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Practical and Stereoselective Synthesis of a Pentacyclic Guanidine System: Synthetic Studies toward Ptilomycalin A and Related Compounds

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Abstract—Symmetrical pentacyclic guanidine compounds **3a**–**c** have been synthesized based on the construction of 2,5-disubstituted pyrrolidines via sequential 1,3-dipolar cycloaddition and the formation of pentacyclic guanidine via guanylation followed by double *N*,*O*-acetalization. The present synthesis will provide a potential route for the synthesis towards ptilomycalin A (**1**) and 13,14,15-isocrambescidin 800 (**2**). © 1999 Elsevier Science Ltd. All rights reserved.

Introduction

The guanidine group, which exists in the side chain of arginine, binds with anionic substrates such as carboxylate or phosphate to stabilize the three-dimensional structure of proteins in enzymes.[1] In nature, a vast amount of guanidine-containing products have been isolated and these attract considerable attention because of their interesting biological activities, mostly arising from hydrogen-bond mediated interactions of guanidinum ions with phosphate-containing biomolecules.[2] Due to the strong ability of guanidine to set a pair of zwitterionic hydrogen bonds with anionic compounds, the guanidine-containing molecules suggest to us their use as a new reaction *vessel*. Actually, synthetic applications have been reported using the cyclic and/or acyclic guanidines as a catalyst for reactions such as the Michael reaction,[3a,b] nitroaldol condensation (Henry reaction),[3c] Strecker reaction[3d] and acylations.[3e] To meet the requirement for the preparation of various types of guanidines, several new synthetic methods have been developed,[4] and the syntheses of many guanidine-containing natural products have been accomplished.[5]

Among the guanidine-containing natural products, ptilomycalin A (**1**)[6] and 13,14,15-isocrambecidin 800 (**2**)[7] have a unique pentacyclic guanidine moiety, which makes them challenging target molecules. Snider[8] and Murphy[9] independently reported the construction of a pentacyclic guanidine system based on a biomimetic route. Recently, Overman has accomplished the syntheses of **1** and **2** with

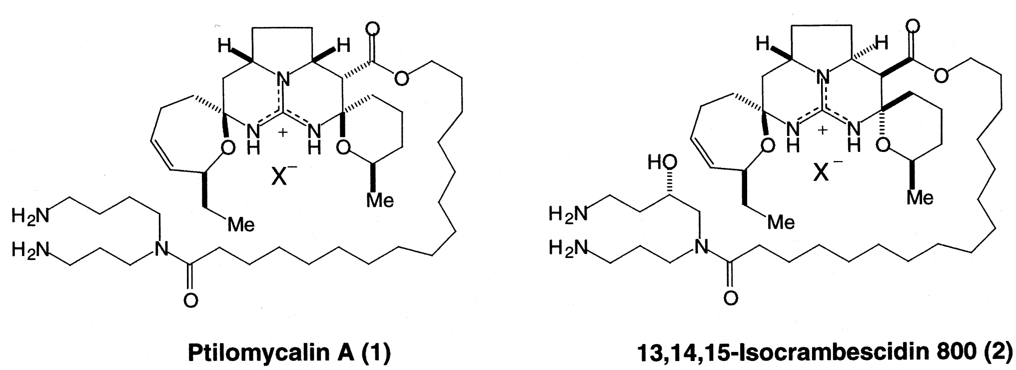

Figure 1.

Keywords: cyclic guanidines; nitrones; 1,3-dipolar cycloaddition reaction; ptilomycalin A.
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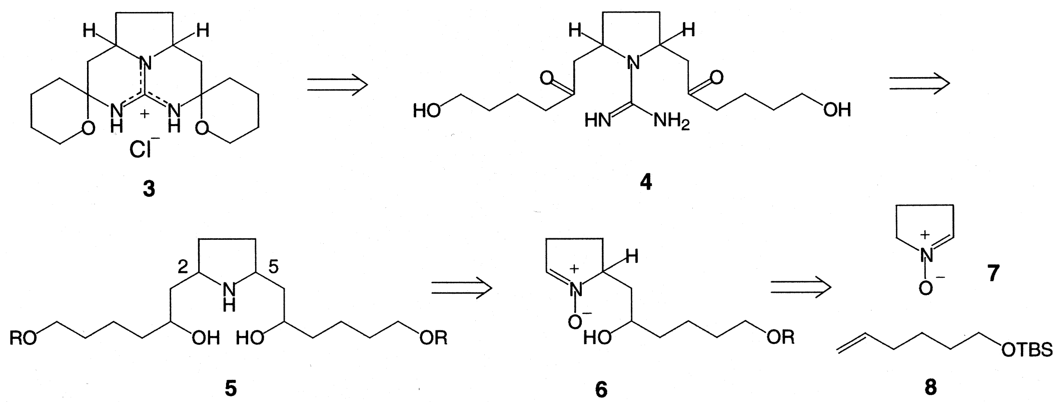


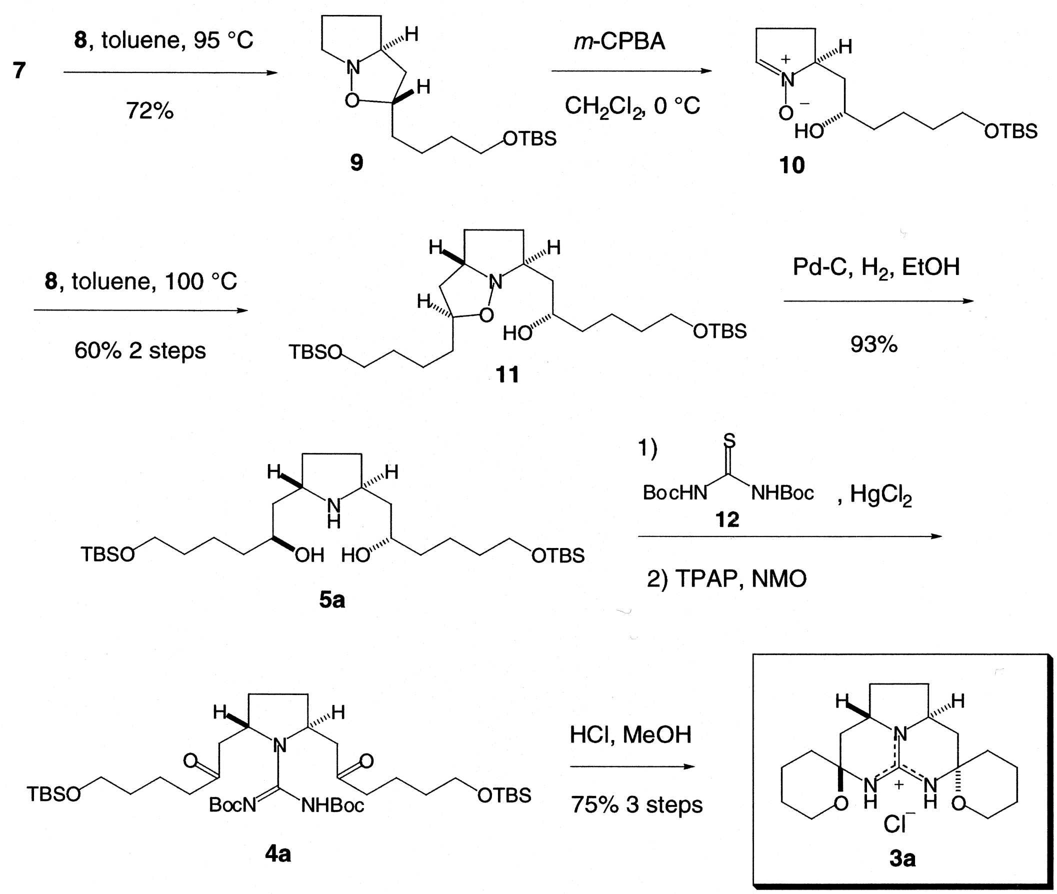
Scheme 1.

a Biginelli condensation reaction as the key step.[10,11] We now report a practical and stereoselective synthetic method for the pentacyclic guanidines **3a–c**, which can be seen as similar core moieties in **1** and **2** (Fig. 1).

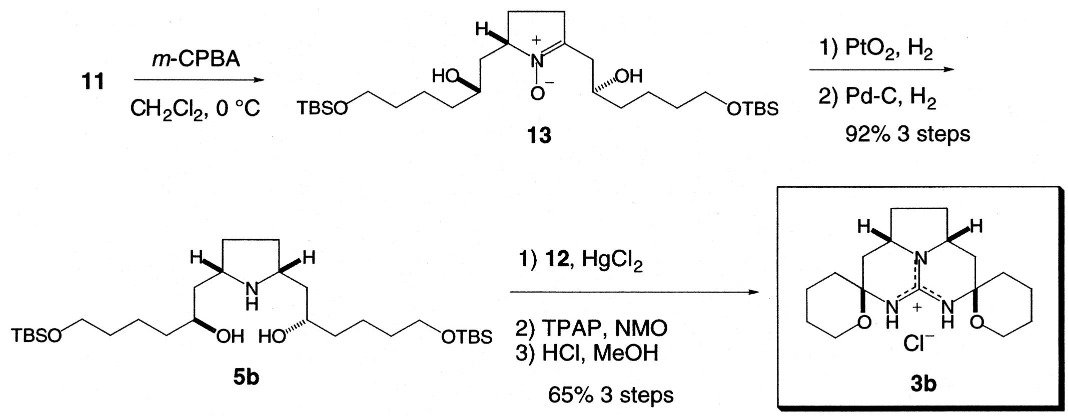
Results and Discussion

Our retrosynthesis is shown in Scheme 1. Pentacyclic guanidine **3** could be prepared from double *N*,*O*-acetalization of guanylated dihydroxy-diketone **4**, which can be obtained from 2,5-disubstituted pyrrolidine **5** having hydroxyl groups on its side chains at the β position. The side chains at the C2 and C5 positions on the pyrrolidine ring could be introduced by sequential 1,3-dipolar cycloaddition reaction between nitrones **7**, **6** and olefin **8**, respectively, with simultaneous introduction of the hydroxyl groups on the side chains (Scheme 1).

First, C_2-symmetric pentacyclic guanidine **3a** was synthesized from 3,4-dihydro-2*H*-pyrrole-1-oxide (**7**)[12] as shown in Scheme 2. Our synthesis started with 1,3-dipolar cycloaddition reaction of nitrone to olefin which is widely used for the synthesis of pyrrolidine-containing natural products.[13]



Scheme 2.



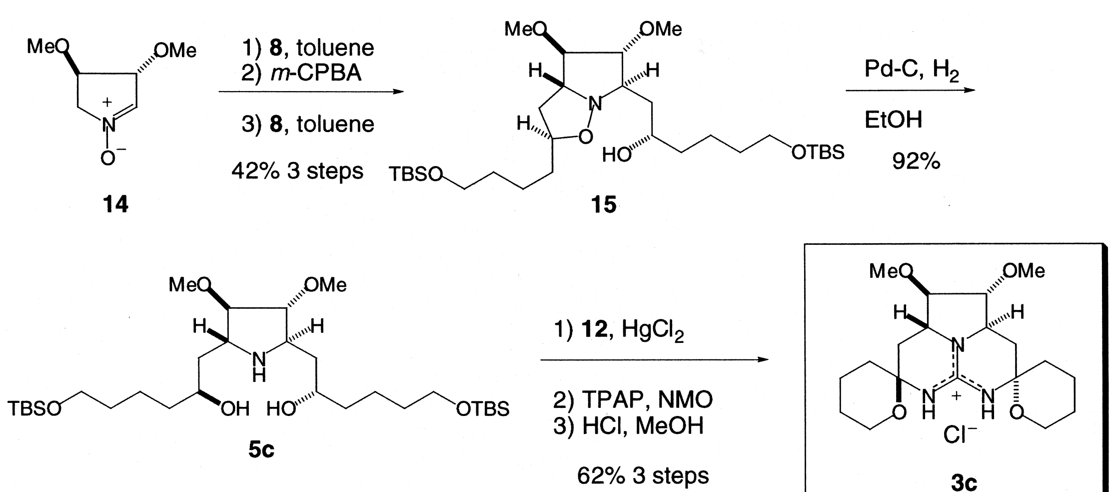
Scheme 3.

Thus, 1,3-dipolar cycloaddition reaction of the nitrone **7** to 1-*tert*-butyldimethylsilyloxy-5-hexene (**8**) in toluene stereoselectively gave isoxazolidine **9** in 72% yield. The isoxazolidine is subjected to *m*-CPBA oxidation to regenerate a nitrone function[14] for the second-1,3-dipolar cycloaddition; oxidation of **9** with *m*-CPBA in dichloromethane at 0°C effected regioselective cleavage to give nitrone **10**.[15] The second 1,3-dipolar cycloaddition of **10** and the olefin **8** stereoselectively took place from the less hindered side in *exo*-mode[15b] to give isoxazolidine **11** in 60% yield from **9**. Hydrogenolysis of **11** in the presence of 10% Pd–C exclusively gave *trans*-2,5-disubstituted pyrrolidine **5a** in 93% yield. The conversion of 2,5-disubstituted pyrrolidine **5a** into pentacyclic guanidine **3a** was then effectively accomplished by a three-step sequence: (1) guanylation, (2) oxidation of the diol, and (3) double *N*,*O*-acetalization. Reaction of **5a** with bis-Boc-thiourea **12** and $HgCl_2$[16] gave *N*-protected guanidine, which was subjected to oxidation with TPAP–NMO[17] to give diketone **4a**. The subsequent deprotection of the Boc and TBS groups in **4a** with methanolic hydrogen chloride led to double *N*,*O*-acetalization to give C_2-symmetric pentacyclic guanidine **3a** in 75% overall yield from **5a**.

Next, *meso*-pentacyclic guanidine **3b** was stereoselectively synthesized via *cis*-2,5-disubstituted pyrrolidine **5b** as shown in Scheme 3. Oxidation of the isoxazolidine **11** with *m*-CPBA in dichloromethane also effected regioselective cleavage to give nitrone **13**.[18] Hydrogenation of the nitrone **13** with PtO_2 stereoselectively gave 2,5-*cis*-*N*-hydroxypyrrolidine,[18] which was then subjected to hydrogenation with Pd–C to give 2,5-*cis*-pyrrolidine **5b**. The same three-step procedure as that of **5a** effectively provided the desired *meso*-pentacyclic guanidine **3b**. The structures of **3a** and **3b** were confirmed by comparison with the reported spectral data of ^{1}H- and ^{13}C NMR.[9c,19]

As shown in Schemes 2 and 3, hydrogenation or *m*-CPBA-oxidation/hydrogenation of the isoxazolidine **11**, prepared via the sequential 1,3-dipolar cycloaddition, stereoselectively provided 2,5-*trans*-pyrrolidine **5a** or *cis*-isomer **5b**, respectively. Thus, combination of the stereoselective construction of pyrrolidine and guanylation followed by double *N*,*O*-acetalization constitutes a highly efficient method for the synthesis of a variety of pentacyclic guanidines. Based on the present method, we could selectively synthesize C_2-symmetric and *meso*-pentacyclic guanidines **3a** and **3b** from the common intermediate **9** in short steps.

The present method for the synthesis of **3a** and **3b** was then successfully applied to the synthesis of chiral C_2-symmetric pentacyclic guanidine **3c** via *trans*-2,5-disubstituted



Scheme 4.

pyrrolidine **5c**, starting from the known chiral nitrone **14**[20] (Scheme 4). 1,3-Dipolar cycloaddition of the nitrone **14** and **8**, oxidative cleavage of the resulting isoxazolidine, and the second 1,3-dipolar cycloaddition reaction with **8** provided **15**. After hydrogenation of **15** with Pd–C, the three-step sequence used in the preparation of **3a** and **3b** also provided **3c**. The structure of **3c** was confirmed by X-ray crystallography.[21] Every cycloaddition reaction in this synthesis took place exclusively from the opposite side of the methoxy group at the α position of the nitrone moiety. Thus, the stereoselective synthesis of the chiral C_2-symmetric pentacyclic guanidine **3c** was accomplished in seven steps and with 24% overall yield from the chiral nitrone **14**.

Conclusion

We have developed a simple and stereoselective method for the synthesis of a novel pentacyclic guanidine system. Our procedure features (1) the stereoselective synthesis of 2,5-disubstituted pyrrolidine based on sequential 1,3-dipolar cycloaddition followed by hydrogenation or oxidation–hydrogenation of the resulting isoxazolidines, and (2) efficient synthesis of pentacyclic guanidine based on guanylation followed by double *N*,*O*-acetalization. This method can be applied to the stereoselective preparation of various types of pentacyclic guanidine compounds. With this method, synthetic efforts towards ptilomycalin A (**1**) and related compounds are in progress in our laboratory.

Experimental

Melting point (mp) was recorded with Yanaco MP-500. Optical rotations were recorded with a JASCO DIP-370 polarimeter. IR spectra were measured with a JASCO VALOR-III FT-IR spectrophotometer. ^{1}H- and ^{13}C NMR were recorded on JEOL JNM-α-400 and JNM-EX-300 instruments. Mass spectra were recorded on JEOL JMA-HX110 spectrometers. Flash column chromatography was performed using silica gel 60 (230–400 mesh; E. Merck, Darmstadt, Germany).

(2*S,3a*S**)-2-[4-(*tert*-Butyldimethylsilyloxy)butyl]-2,3,3a,4,5,6-hexahydropyrrolo[1,2-*b*]isoxazole (9).** A mixture of crude nitrone **7**[12] (7 g) and olefin **8** (10.2 g, 47.66 mmol) in toluene (400 mL) was stirred at 95°C for 3 days. After cooling the reaction mixture to room temperature, the solvent was evaporated in vacuo, and the residue was purified with silica gel chromatography (hexanes/ethyl acetate, 4:1, 1:3) to give **9** (10.3 g, 72% based on olefin **8**). IR (neat) 2950, 1262 cm^{-1}; ^{1}H NMR (400 MHz, $CDCl_3$) δ 4.01 (m, 1H), 3.72 (m, 1H), 3.59 (t, J=6.3 Hz, 2H), 3.10 (m, 2H), 2.08–1.92 (m, 4H), 1.85 (m, 1H), 1.68 (m, 2H), 1.57–1.30 (m, 5H), 0.88 (s, 9H), 0.03 (s, 6H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 76.45, 64.89, 63.03, 57.14, 42.49, 33.72, 32.80, 31.75, 25.97, 24.33, 22.68, 18.34, −5.28; HRMS (direct, M+H$^+$) calcd for $C_{16}H_{34}NO_2Si$ 300.2359, found 300.2356.

(2*S,2′*S**,3a*S**,6*S**)-2-[4-(*tert*-Butyldimethylsilyloxy)-butyl]-6-[(6′-*tert*-butyldimethylsilyloxy-2′-hydroxy-hexyl)]-2,3,3a,4,5,6-hexahydropyrrolo[1,2-*b*]isoxazol (11).** To a solution of **9** (10.30 g, 34.39 mmol) in dichloromethane was added *m*-CPBA (6 g, 35 mmol) at 0°C and the resulting mixture was stirred for 20 min. $Ca(OH)_2$ was added to the reaction mixture and stirred for another 10 min at room temperature. The mixture was filtered through a pad of Celite and the filtrates were concentrated in vacuo to give nitrone **10** as a clear brown oil (13.1 g). A mixture of **10** (13.1 g) and **8** (10 g, 46.72 mmol) in toluene (250 mL) was heated at 100°C for 2 days. After removal of the solvent under reduced pressure, the residue was purified with silica gel chromatography (hexanes/ethyl acetate, 6:1, 1:1) to give **11** (10.9 g, 60%). IR (neat) 3400, 2952, 1265 cm^{-1}; ^{1}H NMR (400 MHz, $CDCl_3$) δ 4.06 (m, 1H), 3.97 (m, 1H), 3.76 (m, 1H), 3.57 (m, 4H), 3.26 (m, 1H), 2.04 (m, 1H), 1.90 (m, 2H), 1.85 (m, 1H), 1.70 (ddd, J=14.1, 9.7, 3.9 Hz, 1H), 1.59 (m, 1H), 1.57–1.30 (m, 14H), 0.86 (s, 18H), 0.01 (s, 12H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 75.15, 68.87, 64.49, 63.80, 63.19, 62.85, 41.83, 39.33, 37.23, 32.91, 32.68, 32.40, 31.09, 29.11, 25.91, 22.78, 21.91, 18.29, −5.33; HRMS (FAB, M+H$^+$) calcd for $C_{28}H_{60}NO_4Si_2$ 530.4061, found 530.4054.

(2*S,2′*S**,5*S**)-2,5-Bis-[6′-(*tert*-butyldimethylsilyloxy)-2′-hydroxyhexyl]pyrrolidine (5a).** A mixture of isoxazolidine **11** (520 mg, 1.01 mmol) and 10% Pd–C (150 mg) in ethanol (5 mL) was stirred at room temperature for 1 day under hydrogen. The reaction mixture was filtered through a pad of Celite and the filtrates were concentrated in vacuo to give **5a** (500 mg, 93%). IR (neat) 3350, 2951, 1272 cm^{-1}; ^{1}H NMR (400 MHz, $CDCl_3$) δ 3.79 (br s, 2H), 3.59 (t, J=6.3 Hz, 4H), 3.52 (br t, 2H), 1.95 (t, J=4.9 Hz, 2H), 1.61 (t, J=5.4 Hz, 4H), 1.60–1.35 (m, 14H), 0.87 (s, 18H), 0.03 (s, 12H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 69.36, 63.12, 55.47, 40.21, 37.18, 32.77, 32.18, 25.95, 22.01, 18.32, −5.28; HRMS (FABM, M+H$^+$) calcd for $C_{28}H_{62}NO_4Si_2$ 532.4217, found 532.4214.

(2a*S,4*S**,7*S**,8a*S**)-4,7-Bis-(2′-tetrahydropyranyl)-2,2a,3,4,6,7,8,8a-octahydro-1*H*-5,6,8b-triaza-acenaphthene hydrochloride (3a).** To a mixture of pyrrolidine **5a** (470 mg, 0.88 mmol), bis-Boc-thiourea **12** (292 mg, 1.06 mmol) and triethylamine (0.36 mL, 2.64 mmol) in DMF (4 mL) was added $HgCl_2$ (287 mg, 1.06 mmol) at 0°C and the resulting mixture was stirred for 30 min. The reaction mixture was diluted with ethyl acetate and filtered through a pad of Celite. The filtrates were washed with brine and the organic phase was dried over $MgSO_4$, filtered and concentrated in vacuo. The residue was purified with silica gel chromatography (hexanes/ethyl acetate, 6:1, 4:1, 2:1) to give the corresponding bis-Boc protected guanidine (563 mg, 83%). To the guanidine (132 mg, 0.17 mmol) in dichloromethane (4 mL) was added 4-methylmorpholine *N*-oxide (80 mg, 0.68 mmol) and a catalytic amount of tetra-propylammonium perruthenate, and the mixture was stirred at room temperature for 30 min. The reaction mixture was loaded on a short silica gel column directly (hexanes/ethyl acetate, 2:1) to give diketone **4a** (121 mg). The diketone **4a** (121 mg) was dissolved in hydrogen chloride solution in methanol (10 mL) and the mixture was stirred at room temperature for 12 h. The reaction mixture was concentrated in vacuo, and the residue was purified with silica gel chromatography (chloroform/methanol, 1:0, 95:5) to give **3a** (52 mg, 90%, two steps). IR (neat) 3260, 3150, 1678, 1625 cm^{-1}; ^{1}H NMR (400 MHz, CDCl$_3$) δ 10.03 (br s, 2H), 3.93 (td, J=12.2, 2.5 Hz, 2H), 3.80 (m, 2H), 3.63 (dd, J=12.2, 3.0 Hz, 2H), 2.32 (m, 2H), 2.18 (m, 4H), 1.85 (br d, 2H), 1.70 (m, 6H), 1.57 (m, 4H), 1.49 (t, J=12.2 Hz, 2H); ^{13}C NMR (100 MHz, CDCl$_3$) δ 149.31, 81.13, 61.76, 51.28, 39.30, 35.10, 30.46, 24.97, 18.37; HRMS (FAB, M+H$^+$) calcd for $C_{17}H_{28}N_3O_2$ 306.2182, found 306.2163.

(2*R,2′*S**,5*S**)-2,5-Bis-[6′-(*tert*-butyldimethylsilyloxy)-2′-hydroxyhexyl]pyrrolidine (5b).** To a mixture of isoxazolidine **11** (252 mg, 0.475 mmol) in dichloromethane (5 mL) was added *m*-CPBA (122 mg, 0.57 mmol) at 0°C. After being stirred for 10 min, Ca(OH)$_2$ was added and the mixture was filtered through a pad of Celite. The filtrates were concentrated in vacuo to give nitrone **13** (332 mg). To the nitrone **13** (332 mg) in ethanol (5 mL) was added PtO$_2$ (20 mg) and the resulting mixture was stirred at room temperature for 12 h under hydrogen. The reaction mixture was filtered through a pad of Celite and the filtrates were concentrated in vacuo. The residue was dissolved in ethanol (5 mL) and 10% Pd–C (30 mg) was added, and the mixture was stirred at room temperature for 12 h under hydrogen. The mixture was filtered through a pad of Celite and the filtrates were concentrated in vacuo. The residue was purified with silica gel chromatography (chloroform/methanol, 1:0, 85:15) to give **5b** (235 mg, 92%). IR (neat) 3400, 2960, 1480, 1400, 1270 cm^{-1}; ^{1}H NMR (400 MHz, CDCl$_3$) δ 3.85–3.65 (m, 3H), 3.53 (m, 5H), 2.20–1.98 (m, 4H), 1.79 (m, 4H), 1.69–1.20 (m, 12H), 0.85 (s, 9H), 0.84 (s, 9H), 0.004 (s, 6H), −0.005 (s, 6H); ^{13}C NMR (100 MHz, CDCl$_3$) δ 70.79, 67.70, 63.09, 63.04, 60.11, 57.43, 39.46, 38.28, 37.97, 36.63, 32.70, 32.65, 30.36, 28.64, 25.94, 21.91, 21.84, 18.29, −5.30; HRMS (FAB, M+H$^+$) calcd for $C_{28}H_{62}NO_4Si_2$ 532.4217, found 532.4222.

(2a*R,4*R**,7*S**,8a*S**)-4,7-Bis-(2′-tetrahydropyranyl)-2,2a,3,4,6,7,8,8a-octahydro-1*H*-5,6,8b-triaza-acenaphthene hydrochloride (3b).** As described for **3a**, **5b** (75 mg, 0.14 mmol) was converted into **3b** (31 mg, 65%). IR (neat) 3250, 3148, 2975, 1686, 1620 cm^{-1}; ^{1}H NMR (400 MHz, CDCl$_3$) δ 9.88 (br s, 2H), 3.92 (m, 2H), 3.85 (dd, J=12.2, 2.5 Hz, 2H), 3.65 (br d, 2H), 2.24 (m, 2H), 2.20 (dd, J=13.6, 3.5 Hz, 2H), 1.85 (br d, 2H), 1.78 (br d, 2H), 1.70–1.55 (m, 10H), 1.37 (t, J=12.6 Hz, 2H); ^{13}C NMR (100 MHz, CDCl$_3$) δ 148.41, 79.41, 61.76, 51.67, 39.60, 34.48, 29.95, 24.90, 18.34; HRMS (FAB, M+H$^+$) calcd for $C_{17}H_{28}N_3O_2$ 306.2182, found 306.2153.

(2*S*,2′*S*,3a*R*,4*R*,5*R*,6*R*)-2-[4-(*tert*-Butyldimethylsilyloxy)-butyl]-6-[6′-(*tert*-butyldimethylsilyloxy)-2′-hydroxyhexyl]-4,5-dimethoxy-2,3,3a,4,5,6-hexahydropyrrolo[1,2-*b*]isoxazol (15). As described for **11**, **14** (2.9 g, 20 mmol) was converted into **15** (5 g, 42%). $[\alpha]_D$=+26.7° (c 3.3, CHCl$_3$); IR (neat) 3500, 2950, 1478, 1270, 1115 cm^{-1}; ^{1}H NMR (400 MHz, CDCl$_3$) δ 4.07 (m, 2H), 3.88 (m, 1H), 3.58 (t, J=6.4 Hz, 2H), 3.57 (t, J=6.4 Hz, 2H), 3.54 (m, 2H), 3.44 (s, 3H), 3.36 (s, 3H), 3.17 (dt, J=8.3, 5.8 Hz, 1H), 2.17 (ddd, J=12.2, 5.9, 3.4 Hz, 1H), 2.05 (dt, J=12.2, 9.3 Hz, 1H), 1.74 (t, J=5.4 Hz, 2H), 1.64 (m, 1H), 1.57–1.32 (m, 11H), 0.872 (s, 9H), 0.870 (s, 9H), 0.025 (s, 6H), 0.023 (s, 6H); ^{13}C-NMR (100 MHz, CDCl$_3$) δ 89.51, 85.92, 75.63, 68.89, 66.62, 65.70, 63.21, 62.83, 58.55, 57.57, 40.90, 38.60, 37.20, 32.92, 32.66, 32.51, 25.96, 25.93, 22.68, 21.94, 18.32, −5.32; HRMS (FAB, M+H$^+$) calcd for $C_{30}H_{64}O_6NSi_2$ 590.4272, found 590.4280.

(2*R*,2′*S*,3*R*,4*R*,5*R*)-2,5-Bis-[6′-(*tert*-butyldimethylsilyl-oxy)-2′-hydroxyhexyl]-3,4-dimethoxy-pyrrolidine (5c). As described for **5a**, **15** (500 mg, 0.85 mmol) was converted into **5c** (460 mg, 92%). $[\alpha]_D$=−3.67° (c 5.4, CHCl$_3$); IR (neat) 3430, 2960, 1480, 1270, 1115 cm^{-1}; ^{1}H NMR (400 MHz, CDCl$_3$) δ 3.76 (m, 2H), 3.60 (t, J=6.3 Hz, 4H), 3.44 (dd, J=3.9, 1.5 Hz, 2H), 3.38 (s, 6H), 3.34 (m, 2H), 1.79 (ddd, J=14.1, 8.3, 2.9 Hz, 2H), 1.58–1.32 (m, 14H), 0.88 (s, 18H), 0.03 (s, 12H); ^{13}C NMR (100 MHz, CDCl$_3$) δ 91.52, 69.89, 63.10, 59.10, 57.41, 38.62, 36.95, 32.77, 25.93, 22.16, 18.31, −5.32; HRMS (FAB, M+H$^+$) calcd for $C_{30}H_{66}NO_6Si_2$ 592.4429, found 592.4406.

(1*R*,2*R*,2a*R*,4*S*,7*S*,8a*R*)-1,2-Dimethoxy-4,7-bis-(2′-tetrahydropyranyl)-2,2a,3,4,6,7,8,8a-octahydro-1*H*-5,6,8b-triaza-acenaphthene hydrochloride (3c). As described for **3a**, **5c** (2.45 g, 4.14 mmol) was guanylated to give *N*-protected guanidine (2.66 g, 77%), which guanidine (148 mg, 0.177 mmol) was converted into **3c** (57 mg, 81%). **3c** was recrystallized from ethyl acetate–chloroform. Mp=264–265°C (decomposition); $[\alpha]_D$=+164.9° (c 2.1, CHCl$_3$); IR (neat) 3270, 2970, 1680, 1600, 1120 cm^{-1}; ^{1}H-NMR (400 MHz, CDCl$_3$) δ 10.14 (br s, 2H), 3.91 (td, J=12.8, 2.4 Hz, 2H), 3.71 (m, 4H), 3.61 (dd, J=6.8, 2.4 Hz, 2H), 3.52 (s, 6H), 2.30 (br s, 4H), 1.90–1.30 (m, 12H); ^{13}C NMR (100 MHz, CDCl$_3$) δ 149.05, 86.18, 80.52, 61.89, 59.31, 52.33, 38.43, 35.00, 24.91, 18.29; HRMS (FAB, M+H$^+$) calcd for $C_{19}H_{32}O_4N_3$ 366.2393, found 366.2393.

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19. For the identification of structure **3a** and **3b**, chloride was exchanged to tetrafluoroborate anion. Data for **3a**: ^{13}C NMR (100 MHz, $CDCl_3$) δ 148.39, 81.47, 61.68, 51.64, 38.87, 34.79, 29.66, 24.64, 17.56; **3b**: ^{13}C NMR (100 MHz, $CDCl_3$) δ 147.62, 80.06, 61.78, 52.08, 39.20, 34.10, 29.81, 24.69, 17.56.
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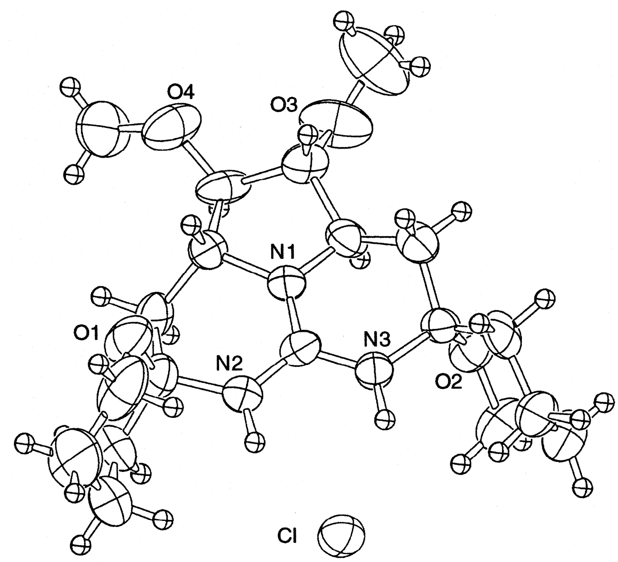
21. The X-ray data were collected on a MXC3KHF four-circle diffractometer (T=296 K). The structures were solved by direct methods (SIR92) and subsequent Fourier recycling (DIRDIF94), and refined by full-matrix least-squares refinement against $|F|$, with all hydrogen atoms fixed at calculated positions. All calculations were performed with the crystallographic software package teXsan (Molecular Structure Corporation, 1985, 1992).



Ortep drawing of **3c**

Crystal data for **3c**: $C_{19}H_{32}O_4N_3Cl$, Mr=401.93, orthorhombic, space group $P2_12_12_1$, a=12.71(2), b=20.16(3), c=8.38(1) Å, V=2147(5) Å^3, Z=4, D_{calc}=1.246 g/cm^3, MoKα radiation (λ=0.71069 Å), μ=2.06 cm^{-1}, $2\theta_{max}$=50.0°, R_1=0.053, R_w=0.065.