CHEMISTRY
A EUROPEAN JOURNAL

DOI: 10.1002/chem.200500784

Synthesis of Nitrogen- and Oxygen-Containing Macrocycles—Derivatives of Lithocholic Acid

Alexei D. Averin, Elena R. Ranyuk, Nikolai V. Lukashev, and Irina P. Beletskaya*[a]

Abstract: Palladium-catalyzed amination of 3,24-bis(3-bromophenoxy)cholane (**4**) with various polyamines and polyoxadiamines **5** taken in 1:1 ratio was used for the synthesis of the macrocycles **6**, which contain steroidal and polyamine moieties and were obtained in 38–65% yields. The same reaction with excess polyamine (2.2–3 equiv) provided bis(polyamino) derivatives of 3,24-diphenoxycholane **7** in excellent yields, whereas the diarylation of polyamines with two equivalents of 3,24-bis(3-bromophenoxy)cholane afforded their bis(steroidal) derivatives **8**. Compounds **7** and **8** were employed in the syntheses of cyclodimers **9**, which possess two steroidal and two polyamine fragments; the efficiency of two methods was compared.

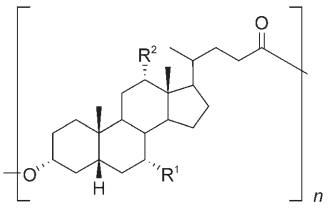
Keywords: amination · catalysis · macrocycles · polyamines · steroids

Introduction

The steroidal scaffold is one of the biggest rigid chiral fragments occurring in nature. Since the time when steroidal dimers were found to be the byproducts in the synthesis of functionalized steroids, a great number of such compounds, synthetic or isolated from living species, have been investigated. The growing interest in the dimers of steroids is explained by the potential of these compounds to be used for modeling biological systems and for the molecular recognition in enzymatic processes.[1]

Macrocycles based on steroidal fragments can be divided into three main groups: cyclocholeates, cholaphanes, and other macrocyclic molecules containing a steroidal moiety (or moieties) and other aromatic or aliphatic linkers. Cyclocholeates are macrocyclic lactones obtained by the cyclization of 2–6 molecules of cholic acid in a head-to-tail manner.

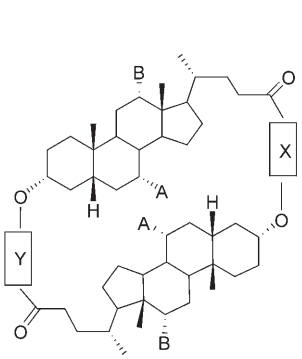
The general approach to such compounds is based on the Yamaguchi macrolactonization of cholic acid monomers or dimers.[2] A number of such macrocycles were obtained by using 2,6-dichlorobenzoyl chloride or dicyclohexylcarbodiimide and 4-*N*,*N*-dimethylaminopyridine.[3–10] Cyclocholeates



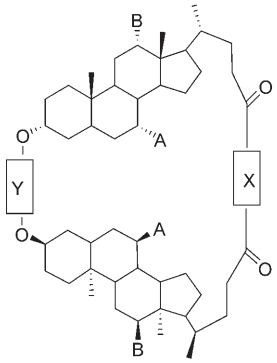
Cyclocholeate

were shown to be macrocyclic molecules with adjustable cavity size for trapping polar molecules of different geometry and dimensions.[7] Brady and Sanders elaborated another approach to the synthesis of cyclodimers based on transesterification reactions, called "living" macrolactonization.[11,12]

Cholaphanes which constitute another class of steroidal macrocycles contain 2–4 cholic acid fragments arranged in a head-to-head or head-to-tail manner linked by means of various functional groups.[13]



head-to-tail
cholaphane

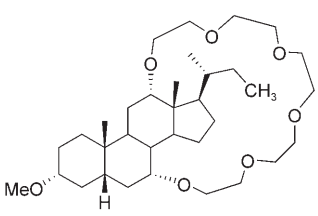


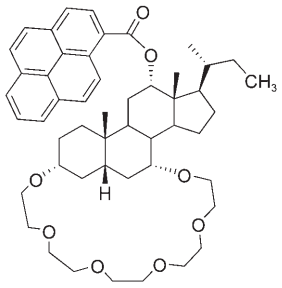
head-to-head
cholaphane

[a] Dr. A. D. Averin, E. R. Ranyuk, Prof. N. V. Lukashev, Prof. I. P. Beletskaya
Department of Chemistry
Lomonosov Moscow State University
Leninskie Gory, Moscow, 119992 (Russia)
Fax: (+7) 095-939-3618
E-mail: beletska@org.chem.msu.ru

Such cyclodimers possess conformational rigidity that makes them useful receptors. Some of them exhibit an extraordinary ability in the strereoselective recognition of carbohydrate derivatives in organic solvents.[14,15] Introduction of various functional groups makes them ideal compounds for molecular recognition.[16] The first synthetic cholaphanes were constructed by using the formation of cyclic amides as a key step.[15,17,18] To improve the flexibility of the macrocycle, ester groups were used for the cyclization.[19–23] Cholaphanes containing amide and ester groups are susceptible to acidic and basic conditions, and to the reduction by metal or hydrogen. Ra, Cho, and Choi developed the synthesis of the cholaphane in which steroidal fragments are linked through ethyleneglycol moieties.[24]

Some other macrocycles contain one steroidal and one polyoxaalkyl chain so that these molecules possess crown ether cavities (examples of which are shown here).[25–28]





The size of the cycle and its geometry can be finely tuned depending on the positions in the steroidal fragment to which polyoxaalkyl chain is attached.

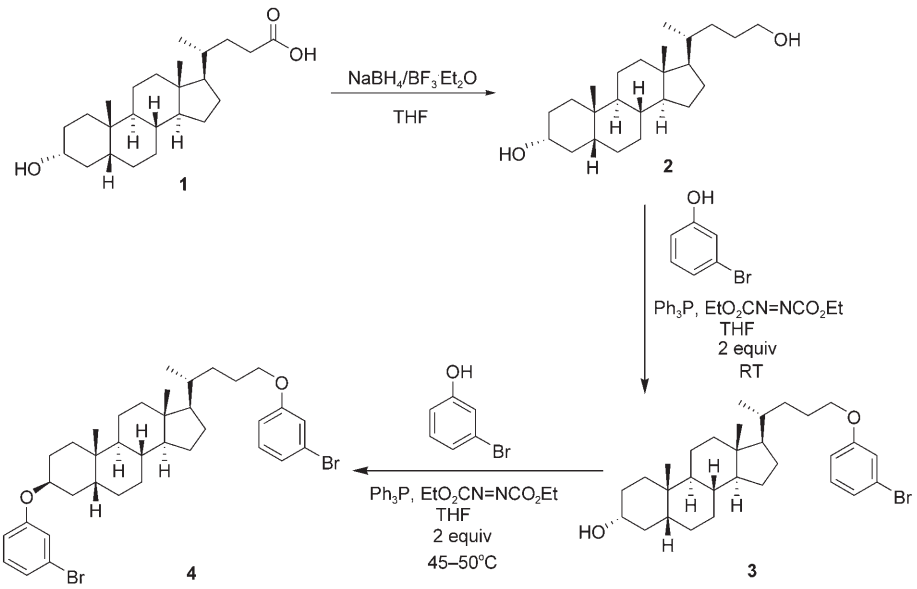
All macrocycles cited above, though they proved to be selective sensors and receptors, have one serious drawback: their syntheses are multistep and laborious, and the yields are often humble. To overcome these difficulties and to synthesize a new series of steroidal macrocycles, we decided to apply the method elaborated recently in our laboratory of the construction of macrocycles by the catalytic intramolecular diamination of dihaloarenes with polyamines and polyoxapolyamines. A series of such polyazamacrocycles has been synthesized that incorporate benzene, pyridine, anthracene, and anthraquinone moieties.[29–32] This method uses palladium-catalyzed amination of aryl halides developed by Buchwald and Hartwig over the last decade.[33]

Results and Discussion

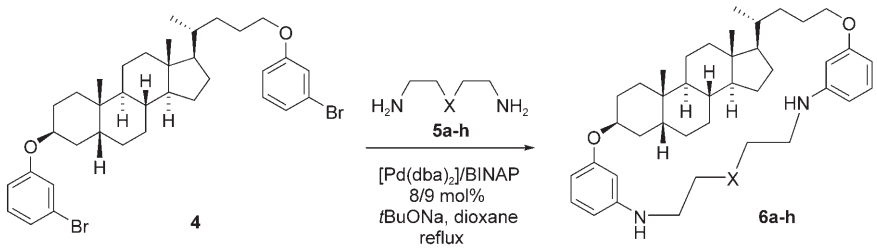
The scaffold of lithocholic acid **1** was chosen as a steroidal fragment to be incorporated into nitrogen- and oxygen-containing macrocycles prepared by the catalytic amination. The A and B rings of this steroid are *cis*-conjugated; this feauture was thought to favor the cyclization. To use this approach we had to functionalize the starting lithocholic acid with halogenoaryl substituents. In the first stage lithocholic acid was reduced with in situ obtained diborane into cholanediol **2**. This compound was transformed into 3,24-bis(3-bromophenoxy)cholane (**4**) by using the Mitsunobu reaction[34] in overall 40% yield (Scheme 1).

3-Bromophenol was used in this reaction because an electron-donor alkoxy group in *ortho*- and *para*-positions would hinder the amination reaction. We have established that the use of two equivalents of 3-bromophenol, triphenyl phosphine, and diethyl azodicarboxylate (DEAD) at room temperature leads to the arylation of only the primary hydroxyl in **2** giving 24-(3-bromophenoxy)-cholan-3-ol (**3**). Diarylated compound **4** is formed only upon the action of additional two equivalents of the reagents, after stirring at 45–50 °C for 8 h. When applying four equivalents of the reagents at once followed by heating, the yield of **4** is somewhat poorer.

The reaction of compound **4** with a number of polyamines **5a–h** (Scheme 2) was achieved with the known $[Pd(dba)_2]$/BINAP (dba = dibenzylideneacetone, BINAP = 2,2′-bis(diphenylphosphino)-1,1′-binaphthyl) catalytic system proposed by Buchwald in 1996 and thoroughly studied by his group to show its great synthetic potential.[35,36] Reagents were taken in equimolar ratio, the reactions were performed in dilute dioxane ($c = 0.02$ M) to suppress the undesirable formation of oligomers. The amount of the catalytic system was 8 mol% $[Pd(dba)_2]$/9 mol% BINAP, and sodium *tert*-butylate was used as a base. The reactions were run to completion in 7–



Scheme 1.



X = CH_2NHCH_2 (**a**); $NH(CH_2)_2NH$ (**b**); $NH(CH_2)_3NH$ (**c**); $CH_2NH(CH_2)_2NHCH_2$ (**d**);
$CH_2NH(CH_2)_3NHCH_2$ (**e**); $NH(CH_2)_2NH(CH_2)_2NH$ (**f**); $O(CH_2)_2O$ (**g**);
$CH_2O(CH_2)_2O(CH_2)_2OCH_2$ (**h**).

Scheme 2.

Table 1. The synthesis of the macrocycles **6a–h**.

	Polyamine	*t* [h]	Product	Yield[a] [%]
1	$NH_2(CH_2)_3NH(CH_2)_3NH_2$ (**5a**)	8	**6a**	44
2	$NH_2(CH_2)_2NH(CH_2)_2NH(CH_2)_2NH_2$ (**5b**)	9	**6b**	44
3	$NH_2(CH_2)_2NH(CH_2)_3NH(CH_2)_2NH_2$ (**5c**)	8.5	**6c**	42
4	$NH_2(CH_2)_3NH(CH_2)_2NH(CH_2)_3NH_2$ (**5d**)	9	**6d**	65
5	$NH_2(CH_2)_3NH(CH_2)_3NH(CH_2)_3NH_2$ (**5e**)	7	**6e**	60
6	$NH_2(CH_2)_2NH(CH_2)_2NH(CH_2)_2NH(CH_2)_2NH_2$ (**5f**)	10	**6f**	38
7	$NH_2(CH_2)_2O(CH_2)_2O(CH_2)_2NH_2$ (**5g**)	8.5	**6g**	40
8	$NH_2(CH_2)_3O(CH_2)_2O(CH_2)_2O(CH_2)_3NH_2$ (**5h**)	7	**6h**	60

[a] Yield after chromatography.

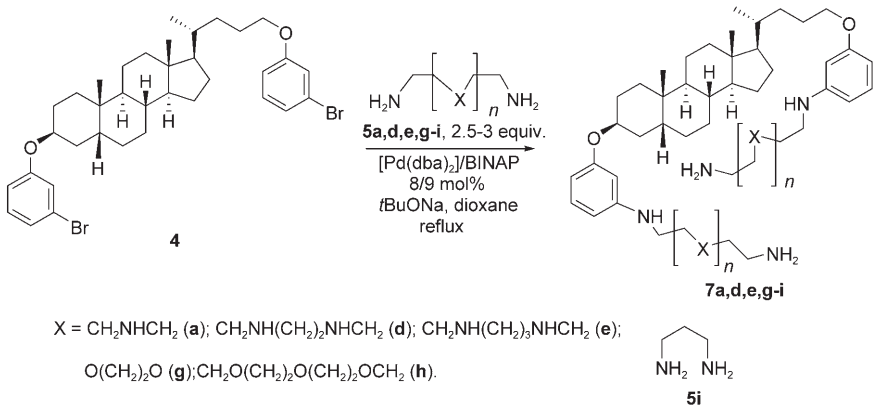
10 h, and the resulting macrocycles **6a–h** were isolated by means of column chromatography on silica. The data are collected in the Table 1. The reaction mixture composition was investigated by ^{1}H and ^{13}C NMR spectroscopy, which revealed that macrocycles **6** were formed in very high yields (about 90%) which is unusual for such types of reactions. For example, in our previous syntheses of macrocycles from 1,8-dichloroanthracene and 1,8-dichloroanthraquinone the yields did not exceed 70%, whereas for the macrocycles derived from 2,6- and 3,5-dibromopyridine they did not exceed 30–40%.[32] Another feature of this reaction is the following: when employing triethylenetetraamine **5b** or tetraethylenepentaamine **5f**, the yields of corresponding macrocycles **6b** and **6f** were almost as high as with other polyamines (entries 2, 6), both in the reaction mixtures and after chromatography. This is opposite to our previous observations in the reactions with 1-bromo-2,6-dichlorobenzene and dihalopyridines.[31,32] We could explain it by the fact that in the present case the amination of bromophenyl groups and not the diamination of dihalobenzene takes place (introduction of the second amino group in the same benzene ring is hindered by the electron-donor character of the amino substituent). Also much better yields of the macrocycles **6** might be due to a possible perfect fitting of polyamines to two steroid-born bromophenoxy moieties. Higher yields (60–65%) of the macrocyles **6d**,**e**,**h** (entries 4, 5, 8) can result from the use of starting polyamines **5d**,**e**,**h** with a more appropriate length (12, 13, and 15 atoms, respectively) and also from better ratios of C to N atoms in the polyamines, especially in the case of trioxadiamine **5h**. This fact is in a good correlation with our previous observations. It could be explained that the more ethylenediamine fragments are present in a molecule of polyamine (like in polyethylenepolyamines), the more important is the formation of chelate palladium–diamine complexes, which withdraw palladium from the catalytic cycle thus hindering the amination reaction.

The compounds **6** were characterized by ^{1}H and ^{13}C NMR spectra and by MALDI-TOF spectroscopy. Protons and carbon atoms of two phenyl rings differ slightly due to their unequal surrounding, whereas protons and quite often carbon atoms of the polyamine chains do not "feel" the unsymmetrical character of the whole molecule and have chemical shifts similar to those found for symmetrically disubstituted polyamines, though their proton signals are often broad and singlets are often observed in place of multiplets (e.g., for **6e**,**f**). In some cases (**6d**,**e**) the carbon atoms of two ends of the polyamine chains differ slightly due to nonsymmetry of the molecule.

According to our evaluations, triamine **5a** is probably the shortest polyamine that can form the cycle upon the reaction with 3,24-bis(3-bromophenoxy)chlolane (**4**) due to the geometry of the latter. Although we did not introduce shorter triamines and diamines in this reaction, propanediamine was used in the synthesis of the cycles containing steroidal moieties; however, this required the presence of two steroidal and two polyamine fragments in such macrocycles, which we call cyclodimers (vide infra).

The change of the reaction conditions can dramatically alter the result of the amination of 3,24-bis(3-bromophenoxy)cholane (**4**). The reaction of **4** with 2.5–3 equivalents of corresponding polyamines **5** in the presence of the same amount of the catalyst, as in the reactions described above, but in more concentrated solutions ($c = 0.1$ M) led to bis(polyamino) substituted steroids **7** (Scheme 3).

Compounds **7a**,**d**,**e**,**g**,**h** were formed in excellent yields (over 90%) according to ^{1}H and ^{13}C NMR spectra. As a result of the use of more concentrated solutions, no macrocycles **6** were registered in the reaction mixtures. In the case of propanediamine **5i**, the main product **7i** was formed in 60% yield together with cyclodimer **9i** (40% yield). MALDI-TOF spectra supported the formation of diaminated products **7**; also linear oligomers that contained several steroidal and polyamine fragments were not detected. Compounds **7g** and **7h** were isolated by column chromatography

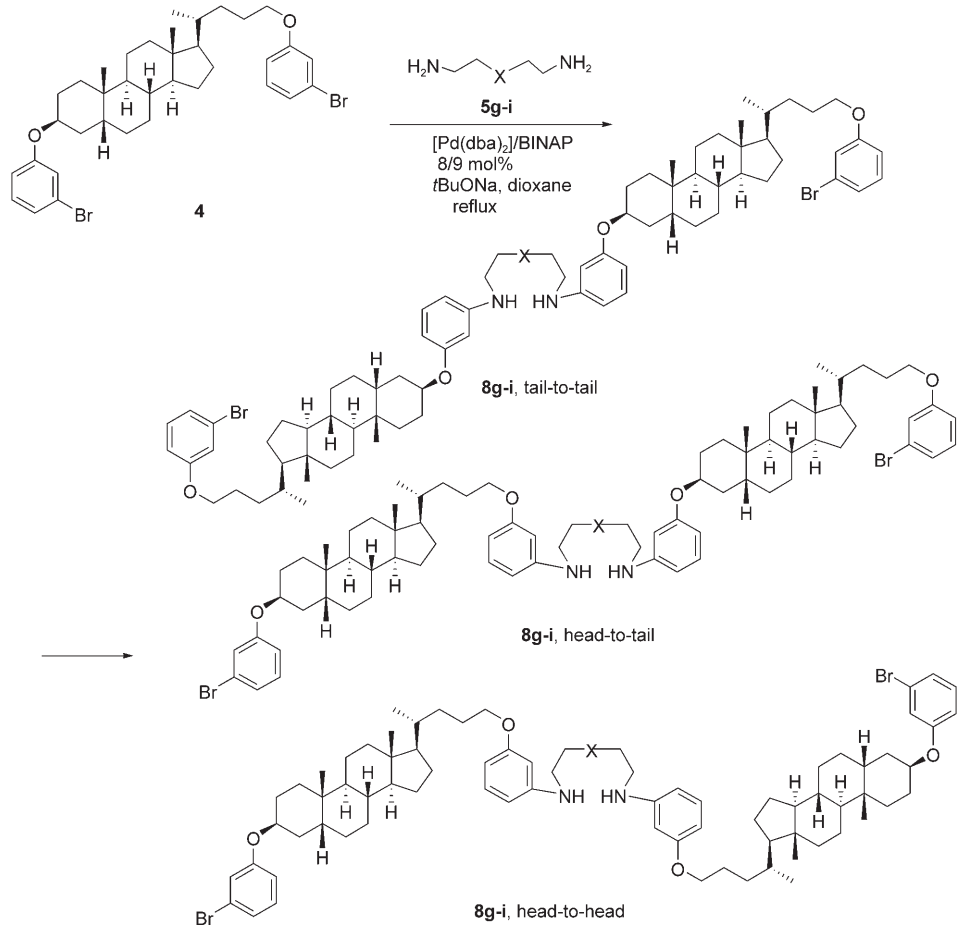


Scheme 3.

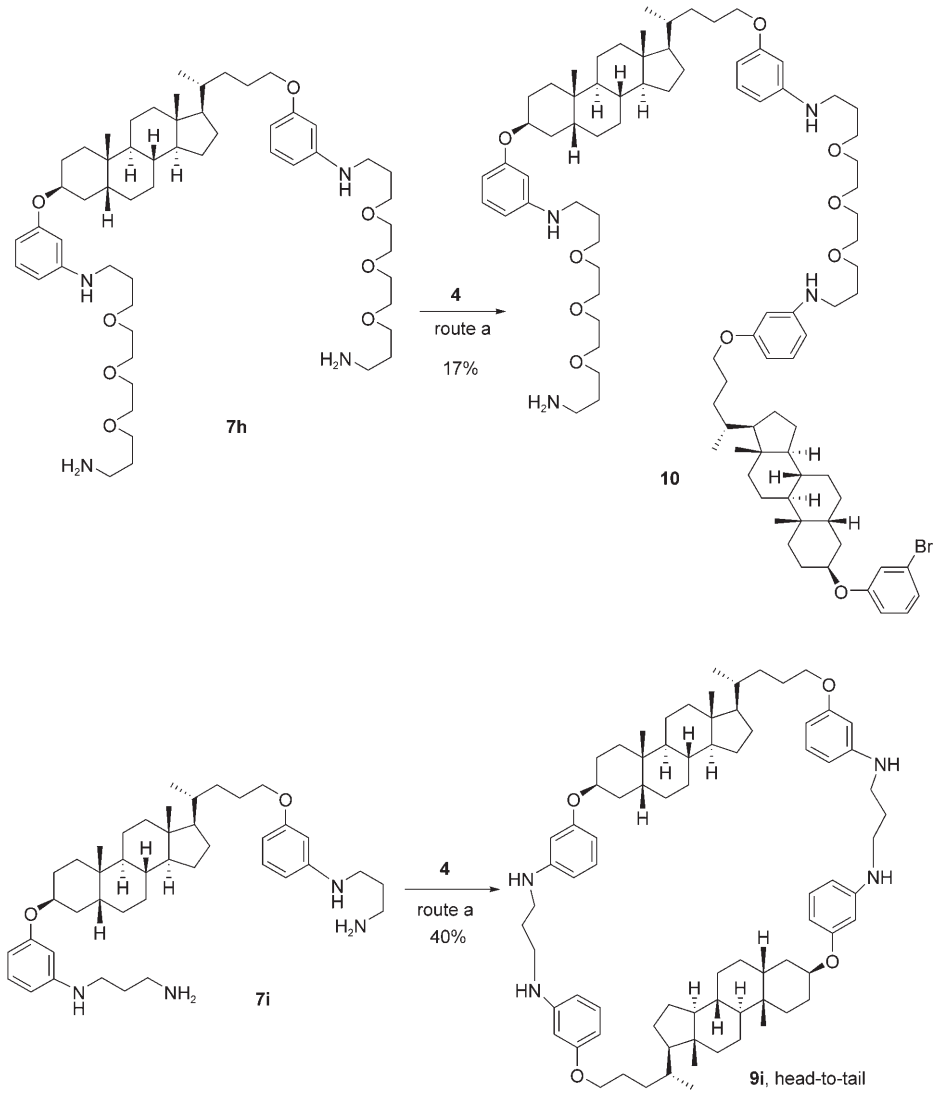
in 45 and 82% yields, respectively. The chromatography of other bis(polyamino) substituted steroids **7a**,**d**,**e**,**g** poses a serious problem due to the presence of several amino groups, which results in a strong affinity to silica of such compounds.

The application of two equivalents of compound **4** in the reactions with corresponding polyamines **5** afforded the synthesis of another series of linear derivatives of cholanediol, that is, the bis(steroidal) derivatives of polyamines **8g–i** (Scheme 4). These reactions were run under the same conditions as those mentioned above and the yields of target compounds in the reaction mixtures were about 90% (estimated by NMR spectroscopy). Compounds **8g** and **8h** were isolated by column chromatography to give 43 and 39% yields, respectively, while the compound **8i** was used in situ for further cyclization. This reaction is also notable for the fact that it ran smoothly and was not complicated by the formation of by-products like linear oligomers or macrocycles **6**, although they are easily produced as mentioned above. The product **8** may be a mixture of three possible regioisomers: head-to-head, head-to-tail, and tail-to-tail. In ^{1}H and ^{13}C NMR spectra of compounds **8**, the signals of bromophenyl and aminophenyl rings differ substantially, while the patterns of steroidal moieties are complicated. Two different singlets for the protons at C3 atoms are observed in ^{1}H NMR spectra at $\delta = 4.5$–4.6 ppm, depending on the substituent (bromophenoxy or aminophenoxy) attached to this atom, but the difference does not exceed 0.02 ppm. In ^{13}C NMR spectra two signals are observed for some carbon atoms of the steroidal scaffold, but these data are not sufficient to discern between shown regioisomers.

Macrocycles with larger cavity size are of particular interest due to their potential to selectively bind big ions and polar molecules. To synthesize such macrocycles that contain two steroidal and two polyamine moieties we used two alternative approaches. The first one (route a) is based on the synthesis of bis(polyamino)-substituted steroids **7** followed by their reaction with the second molecule of **4**; the second approach includes the synthesis of N^{α},N^{ω}-bis(steroidal) derivatives of polyamines followed by their reaction with the second molecule of polyamine.



Scheme 4.



Scheme 5.

The synthesis of cyclodimers **9** by route a was carried out by using diluted solutions of the reagents in dioxane ($c = 0.02$ M) and the same amount of the catalyst, but longer reflux (18–28 h) was applied to favour the cyclization. Starting compounds **7g–i** and **4** were taken in equimolar amounts (Scheme 5). Data about the yields of corresponding cyclodimers **9** are presented in the Table 2.

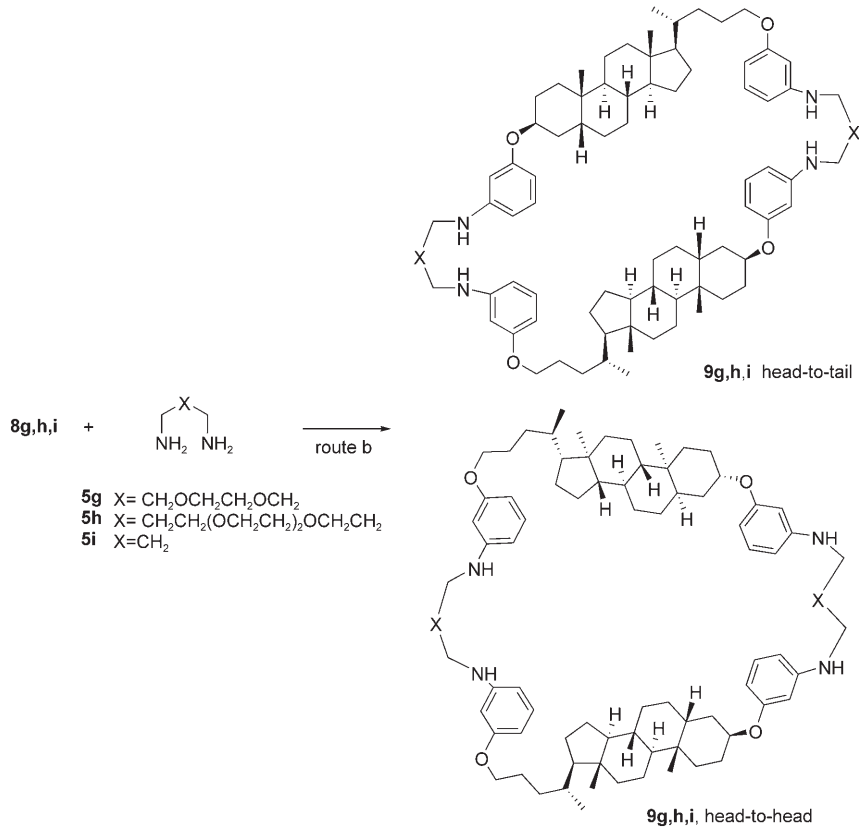
This method proved to be inefficient for the synthesis of cyclodimers **9g**,**h** (Table 2, entries 1, 2), in the reaction of **7h** with bisphenoxycholane **4**, only noncyclic compound **10** was isolated in 17% yield; this compound is an intermediate on the way to cyclodimer **9h**. Nevertheless further prolonged heating of this intermediate with an additional amount of the catalyst did not afford desirable macrocycle. This compound might be a mixture of four possible regioisomers (only one is shown at the Scheme 5), but as in the case of compounds **8** they cannot be distinguished by NMR spectroscopy (if all of them are formed). In contrast, route a was found to be efficient for the synthesis of cyclodimer **9i**, which was formed in approximately 90% yield in the reaction mixture (40% after chromatography, entry 3). This fact can be explained by a comparative rigidity of the starting molecule **7i** in comparison with **7g**,**h**, which possess longer and much more flexible polyamine chains. It was mentioned above that even in the synthesis of **7i** the formation of cyclodimer **9i** in 40% yield was observed, though the reaction conditions in that case were not favorable (high concentration, excess of diamine). Thus one may assume that compounds **7i** and **4** fit each other as regards their geometry.

Table 2. Synthesis of cyclodimers **9** by route a.

	Polyamine	Aryl halide	t [h]	Product	Yield[a] [%]
1	**7g**	**4**	24	–	0
2	**7h**	**4**	24	–	0[b]
3	**7i**	**4**	28	**9i**	40

[a] Yield after chromatography. [b] Non-cyclic intermediate **10** was isolated in 17% yield.

The synthesis of cyclodimers **9** according to route b is based on the reaction of equimolar amounts of bis(steroidal)-substituted polyamines **8g–i** with corresponding polyamines **5g–i** (Scheme 6). The same reaction conditions as those described for route a were applied. Route b was found to be efficient for the synthesis of all cyclodimers **9g–i**; the better yields after chromatography were registered for **9g**,**h** (Table 3, entries 1, 2). The synthesis of cyclodimer **9i** was found to be more efficient through route a, as route b provided only 20% yield of this compound (entry 3). It is to be noted that NMR spectra of the reaction mixtures revealed near to quantitative yields of all target cyclodimers in this reaction. Compounds **9** can be the mixtures of two regioisomers (head-to-head and head-to-tail), but they are totally indistinguishable by their NMR spectra. The head-to-head isomer of **9** is produced from the head-to-head and tail-to-tail isomers of **8**, whereas the head-to-tail isomer of **9** is a result of the reaction of the head-to-tail isomer of **8**.



Scheme 6.

Table 3. Synthesis of cyclodimers **9g–i** by route b.

	Polyamine	Aryl halide	*t* [h]	Product	Yield[a] [%]
1	**5g**	**8g**	18	**9g**	35
2	**5h**	**8h**	24	**9h**	34
3	**5i**	**8i**	28	**9i**	20

[a] Yield after chromatography.

Conclusion

To sum up, we have elaborated a convenient method for the synthesis of nitrogen- and oxygen-containing macrocycles incorporating steroidal moieties; the method is based on intramolecular catalytic diamination of 3,24-bis(3-bromophenoxy)cholane. This approach provided unusually high yields of macrocycles containing various numbers of nitrogen and oxygen atoms. Two routes have been elaborated for the synthesis of cyclodimers: either the use of bis(polyamino) derivatives of diphenoxycholane or by utilizing bis(steroidal) derivatives of polyamines; their efficiency has been compared for different polyamines. The research is to be continued; the proposed method will be applied to the synthesis of various macrocycles containing other steroidal and aromatic spacers and polyamine chains of different length.

Experimental Section

All reactions were conducted under dry argon using absolute solvents. Dioxane and THF were purified by the distillation over NaOH and sodium; dichloromethane was distilled over CaH_2. Triphenyl phosphine was recrystallized from ethanol; other commercially available compounds except tetraethylenepentaamine were employed without special purification. Tetraethylenepentaamine (technical quality) was purified by several recrystallizations of its monohydrate from toluene at −18 °C followed by the decomposition of the hydrate in vacuum at 100 °C. Free triethylenetetraamine was synthesized from its dihydrochloride by the action of KOH in methanol. $[Pd(dba)_2]$ was prepared according to the described procedure.[37] Column chromatography was carried out on silica gel (Merck, 40–60 μm). ^1H and ^{13}C NMR spectra were recorded with the Bruker Avance-400 spectrometer (400 and 100.6 MHz, respectively); MALDI-TOF spectra were registered using Bruker Daltonics Proflex III mass spectrometer.

(3α,5β)-Cholane-3,24-diol (2): An argon-flushed three-necked flask, equipped with a condenser, dropping funnel, and a magnetic stirrer, was charged with sodium borohydride (113 mmol, 3.92 g), lithocholic acid **1** (15 mmol, 5.61 g), absolute THF (150 mL). $BF_3{\cdot}Et_2O$ (150 mmol, 18.5 mL) was added dropwise with stirring; after which the stirring was continued for 2 h. The reaction mass was slowly treated with water (100 mL) to dissolve resulting boric acid and extracted with dichloromethane (300 mL). The emulsion that was formed during extraction was destroyed by the addition of a concentrated aqueous solution of sodium chloride. The water layer was washed with dichloromethane (2×50 mL), combined organic layers were dried over sodium sulfate, and the crude product was obtained after the evaporation of the solvent in vacuum. Diol **2** was recrystallized from acetone (400 mL). Yield: 4.34 g (80 %); M.p. 172–173 °C.[24] ^1H NMR (400 MHz, $CDCl_3$): $\delta = 0.63$ (s, 3H), 0.91 (s, 3H), 0.92 (d, $J = 5.6$ Hz, 3H), 0.95–1.89 (m, 27H), 1.93–1.97 (m, 1H), 3.55–3.65 ppm (m, 3H); ^{13}C NMR (100.6 MHz, $CDCl_3$): $\delta = 12.03$, 18.63, 20.82, 23.36, 24.21, 26.42, 27.19, 28.30, 29.43, 30.55, 31.82, 34.56, 35.34, 35.57, 35.85, 36.46, 40.19, 40.45, 42.10, 42.70, 56.18, 56.51, 63.59, 71.86 ppm.

(3α,5β)-24-(3-Bromophenoxy)cholan-3-ol (3): A two-necked flask flushed with argon, equipped with a condenser and magnetic stirrer, was charged with absolute THF (25 mL), cholanediol **2** (1 mmol, 362 mg), 3-bromophenol (2 mmol, 346 mg), triphenyl phosphine (2 mmol, 524 mg), and solution of DEAD in toluene (40 %, 2 mmol, 0.92 mL). The reaction mixture was stirred at room temperature for 2 days and concentrated in vacuum up to the volume of 5 mL, diethyl ether (5 mL) was added, and the precipitation of triphenyl phosphine oxide was observed. The solution was filtered off, the precipitate was washed with diethyl ether, the solvent was evaporated in vacuum, and the crude product was obtained as a pale-yellow oil. The oil was subjected to chromatography on silica with CH_2Cl_2 as an eluent. Yield (colourless oil): 204 mg (39 %); ^1H NMR (400 MHz, $CDCl_3$): $\delta = 0.64$ (s, 3H), 0.90 (s, 3H), 0.93 (d, $J = 6.6$ Hz, 3H), 0.97–1.87 (m, 26H), 1.95 (dd, $J = 11.9$, 3.2 Hz, 1H), 2.19 (br s, 1H), 3.61 (ddd, $J = 15.4$, 10.8, 4.6 Hz, 1H), 3.87 (m, 2H), 6.80 (ddd, $J = 8.4$, 2.6, 1.3 Hz, 1H), 7.01–7.05 (m, 2H), 7.10 ppm (t, $J = 8.4$ Hz, 1H); ^{13}C NMR (100.6 MHz, $CDCl_3$): $\delta = 11.98$, 18.53, 20.74, 23.30, 24.13, 25.69, 26.35,

27.12, 28.19, 30.37, 31.94, 34.46, 35.29, 35.41, 35.74, 36.27, 40.10, 40.37, 42.02, 42.60, 56.02, 56.39, 68.66, 71.73, 113.45, 117.68, 122.67, 123.42, 130.35, 159.84 ppm.

(3β,5β)-3,24-Bis(3-bromophenoxy)cholane (4): A two-necked flask flushed with argon, equipped with a condenser and magnetic stirrer, was charged with absolute THF (250 mL), cholanediol **2** (10 mmol, 3.62 g), 3-bromophenol (20 mmol, 3.46 g), triphenylphosphine (20 mmol, 5.24 g), and a solution of DEAD in toluene (40%, 20 mmol, 9.2 mL). The reaction mixture was stirred at room temperature for 2 days. Then the additional amount of 3-bromophenol (3.46 g, 20 mmol), triphenylphosphine (20 mmol, 5.24 g), and a solution of DEAD in toluene (40%, 20 mmol, 9.2 mL) was added, and the reaction mixture was stirred at 45–50 °C for 24 h. Then the reaction mixture was concentrated in vacuum up to the volume of 25 mL, diethyl ether (25 mL) was added, and the precipitation of triphenylphosphine oxide was observed. The solution was filtered off, the precipitate was washed with diethyl ether, the solvent was evaporated in vacuum, and the crude product was obtained as a pale-yellow oil. The oil was subjected to chromatography on silica with CH_2Cl_2 as an eluent. Yield (colourless oil): 2.89 g (43%); ^{1}H NMR (400 MHz, $CDCl_3$): δ = 0.67 (s, 3H), 0.96 (d, J = 6.3 Hz, 3H), 0.98 (s, 3H), 1.00–2.01 (m, 28H), 3.85–3.93 (m, 2H), 4.56 (brs, 1H), 6.80–6.84 (m, 2H), 7.01–7.07 (m, 4H), 7.11 (t, J = 8.0 Hz, 1H), 7.12 ppm (t, J = 8.4 Hz, 1H); ^{13}C NMR (100.6 MHz, $CDCl_3$): δ = 12.06 (1C), 18.60 (1C), 21.09 (1C), 23.80 (1C), 24.18 (1C), 24.49 (1C), 25.74 (1C), 26.21 (1C), 26.54 (1C), 28.26 (1C), 30.25 (1C), 30.32 (1C), 32.02 (1C), 34.82 (1C), 35.47 (1C), 35.64 (1C), 36.92 (1C), 40.01 (1C), 40.23 (1C), 42.72 (1C), 56.15 (1C), 56.61 (1C), 68.71 (1C), 73.08 (1C), 113.51 (1C), 114.74 (1C), 117.71 (1C), 119.28 (1C), 122.74 (1C), 123.31 (1C), 123.49 (1C), 130.43 (br, 3C), 158.60 (1C), 159.92 ppm (1C).

General method for the synthesis of macrocycles 6a–h: A two-necked flask equipped with a condenser and flushed with argon was charged with compound **4** (0.25–0.5 mmol, 168–336 mg), $[Pd(dba)_2]$ (8 mol%, 12–24 mg), BINAP (9 mol%, 14–28 mg), absolute dioxane (12–25 mL), appropriate polyamine (0.25–0.5 mmol), and sodium *tert*-butylate (1–2 mmol, 100–200 mg). The reaction mixture was refluxed for 7–10 h and then cooled to ambient temperature. The NaBr precipitate was filtered off, dioxane was evaporated in vacuum, and a solid or oily residue was obtained. The residue was subjected to chromatography on silica with a sequence of eluents: CH_2Cl_2, CH_2Cl_2/MeOH 100:1–3:1, CH_2Cl_2/MeOH/NH_3 100:20:1–10:3:1. Amount of silica used: 40 mL/0.5 mmol.

Compound 6a: From **4** (0.25 mmol, 168 mg) and triamine **5a** (0.25 mmol, 33 mg), in the presence of $[Pd(dba)_2]$ (12 mg), BINAP (14 mg), and *t*BuONa (100 mg) in dioxane (12 mL), and after 8 h of reflux, macrocycle **6a** was obtained as a viscous pale-yellow oil. Yield: 71 mg (44%); eluent CH_2Cl_2/MeOH/NH_3 100:20:3–10:3:1; ^{1}H NMR (400 MHz, $CDCl_3$): δ = 0.65 (s, 3H), 0.93 (d, J = 6.6 Hz, 3H), 0.96 (s, 3H), 0.98–2.07 (m, 28H), 1.84 (q, J = 7.6 Hz, 4H), 2.78 (t, J = 6.3 Hz, 4H), 3.17 (t, J = 6.9 Hz, 4H), 3.81–3.90 (m, 2H), 4.53 (s, 1H), 6.11–6.26 (m, 6H), 6.98–7.06 ppm (m, 2H) (here and in the following ^{1}H NMR spectra signals for NH protons are omitted for the reason of their inconstancy); ^{13}C NMR (100.6 MHz, $CDCl_3$): δ = 12.04 (1C), 18.59 (1C), 21.06 (1C), 23.80 (1C), 24.18 (1C), 24.64 (1C), 25.94 (1C), 26.23 (1C), 26.58 (1C), 28.24 (1C), 29.36 (1C), 29.49 (1C), 29.63 (2C), 32.08 (1C), 34.81 (1C), 35.50 (1C), 35.64 (1C), 36.93 (1C), 39.98 (1C), 40.24 (1C), 42.70 (2C), 42.83 (1C), 48.22 (2C), 56.17 (1C), 56.63 (1C), 68.23 (1C), 72.25 (1C), 99.18 (1C), 100.83 (1C), 102.79 (1C), 102.90 (1C), 105.57 (1C), 105.78 (1C), 129.77 (1C), 129.81 (1C), 149.81 (1C), 149.89 (1C), 158.97 (1C), 160.37 ppm (1C); MALDI-TOF (dithranol): m/z: 642.12 $[M+H]^+$.

Compound 6b: From **4** (0.28 mmol, 195 mg) and tetraamine **5b** (0.28 mmol, 41 mg), in the presence of $[Pd(dba)_2]$ (13 mg), BINAP (16 mg), and *t*BuONa (108 mg) in dioxane (14 mL) and after 9 h of reflux, macrocycle **6b** was obtained as beige crystals. M.p. 108–110 °C; yield 81 mg (44%); eluent CH_2Cl_2/MeOH/NH_3 10:3:1; ^{1}H NMR (400 MHz, $CDCl_3$): δ = 0.65 (s, 3H), 0.94 (d, J = 6.6 Hz, 3H), 0.96 (s, 3H), 0.99–2.01 (m, 28H), 2.73 (s, 4H), 2.85 (t, J = 5.4 Hz, 4H), 3.18 (t, J = 5.4 Hz, 4H), 3.86 (s, 2H), 4.53 (s, 1H), 6.11–6.29 (m, 6H), 7.02 (t, J = 7.9 Hz, 1H), 7.03 ppm (t, J = 8.0 Hz, 1H); ^{13}C NMR (100.6 MHz, $CDCl_3$): δ = 12.04 (1C), 18.58 (1C), 21.06 (1C), 23.79 (1C), 24.16 (1C), 24.65 (1C), 25.92 (1C), 26.23 (1C), 26.58 (1C), 28.23 (1C), 29.61 (1C), 30.44 (1C), 32.08 (1C), 34.80 (1C), 35.49 (1C), 35.63 (1C), 36.93 (1C), 39.99 (1C), 40.24 (1C), 42.70 (1C), 43.45 (2C), 48.42 (2C), 48.97 (2C), 56.17 (1C), 56.62 (1C), 68.23 (1C), 72.29 (1C), 99.43 (1C), 101.12 (1C), 103.17 (1C), 104.71 (1C), 105.69 (1C), 105.92 (1C), 129.75 (1C), 129.79 (1C), 149.81 (2C), 158.93 (1C), 160.34 ppm (1C); MALDI-TOF (dithranol): m/z: 1313.70 $[2M+H]^+$, 1969.90 $[3M]^+$.

Compound 6c: From **4** (0.25 mmol, 168 mg) and tetraamine **5c** (0.25 mmol, 40 mg), in the presence of $[Pd(dba)_2]$ (12 mg), BINAP (14 mg), and *t*BuONa (100 mg) in dioxane (12 mL) and after 8.5 h of reflux, macrocycle **6c** was obtained as a viscous pale-yellow oil. Yield: 70 mg (42%); eluent CH_2Cl_2/MeOH/NH_3 100:20:3; ^{1}H NMR (400 MHz, $CDCl_3$): δ = 0.64 (s, 3H), 0.93 (d, J = 6.5 Hz, 3H), 0.95 (s, 3H), 0.99–2.05 (m, 30H), 2.89 (brs, 8H), 3.28 (brs, 4H), 3.84 (brs, 2H), 4.51 (s, 1H), 6.10–6.29 (m, 6H), 6.96–7.05 ppm (m, 2H); ^{13}C NMR (100.6 MHz, $CDCl_3$): δ = 12.06 (1C), 18.60 (1C), 21.07 (1C), 23.82 (1C), 24.18 (1C), 24.61 (1C), 25.95 (1C), 26.23 (1C), 26.59 (1C), 28.26 (1C), 30.45 (br, 3C), 32.09 (1C), 34.82 (1C), 35.54 (1C), 36.63 (1C), 36.95 (1C), 39.97 (1C), 40.23 (1C), 42.06 (2C), 42.70 (1C), 47.66 (2C), 48.89 (2C), 56.17 (1C), 56.60 (1C), 68.31 (1C), 72.31 (1C), 99.26 (1C), 100.84 (1C), 103.34 (1C), 104.62 (1C), 105.59 (1C), 105.81 (1C), 129.93 (1C), 130.01 (1C), 149.29 (2C), 158.99 (1C), 160.40 ppm (1C) ppm; MALDI-TOF (dithranol): m/z: 671.16 $[M+H]^+$.

Compound 6d: From **4** (0.28 mmol, 195 mg) and tetraamine **5d** (0.28 mmol, 48 mg), in the presence of $[Pd(dba)_2]$ (13 mg), BINAP (16 mg), and *t*BuONa (108 mg) in dioxane (14 mL) and after 9 h of reflux, macrocycle **6d** was obtained as a viscous pale-yellow oil. Yield: 130 mg (65%); eluent CH_2Cl_2/MeOH/NH_3 100:20:3–10:3:1; ^{1}H NMR (400 MHz, $CDCl_3$): δ = 0.65 (s, 3H), 0.94 (d, J = 5.6 Hz, 3H), 0.96 (s, 3H), 0.99–2.08 (m, 28H), 1.77 (q, J = 6.2 Hz, 4H), 2.71 (s, 4H), 2.72 (t, J = 6.3 Hz, 4H), 3.15 (t, J = 5.2 Hz, 4H), 3.87 (brs, 2H), 4.54 (brs, 1H), 6.09–6.28 (m, 6H), 6.97–7.06 ppm (m, 2H); ^{13}C NMR (100.6 MHz, $CDCl_3$): δ = 12.04 (1C), 18.59 (1C), 21.07 (1C), 23.80 (1C), 24.18 (1C), 24.66 (1C), 25.95 (1C), 26.23 (1C), 26.58 (1C), 28.24 (1C), 29.54 (2C), 29.62 (2C), 32.08 (1C), 34.81 (1C), 35.49 (1C), 35.64 (1C), 36.93 (1C), 39.99 (1C), 40.24 (1C), 42.59 (1C), 42.66 (1C), 42.70 (1C), 48.08 (2C), 49.42 (2C), 56.18 (1C), 56.62 (1C), 68.23 (1C), 72.27 (1C), 99.22 (1C), 100.90 (1C), 102.84 (1C), 104.37 (1C), 105.56 (1C), 105.76 (1C), 129.72 (1C), 129.77 (1C), 149.89 (1C), 149.93 (1C), 158.96 (1C), 160.36 ppm (1C); MALDI-TOF (dithranol): m/z: 685.46 $[M+H]^+$, 1369.9 $[2M+H]^+$.

Compound 6e: From **4** (0.25 mmol, 168 mg) and tetraamine **5e** (0.25 mmol, 47 mg), in the presence of $[Pd(dba)_2]$ (12 mg), BINAP (14 mg), and *t*BuONa (100 mg) in dioxane (12 mL) and after 7 h of reflux, macrocycle **6e** was obtained as a viscous pale-yellow oil. Yield: 104 mg (60%); eluent CH_2Cl_2/MeOH/NH_3 10:3:1; ^{1}H NMR (400 MHz, $CDCl_3$): δ = 0.64 (s, 3H), 0.93 (d, J = 6.5 Hz, 3H), 0.96 (s, 3H), 0.98–2.02 (m, 28H), 1.79 (brs, 6H), 2.70–2.83 (m, 8H), 3.12 (brs, 4H), 3.85 (brs, 2H), 4.53 (s, 1H), 6.10–6.26 (m, 6H), 7.00 (t, J = 8.0 Hz, 1H), 7.03 ppm (t, J = 8.1 Hz, 1H); ^{13}C NMR (100.6 MHz, $CDCl_3$): δ = 11.90 (1C), 18.45 (1C), 20.92 (1C), 23.67 (1C), 24.03 (1C), 24.51 (1C), 25.81 (1C), 26.09 (1C), 26.44 (1C), 28.10 (1C), 29.22 (2C), 29.48 (1C), 30.17 (1C), 30.32 (1C), 31.95 (1C), 33.62 (1C), 34.67 (1C), 35.36 (1C), 35.49 (1C), 36.80 (1C), 39.84 (1C), 40.11 (1C), 40.14 (1C), 42.56 (1C), 42.62 (1C), 47.69 (1C), 48.16 (1C), 48.24 (1C), 56.04 (1C), 56.47 (1C), 68.05 (1C), 72.07 (1C), 99.02 (1C), 100.69 (1C), 102.59 (1C), 104.15 (1C), 105.41 (1C), 105.62 (1C), 129.59 (2C), 149.78 (1C), 149.82 (1C), 158.80 (1C), 160.21 ppm (1C).

Compound 6f: From **4** (0.25 mmol, 168 mg) and pentaamine **5f** (0.25 mmol, 47 mg), in the presence of $[Pd(dba)_2]$ (12 mg), BINAP (14 mg), and *t*BuONa (100 mg) in dioxane (12 mL) and after 10 h of reflux, macrocycle **6f** was obtained as a viscous pale-yellow oil. Yield: 66 mg (38%); eluent CH_2Cl_2/MeOH/NH_3 100:20:3–10:3:1; ^{1}H NMR (400 MHz, $CDCl_3$): δ = 0.66 (s, 3H), 0.97 (brs, 6H), 0.86–2.05 (m, 28H), 2.70 (s, 8H), 2.84 (brs, 4H), 3.16 (brs, 4H), 3.87 (brs, 2H), 4.54 (s, 1H), 6.08–6.30 (m, 6H), 6.97–7.03 ppm (m, 2H); ^{13}C NMR (100.6 MHz, $CDCl_3$): δ = 12.06 (1C), 18.60 (1C), 21.08 (1C), 23.83 (1C), 24.19 (1C), 24.65 (1C), 25.95 (1C), 26.24 (1C), 26.58 (1C), 28.26 (1C), 30.45 (2C), 32.08 (1C), 34.83 (1C), 35.52 (1C), 35.64 (1C), 36.94 (1C), 39.99 (1C),

40.24 (1C), 42.72 (1C), 43.42 (2C), 48.42 (2C), 48.99 (2C), 49.22 (2C), 56.17 (1C), 56.63 (1C), 68.25 (1C), 72.28 (1C), 99.42 (1C), 101.12 (1C), 103.10 (1C), 104.68 (1C), 105.72 (1C), 105.94 (1C), 129.78 (1C), 129.85 (1C), 149.79 (1C), 149.83 (1C), 158.93 (1C), 160.34 ppm (1C); MALDI-TOF (dithranol): m/z: 700.13 $[M+H]^+$.

Compound 6g: From **4** (0.28 mmol, 195 mg) and dioxadiamine **5g** (0.28 mmol, 42 mg), in the presence of $[Pd(dba)_2]$ (13 mg), BINAP (16 mg), and *t*BuONa (110 mg) in dioxane (14 mL) and after 9 h of reflux, macrocycle **6g** was obtained as a viscous pale-yellow oil. Yield: 74 mg (40%); eluent CH_2Cl_2/MeOH 10:1–5:1; ^{1}H NMR (400 MHz, $CDCl_3$): δ = 0.65 (s, 3H), 0.94 (d, J = 6.6 Hz, 3H), 0.96 (s, 3H), 0.99–2.04 (m, 28H), 3.27 (t, J = 4.7 Hz, 4H), 3.63 (s, 4H), 3.69 (t, J = 4.7 Hz, 4H), 3.86 (brs, 2H), 4.53 (s, 1H), 6.15–6.28 (m, 6H), 7.03 (t, J = 8.0 Hz, 1H), 7.04 ppm (t, J = 8.3 Hz, 1H); ^{13}C NMR (100.6 MHz, $CDCl_3$): δ = 12.06 (1C), 18.61 (1C), 21.09 (1C), 23.82 (1C), 24.19 (1C), 24.66 (1C), 25.95 (1C), 26.25 (1C), 26.60 (1C), 28.26 (1C), 29.64 (1C), 30.46 (1C), 32.10 (1C), 34.83 (1C), 35.52 (1C), 35.66 (1C), 36.96 (1C), 40.01 (1C), 40.27 (1C), 42.73 (1C), 43.42 (2C), 56.20 (1C), 56.64 (1C), 68.26 (1C), 69.60 (2C), 70.19 (2C), 72.34 (1C), 99.65 (1C), 101.36 (1C), 103.40 (1C), 104.93 (1C), 105.89 (1C), 106.10 (1C), 129.79 (1C), 129.83 (1C), 149.49 (1C), 149.55 (1C), 158.95 (1C), 160.35 ppm (1C).

Compound 6h: From **4** (0.5 mmol, 336 mg) and trioxadiamine **5h** (0.5 mmol, 110 mg), in the presence of $[Pd(dba)_2]$ (23 mg), BINAP (28 mg), and *t*BuONa (200 mg) in dioxane (25 mL) and after 7 h of reflux, macrocycle **6h** was obtained as yellow crystals. M.p. 90–92 °C; yield 220 mg (60%); eluent CH_2Cl_2/MeOH 10:1–3:1; ^{1}H NMR (400 MHz, $CDCl_3$): δ = 0.65 (s, 3H), 0.94 (d, J = 6.3 Hz, 3H), 0.97 (s, 3H), 1.00–2.02 (m, 28H), 1.86 (q, J = 6.4 Hz, 4H), 3.19 (t, J = 6.5 Hz, 2H), 3.20 (t, J = 6.5 Hz, 2H), 3.58–3.69 (m, 12H), 3.84–3.88 (m, 2H), 4.53 (brs, 1H), 6.12–6.25 (m, 6H), 7.01 (t, J = 7.9 Hz, 1H), 7.02 ppm (t, J = 8.1 Hz, 1H); ^{13}C NMR (100.6 MHz, $CDCl_3$): δ = 12.06 (1C), 18.62 (1C), 21.10 (1C), 23.83 (1C), 24.21 (1C), 24.70 (1C), 26.00 (1C), 26.26 (1C), 26.61 (1C), 28.26 (1C), 29.13 (1C), 29.19 (1C), 30.49 (2C), 32.13 (1C), 34.85 (1C), 35.54 (1C), 35.68 (1C), 36.98 (1C), 40.03 (1C), 40.28 (1C), 41.68 (2C), 42.74 (1C), 56.23 (1C), 56.66 (1C), 68.27 (1C), 69.70 (2C), 70.24 (2C), 70.62 (2C), 72.30 (1C), 99.25 (1C), 100.95 (1C), 102.78 (1C), 104.30 (1C), 105.62 (1C), 105.83 (1C), 129.71 (1C), 129.77 (1C), 149.90 (1C), 149.96 (1C), 158.99 (1C), 160.40 ppm (1C); MALDI-TOF (dithranol): m/z: 731.35 $[M+H]^+$.

General method for the synthesis of bis(polyamino)-substituted steroids 7a,d,e,g–i: A two-necked flask, equipped with a condenser and flushed with argon, was charged with **4** (0.22–1.35 mmol, 148–907 mg), $[Pd(dba)_2]$ (8 mol%, 10–62 mg), BINAP (9 mol%, 12–76 mg), absolute dioxane (2–13 mL), the appropriiate polyamine (0.55–5.4 mmol), and *t*BuONa (0.9–5.4 mmol, 90–520 mg). The reaction mixture was refluxed for 5–8 h and then cooled down. NaBr was filtered off, dioxane was evaporated in vacuum, and the residue was subjected to chromatography on silica using a sequence of eluents: CH_2Cl_2, CH_2Cl_2/MeOH 100:1–3:1 (in the case of **7g**,**h**).

Compound 7a: From **4** (0.22 mmol, 150 mg) and triamine **5a** (0.66 mmol, 86 mg), in the presence of $[Pd(dba)_2]$ (10 mg), BINAP (12 mg), and *t*BuONa (85 mg) in absolute dioxane (2 mL) and after refluxing for 5 h, bis(polyamino) derivative **7a** was obtained as a pale-yellow oil. Yield in the reaction mixture >90%. ^{1}H NMR (400 MHz, $CDCl_3$): δ = 0.64 (s, 3H), 0.94 (d, J = 6.5 Hz, 3H), 0.97 (s, 3H), 0.98–1.94 (m, 28H), 1.61 (q, J = 6.9 Hz, 4H), 1.77 (q, J = 6.6 Hz, 4H), 2.64 (t, J = 7.1 Hz, 4H), 2.71 (t, J = 5.8 Hz, 4H), 2.75 (t, J = 5.8 Hz, 4H), 3.14 (t, J = 5.7 Hz, 4H), 3.76–3.85 (m, 2H), 4.54 (brs, 1H), 6.06–6.20 (m, 6H), 7.02 (t, J = 7.8 Hz, 1H), 7.03 ppm (t, J = 8.0 Hz, 1H); ^{13}C NMR (100.6 MHz, $CDCl_3$): δ = 11.90 (1C), 18.44 (1C), 20.91 (1C), 23.66 (1C), 24.02 (1C), 24.49 (1C), 25.78 (1C), 26.07 (1C), 26.42 (1C), 28.10 (1C), 29.20 (1C), 29.25 (1C), 30.29 (2C), 31.92 (1C), 33.59 (2C), 34.66 (1C), 35.35 (1C), 35.48 (1C), 36.79 (1C), 39.82 (1C), 40.11 (1C), 40.16 (2C), 42.54 (1C), 42.66 (2C), 47.64 (2C), 48.23 (2C), 56.00 (1C), 56.46 (1C), 68.06 (1C), 72.07 (1C), 98.97 (1C), 100.64 (1C), 102.59 (1C), 104.16 (1C), 105.41 (1C), 105.62 (1C), 129.56 (1C), 129.61 (1C), 149.75 (1C), 149.79 (1C), 158.79 (1C), 160.20 ppm (1C); MALDI-TOF (dithranol): m/z: 773.64 $[M+H]^+$.

Compound 7d: From **4** (0.22 mmol, 150 mg) and tetraamine **5d** (0.66 mmol, 115 mg), in the presence of $[Pd(dba)_2]$ (10 mg), BINAP (12 mg), and *t*BuONa (85 mg) in absolute dioxane (2 mL) and after refluxing for 5 h, bis(polyamino) derivative **7d** was obtained as a pale-yellow oil. Yield in the reaction mixture >90%. ^{1}H NMR (400 MHz, $CDCl_3$): δ = 0.66 (s, 3H), 0.94 (d, J = 6.3 Hz, 3H), 0.97 (s, 3H), 1.00–2.02 (m, 28H), 1.62 (q, J = 7.0 Hz, 4H), 1.78 (q, J = 6.5 Hz, 4H), 2.65 (t, J = 7.0 Hz, 4H), 2.69–2.72 (m, 12H), 2.74 (t, J = 6.5 Hz, 4H), 3.15 (t, J = 6.6 Hz, 4H), 3.87 (brs, 2H), 4.54 (brs, 1H), 6.12–6.25 (m, 6H), 7.02 (t, J = 7.8 Hz, 1H), 7.04 ppm (t, J = 8.1 Hz, 1H); ^{13}C NMR (100.6 MHz, $CDCl_3$): δ = 11.92 (1C), 18.47 (1C), 20.94 (1C), 23.69 (1C), 24.05 (1C), 24.51 (1C), 25.80 (1C), 26.10 (1C), 26.45 (1C), 28.12 (1C), 29.32 (1C), 29.36 (1C), 30.32 (2C), 31.95 (1C), 33.64 (2C), 34.69 (1C), 35.38 (1C), 35.50 (1C), 36.81 (1C), 39.84 (1C), 40.10 (3C), 42.48 (2C), 42.57 (1C), 47.53 (2C), 47.93 (2C), 49.28 (4C), 56.03 (1C), 56.49 (1C), 68.09 (1C), 72.10 (1C), 99.04 (1C), 100.72 (1C), 102.63 (1C), 104.19 (1C), 105.42 (1C), 105.64 (1C), 129.59 (1C), 129.64 (1C), 149.75 (1C), 149.80 (1C), 158.82 (1C), 160.23 ppm (1C); MALDI-TOF (dithranol): m/z: 859.76 $[M+H]^+$.

Compound 7e: From **4** (0.22 mmol, 150 mg) and tetraamine **5e** (0.66 mmol, 124 mg), in the presence of $[Pd(dba)_2]$ (10 mg), BINAP (12 mg), and *t*BuONa (85 mg) in absolute dioxane (2 mL) and after refluxing for 5 h, bis(polyamino) derivative **7e** was obtained as a pale-yellow oil. Yield in the reaction mixture >90%. ^{1}H NMR (400 MHz, $CDCl_3$): δ = 0.65 (s, 3H), 0.94 (d, J = 6.5 Hz, 3H), 0.96 (s, 3H), 0.99–1.98 (m, 28H), 1.61 (q, J = 6.9 Hz, 4H), 1.65 (q, J = 6.9 Hz, 4H), 1.76 (q, J = 6.1 Hz, 4H), 2.59–2.73 (m, 20H), 3.14 (brs, 4H), 3.86 (brs, 2H), 4.53 (brs, 1H), 6.10–6.24 (m, 6H), 7.01 (t, J = 7.6 Hz, 1H), 7.02 ppm (t, J = 7.8 Hz, 1H); ^{13}C NMR (100.6 MHz, $CDCl_3$): δ = 11.84 (1C), 18.39 (1C), 20.85 (1C), 23.61 (1C), 23.97 (1C), 24.43 (1C), 25.72 (1C), 26.02 (1C), 26.37 (1C), 28.04 (1C), 29.14 (1C), 29.19 (1C), 30.08 (2C), 30.24 (2C), 31.87 (1C), 33.56 (2C), 34.60 (1C), 35.29 (1C), 35.42 (1C), 36.72 (1C), 39.76 (1C), 40.01 (1C), 40.09 (2C), 42.48 (1C), 42.55 (2C), 47.60 (2C), 48.10 (2C), 48.24 (2C), 48.32 (2C), 55.95 (1C), 56.40 (1C), 67.99 (1C), 71.99 (1C), 98.92 (1C), 100.59 (1C), 102.50 (1C), 104.07 (1C), 105.33 (1C), 105.55 (1C), 129.48 (1C), 129.53 (1C), 149.70 (1C), 149.74 (1C), 158.72 (1C), 160.13 ppm (1C); MALDI-TOF (dithranol): m/z: 887.82 $[M+H]^+$.

Compound 7g: From **4** (0.7 mmol, 470 mg) and dioxadiamine **5g** (1.75 mmol, 259 mg), in the presence of $[Pd(dba)_2]$ (23 mg), BINAP (39 mg), and *t*BuONa (270 mg) in absolute dioxane (6 mL) and after refluxing for 7 h, bis(polyamino) derivative **7g** was obtained as a pale-yellow oil. Yield: 225 mg (40%); eluent CH_2Cl_2/MeOH 5:1; ^{1}H NMR (400 MHz, $CDCl_3$): δ = 0.64 (s, 3H), 0.93 (d, J = 6.6 Hz, 3H), 0.96 (s, 3H), 0.99–2.00 (m, 28H), 2.85 (brs, 4H), 3.25 (t, J = 4.8 Hz, 4H), 3.49 (brs, 4H), 3.59 (s, 8H), 3.66 (t, J = 5.0 Hz, 4H), 3.81–3.89 (m, 2H), 4.52 (brs, 1H), 6.15–6.28 (m, 6H), 7.00 (t, J = 7.8 Hz, 1H), 7.02 ppm (t, J = 7.9 Hz, 1H); ^{13}C NMR (100.6 MHz, $CDCl_3$): δ = 12.01 (1C), 18.59 (1C), 21.03 (1C), 23.78 (1C), 24.15 (1C), 24.60 (1C), 25.88 (1C), 26.19 (1C), 26.55 (1C), 28.21 (1C), 30.41 (1C), 32.04 (1C), 34.78 (1C), 35.47 (1C), 35.60 (1C), 36.91 (1C), 39.95 (1C), 40.20 (1C), 41.10 (1C), 42.67 (1C), 43.42 (2C), 56.12 (1C), 56.58 (1C), 68.22 (1C), 69.56 (2C), 69.60 (2C), 70.09 (4C), 71.92 (2C), 72.26 (1C), 99.51 (1C), 101.19 (1C), 103.16 (1C), 104.82 (1C), 105.79 (1C), 106.04 (1C), 129.74 (1C), 129.79 (1C), 149.54 (1C), 149.59 (1C), 158.88 (1C), 160.29 ppm (1C); MALDI-TOF (dithranol): m/z: 807.48 $[M+H]^+$.

Compound 7h: From **4** (1.35 mmol, 908 mg) and trioxadiamine **5h** (5.4 mmol, 1.19 g), in the presence of $[Pd(dba)_2]$ (62 mg), BINAP (76 mg), and *t*BuONa (520 mg) in absolute dioxane (13 mL) and after refluxing for 8 h, bis(polyamino) derivative **7h** was obtained as a pale-yellow oil. Yield: 1.05 g (82%); eluent CH_2Cl_2/MeOH 5:1; ^{1}H NMR (400 MHz, $CDCl_3$): δ = 0.63 (s, 3H), 0.92 (d, J = 6.6 Hz, 3H), 0.95 (s, 3H), 0.98–2.02 (m, 28H), 1.84 (brs, 4H), 1.89 (q, J = 6.3 Hz, 4H), 2.99 (t, J = 5.5 Hz, 4H), 3.18 (t, J = 5.7 Hz, 4H), 3.55–3.66 (m, 24H), 3.82–3.88 (m, 2H), 4.52 (brs, 1H), 6.10–6.26 (m, 6H), 6.99 (t, J = 7.8 Hz, 1H), 7.00 ppm (t, J = 8.0 Hz, 1H); ^{13}C NMR (100.6 MHz, $CDCl_3$): δ = 12.01 (1C), 18.57 (1C), 21.04 (1C), 23.78 (1C), 24.14 (1C), 24.63 (1C), 25.89 (1C), 26.19 (1C), 26.55 (1C), 28.11 (1C), 28.21 (2C), 28.81 (1C), 28.98 (2C), 30.43

(1C), 32.06 (1C), 34.79 (1C), 35.47 (1C), 35.61 (1C), 36.93 (1C), 39.74 (2C), 39.96 (1C), 40.21 (1C), 41.61 (2C), 42.67 (1C), 56.11 (1C), 56.59 (1C), 68.24 (1C), 69.56 (2C), 69.78 (2C), 69.87 (2C), 69.97 (4C), 70.38 (2C), 72.24 (1C), 99.45 (1C), 101.06 (1C), 103.00 (1C), 104.72 (1C), 105.84 (1C), 106.08 (1C), 129.71 (1C), 129.74 (1C),149.83 (1C), 149.86 (1C), 158.90 (1C), 160.31 ppm (1C); MALDI-TOF (dithranol), *m*/*z*: 951.60 $[M+H]^+$.

Compound 7i: From **4** (0.22 mmol, 150 mg) and diaminopropane **5i** (0.66 mmol, 124 mg), in the presence of $[Pd(dba)_2]$ (10 mg), BINAP (12 mg), and *t*BuONa (85 mg) in absolute dioxane (2 mL) and after refluxing for 5 h, bis(polyamino) derivative **7i** was obtained as a pale-yellow oil. Yield in the reaction mixture *ca* 60%. ^{1}H NMR (400 MHz, $CDCl_3$): $\delta = 0.68$ (s, 3H), 0.99 (brs, 6H), 1.03–2.05 (m, 28H), 1.73 (brs, 4H), 2.80 (brs, 4H), 3.16 (brs, 4H), 3.89 (brs, 2H), 4.55 (brs, 1H), 6.14–6.30 (m, 6H), 7.01–7.09 ppm (m, 2H); ^{13}C NMR (100.6 MHz, $CDCl_3$): $\delta = 11.98$ (1C), 18.55 (1C), 21.02 (1C), 23.74 (1C), 24.12 (1C), 24.61 (1C), 25.89 (1C), 26.18 (1C), 26.53 (1C), 28.17 (1C), 30.41 (2C), 32.05 (1C), 32.77 (2C), 34.75 (1C), 35.42 (1C), 35.60 (1C), 36.89 (1C), 39.96 (2C), 40.19 (1C), 41.79 (2C), 41.95 (1C), 42.65 (1C), 56.14 (1C), 56.57 (1C), 68.18 (1C), 72.24 (1C), 99.19 (1C), 100.87 (1C), 102.89 (1C), 104.43 (1C), 105.49 (1C), 105.69 (1C), 129.66 (1C), 129.71 (1C), 149.53 (1C), 149.80 (1C), 158.93 (1C), 160.34 ppm (1C); MALDI-TOF (dithranol): *m*/*z*: 658.83 $[M]^+$.

General method for the synthesis of bis(steroidal) derivatives of polyamines 8g–i: A two-necked flask equipped with a condenser and flushed with argon was charged with compound **4** (0.78–1.97 mmol, 0.52–1.32 g), $[Pd(dba)_2]$ (8 mol%, 14–41 mg), BINAP (9 mol%, 17–50 mg), the corresponding polyamine (0.31–0.9 mmol), absolute dioxane (3–9 mL), and *t*BuONa (1.2–3.6 mmol, 120–350 mg). The reaction mixture was refluxed for 4.5–5 h and then cooled down. The precipitate of NaBr was filtered off, and dioxane was evaporated in vacuum. The residue was subjected to chromatography on silica with a sequence of eluents: CH_2Cl_2, CH_2Cl_2/MeOH 500:1–3:1 (in the case of **8g**,**h**).

Compound 8g: From **4** (1.97 mmol, 1.32 g) and dioxadiamine **5g** (0.9 mmol, 133 mg), in the presence of $[Pd(dba)_2]$ (41 mg), BINAP (50 mg), and *t*BuONa (350 mg) in absolute dioxane (9 mL) and after 4.5 h reflux, bis(steroidal) derivative **8g** was obtained as a yellowish oil. Yield: 500 mg (43%); eluent CH_2Cl_2/MeOH 250:1, 10:1–3:1. ^{1}H NMR (400 MHz, $CDCl_3$, a mixture of 3 possible isomers): $\delta = 0.68$ (s, 6H), 0.96 (d, $J = 6.4$ Hz, 6H), 0.99 (s, 6H), 1.01–2.03 (m, 56H), 3.29 (t, $J = 4.8$ Hz, 4H), 3.64 (s, 8H), 3.69 (t, $J = 4.8$ Hz, 4H), 3.85–3.94 (m, 4H), 4.54 (brs, 1H), 4.56 (brs, 1H), 6.15–6.30 (m, 6H), 6.82 (d, $J = 8.0$ Hz, 2H), 7.00–7.07 (m, 6H), 7.11 (t, $J = 8.0$ Hz, 1H), 7.12 ppm (t, $J = 8.1$ Hz, 1H); ^{13}C NMR (100.6 MHz, $CDCl_3$, a mixture of 3 possible isomers): $\delta = 12.06$ (2C-ster), 18.61 (2C-ster), 21.10 (2C-ster), 23.81 (2C-ster), 24.18 (2C-ster), 24.51 and 24.69 (2C-ster), 25.76 and 25.97 (2C-ster), 26.15 (2C-ster), 26.56 and 26.61 (2C-ster), 28.24 (2C-ster), 30.29 and 30.32 (2C-ster), 30.48 (2C-ster), 32.04 and 32.12 (2C-ster), 34.83 (2C-ster), 35.47 and 35.50 (2C-ster), 35.68 (2C-ster), 36.95 (2C-ster), 40.05 (2C-ster), 40.27 (2C-ster), 42.74 (2C-ster), 43.52 (NCH_2, 2C-diamine), 56.20 (2C-ster), 56.64 (2C-ster), 68.26 and 68.74 (2C-ster), 69.64 and 69.68 (OCH_2, 2C-diamine), 70.20 (OCH_2, 2C-diamine), 72.36 and 73.16 (2C-ster), 99.67 (1C-Ar), 101.36 (1C-Ar), 103.41 (1C-Ar), 105.02 (1C-Ar), 105.87 (1C-Ar), 106.09 (1C-Ar), 113.53 (1C-Ar), 114.77 (1C-Ar), 117.76 (1C-Ar), 119.32 (1C-Ar), 122.72 (1C-Ar), 123.32 (1C-Ar), 123.49 (1C-Ar), 129.31 (1C-Ar), 129.78 (1C-Ar), 129.82 (1C-Ar), 130.41 (2C-Ar), 149.54 (1C-Ar), 149.59 (1C-Ar), 158.63 (1C-Ar), 158.97 (1C-Ar), 159.94 (1C-Ar), 160.37 ppm (1C-Ar).

Compound 8h: From **4** (0.78 mmol, 525 mg) and trioxadiamine **5h** (0.31 mmol, 69 mg), in the presence of $[Pd(dba)_2]$ (14 mg), BINAP (17 mg), and *t*BuONa (120 mg) in absolute dioxane (3 mL) and after 5 h reflux, bis(steroidal) derivative **8h** was obtained as a yellowish oil. Yield: 170 mg (39%); eluent CH_2Cl_2/MeOH 250:1, 10:1. ^{1}H NMR (400 MHz, $CDCl_3$, a mixture of 3 possible isomers): $\delta = 0.67$ (s, 6H), 0.95 (d, $J = 6.3$ Hz, 6H), 0.98 (s, 6H), 1.00–2.03 (m, 56H), 1.87 (q, $J = 6.1$ Hz, 4H), 3.20 (t, $J = 6.6$ Hz, 2H), 3.21 (t, $J = 6.3$ Hz, 2H), 3.55–3.69 (m, 12H), 3.83–3.93 (m, 4H), 4.55 (brs, 1H), 4.56 (brs, 1H), 6.13–6.26 (m, 6H), 6.82 (d, $J = 7.9$ Hz, 2H), 7.00–7.07 (m, 6H), 7.11 (t, $J = 8.1$ Hz, 1H), 7.12 ppm (t, $J = 8.3$ Hz, 1H); ^{13}C NMR (100.6 MHz, $CDCl_3$, a mixture of 3 possible isomers): $\delta = 12.06$ (2C-ster), 18.60 (2C-ster), 21.08 (2C-ster), 23.81 (2C-ster), 24.18 (2C-ster), 24.47 and 24.67 (2C-ster), 25.73 and 25.95 (2C-ster), 26.21 and 26.24 (2C-ster), 26.54 and 26.58 (2C-ster), 28.26 (2C-ster), 29.08 and 29.14 ($NCH_2CH_2CH_2O$, 2C-diamine), 30.22 and 30.30 (2C-ster), 30.47 (2C-ster), 32.01 and 32.09 (2C-ster), 34.82 (2C-ster), 35.47 and 35.52 (2C-ster), 35.64 (2C-ster), 36.92 (2C-ster), 40.00 (2C-ster), 40.24 (2C-ster), 41.68 (NCH_2, 2C-diamine), 42.72 (2C-ster), 56.15 (2C-ster), 56.63 (2C-ster), 68.22 and 68.71 (2C-ster), 69.70 (OCH_2, 2C-diamine), 70.23 (OCH_2, 2C-diamine), 70.62 (OCH_2, 2C-diamine), 72.22 and 73.07 (2C-ster), 99.16 (1C-Ar), 100.84 (1C-Ar), 102.68 (1C-Ar), 104.24 (1C-Ar), 105.57 (1C-Ar), 105.81 (1C-Ar), 113.52 (1C-Ar), 114.74 (1C-Ar), 117.68 (1C-Ar), 119.25 (1C-Ar), 122.72 (1C-Ar), 123.29 (1C-Ar), 123.47 (1C-Ar), 129.34 (1C-Ar), 129.71 (1C-Ar), 129.77 (1C-Ar), 130.43 (2C-Ar), 149.89 (1C-Ar), 149.94 (1C-Ar), 158.59 (1C-Ar), 158.95 (1C-Ar), 159.90 (1C-Ar), 160.36 ppm (1C-Ar).

Compound 8i: From **4** (0.78 mmol, 520 mg), diaminopropane **5i** (0.39 mmol, 29 mg), in the presence of $[Pd(dba)_2]$ (18 mg), BINAP (22 mg), and *t*BuONa (150 mg) in absolute dioxane (4 mL) and after 4.5 h reflux, bis(steroidal) derivative **8i** was obtained as a yellowish oil. Yield in the reaction mixture *ca* 90%. ^{1}H NMR (400 MHz, $CDCl_3$, a mixture of 3 possible isomers): $\delta = 0.68$ (s, 6H), 0.99 (brs, 12H), 1.03–2.05 (m, 58H), 3.21 (brs, 4H), 3.89 (brs, 4H), 4.55 (brs, 2H), 6.11–6.30 (m, 6H), 6.78–6.85 (m, 2H), 7.00–7.18 ppm (m, 8H); ^{13}C NMR (100.6 MHz, $CDCl_3$, a mixture of 3 possible isomers): $\delta = 11.99$ (2C-ster), 18.54 (2C-ster), 21.03 (2C-ster), 23.72 (2C-ster), 24.11 (2C-ster), 24.42 and 24.61 (2C-ster), 25.68 and 25.91 (2C-ster), 26.15 (2C-ster), 26.47 and 26.53 (2C-ster), 28.18 (2C-ster), 29.10 and 29.57 (2C-ster), 30.20 and 30.25 (2C-ster), 30.42 ($NCH_2CH_2CH_2N$, 1C-diamine), 31.97 and 32.05 (2C-ster), 34.75 (2C-ster), 35.39 (2C-ster), 35.58 (2C-ster), 36.85 (2C-ster), 39.96 (2C-ster), 40.17 (2C-ster), 41.79 (NCH_2, 2C-diamine), 42.65 (2C-ster), 56.10 (2C-ster), 56.55 (2C-ster), 68.17 and 68.63 (2C-ster), 72.24 and 73.04 (2C-ster), 99.32 (1C-Ar), 100.95 (1C-Ar), 103.16 (1C-Ar), 104.68 (1C-Ar), 105.59 (1C-Ar), 105.78 (1C-Ar), 113.44 (1C-Ar), 114.66 (1C-Ar), 117.68 (1C-Ar), 119.23 (1C-Ar),122.65 (1C-Ar), 123.24 (1C-Ar), 123.41 (1C-Ar), 127.91 (1C-Ar), 129.77 (2C-Ar), 130.34 (2C-Ar), 149.47 (1C-Ar), 149.53 (1C-Ar), 158.56 (1C-Ar), 158.95 (1C-Ar), 159.87 (1C-Ar), 160.35 ppm (1C-Ar).

Cyclodimer 9g: A two-necked flask, equipped with a condenser and flushed with argon, was charged with **8g** (0.21 mmol, 280 mg), dioxadiamine **5g** (0.21 mmol, 31 mg), $[Pd(dba)_2]$ (10 mg), BINAP (12 mg), *t*BuONa (0.84 mmol, 80 mg), and absolute dioxane (10.5 mL), and the reaction mixture was refluxed for 18 h. After cooling down to ambient temperature, and filtration and evaporation of the solvent, the crude product was subjected to chromatography on silica to obtain cyclodimer **9g** as a yellowish oil. Yield: 97 mg (35%); eluent CH_2Cl_2/MeOH 200:1, 10:1–2.5:1; ^{1}H NMR (400 MHz, $CDCl_3$, a mixture of 2 possible isomers): $\delta =$ 0.66 (s, 6H), 0.94 (d, $J = 5.6$ Hz, 6H), 0.97 (s, 6H), 1.00–2.03 (m, 56H), 3.28 (t, $J = 5.0$ Hz, 8H), 3.63 (s, 8H), 3.69 (t, $J = 4.9$ Hz, 8H), 3.83–3.90 (m, 4H), 4.53 (brs, 2H), 6.15–6.29 (m, 12H), 7.02 (t, $J = 8.1$ Hz, 2H), 7.03 ppm (t, $J = 8.0$ Hz, 2H); ^{13}C NMR (100.6 MHz, $CDCl_3$, a mixture of 2 possible isomers): $\delta = 12.09$ (2C), 18.64 (2C), 21.13 (2C), 23.84 (2C), 24.21 (2C), 24.71 (2C), 26.02 (2C), 26.29 (2C), 26.63 (2C), 28.27 (2C), 29.66 (2C), 30.50 (2C), 32.15 (2C), 34.87 (2C), 35.55 (2C), 35.71 (2C), 37.01 (2C), 40.08 (2C), 40.31 (2C), 42.78 (2C), 43.55 (4C), 56.26 (2C), 56.69 (2C), 68.32 (2C), 69.68 (2C), 69.72 (2C), 70.24 (4C), 72.42 (2C), 99.72 (2C), 101.43 (2C), 103.46 (2C), 105.04 (2C), 105.94 (2C), 106.15 (2C), 129.81 (2C), 129.86 (2C), 149.57 (2C), 149.62 (2C), 159.01 (2C), 160.42 ppm (2C).

Cyclodimer 9h: A two-necked flask, equipped with a condenser and flushed with argon, was charged with **8h** (0.09 mmol, 120 mg), trioxadiamine **5h** (0.09 mmol, 20 mg), $[Pd(dba)_2]$ (4 mg), BINAP (5 mg), *t*BuONa (0.36 mmol, 35 mg), and absolute dioxane (4.5 mL), and the reaction mixture was refluxed for 24 h. After cooling down to ambient temperature, and filtration and evaporation of the solvent, the crude product was subjected to chromatography on silica to obtain cyclodimer **9h** as a yellowish oil. Yield: 45 mg (34%); eluent CH_2Cl_2/MeOH 10:1–5:1; ^{1}H NMR (400 MHz, $CDCl_3$, a mixture of 2 possible isomers): $\delta = 0.65$ (s,

6H), 0.94 (d, $J=6.6$ Hz, 6H), 0.96 (s, 6H), 0.99–2.01 (m, 56H), 1.86 (q, $J=6.1$ Hz, 8H), 3.19 (t, $J=6.6$ Hz, 8H), 3.54–3.68 (m, 24H), 3.82–3.90 (m, 4H), 4.53 (brs, 2H), 6.12–6.30 (m, 12H), 7.01 (t, $J=7.8$ Hz, 2H), 7.02 ppm (t, $J=7.9$ Hz, 2H); ^{13}C NMR (100.6 MHz, $CDCl_3$, a mixture of 2 possible isomers): $\delta=12.05$ (2C), 18.60 (2C), 21.07 (2C), 23.83 (2C), 24.18 (2C), 24.64 (2C), 25.95 (2C), 26.23 (2C), 26.58 (2C), 28.26 (2C), 29.04 (2C), 29.09 (2C), 29.65 (2C), 30.45 (2C), 32.08 (2C), 34.82 (2C), 35.52 (2C), 35.63 (2C), 36.95 (2C), 39.97 (2C), 40.24 (2C), 41.68 (4C), 42.70 (2C), 56.17 (2C), 56.62 (2C), 68.22 (2C), 69.69 (4C), 70.21 (4C), 70.60 (4C), 72.21 (2C), 99.16 (2C), 100.87 (2C), 102.69 (2C), 104.23 (2C), 105.59 (2C), 105.81 (2C), 129.70 (2C), 129.76 (2C), 149.84 (2C), 149.88 (2C), 158.93 (2C), 160.34 ppm (2C).

Cyclodimer 9i

Route a: A two-necked flask, equipped with a condenser and flushed with argon, was charged with in situ obtained **7i** (0.65 mmol, 428 mg), **4** (0.65 mmol, 437 mg), [Pd(dba)$_2$] (30 mg), BINAP (36 mg), *t*BuONa (2.6 mmol, 250 mg), and absolute dioxane (26 mL), and the reaction mixture was refluxed for 28 h. After cooling down to ambient temperature, and filtration and evaporation of the solvent, the crude product was subjected to chromatography on silica to obtain cyclodimer **9i** as a yellowish oil. Yield: 307 mg (40%); eluent CH_2Cl_2/MeOH 250:1, 10:1–5:1.

Route b: A two-necked flask, equipped with a condenser and flushed with argon, was charged with in situ obtained **8i** (0.39 mmol, 490 mg), diaminopropane **5i** (0.39 mmol, 29 mg), [Pd(dba)$_2$] (18 mg), BINAP (22 mg), *t*BuONa (1.56 mmol, 150 mg), and absolute dioxane (16 mL), and the reaction mixture was refluxed for 28 h. After cooling down to ambient temperature, and filtration and evaporation of the solvent, the crude product was subjected to chromatography on silica to obtain cyclodimer **9i** as a yellowish oil. Yield: 92 mg (20%); eluent CH_2Cl_2/MeOH 100:1, 10:1–3:1; ^{1}H NMR (400 MHz, $CDCl_3$, a mixture of 2 possible isomers): $\delta=0.67$ (s, 6H), 0.95 (d, $J=6.3$ Hz, 6H), 0.98 (s, 6H), 1.00–2.03 (m, 56H), 1.91 (q, $J=6.4$ Hz, 4H), 3.19–3.27 (m, 8H), 3.85–3.91 (m, 4H), 4.54 (brs, 2H), 6.15–6.30 (m, 12H), 7.00–7.08 ppm (m, 4H); ^{13}C NMR (100.6 MHz, $CDCl_3$, a mixture of 2 possible isomers): $\delta=12.01$ (2C), 18.57 (2C), 21.04 (2C), 23.76 (2C), 24.14 (2C), 24.62 (2C), 25.91 (2C), 26.21 (2C), 26.55 (2C), 28.20 (2C), 29.09 (2C), 29.57 (2C), 30.43 (2C), 32.07 (2C), 34.87 (2C), 35.45 (2C), 35.61 (2C), 36.91 (2C), 39.98 (2C), 40.22 (2C), 41.80 (4C), 56.17 (2C), 56.59 (2C), 68.20 (2C), 72.27 (2C), 99.32 (2C), 100.97 (2C), 103.17 (2C), 104.68 (2C), 105.61 (2C), 105.79 (2C), 129.75 (2C), 129.79 (2C), 149.49 (2C), 149.54 (2C), 158.96 (2C), 160.36 ppm (2C).

Compound 10: A two-necked flask, equipped with a condenser and flushed with argon, was charged with **7h** (0.21 mmol, 198 mg), **4** (0.21 mmol, 148 mg), [Pd(dba)$_2$] (10 mg), BINAP (12 mg), *t*BuONa (0.84 mmol, 80 mg), and absolute dioxane (10.5 mL), and the reaction mixture was refluxed for 18 h. After cooling down to ambient temperature, and filtration and evaporation of the solvent, the crude product was subjected to chromatography on silica to obtain compound **10** as a yellowish oil. Yield: 56 mg (17%); eluent CH_2Cl_2/MeOH 5:1–2.5:1. ^{1}H NMR (400 MHz, $CDCl_3$, a mixture of 4 possible isomers): $\delta=0.64$ (s, 6H), 0.93 (d, $J=6.3$ Hz, 6H), 0.96 (s, 6H), 0.97–2.05 (m, 64H), 3.06 (brs, 2H), 3.14–3.22 (m, 6H), 3.45–3.70 (m, 24H), 3.86 (brs, 4H), 4.52 (brs, 2H), 6.10–6.32 (m, 9H), 6.80 (d, $J=8.6$ Hz) and 6.85 (d, $J=7.8$ Hz) (1H, two signals correspondent to different isomers), 6.95–7.04 (m, 5H), 7.09 (t, $J=8.0$ Hz) and 7.10 ppm (t, $J=8.2$ Hz) (1H, two signals correspondent to different isomers); ^{13}C NMR (100.6 MHz, $CDCl_3$, a mixture of 4 possible isomers): $\delta=12.05$ (2C), 18.59 (2C), 21.08 (2C), 23.79 (2C), 24.18 (2C), 24.48 and 24.66 (2C), 25.82 and 25.96 (2C), 26.22 (2C), 26.58 (2C), 28.23 (4C), 28.90, 29.10, 29.14 and 29.61 (2C), 30.27 and 30.37 (2C), 30.46 (2C), 32.09 (2C), 34.81 (2C), 35.49 (2C), 35.64 (2C), 36.94 (2C), 39.99 (2C), 40.23 (2C), 41.66 (4C), 42.70 (2C), 56.15 (2C), 56.62 (2C), 68.23 and 68.30 (2C), 69.59–70.59 (m, 12C), 72.26 (2C), 99.16 (3C), 100.84 (3C), 102.69 (3C), 104.23 (3C), 105.58 (3C), 105.80 (3C), 113.52 (1C), 114.75 (1C), 117.70 (1C), 119.26 (1C), 122.72 (1C), 123.30 (1C), 123.48 (1C), 129.70 (3C), 129.75 (3C), 130.42 (3C), 149.89 (3C), 149.94 (3C), 158.59 (1C), 158.96 (3C), 159.91 (1C), 160.37 ppm (3C).

Acknowledgements

This work was supported by RFBR grants N 03-03-32627 and 03-03-22001.

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Received: July 7, 2005
Published online: September 27, 2005

