Template-Directed Synthesis of Symmetric as well as Unsymmetric Macrocycles from Rigid or Flexible Building Blocks

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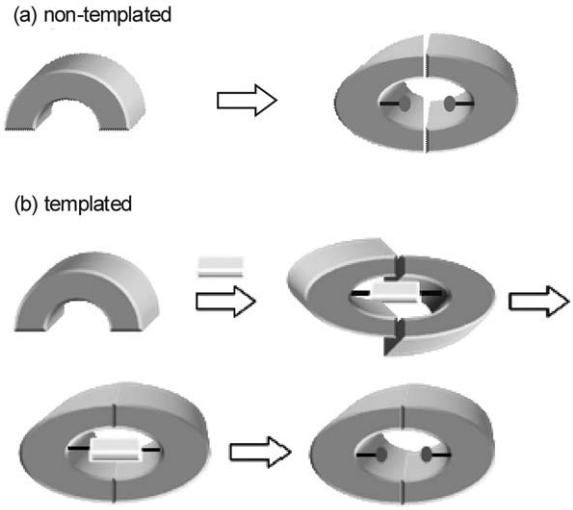
Abstract: 'Arc'-shaped oligophenyl derivatives with terminal alkene moieties can be used to form macrocycles by 'dimerization' through ring-closing metathesis. Hereby the introduction of templates connecting the two building blocks favors the dimerization over oligomerization or polymerization reactions. Attachment of the template through imine formation allows the removal of the template simultaneous to the reduction of the double bonds formed during ring-closing metathesis. Unsymmetric macrocyles can be obtained either by successive attachment of different 'arc'-shaped molecules to the template or by direct imine connection of two different ring precursors. In the latter case, the imine unit cannot be cleaved in the case of the investigated examples but 'figure-8'-shaped macrobicycles are obtained. The studied template-directed macrocyclization depends on the one hand on the preorganization of the building blocks, and on the other on their flexibility.

Key words: macrocycles, template, ring closing metathesis, imines

Functionalized macrocyclic compounds are important for the preparation of not only novel receptor type molecules but also for new materials and topologically interesting species. Macrocycles were already important in the early days of supramolecular chemistry in order to bind cationic,[1] neutral[2] or, anionic guests.[3] Later on they were used to mimic active centers in naturally occurring systems (e.g., enzymes),[4] to prepare catenanes or rotaxanes,[5] and to promote or catalyze chemical reactions.[6] Today they still play a crucial role and some novel aspects like their interaction with surfaces and two-dimensional self-assembly have come into the focus of attention.[7]

Although many preparative approaches towards macrocycles were developed during the last decades, there is still a need for new methodologies to obtain tailor-made compounds for specific purposes.[8] Templating proved to be an efficient tool in the construction of macrocycles. Hereby, the template can be noncovalently bound, as was already demonstrated by Pedersen in his ground-breaking discovery of the crown ethers. On the other hand, covalent attachment of the template and cleavage after cyclization is an important strategy for the synthesis of well-designed huge cyclic compounds.[9]

Despite the use of templates for the control of ring size, appropriate coupling reactions have to be introduced for mild but high-yielding formation of the ring systems. Recently, ring-closing metathesis (RCM) was shown to be highly efficient for this purpose.[10,11]



Scheme 1 Nontemplated (a) and templated (b) approach towards macrocyclic compounds. Despite the higher number of reaction steps, there are often advantages in the overall yields of the templated sequence.

Based on a template-directed RCM for the preparation of inside-functionalized macrocycles communicated by us recently,[12] we now present a more thorough investigation, in which we test rigid ('preorganized') building blocks versus flexible ones and try to approach unsymmetric macrocycles and 'figure-8'-shaped compounds (Scheme 1).

Symmetric Macrocycles

Our recent study on the formation of a huge macrocycle **3** by ring-closing dimerization of an 'arc'-shaped building block **2** (which is obtained in a few steps from **1**) is depicted in Scheme 2. The compound **3** was obtained from **2** in a nontemplated two-step procedure by RCM using the Grubbs catalyst of the first or second generation[13] followed by hydrogenation of the double bond. In the templated procedure two units of **2** formed the bisimine with terephthalic aldehyde, which was then cyclized by RCM. Finally the double bonds were hydrogenated with subsequent reductive removal of the template. Despite more reaction steps the templated sequence afforded the product

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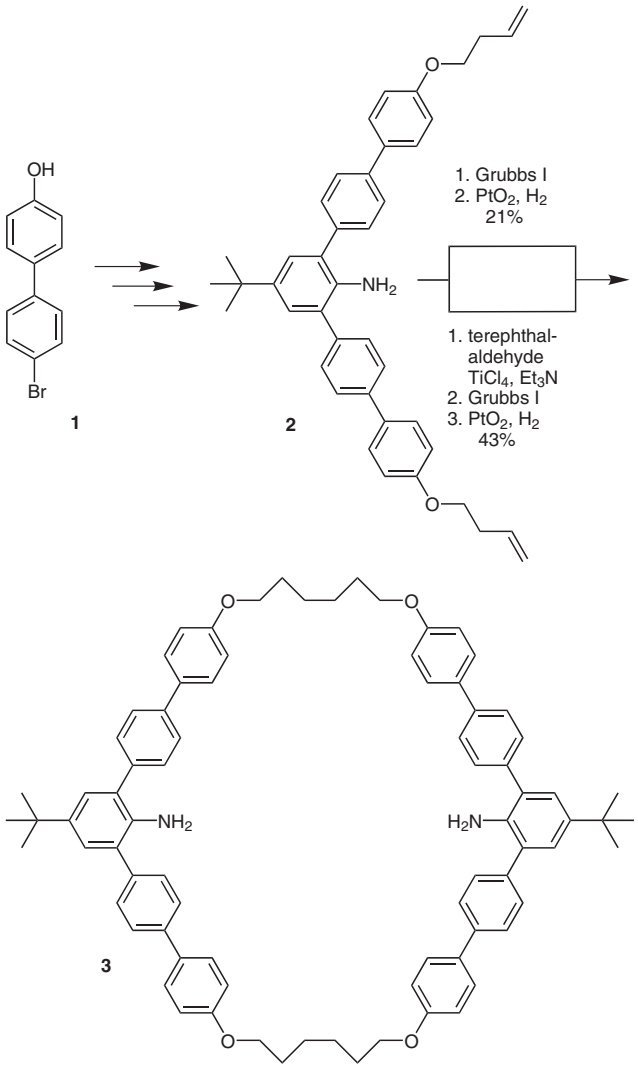


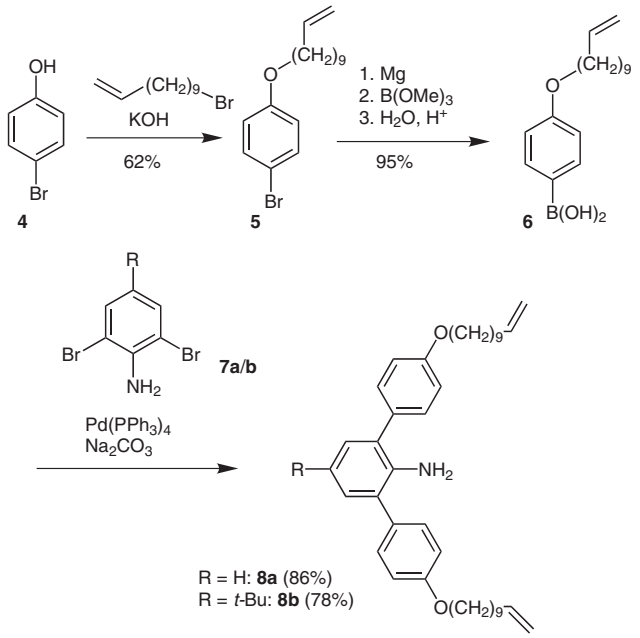
Scheme 2 Macrocycle **3** was prepared recently, following a templated as well as a nontemplated protocol (Grubbs I = $[(cyclohexyl)_3P)_2Cl_2Ru{=}CHPh]$).

3 in 43% yield while the nontemplated approach yielded only 21%.[12]

The introduced building block **2** is rigid and highly preorganized. We wondered if this is important for the formation of the macrocycle and prepared the more flexible compounds **8a/b** for comparison.

The synthesis of the 'arc'-shaped building block **8** started with 4-bromophenol (**4**), which reacted in a Williamson ether synthesis with 11-bromoundec-1-ene to form the corresponding alkyl aryl ether **5** in 62% yield. Compound **5** was transformed into the boronic acid **6** by generation of the Grignard reagent, which in situ was trapped by $B(OMe)_3$. Compound **6** was obtained in 95% after hydrolytic workup. Finally, Suzuki coupling[15] with the 2,6-dibromoanilinium derivatives **7a/b**[14] afforded the half cycles **8a** (86%) or **8b** (78%) (Scheme 3).

In contrast to the more rigid macrocycle precursor **2**, compounds **8a** or **8b** could not be cyclized by RCM without the support of a template. No 'dimeric' product was observed despite several attempts to perform the reaction under different reaction conditions. Probably polymeric/oligomeric compounds were formed.



Scheme 3 Preparation of the building blocks **8a/b**.

On the other hand, the macrocycles **10a/b** were obtained in the template-directed reaction. Thus, two equivalents of the aniline derivatives **8a/b** were reacted with terephthalic dialdehyde in the presence of titanium tetrachloride and triethylamine[16] to obtain the corresponding diimines in 40% (**9a**) or 46% (**9b**), respectively. RCM with Grubbs II catalyst and subsequent hydrogenation with concomitant removal of the template afforded the macrocycle **10a** in 68% and **10b** in 67% yield (Scheme 4).

The macrocycles were characterized by standard spectroscopic methods. For example, positive ESI-MS showed the peak for $[\mathbf{10a}{\cdot}H]^+$ at $m/z = 1111.8$ and for $[\mathbf{10b}{\cdot}H]^+$ at $m/z = 1223.9$. ^1H NMR spectroscopy ($CDCl_3$) revealed the expected signals (see Experimental section and Figure 1).

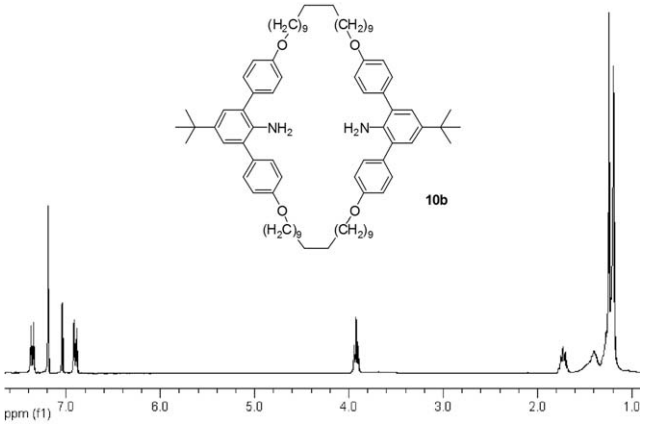
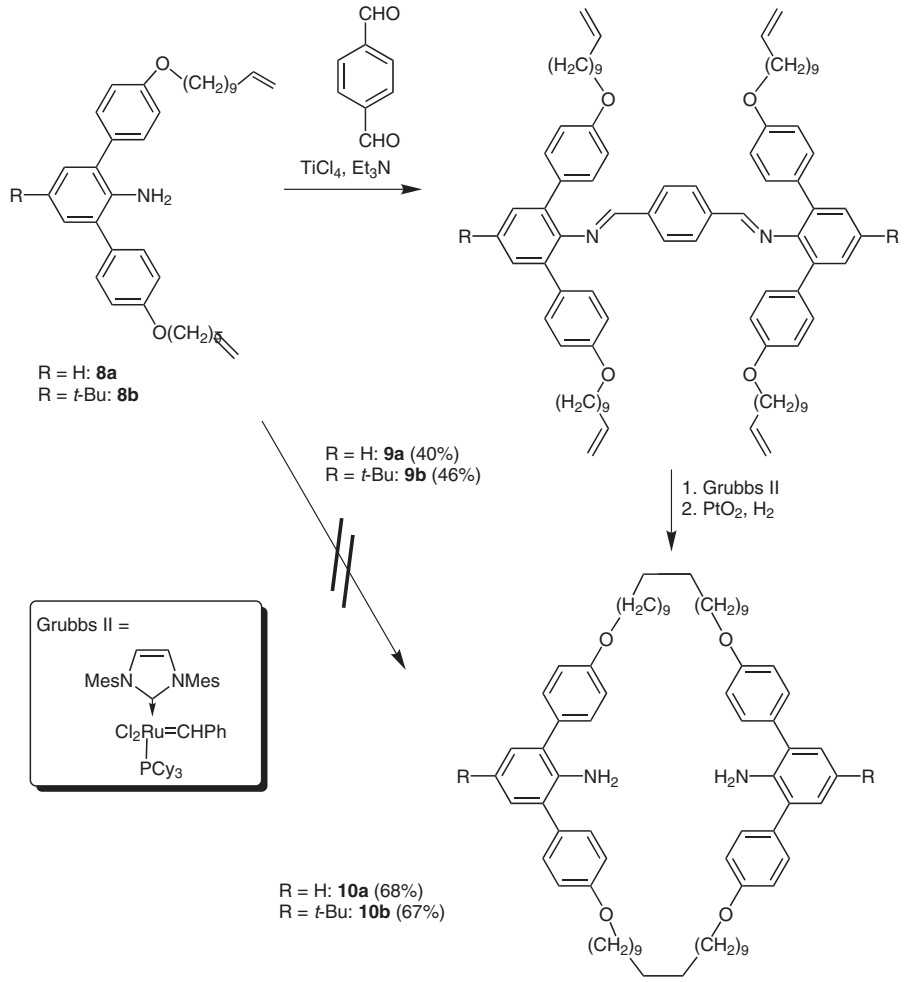


Figure 1 ^1H NMR spectrum of **10b** in $CDCl_3$.

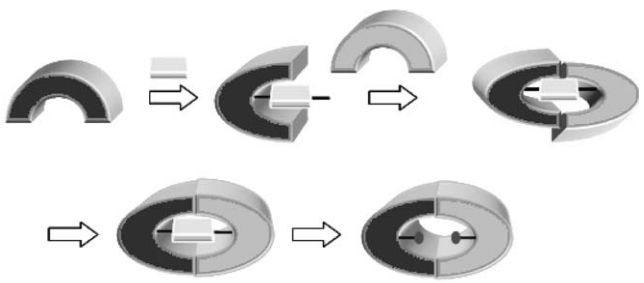


Scheme 4 Template-directed synthesis of the macrocycles **10a/b**.

Unsymmetric Macrocycles

The strategy used for the formation of unsymmetric molecules by successive attachment of two different half circles to a ditopic template followed by cyclization and cleavage of the template is illustrated in Scheme 5.

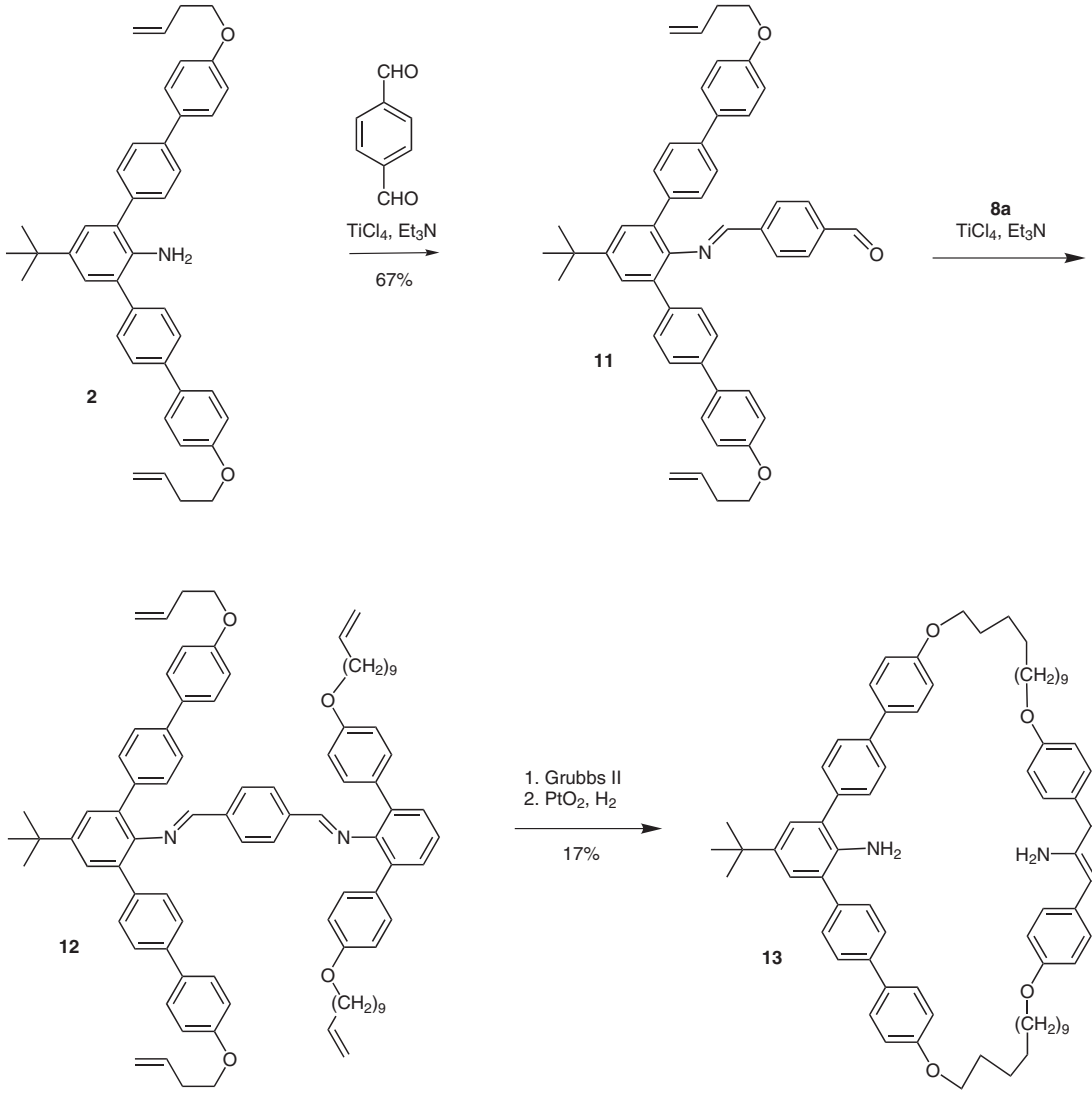
Thus, the reaction of only one equivalent of aniline derivative **2** with terephthalic aldehyde proceeded very well and the monoimine **11** was obtained in 67% yield upon addition of titanium tetrachloride and triethylamine. Although the second imination with aniline **8a** occurred also well, problems in the purification of the product were encountered. An amount of 20–30% of impurities (by NMR) could not be removed, due to simultaneous decomposition of the diimine. Therefore, we performed the macrocyclization by RCM with the crude product of **12** and immediately reduced the double bonds with removal of the template. Due to the impurities and extensive purification of the product, the unsymmetric macrocycle **13** could be obtained in only 17% yield (over 3 steps) (Scheme 6). Compound **13** was characterized by positive ESI-MS (m/z = 1123.5 [**13**·H]$^+$) and showed the characteristic ^{1}H NMR signals (see experimental section).



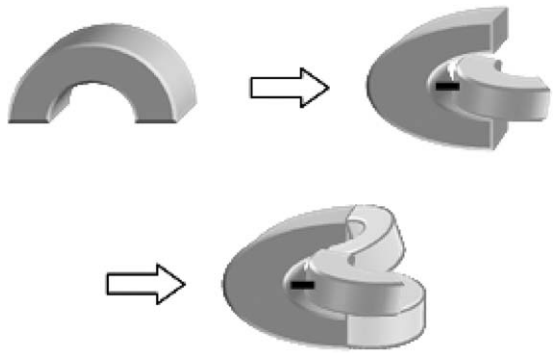
Scheme 5 Formation of unsymmetric macrocycles by successive attachment of two different half circles to a ditopic template followed by cyclization and cleavage of the template.

Bicyclic 'Figure-8'-Shaped Macrocycles

An alternative way to template the unsymmetric dimerization between two 'arc'-shaped building blocks is to use a direct bond for connection of the two moieties. After cyclization, this bond has to be cleaved in order to obtain the macrocycle. In our approach, which is outlined in Scheme 7, the final bond cleavage did not occur.

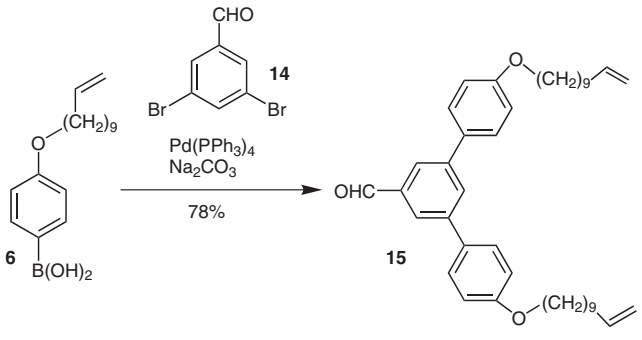


Scheme 6 Formation of the unsymmetric macrocycle **13**.



Scheme 7 Formation of an unsymmetric 'figure-8'-shaped macrocycle with the use of a direct bond as a template. Additional cleavage of the central bond would result in the 'open' macrocycle.

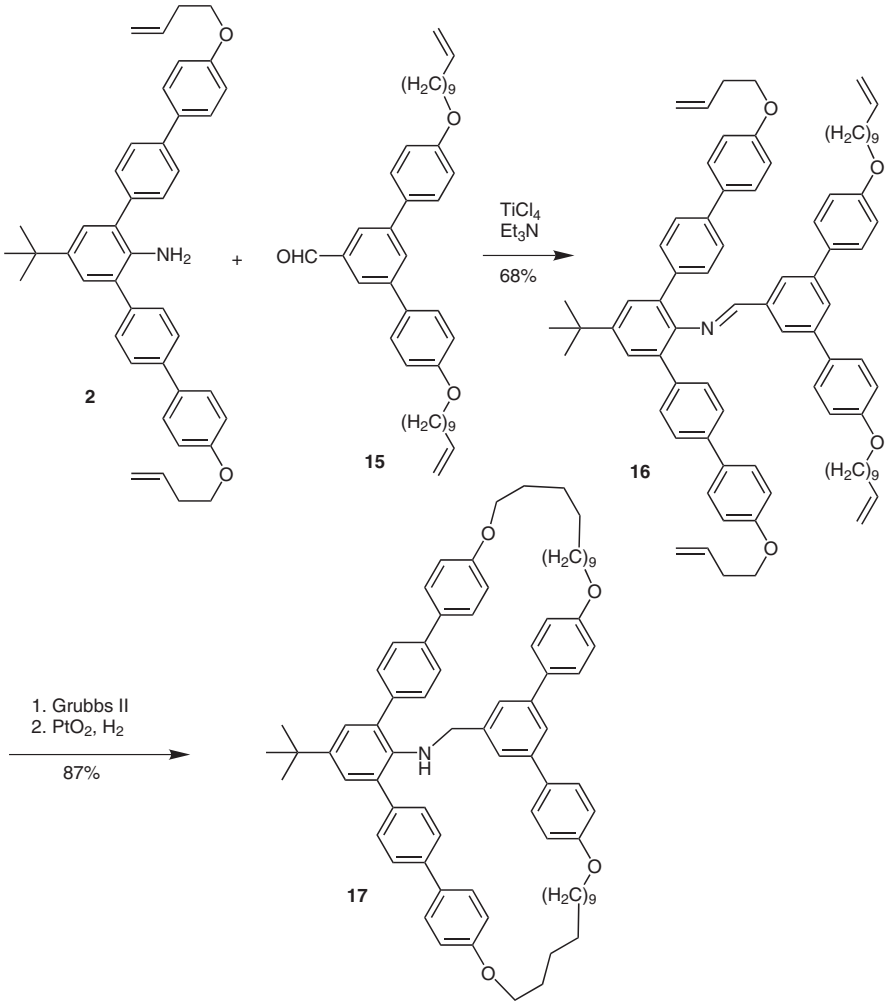
In order to follow the concept which is shown in Scheme 7, we first had to prepare an appropriate building block with a functional group on the convex face of the 'arc', which can be condensed with the amine of building blocks **2** or **8a/b**. Therefore, we used the already described



Scheme 8 Synthesis of the aldehyde **15**.

boronic acid **6** and coupled it in a Suzuki coupling reaction with 3,5-dibromobenzaldehyde (**14**). The aldehyde **15** was obtained in a yield of 78% (Scheme 8).

Aldehyde **15** was condensed with the rigid quinquephenylene derivative **2** (in the presence or $TiCl_4$ and Et_3N) to obtain the imine **16** in 68% yield. The following macrocyclization with subsequent reduction of the double bonds as



Scheme 9 Synthesis of the 'figure-8'-shaped compound **17**.

well as of the imine proceeded to give **17** in 87% yield (Scheme 9). To our surprise, the benzylic amine of **17** was not further reductively cleaved. Probably, the benzylic position, which can be recognized by the ^{1}H NMR signal of the methylene unit at $\delta = 3.67$, is hidden in the interior of the 'figure-8'-shaped molecule and is not accessible to the heterogeneous PtO_2 catalyst.

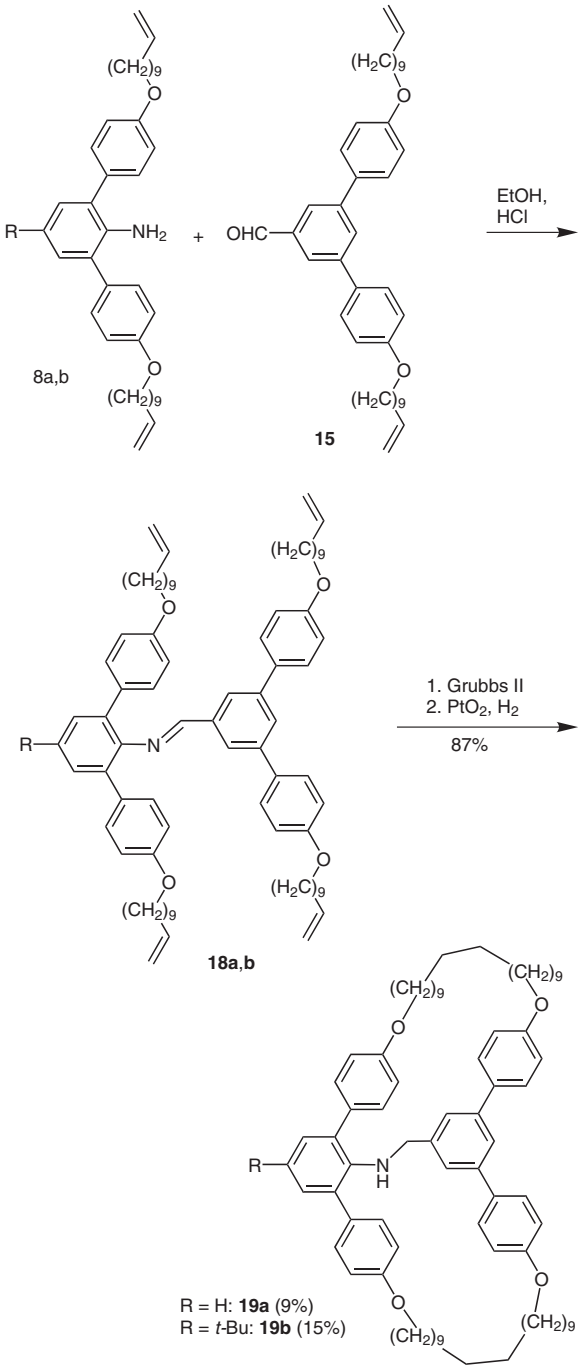
The analogous imine-condensation of **8a** or **8b** (**a**: R = H; **b**: R = *t*-Bu) followed by RCM and reduction of the double bond resulted in the formation of the macrobicycles **19a/b** (**a**: 9%, **b**: 15%; over three steps) in which again the central benzylamine unit was remained (Scheme 10). The low yields were caused by two factors: (1) The intermediate imines **18a** and **18b** could not be isolated in pure form and had to be introduced into the ring closing reaction as crude product, and (2) the high flexibility of the undecenyl chains led to a low preorganization of the two half circles for cyclization.

The bicyclic derivatives were characterized by positive ESI MS (*m*/*z* = 1114.7 [**19a**·Li]$^+$, 1164.4 [**19b**·H]$^+$) and by ^{1}H NMR (see experimental section).

In this article, we have presented a simple approach for the preparation of macrocyclic as well as macrobicyclic compounds. For this purpose, we connected two preorganized 'arc'-shaped building blocks through an appropriate template (terephthalic unit, direct bond) as imines to each other. Ring-closing metathesis leads to macrocyclization. In the case of terephthalic diimine as the template, it is removed upon reduction of the double bonds. In the case of a direct bond, the imine is burrowed in the internal of the macrocyle and it is only reduced to the amine, but the benzylic amine is not further cleaved.

Our studies show that the yield of the macrocyclization depends on the preorganization and rigidity of the introduced building blocks. It will be of interest to use our inside-functionalized macrocycles as receptors for guest species or to further functionalize them to perform and control reactions inside of the macrocycles.[17]

^{1}H and ^{13}C NMR spectra were recorded on a Varian Inova 400 or Mercury 300 NMR spectrometer. FT-IR spectra were recorded on a Bruker IFS spectrometer (KBr or neat). Mass spectra were taken on a Varian MAT 212, Finnigan SSQ 7000 (EI, 70 eV) or LCQ Deca XP Plus Thermo Finnigan (ESI). Elemental analyses were obtained



Scheme 10 Synthesis of the 'figure-8'-shaped compounds **19a/b**.

with a Heraeus CHN-O-Rapid analyzer. Melting points: Büchi B-540 (uncorrected). Preparative column chromatography: Merck silica gel 60, particle size 0.040–0.063 mm (230–400 mesh, flash).

4,4‴″-Bis(but-3-en-1-yloxy)-5″-*tert*-butyl-1,1′:4′,1″:3″,1‴:4‴,1‴″-quinquephenyl-2″-amine (2)

4′-Bromo-1,1′-biphenyl-4-ylbut-3-enyl Ether: To a solution of 4-(4-bromophenyl)phenol (6.00 g, 24.09 mmol, 1.0 equiv) and NaOH (1.18 g, 29.50 mmol, 1.2 equiv) in EtOH (70 mL) was added slowly 4-bromobut-1-ene (3.7 mL, 36.45 mmol, 1.5 equiv). The mixture was heated at reflux for 50 h and the solvent was removed under vacuum. The residue was dissolved in Et_2O (100 mL) and the Et_2O phase was washed with brine (60 mL). The aqueous phase was extracted with Et_2O (3 × 20 mL) and the combined organic phases were dried ($MgSO_4$). The solvent was removed and the residue was purified by column chromatography on silica gel (Et_2O–hexane, 20:80) to give a colorless solid; yield: 4.41 g (60%); mp 128 °C.

IR ($CDCl_3$): 1608 (w), 1481 (m), 1286 (w), 1247 cm^{-1} (m).

^1H NMR (300 MHz, $CDCl_3$): δ = 7.44 (d, ^3J = 8.5 Hz, 2 H_{arom}), 7.39 (d, ^3J = 8.5 Hz, 2 H_{arom}), 7.32 (d, ^3J = 8.6 Hz, 2 H_{arom}), 6.88 (d, ^3J = 8.6 Hz, 2 H_{arom}), 5.84 (ddt, $^3J_{trans}$ = 17.1, $^3J_{cis}$ = 10.1, ^3J = 6.7 Hz, 1 H, HC=), 5.11 (dm, $^3J_{trans}$ = 17.1 Hz, 1 H, =CH_{trans}), 5.05 (dm, $^3J_{cis}$ = 10.1 Hz, 1 H, =CH_{cis}), 3.98 (t, ^3J = 6.7 Hz, 2 H, CH_2), 2.49 (qt, ^3J = 6.7, ^4J = 1.2 Hz, 2 H, CH_2).

^{13}C NMR (75 MHz, $CDCl_3$): δ = 158.8 (C), 139.8 (C), 134.4 (CH), 132.5 (C), 131.8 (CH), 128.3 (CH), 128.0 (CH), 120.8 (C), 117.2 (CH_2), 115.0 (CH), 67.4 (CH_2), 33.7 (CH_2).

MS (EI, 70 eV): *m/z* (%) = 302.0 (72, M^+, $C_{16}H_{15}BrO$), 248 (100), 168 (4), 152 (16).

Anal. Calcd for $C_{16}H_{15}BrO$: C, 63.38; H, 4.99. Found: C, 63.38; H, 5.00.

[4′-(But-3-en-1-yloxy)biphenyl-4-yl]boronic Acid: One crystal of I_2 was added to Mg turnings (218 mg, 8.97 mmol) in degassed anhyd THF (0.5 mL) and the mixture was heated at reflux for 30 min. A solution of 4′-bromo-1,1′-biphenyl-4-ylbut-3-enyl ether (1.80 g, 5.94 mmol, 1.0 equiv) in anhyd THF (3 mL) was added. Additional anhyd THF (10 mL) was added and the mixture was heated for 3 h. After cooling, trimethyl borate (0.86 mL, 7.72 mmol, 1.3 equiv) in anhyd THF (32 mL) was added at –78 °C. The mixture was warmed up to r.t. overnight and poured onto ice (30 g) containing concd H_2SO_4 (1.5 mL). After stirring for 1 h, the mixture was extracted with Et_2O (5 × 60 mL). The organic phase was dried (Na_2SO_4) and the solvent was removed under vacuum; yield: 1.07 g (67%); mp 179–186 °C.

IR (KBr): 3360 (m), 1605 (s), 1526 (m), 1501 (m), 1346 (vs), 1285 (m), 1248 cm^{-1} (s).

^1H NMR (400 MHz, acetone-d_6): δ = 7.94 (d, ^3J = 8.2 Hz, 2 H_{arom}), 7.63 (d, ^3J = 8.6 Hz, 2 H_{arom}), 7.61 (d, ^3J = 8.2 Hz, 2 H_{arom}), 7.18 (s, 1 H, OH), 7.04 (d, ^3J = 8.6 Hz, 2 H_{arom}), 5.98 (ddt, $^3J_{trans}$ = 17.0, $^3J_{cis}$ = 10.2, ^3J = 6.6 Hz, 1 H, HC=), 5.19 (dm, $^3J_{trans}$ = 17.0 Hz, 1 H, =CH_{trans}), 5.09 (dm, $^3J_{cis}$ = 10.2 Hz, 1 H, =CH_{cis}), 4.10 (t, ^3J = 6.6 Hz, 2 H, CH_2), 2.55 (qt, ^3J = 6.6, ^4J = 1.4 Hz, 2 H, CH_2).

^{13}C NMR (100 MHz, acetone-d_6): δ = 159.5 (C), 143.0 (C), 135.5 (C), 135.4 (CH), 133.9 (C), 129.6 (CH), 128.6 (CH), 126.1 (CH), 117.0 (CH_2), 115.6 (CH), 67.8 (CH_2), 34.3 (CH_2).

MS (EI, 70 eV): *m/z* (%) = 324.2 (100, $C_{20}H_{25}BO_3^+$), 310.2 (4), 296.2 (4), 270.2 (28), 269.2 (2, MH^+, $C_{16}H_{17}BO_3^+$).

Anal. Calcd for $C_{16}H_{17}BO_3$: C, 71.67; H, 6.39. Found: C, 71.13; H, 6.30.

*Quinquephenylamine **2***: The reaction was performed under N_2 with exclusion of light. [4′-(But-3-en-1-yloxy)biphenyl-4-yl]boronic acid (3.00 g, 0.01 mol, 3 equiv) and 2,6-dibromo-4-*tert*-butylaniline (1.2 g, 3.8 mmol, 1 equiv) were dissolved in toluene (50 mL) containing EtOH (7.5 mL). Aq 2 M Na_2CO_3 (11.5 mL, 0.02 mol, 6 equiv) and $Pd(PPh_3)_4$ (0.52 g, 0.45 mmol, 0.12 equiv) were added successively and the mixture was heated at reflux for 4 d. After cooling, toluene (50 mL) was added. The organic phase was separated and the aqueous phase was extracted with CH_2Cl_2 (3 × 20 mL). The combined organic phases were dried ($MgSO_4$) and the residue was purified by column chromatography (CH_2Cl_2); yield: 1.72 g (76%); mp 198 °C.

IR (KBr): 3444 (w), 3366 (m), 2949 (m), 2868 (m), 1606 (s), 1493 (s), 1466 (s), 1249 cm^{-1} (s).

^1H NMR (400 MHz, $CDCl_3$): δ = 7.58 (d, ^3J = 8.5 Hz, 4 H_{arom}), 7.53 (d, ^3J = 8.5 Hz, 4 H_{arom}), 7.49 (d, ^3J = 8.8 Hz, 4 H_{arom}), 7.15 (s, 2

H_{arom}), 6.92 (d, ^3J = 8.8 Hz, 4 H_{arom}), 5.86 (ddt, $^3J_{trans}$ = 17.0, $^3J_{cis}$ = 10.4, ^3J = 6.7 Hz, 2 H, HC=), 5.12 (dm, $^3J_{trans}$ = 17.0 Hz, 2 H, =CH_{trans}), 5.05 (dm, $^3J_{cis}$ = 10.4 Hz, 2 H, =CH_{cis}), 4.00 (t, ^3J = 6.7 Hz, 4 H, CH_2), 2.51 (q, ^3J = 6.7 Hz, 4 H, CH_2), 1.28 (s, 9 H, *t*-C_4H_9).

^{13}C NMR (100 MHz, $CDCl_3$): δ = 158.5 (C), 141.7 (C), 139.7 (C), 138.3 (C), 137,5 (C), 134.4 (CH), 133.2 (C), 129.8 (CH), 128.0 (CH), 127.8 (C), 127.0 (CH), 126.9 (CH), 117.1 (CH_2), 114.9 (CH), 67.4 (CH_2), 34.2 (C), 33.8 (CH_2), 31.7 (CH_3).

MS (EI): *m*/*z* (%) = 593.3 (100, M^+, $C_{42}H_{43}NO_2^+$), 578.2 (97), 538.2 (3), 523.2 (12).

Anal. Calcd for $C_{42}H_{43}NO_2 \cdot 0.5\ H_2O$: C, 83.68; H, 7.36; N, 2.32. Found: C, 83.76; H, 7.35; N, 2.11.

Macrocycle 3

*Diimine from Terephthalic Dialdehyde and **2***: To a solution of quinquephenylamine **2** (100 mg, 0.168 mmol, 2 equiv), terephthalic aldehyde (11 mg, 0.082 mmol, 1 equiv), and Et_3N (70 μL, 0.504 mmol, 6 equiv) in anhyd CH_2Cl_2 (10 mL) at 0 °C was added a solution of $TiCl_4$ (11 μL, 0.101 mmol, 1.2 equiv) in CH_2Cl_2 (1 mL). After stirring overnight, the mixture was filtered over Celite and the solvent was removed under vacuum. The residue was dissolved in toluene (50 mL), filtered again over Celite, and the solvent was removed under vacuum. Precipitation of the product from toluene by the addition of pentane afforded a yellow solid; yield: 67 mg (63%); mp >250 °C.

IR (KBr): 3437 (vs), 2954 (m), 2865 (m), 1616 (s), 1496 (s), 1246 (vs), 1178 cm^{-1} (m).

^{1}H NMR (400 MHz, $CDCl_3$): δ = 7.96 (s, 2 H, N=CH), 7.52–7.47 (m, 24 H_{arom}), 7.45 (s, 4 H_{arom}), 7.39 (s, 4 H_{arom}), 6.94 (d, ^3J = 8.8 Hz, 8 H_{arom}), 5.91 (ddt, $^3J_{trans}$ = 17.3, $^3J_{cis}$ = 10.4, ^3J = 6.8 Hz, 4 H, HC=), 5.18 (dm, $^3J_{trans}$ = 17.3 Hz, 4 H, =CH_{trans}), 5.11 (dm, $^3J_{cis}$ = 10.4 Hz, 4 H, =CH_{cis}), 4.03 (t, ^3J = 6.8 Hz, 8 H, CH_2), 2.55 (q, ^3J = 6.8 Hz, 8 H, CH_2), 1.41 (s, 18 H, *t*-C_4H_9).

MS (ESI, positive): *m*/*z* = 1285.7 (MH^+, $C_{92}H_{88}N_2O_4 + H^+$).

Anal. Calcd for $C_{92}H_{88}N_2O_4$: C, 85.94; H, 6.90; N, 2.18. Found: C, 86.41; H, 6.98; N, 1.81.

Ring-Closing Metathesis: The diimine precursor of macrocycle **3** (60 mg, 0.047 mmol, 1 equiv) was heated at reflux in anhyd CH_2Cl_2 (100 mL) under N_2 and a solution of Grubbs II catalyst (approximately 0.1–0.5 mg, 0.25–1.25 mol%) in anhyd CH_2Cl_2 (10 mL) was added. The mixture was heated at reflux for 6 h and two-thirds of the solvent was removed under vacuum. The precipitate was collected by filtration and washed with pentane (30 mL); yield: 51 mg (88%, *E*/*Z* = 1:3); mp >250 °C.

IR (KBr): 3436 (m), 3033 (w), 2957 (m), 2898 (m), 1618 (s), 1497 (vs), 1245 (vs), 1180 cm^{-1} (s).

^{1}H NMR (300 MHz, $CDCl_3$): δ = 8.02 (s, 2 H, N=CH), 7.56/7.54 (2 s, 4 H_{arom}), 7.50–7.35 (m, 28 H_{arom}), 6.86/6.82 (2 overlapping d, ^3J = 8.7/8.9 Hz, 1:3 *E*/*Z*, 8 H_{arom}), 5.64–5.60 (m, 4 H, HC=CH), 4.05–3.95 (m, 8 H, CH_2), 2.58/2.42 (2 m, 1:3 *E*/*Z*, 8 H, CH_2), 1.48 (s, 18 H, *t*-C_4H_9).

MS (ESI, positive): *m*/*z* = 1229.7 (MH^+, $C_{88}H_{80}N_2O_4 + H^+$).

Anal. Calcd for $C_{88}H_{80}N_2O_4$: C, 85.96; H, 6.56, N, 2.28. Found: C, 86.30; H, 6.91; N, 2.09.

*Macrocycle **3***: A suspension of the unsaturated macrocyclic product of the RCM (45 mg, 0.040 mmol) and PtO_2 (5 mg) in CH_2Cl_2 (50 mL) was stirred for 2 d in an autoclave under an H_2 atmosphere (20 bar). The mixture was filtered over Celite and the solvent removed under vacuum. The product was purified by column chromatography on silica gel (CH_2Cl_2); yield: 32 mg (77%); mp >250 °C.

IR (KBr): 3443 (s), 3028 (m), 2939 (vs), 2865 (s), 1609 (vs), 1524 (m), 1497 (vs), 1467 (s), 1391 (m), 1287 (s), 1246 (vs), 1176 cm^{-1} (s).

^{1}H NMR (300 MHz, $CDCl_3$): δ = 7.53 (d, ^3J = 8.4 Hz, 8 H_{arom}), 7.49–7.40 (m, 16 H_{arom}), 7.12 (s, 4 H_{arom}), 6.86 (d, ^3J = 8.7 Hz, 8 H_{arom}), 3.98 (t, ^3J = 6.2 Hz, 8 H, CH_2), 1.82 (m, 8 H, CH_2), 1.53 (m, 8 H, CH_2), 1.26 (s, 18 H, *t*-C_4H_9).

^{13}C NMR (75 MHz, $CDCl_3$): δ = 158.7 (C), 141.0 (C), 139.6 (C), 138.5 (C), 138.4 (C), 133.1 (C), 129.8 (CH), 128.0 (CH), 127.3 (C), 127.0 (CH), 126.6 (CH), 115.0 (CH), 67.5 (CH_2), 34.1 (C), 31.6 (CH_3), 28.6 (CH_2), 25.0 (CH_2).

MS (ESI, positive): *m*/*z* = 1135.4 (MH^+, $C_{80}H_{82}N_2O_4 + H^+$).

Anal. Calcd for $C_{80}H_{82}N_2O_4 \cdot H_2O$: C, 83.30; H, 7.34; N, 2.43. Found: C, 83.47; H, 7.37; N, 1.99.

1-Bromo-4-(undec-10-enyloxy)benzene (5)

To a solution of KOH (7.17 g, 0.128 mol, 1.1 equiv) and 4-bromophenol (**4**; 20 g, 0.116 mol, 1 equiv) in ethylene glycol monomethyl ether (60 mL) was added 11-bromoundec-1-ene (30.3 mL, 32.5 g, 0.139 mol, 1.2 equiv) and the mixture was heated at reflux for 5 h. After cooling to r.t., H_2O (120 mL) and petroleum ether (bp 30–60 °C, 95 mL) were added. The phases were separated and the organic phase was washed with 15% aq KOH (3 × 50 mL) and H_2O (3 × 50 mL), and dried (K_2CO_3). The solvent was removed and the residual oil was distilled under vacuum; yield: 23.5 g (62%).

IR (neat): 3378 (s), 2926 (vs), 2857 (s), 1587 (m), 1482 (s), 1286 (m), 1243 (s), 1069 (m), 1022 cm^{-1} (m).

^{1}H NMR (300 MHz, $CDCl_3$): δ = 7.32 (dt, ^3J = 9.0, ^5J = 2.2 Hz, 2 H_{arom}), 6.73 (d, ^3J = 9.0 Hz, 2 H_{arom}), 5.80 (ddt, $^3J_{trans}$ = 17.1, $^3J_{cis}$ = 10.1, ^3J = 6.7 Hz, 1 H, HC=), 4.98 (dm, $^3J_{trans}$ = 17.1 Hz, 1 H, =CH_{trans}), 4.92 (dm, $^3J_{cis}$ = 10.1 Hz, 1 H, =CH_{cis}), 3.87 (t, ^3J = 6.7, 2 H, CH_2), 2.03 (q, ^3J = 6.7 Hz, 2 H, CH_2), 1.76 (quint, ^3J = 6.7 Hz, 2 H, CH_2), 1.50–1.20 (m, 12 H, CH_2).

^{13}C NMR (75 MHz, $CDCl_3$): δ = 158.3 (C), 139.2 (CH), 132.2 (CH), 116.3 (CH), 114.2 (CH_2), 112.6 (C), 68.2 (CH_2), 33.9 (CH_2), 29.6–29.0 (CH_2), 26.1 (CH_2).

MS (EI, 70 eV): *m*/*z* (%) = 327.0 (9), 326.0 (M^+ + 2), 325.1 (11), 324.0 (49, M^+, $C_{17}H_{25}BrO^+$), 173.9 (100), 171.9 (93).

4-(Undec-10-enyloxy)phenylboronic Acid (6)

A suspension of Mg turnings (2.55 g, 105 mmol, 1.5 equiv) in anhyd THF (5 mL) was activated under N_2 at reflux by adding a crystal of I_2. After 1 h, the bromide **5** (16.5 g, 70 mmol, 1.0 equiv) in anhyd THF (15 mL) was added. An additional amount of anhyd THF (10 mL) was added and the mixture was heated at reflux for 3 h. After cooling to r.t., trimethyl borate (10.3 mL, 91 mmol, 1.3 equiv) in anhyd THF (20 mL) was added at –78 °C. After warming overnight to r.t., the mixture was poured onto ice (320 g) containing concd H_2SO_4 (18 mL). After stirring for 1 h, the mixture was extracted with Et_2O (5 × 100 mL). The organic phase was dried (Na_2SO_4), the solvent was removed under vacuum, and the residue was washed with pentane (2 × 20 mL); yield: 19.3 g (95%); mp 78–83 °C.

IR (KBr): 3431 (m), 2924 (vs), 2855 (s), 1603 (vs), 1515 (m), 1356 (vs), 1243 (vs), 1168 (s), 1022 cm^{-1} (m).

^{1}H NMR (400 MHz $CDCl_3$): δ = 8.07 (d, ^3J = 8.2 Hz, 2 H_{arom}), 6.92 (d, ^3J = 8.2 Hz, 2 H_{arom}), 5.76 (ddt, $^3J_{trans}$ = 17.0, $^3J_{cis}$ = 10.2, ^3J = 6.6 Hz, 1 H, HC=), 4.93 (dm, $^3J_{trans}$ = 17.0 Hz, 1 H, =CH_{trans}), 4.86 (dm, $^3J_{cis}$ = 10.2 Hz, 1 H, =CH_{cis}), 3.96 (t, ^3J = 6.6 Hz, 2 H, CH_2), 1.98 (q, ^3J = 6.6 Hz, 2 H, CH_2), 1.74 (quint, ^3J = 6.6 Hz, 2 H, CH_2), 1.40–1.15 (m, 12 H, CH_2).

^{13}C NMR (100 MHz, $CDCl_3$): δ = 162.7 (C), 139.2 (CH), 137.4 (CH), 122.0 (C), 114.1 (CH_2), 114.0 (CH), 67.9 (CH_2), 33.9 (CH_2), 29.6–29.1 (CH_2), 26.2 (CH_2).

MS (EI, 70 eV): *m/z* (%) = 346.3 (58, $C_{21}H_{35}BO_3$), 194.1 (100, $C_{10}H_{15}BO_3$).

Terphenylamines 8a and 8b

To a solution of boronic acid **6** (500 mg, 1.72 mmol, 3 equiv) and 2,6-dibromoaniline (**7a**; 142 mg, 0.57 mmol, 1 equiv) or 2,6-dibromo-4-*tert*-butylaniline (**7b**; 175 mg, 0.57 mmol, 1 equiv) in a mixture of EtOH (3 mL) and toluene (25 mL) was added aq 2 M Na_2CO_3 (1.71 mL, 3.42 mmol, 6 equiv). After the addition of $Pd(PPh_3)_4$ (80 mg, 0.068 mmol, 0.12 equiv), the mixture was heated at reflux under N_2 for 3 d. Toluene (50 mL) was added and the organic phase was washed with aq NaOH (3 × 30 mL). The combined aqueous phases were back-extracted with CH_2Cl_2 (3 × 50 mL). The combined organic phases were dried ($MgSO_4$) and the solvent was removed under vacuum. The crude product was purified by chromatography over silica gel using CH_2Cl_2 as solvent.

8a

Yield: 286 mg (86%); mp 85 °C.

IR (KBr): 3853 (vs), 3743 (vs), 3671 (m), 3617 (m), 3071 (m), 2922 (vs), 2853 (s), 2361 (vs), 1835 (m), 1698 (m), 1640 (m), 1618 (m), 1518 (vs), 1458 (s), 1391 (m), 1248 (vs), 1003 cm^{-1} (m).

^1H NMR (400 MHz, $CDCl_3$): δ = 7.34 (d, ^3J = 8.8 Hz, 4 H_{arom}), 7.01 (d, ^3J = 7.4 Hz, 2 H_{arom}), 6.90 (d, ^3J = 8.8 Hz, 4 H_{arom}), 6.77 (t, ^3J = 7.4 Hz, 1 H_{arom}), 5.74 (ddt, $^3J_{trans}$ = 17.0, $^3J_{cis}$ = 10.2 ^3J = 6.6 Hz, 2 H, HC=), 4.92 (dm, $^3J_{trans}$ = 17.0 Hz, 2 H, =CH_{trans}), 4.86 (dm, $^3J_{cis}$ = 10.2 Hz, 2 H, =CH_{cis}), 3.92 (t, ^3J = 6.6 Hz, 4 H, CH_2), 3.80 (s, 2 H, NH_2), 1.98 (q, ^3J = 6.6 Hz, 4 H, CH_2), 1.73 (quint, ^3J = 6.6 Hz, 4 H, CH_2), 1.40–1.15 (m, 24 H, CH_2).

^{13}C NMR (100 MHz, $CDCl_3$): δ = 158.3 (C), 141.1 (C), 139.2 (CH), 131.8 (C), 130.3 (CH), 129.4 (CH), 127.6 (C), 118.0 (CH), 114.7 (CH), 114.1 (CH_2), 68.1 (CH_2), 33.9 (CH_2), 29.6–29.0 (CH_2), 26.2 (CH_2).

MS (EI, 70 eV): *m/z* (%) = 581.5 (100, M^+, $C_{40}H_{55}NO_2^+$), 429.2 (5), 277.0 (17).

Anal. Calcd for $C_{40}H_{55}NO_2$: C, 82.57; H, 9.53; N, 2.41. Found: C, 82.84; H, 9.17; N, 2.13.

8b

Yield: 285 mg (78%); mp 130 °C.

IR (KBr): 3389 (s), 2921 (vs), 2852 (vs), 1609 (s), 1509 (s), 1468 (s), 1283 (m), 1243 (vs), 1173 (m), 1109 (m), 1032 cm^{-1} (m).

^1H NMR (400 MHz, $CDCl_3$): δ = 7.47 (d, ^3J = 8.8 Hz, 4 H_{arom}), 7.15 (s, 2 H_{arom}), 6.98 (d, ^3J = 8.8 Hz, 4 H_{arom}), 5.82 (ddt, $^3J_{trans}$ = 17.0, $^3J_{cis}$ = 10.2, ^3J = 6.6 Hz, 2 H, HC=), 5.00 (dm, $^3J_{trans}$ = 17.0 Hz, 2 H, =CH_{trans}), 4.93 (dm, $^3J_{cis}$ = 10.2 Hz, 2 H, =CH_{cis}), 3.99 (t, ^3J = 6.6 Hz, 4 H, CH_2), 2.04 (q, ^3J = 6.6 Hz, 4 H, CH_2), 1.80 (quint, ^3J = 6.6 Hz, 4 H, CH_2), 1.50–1.28 (m, 33 H, CH_2 + *t*-C_4H_9).

^{13}C NMR (100 MHz, $CDCl_3$): δ = 158.5 (C), 141.1 (C), 139.2 (CH), 133.2 (C), 131.6 (C), 130.5 (CH), 126.6 (CH), 114.8 (CH), 114.1 (CH_2), 68.1 (CH_2), 33.9 (CH_2), 31.6 (CH_3), 29.6–29.0 (CH_2), 26.2 (CH_2).

MS (EI, 70 eV): *m/z* (%) = 637.7 (100, M^+, $C_{44}H_{63}NO_2^+$), 622.6 (52), 484.4 (4), 470.4 (5).

Anal. Calcd for $C_{44}H_{63}NO_2 \cdot 0.5\ H_2O$: C, 81.68; H, 9.97; N, 2.16. Found: C, 81.91; H, 9.97; N, 1.98.

Terephthalic Diimines 9a and 9b

The aniline **8a** (80 mg, 0.137 mmol, 2 equiv) or the *tert*-butyl-substituted **8b** (87 mg, 0.136 mmol, 2 equiv), terephthalic dialdehyde (9 mg, 0.067 mmol, 1 equiv), and Et_3N (57 μL, 0.412 mmol, 6 equiv) were dissolved in anhyd CH_2Cl_2 (10 mL) under N_2. At 0 °C, $TiCl_4$ (9 μL, 0.08 mmol, 1.2 equiv) in CH_2Cl_2 (1 mL) was added and the mixture was stirred for 1 d. The mixture was filtered over Celite and the solvent was removed under vacuum. The residue was dissolved in toluene (40 mL) and filtered again over Celite. After removal of the solvent, the residue was recrystallized from EtOH.

9a

Yield: 34 mg (40%).

^1H NMR (300 MHz, $CDCl_3$): δ = 7.87 (s, 2 H, N=CH), 7.36 (s, 4 H_{arom}), 7.30–7.22 (m, 14 H_{arom}), 6.77 (d, ^3J = 8.6 Hz, 8 H_{arom}), 5.73 (ddt, $^3J_{trans}$ = 16.8, $^3J_{cis}$ = 10.1, ^3J = 6.7 Hz, 4 H, HC=), 4.91 (dm, $^3J_{trans}$ = 16.8 Hz, 4 H, =CH_{trans}), 4.85 (dm, $^3J_{cis}$ = 10.1 Hz, 4 H, =CH_{cis}), 3.85 (t, ^3J = 6.7 Hz, 8 H, CH_2), 1.96 (q, ^3J = 6.7 Hz, 8 H, CH_2), 1.69 (quint, ^3J = 6.7 Hz, 8 H, CH_2), 1.40–1.15 (m, 48 H, CH_2).

MS (ESI, positive): *m/z* = 1262.0 (MH^+, $C_{88}H_{112}N_2O_4 + H^+$).

9b

Yield: 42 mg (46%); mp 104 °C.

IR (KBr): 3426 (vs), 3074 (m), 2926 (vs), 2853 (s), 2550 (m), 1634 (s), 1510 (s), 1461 (m), 1285 (m), 1247 (s), 1180 (m), 1056 cm^{-1} (m).

^1H NMR (300 MHz, $CDCl_3$): δ = 7.86 (s, 2 H, N=CH), 7.34 (s, 4 H_{arom}), 7.30–7.23 (m, 12 H_{arom}), 6.78 (d, ^3J = 8.9 Hz, 8 H_{arom}), 5.73 (ddt, $^3J_{trans}$ = 17.1, $^3J_{cis}$ = 10.2, ^3J = 6.5 Hz, 4 H, HC=), 4.91 (dm, $^3J_{trans}$ = 17.1 Hz, 4 H, =CH_{trans}), 4.85 (dm, $^3J_{cis}$ = 10.2 Hz, 4 H, =CH_{cis}), 3.86 (t, ^3J = 6.5 Hz, 8 H, CH_2), 1.95 (q, ^3J = 6.5 Hz, 8 H, CH_2), 1.75–1.64 m, 8 H, CH_2), 1.40–1.15 (m, 66 H, CH_2 + *t*-C_4H_9).

MS (ESI, positive): *m/z* = 1374.3 (MH^+, $C_{96}H_{128}N_2O_4 + H^+$).

Anal. Calcd for $C_{96}H_{128}N_2O_4 \cdot H_2O$: C, 82.83; H, 9.41; N, 2.01. Found: C, 82.75; H, 9.51; N, 1.88.

Two-Step Procedure for the Preparation of Macrocycles 10a and 10b

Metathesis Reaction: Bisimine **9a** (10 mg, 0.008 mmol, 1 equiv) or **9b** (10 mg, 0.007 mmol, 1 equiv) was dissolved in anhyd CH_2Cl_2 (20 mL) under N_2. At reflux, Grubbs II catalyst (0.1–0.5 mg, 1.5–7.5 mol%) in anhyd CH_2Cl_2 (5 mL) was slowly added. The mixture was heated at reflux for 2 d and then filtered over Celite. Removal of the solvent resulted in the macrocyclic precursors for **10a/b** as crude products, which were used further without purification.

Precursor of 10a

^1H NMR (300 MHz, $CDCl_3$): δ = 7.87 (s, 2 H, N=CH), 7.39 (s, 4 H_{arom}), 7.29–7.21 (m, 12 H_{arom}), 6.90 (t, ^3J = 8.6 Hz, 2 H_{arom}), 6.77 (d, ^3J = 8.6 Hz, 8 H_{arom}), 5.33–5.26 (m, 4 H, HC=CH), 3.84 (t, ^3J = 6.7 Hz, 8 H, CH_2), 2.00–1.86 (m, 8 H, CH_2), 1.75–1.62 (m, 8 H, CH_2), 1.44–1.15 (m, 48 H, CH_2).

MS (ESI, positive): *m/z* = 1205.9 (MH^+, $[C_{84}H_{104}N_2O_4 + H]^+$).

Precursor of 10b

^1H NMR (400 MHz, $CDCl_3$): δ = 7.88 (s, 2 H, N=CH), 7.38 (s, 4 H_{arom}), 7.30–7.24 (m, 12 H_{arom}), 6.77 (d, ^3J = 8.8 Hz, 8 H_{arom}), 5.30–5.27 (m, 4 H, HC=CH), 3.86 (t, ^3J = 6.6 Hz, 8 H, CH_2), 2.00–1.85 (m, 8 H, CH_2), 1.75–1.64 (m, 8 H, CH_2), 1.40–1.17 (m, 66 H, CH_2 + *t*-C_4H_9).

Reduction: The crude product of the RCM and PtO_2 (3 mg) were stirred in CH_2Cl_2 (50 mL) under an H_2 atmosphere (20 bar) for 2 d and then the mixture was filtered over Celite. The solvent was removed and the residue was purified by column chromatography on silica (CH_2Cl_2).

10a

Yield: 6 mg (68% over two steps); mp 152 °C.

IR ($CHCl_3$): 2924 (vs), 2853 (s), 1604 (m), 1510 (m), 1453 (m), 1286 (m), 1244 (s), 1178 (m), 1114 cm^{-1} (w).

^1H NMR (300 MHz, $CDCl_3$): δ = 7.37–7.28 (m, 10 H_{arom}), 7.03 (d, ^3J = 6.9 Hz, 4 H_{arom}), 6.90 (d, ^3J = 8.7 Hz, 8 H_{arom}), 3.91 (t, ^3J = 6.4 Hz, 8 H, CH_2), 1.73 (quint, ^3J = 6.4 Hz, 8 H, CH_2), 1.34–1.17 (m, 64 H, CH_2).

MS (ESI, positive): *m/z* = 1111.8 (MH^+, $C_{76}H_{106}N_2O_4 + H^+$).

HRMS (ESI, positive): *m/z* calcd for $[C_{76}H_{106}N_2O_4 + H]^+$: 1111.82254; found: 1111.82476.

10b

Yield: 6 mg (67% over 2 steps); mp 87–95 °C.

IR ($CHCl_3$): 2925 (vs), 2853 (s), 1609 (m), 1509 (s), 1466 (m), 1286 (m), 1245 (s), 1175 (m), 1110 cm^{-1} (w).

^1H NMR (300 MHz, $CDCl_3$): δ = 7.36 (d, ^3J = 8.7 Hz, 8 H_{arom}), 7.04 (s, 4 H_{arom}), 6.90 (d, ^3J = 8.7 Hz, 8 H_{arom}), 3.92 (t, ^3J = 6.4 Hz, 8 H, CH_2), 1.73 (quint, ^3J = 6.4 Hz, 8 H, CH_2), 1.45–1.35 (m, 8 H, CH_2), 1.28–1.17 (m, 74 H, CH_2 + *t*-C_4H_9).

MS (ESI, positive): *m/z* = 1223.9 (MH^+, $[C_{84}H_{122}N_2O_4 + H]^+$).

HRMS (ESI, positive): *m/z* calcd for $[C_{84}H_{122}N_2O_4 + H]^+$: 1223.94774; found: 1223.94799.

Terephthalic Aldehyde Monoimine 11

At 0 °C, a solution of $TiCl_4$ (11 μL, 0.101 mmol, 0.6 equiv) in CH_2Cl_2 (1 mL) was added to a solution of *tert*-butylquinquephenylamine **2** (100 mg, 0.168 mmol, 1 equiv), terephthalic aldehyde (23 mg, 0.171 mmol, 1 equiv), and Et_3N (70 L, 0.504 mmol, 3 equiv) in anhyd CH_2Cl_2 (40 mL) under N_2. The mixture was allowed to warm to r.t. overnight and then filtered over Celite. Half of the solvent was removed under vacuum and cold pentane was added to precipitate the product as a yellow solid; yield: 80 mg (67%).; mp 145 °C.

IR (KBr): 3442 (vs), 3250 (m), 2947 (m), 2868 (m), 1698 (s), 1607 (s), 1495 (s), 1384 (m), 1245 (vs), 1190 (s), 1034 cm^{-1} (m).

^1H NMR (300 MHz, $CDCl_3$): δ = 10.07 (s, 1 H, CHO), 7.99 (s, 4 H_{arom}), 7.61 (s, 8 H_{arom}), 7.54 (s, 1 H, N=CH), 7.50 (d, ^3J = 8.8 Hz, 4 H_{arom}), 7.22 (s, 2 H_{arom}), 6.93 (d, ^3J = 8.8 Hz, 4 H_{arom}), 5.87 (m, 2 H, HC=), 5.13 (dm, $^3J_{trans}$ = 17.3 Hz, 2 H, =CH_{trans}), 5.06 (dm, $^3J_{cis}$ = 10.4 Hz, 2 H, =CH_{cis}), 4.01 (t, ^3J = 6.7 Hz, 4 H, CH_2), 2.53 (q, ^3J = 6.7 Hz, 4 H, CH_2), 1.30 (s, 9 H, CH_3).

MS (ESI, positive): *m/z* = 742.3 ($C_{51}H_{51}NO_4 + H^+$), 710.2 (MH^+, $C_{50}H_{47}NO_3 + H^+$).

Anal. Calcd for $C_{50}H_{47}NO_3 \cdot H_2O$: C, 82.50; H, 6.78; N, 1.92. Found: C, 82.98; H, 6.58; N, 1.74.

Macrocycle 13

*Unsymmetric Bisimine **12***: At 0 °C, monoimine **11** (80 mg, 0.1128 mmol, 1 equiv), terphenylamine **8a** (250 mg, 0.4296 mmol, 3.8 equiv), and Et_3N (70 μL, 0.504 mmol) were dissolved in anhyd CH_2Cl_2 (30 mL) under N_2. A solution of $TiCl_4$ (11 μL, 0.101 mmol, 0.6 equiv) in CH_2Cl_2 (1 mL) was slowly added and the solution warmed to r.t. overnight. The mixture was filtered over Celite, the solvent removed, and the residue dissolved in toluene (40 mL). After filtering over Celite, the solvent was removed again and the solid material was dissolved in toluene (30 mL). This solution was slowly added to cold pentane (50 mL). The mixture was reduced in volume to 20 mL and hexane (100 mL) was added. After filtration, the filtrate was concentrated to 10 mL. To the residue were added EtOH (40 mL), Et_2O (50 mL), and hexane (40 mL). The precipitate formed was removed and the filtrate was taken to dryness. The crude product obtained was directly used in the next step for RCM.

MS (ESI, positive): *m/z* = 1273.5 (MH^+, $[C_{90}H_{100}N_2O_4 + H]^+$).

*RCM of **12** Followed by Reduction*: A solution of the crude product **12** (40 mg) in anhyd CH_2Cl_2 (50 mL) was heated at reflux under N_2. A solution of Grubbs II catalyst (0.1–0.5 mg) in anhyd CH_2Cl_2 (2 mL) was added and the mixture was heated at reflux for 6 d. During this time, additional catalyst was added (2 × 0.5 mg). The mixture was filtered and the solvent was removed. The residue was dissolved in CH_2Cl_2 (50 mL), PtO_2 (3 mg) was added and reduction took place overnight in an autoclave at 30 bar H_2 pressure. The mixture was filtered over Celite, the solvent removed, and the residue purified by column chromatography on silica gel (CH_2Cl_2–hexane, 2:1) to give **13**; yield: 6 mg (17% over three steps); mp >250 °C.

IR ($CHCl_3$): 3548 (s), 3405 (s), 3040 (m), 2930 (vs), 2859 (s), 1607 (s), 1496 (s), 1445 (vs), 1384 (m), 1361 (w), 1338 (w), 1318 (m), 1286 (m), 1247 (s), 1180 (m), 1162 (m), 1121 (m), 1064 (m), 1021 (m), 1005 cm^{-1} (m).

^1H NMR (300 MHz, $CDCl_3$): δ = 7.60–7.46 (m, 12 H_{arom}), 7.30 (d, ^3J = 8.5 Hz, 4 H_{arom}), 7.17 (s, 2 H_{arom}), 6.98 (d, ^3J = 7.4 Hz, 2 H_{arom}), 6.92 (d, ^3J = 8.9 Hz, 4 H_{arom}), 6.87 (d, ^3J = 8.5 Hz, 4 H_{arom}), 6.74 (t, ^3J = 7.4 Hz, 1 H_{arom}), 3.98 (t, ^3J = 6.4 Hz, 4 H, CH_2), 3.89 (t, ^3J = 6.4 Hz, 4 H, CH_2), 1.80–1.65 (m, 8 H, CH_2), 1.60–1.20 (m, 45 H, CH_2 + CH_3).

MS (ESI, positive): *m/z* = 1123.5 (100%, MH^+, $C_{78}H_{94}N_2O_4 + H^+$).

Convex Aldehyde 15

To a solution of 4-(undec-10-enyloxy)phenylboronic acid (**6**; 500 mg, 1.72 mmol, 3 equiv), 3,5-dibromobenzaldehyde (**14**; 152 mg, 0.57 mmol, 1 equiv), EtOH (3 mL), and aq 2 M Na_2CO_3 (1.7 mL, 3.42 mmol, 6 equiv) in toluene (25 mL) was added $Pd(PPh_3)_4$ (80 mg, 0.068 mmol, 0.12 equiv) under N_2. The mixture was heated at reflux for 3 d and then toluene (50 mL) was added. The mixture was washed with aq NaOH (3 × 50 mL) and dried ($MgSO_4$). Removal of solvent and column chromatography of the residue using CH_2Cl_2 as eluent afforded the terphenyl aldehyde **15**; yield: 263 mg (78%); mp 78 °C.

IR (KBr): 3439 (m), 2925 (vs), 2853 (s), 1698 (vs), 1641 (w), 1606 (s), 1514 (s), 1462 (m), 1386 (m), 1336 (m), 1283 (m), 1251 (vs), 1167 (s), 1114 (w), 1017 cm^{-1} (s).

^1H NMR (300 MHz, $CDCl_3$): δ = 10.05 (s, 1 H, CHO), 7.91 (s, 3 H_{arom}), 7.53 (d, ^3J = 8.9 Hz, 4 H_{arom}), 6.94 (d, ^3J = 8.9 Hz, 4 H_{arom}), 5.75 (ddt, $^3J_{trans}$ = 17.1, $^3J_{cis}$ = 10.1, ^3J = 6.7 Hz, 2 H, HC=), 4.92 (dm, $^3J_{trans}$ = 17.1 Hz, 2 H, =CH_{trans}), 4.86 (dm, $^3J_{cis}$ = 10.1 Hz, 2 H, =CH_{cis}), 3.94 (t, ^3J = 6.7 Hz, 4 H, CH_2), 1.97 (q, ^3J = 6.7 Hz, 4 H, CH_2), 1.74 (quint, ^3J = 6.7 Hz, 4 H, CH_2), 1.35–1.20 (m, 24 H, CH_2).

^{13}C NMR (75 MHz, $CDCl_3$): δ = 192.5 (CHO), 159.3 (C), 142.3 (C), 139.2 (CH), 137.4 (C), 132.1 (C), 130.9 (CH), 128.2 (CH), 126.1 (CH), 115.0 (CH), 114.1 (CH_2), 68.2 (CH_2), 33.8 (CH_2), 29.5–29.1 (CH_2), 26.0 (CH_2).

MS (EI, 70 eV): *m/z* (%) = 594.6 (100, M^+, $C_{41}H_{54}O_3^+$), 442.3 (10), 290.0 (62).

Anal. Calcd for $C_{41}H_{54}O_3 \cdot 0.5\ H_2O$: C, 81.55; H, 9.18. Found: C, 81.74; H, 9.08.

Imine 16

tert-Butylquinquephenylamine **2** (50 mg, 0.084 mmol, 1 equiv), terphenylaldehyde **15** (50 mg, 0.084 mmol, 1 equiv), and Et_3N (35 μL, 0.251 mmol, 3 equiv) were dissolved in anhyd CH_2Cl_2 (10 mL) under N_2. At 0 °C, a solution of $TiCl_4$ (5 μL, 0.045 mmol, 0.5 equiv) in CH_2Cl_2 (2 mL) was added. The mixture was stirred for 3 d at r.t. and then filtered over Celite. The solvent was removed under vacuum, the residue was dissolved in toluene (50 mL) and filtered again over Celite. The solvent was removed and the residue was dissolved in CH_2Cl_2 (30 mL). The product precipitated upon addition of pen-

tane (50 mL). The latter procedure was repeated with the remaining solution to optimize the yield; yield: 67 mg (68%); mp 179 °C.

IR (KBr): 3420 (s), 2937 (vs), 2861 (s), 1715 (vs), 1606 (m), 1501 (m), 1456 (m), 1349 (vs), 1237 (m), 1165 (vs), 1034 cm^{-1} (m).

^1H NMR (400 MHz, $CDCl_3$): δ = 8.02 (s, 1 H, N=CH), 7.63 (s, 1 H_{arom}), 7.49–7.46 (m, 12 H_{arom}), 7.43 (d, ^3J = 8.5 Hz, 4 H_{arom}), 7.38 (d, ^3J = 8.8 Hz, 4 H_{arom}), 6.88 (d, ^3J = 8.8 Hz, 4 H_{arom}), 6.79 (d, ^3J = 8.5 Hz, 4 H_{arom}), 5.85 (ddt, $^3J_{trans}$ = 17.0, $^3J_{cis}$ = 10.2, ^3J = 6.7 Hz, 2 H, HC=), 5.73 (ddt, $^3J_{trans}$ = 17.0, $^3J_{cis}$ = 10.2, ^3J = 6.7 Hz, 2 H, HC=), 5.11 (dm, $^3J_{trans}$ = 17.0 Hz, 2 H, =CH_{trans}), 5.04 (dm, $^3J_{cis}$ = 10.2 Hz, 2 H, =CH_{cis}), 4.92 (dm, $^3J_{trans}$ = 17.0 Hz, 2 H, =CH_{trans}), 4.86 (dm, $^3J_{cis}$ = 10.2 Hz, 2 H, =CH_{cis}), 3.98 (t, ^3J = 6.7 Hz, 4 H, CH_2), 3.88 (t, ^3J = 6.7 Hz, 4 H, CH_2), 2.50 (q, ^3J = 6.7 Hz, 4 H, CH_2), 1.97 (q, ^3J = 6.7 Hz, 4 H, CH_2), 1.72 (quint, ^3J = 6.7 Hz, 4 H, CH_2), 1.30–1.20 (m, 24 H, CH_2).

MS (ESI, positiv): *m/z* = 1170.9 (100%, MH^+, $C_{83}H_{95}NO_4 + H^+$).

Bicycle 17

To a refluxing solution of the imine **16** (12 mg, 0.01025 mmol, 1 equiv) in anhyd CH_2Cl_2 (20 mL) was added Grubbs II catalyst (0.1–0.5 mg, 1–5 mol%) in anhyd CH_2Cl_2 (1 mL). After being heated at reflux for 2 d under N_2, the mixture was allowed to cool to r.t. and filtered over Celite. The solvent was removed, the residue was dissolved in CH_2Cl_2 (30 mL) and PtO_2 (3 mg) was added. After stirring for 3 d under 40 bar of H_2 atmosphere, the mixture was filtered over Celite, the solvent was removed and the residue was purified by column chromatography (silica gel, CH_2Cl_2); yield: 10 mg (87%, over 2 steps); mp >250 °C.

IR (KBr): 3434 (vs), 2926 (s), 2853 (m), 1616 (s), 1507 (m), 1455 (m), 1391 (w), 1250 (s), 1176 (m), 1116 cm^{-1} (m).

^1H NMR (400 MHz, $CDCl_3$): δ = 7.65 (s, 8 H_{arom}), 7.52 (d, ^3J = 8.8 Hz, 4 H_{arom}), 7.42 (s, 1 H_{arom}), 7.29 (d, ^3J = 8.5 Hz, 4 H_{arom}), 7.27 (s, 2 H_{arom}), 6.96 (d, ^3J = 8.8 Hz, 4 H_{arom}), 6.88 (s, 2 H_{arom}), 6.73 (d, ^3J = 8.5 Hz, 4 H_{arom}), 3.98 (t, ^3J = 6.3 Hz, 4 H, CH_2), 3.87 (t, ^3J = 6.3 Hz, 4 H, CH_2), 3.67 (s, 2 H, CH_2), 1.80–1.65 (m, 8 H, CH_2), 1.32 (s, 9 H, *t*-C_4H_9), 1.31–1.20 (m, 36 H, CH_2).

MS (ESI, positive): *m/z* = 1122.9 (100%, $C_{79}H_{95}NO_4 + H^+$).

Anal. Calcd for $C_{79}H_{93}NO_4 \cdot 4\ H_2O$: C, 79.56; H, 8.54; N, 1.17. Found: C, 79.44; H, 8.57; N, 0.90.

Macrobicycles 19a and 19b

Terphenylamine **8a** or **8b** (0.0842 mmol, 1 equiv), terphenyl aldehyde **15** (50 mg, 0.0841 mmol, 1 equiv), and one drop of HCl were heated at reflux overnight in anhyd EtOH (30 mL). The volume of the solvent was reduced and the precipitate formed was heated at reflux in anhyd CH_2Cl_2 (25 mL) under N_2. Grubbs II catalyst (0.1–0.5 mg) in anhyd CH_2Cl_2 (2 mL) was added and the mixture was heated at reflux for 4 d. The mixture was filtered over Celite and the solvent removed. The residue was dissolved in CH_2Cl_2 (30 mL) and PtO_2 (3 mg) was added. The mixture was stirred under H_2 atmosphere (40 bar) for 1 d and then filtered over Celite. After removal of the solvent, the crude product was purified by chromatography (silica gel, CH_2Cl_2–hexane, 2:1).

Bicycle 19a

Yield: 8 mg (9%, over three steps); mp >250 °C.

IR (KBr): 3420 (vs), 3089 (m), 3052 (m), 2936 (s), 2870 (m), 1633 (s), 1459 (m), 1384 (m), 1250 (m), 1112 (m), 1076 cm^{-1} (m).

^1H NMR (300 MHz, $CDCl_3$): δ = 7.43–7.32 (m, 9 H_{arom}), 7.07 (d, ^3J = 7.7 Hz, 2 H_{arom}), 6.95–6.84 (m, 11 H_{arom}), 3.94 (t, ^3J = 6.4 Hz, 4 H, CH_2), 3.86 (t, ^3J = 6.4 Hz, 4 H, CH_2), 3.64 (s, 2 H, CH_2), 1.80–1.67 (m, 8 H, CH_2), 1.45–1.16 (m, 64 H, CH_2).

MS (ESI, positive): *m/z* = 1114.7 (100%, M + Li^+, $[C_{77}H_{105}NO_4 + Li]^+$).

Bicycle 19b

Yield: 15 mg (15%, over 3 steps); mp >250 °C.

IR (KBr): 3430 (vs), 3003 (m), 2941 (m), 2872 (w), 1742 (vs), 1623 (m), 1522 (m), 1383 (w), 1354 (m), 1261 (m), 1164 (m), 1104 (w), 1055 (w), 1028 cm^{-1} (m).

^1H NMR (300 MHz, $CDCl_3$): δ = 7.44–7.30 (m, 9 H_{arom}), 7.10 (s, 2 H_{arom}), 6.93–6.83 (m, 10 H_{arom}), 3.94 (t, ^3J = 6.4 Hz, 4 H, CH_2), 3.86 (t, ^3J = 6.4 Hz, 4 H, CH_2), 3.76 (br s, 2 H, NH_2), 3.63 (s, 2 H, CH_2), 1.80–1.65 (m, 8 H, CH_2), 1.45–1.16 (m, 73 H, CH_2 + CH_3).

MS (ESI, positive): *m/z* = 1164.4 (100%, MH^+, $[C_{81}H_{113}NO_4 + H]^+$).

Anal. Calcd for $C_{81}H_{113}NO_4 \cdot H_2O$: C, 82.25; H, 9.80; N, 1.18. Found: C, 82.24; H, 9.21; N, 1.22.

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