and T. Hino, *ibid.*, **99**, 4424 (1977).

(7) M. Nakagawa, T. Kaneko, K. Yoshikawa, and T. Hino, *J. Am. Chem. Soc.*, **96**, 624 (1974); M. Nakagawa, K. Yoshikawa, and T. Hino, *ibid.*, **97**, 6496 (1975).

(8) M. Nakagawa, T. Kaneko, H. Yamaguchi, T. Kawashima, and T. Hino, *Tetrahedron*, **30**, 2591 (1974); M. Nakagawa, T. Kaneko, and H. Yamaguchi, *J. Chem. Soc., Chem. Commun.*, 603 (1972).

(9) R. H. Burnell, A. Chapelle, and M. F. Khalil, *Can. J. Chem.*, **52**, 2327 (1974).

absorbing at 246 and 306 nm.

Experimental Section

Mass spectra were recorded at 70 eV on a VG MM 7070F instrument; precise mass measurements were obtained by the peak-matching method. UV spectra were recorded on a Unicam SP 18 instrument and IR spectra on a Perkin-Elmer 580 spectrometer. ^{13}C NMR spectra were recorded at 67.889 MHz and ^1H NMR spectra at 270 MHz on a Bruker HX-270 FT instrument. In the case of the NOE difference measurements, the method described in ref 1 was used on argon-flushed and dust-free samples. All NMR spectra were recorded in $CDCl_3$, and chemical shifts are reported in parts per million downfield from internal Me_4Si.

Isolation of Flustramine C and Flustraminol A and B. *Flustra foliacea* (L.) (2.5 kg, dry weight) was extracted with 70% ethanol and 96% ethanol, respectively. The combined ethanolic extracts were separated into an ether- and a water-soluble part. After evaporation, the ether soluble part was extracted with pentane. Evaporation left 30 g of crude oil with a bromine content of 6%. A separation between basic and nonbasic parts gave 400 mg of basic black oil. On the basis of UV absorption (254 and 280 nm), this oil was separated into several fractions by column chromatography (silica gel, A 60 Lobar size C, Merck) with ethyl acetate as the eluant. Three of these fractions were purified further and are given in the order of increasing polarity as follows.

Flustraminol A was rechromatographed on silica gel RP-8 (Merck) and silica gel A60 (Merck), respectively, by using ethyl acetate as the eluant. This gave 16 mg of flustraminol A as a brown oil (6×10^{-4}% of dry weight).

Flustramine C was rechromatographed on silica gel A60 (Merck) with ethyl acetate as the eluant. This gave 8 mg of flustramine C as a colorless oil (3×10^{-4}% of dry weight).

Flustraminol B was rechromatographed on silica gel A60 (Merck) by using ethyl acetate and ethyl acetate/methanol (9:1) as eluents, respectively. This gave 2 mg of impure flustraminol B as a brown oil (8×10^{-5}% of dry weight).

Spectroscopic Data. Flustraminol A: $C_{16}H_{21}BrN_2O$; mass spectrum (100 °C), m/e (relative intensity) 338/336 (0.8), 269/267 (100), 212/210 (10); metastable ions at m/e 167.1/165.2 indicate the fragmentations m/e 269/267 → 212/210; high-resolution measurements, m/e 336.083 (calcd for $C_{16}H_{21}BrN_2O$ m/e 336.083), 269.0111 (calcd for $C_{11}H_{12}BrN_2O$ 269.0113); UV (EtOH) λ_{max} 215 nm (ϵ 1.7×10^4), 256 (6.5×10^3), 318 (2.3×10^3); UV (0.5 N ethanolic HCl) 215 nm (ϵ 1.8×10^4) 234 (sh, 8.6×10^3), 246 (5.4×10^3), 306 (23×10^3); IR ($CHCl_3$) 3540 (w, br), 3450 (w, br), 3010 (m), 2970 (s), 2940 (s), 1715 (m), 1675 (w), 1600 (s), 1570 (s), 1490 cm^{-1} (s).

Flustramine C: $C_{16}H_{19}BrN_2$; mass spectrum (100 °C), m/e (relative intensity) 320/318 (34), 251/249 (100), 210/208 (6), 170 (49), 129 (16), 69 (9); metastable ions at m/e 116.1/115.1 indicate the fragmentations m/e 251/249 → 170 (loss of bromine); high-resolution measurements, m/e 318.073 (calcd for $C_{16}H_{19}BrN_2$ m/e 318.073); UV (EtOH) λ_{max} 210 nm (sh, ϵ 1.0×10^4), 232 (2.7×10^4), 290 (9.4×10^3), 307 (4.3×10^3); UV (0.5 N ethanolic HCl): 210 nm (sh, ϵ 1.3×10^4), 230 (2.3×10^4), 280 (4.6×10^3); IR ($CHCl_3$) 2970 (s), 1635 (s), 1585 (s), 1565 (s), 1435 (s), 1415 cm^{-1} (s).

Debromo-8,8a-dihydroflustramine C. A solution of 4 mg (0.013 mmol) of flustramine C in 1 mL of dry ether was added to a stirred suspension of 2 mg (0.053 mmol) of LAH in 1 mL of dry ether at room temperature. The stirring was continued for 1 h at room temperature. The reaction mixture was diluted with water and extracted with ether. The dried etheral extract gave upon evaporation debromo-8,8a-dihydroflustramine C as a colorless oil: 3.5 mg (87.5%); mass spectrum (70 °C), m/e (relative intensity) 242 (24), 173 (100), 130 (44); metastable ion at m/e 97.7 indicates the fragmentation m/e 173 → 130; ^1H NMR (270 MHz, $CDCl_3$) δ 1.01, 1.08 (s, 3, H-10, H-11), 2.42 (s, 3, H-14), 4.42 (s, 1, H-8a), 5.04 (m, 2, H-13), 6.59, 7.13 (d, 1, H-4, H-7), 6.70, 7.05 (t, 1, H-5, H-6); ^{13}C NMR (69.89 MHz, $CDCl_3$) δ 53.2 (C-2), 34.5[§] (C-3), 64.5 (C-3a), 125.1[†] (C-4), 118.5 (C-5), 127.8[†] (C-6), 109.1 (C-7), 84.4(C-8a), 41.4 (C-9), 23.2* (C-10), 22.5* (C-11), 144.8 (C-12), 113.0 (C-13), 36.8[§] (C-14). Assignments for values marked with the same symbols may be interchanged.

Flustraminol B: $C_{16}H_{21}BrN_2O$; mass spectrum (130 °C), m/e (relative intensity) 338/336 (57), 320/218 (20), 305/303 (6), 281/279 (29), 266/264 (27), 226/224 (21), 210/208 (21), 69 (100); metastable ions at m/e 302.9/300.9 indicate the fragmentations m/e 338/336 → 320/318 (loss of H_2O); high-resolution measurements, m/e 336.087 (calcd for $C_{16}H_{21}BrN_2O$ m/e 336.084); UV (EtOH) λ_{max} 220 nm (ϵ 1.7×10^4), 256 (6.3×10^3), 310 (2.3×10^3); UV (0.5 N ethanolic HCl) 220 nm (ϵ 1.7×10^4), 240 (sh, 6.3×10^3), 298 (2.3×10^3); IR ($CHCl_3$) 3590 (w), 3360 (wb), 3020 (m), 2980 (s), 2940 (s), 1670 (s), 1600 (s), 1485 cm^{-1} (s).

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Registry No. 1, 78127-86-3; 1 debromo-8,8a-dihydro, 78127-87-4; 2, 78127-88-5; 3, 78127-89-6.

Studies in Biomimetic Alkaloid Syntheses. 7. Stereospecific Total Syntheses of Ibophyllidine and 20-Epiibophyllidine

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The alkaloids ibophyllidine (1) and 20-epiibophyllidine (2) were selectively synthesized by utilizing reaction pathways which pass respectively either through a biomimetic ring D–seco intermediate, 8, or through a norsecodine intermediate, 13.

While the indole and dihydroindole alkaloids, which are biosynthetically derived from tryptamine and secologanine, exhibit a rich diversity of structural variations based on skeletal rearrangements, they generally maintain all carbons of their biosynthetic precursors. An exception is found in the recently isolated and characterized alkaloids ibophyllidine (1) and 20-epiibophyllidine (2).[1,2] The structural similarity of these compounds to the C-20 epimeric Ψ-vincadifformines (3, 4) and pandolines (5, 6)

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