cm^{-1}; MS, m/e calcd for $C_{16}H_{23}NO_6$: 325.1526. Found: 325.1491.

7-*syn*-[(*tert*-Butyloxycarbonyl)amino]bicyclo[2.2.1]-hept-5-ene-2-*exo*-carbonitrile (6, R^1 = CN, R^2 = R^3 = R^4 = H). The crude product from the thermolysis of acyl azide **5**, R^1 = CN, R^2 = R^3 = R^4 = H (30 mg, 0.16 mmol), was eluted from the LC column with diethyl ether. The solvent was removed under reduced pressure to afford carbamate **6**, R^1 = CN, R^2 = R^3 = R^4 = H, as a white solid (14 mg, 40%): mp 134–136 °C; ^1H NMR ($CDCl_3$, 250 MHz) δ 6.16 (dd, 1, J = 3.0, 5.7 Hz, CH=), 6.03 (dd, 1, J = 3.0, 5.7 Hz, CH=), 4.72 (m, 1, N*H*), 4.04 (m, 1, H7-*anti*), 3.13 (br s, 1, H1), 3.00 (m, 1, H4), 2.18–2.01 (m, 3, H2-*endo*, H3-*endo*, H3-*exo*); 1.23 (s, 9, $(CH_3)_3C$); IR (KBr) ν 3255 (NH), 2236 (C≡N), 1696 (C=O), 1164, 1382, 1365 cm^{-1}; MS, m/e calcd for $C_{13}H_{18}N_2O_2$: 234.1368. Found: 234.1375.

7-*syn*-[(*tert*-Butyloxycarbonyl)amino]bicyclo[2.2.1]-hept-5-ene-2-*endo*-carbonitrile (6, R^1 = R^2 = R^4 = H, R^3 = CN). The crude product from the thermolysis of acyl azide **5**, R^1 = R^2 = R^4 = H, R^3 = CN (7 mg, 0.04 mmol), was eluted from the LC column with diethyl ether. The solvent was removed under reduced pressure to give carbamate **6**, R^1 = R^2 = R^4 = H, R^3 = CN, as a white solid (7.3 mg, 85%): ^1H NMR ($CDCl_3$, 250 MHz) δ 6.33 (dd, 1, J = 2.9, 5.7 Hz, CH=), 6.19 (dd, 1, J = 2.7, 5.7 Hz, CH=), 4.78 (m, 1, N*H*), 3.67 (d, 1, J = 9.1 Hz, H7-*anti*), 3.17 (m, 1, H1), 2.97 (dd, 1, J = 3.9, 7.7 Hz, H2-*exo*), 2.93 (d, 1, J = 3.7 Hz, H4), 2.25 (ddd, 1, J = 3.6, 0.2, 12.8 Hz, H3-*exo*), 1.39 (s, 9, $(CH_3)_3C$), 1.28 (dd, 1, J = 4.3, 12.4 Hz, H3-*endo*); IR (KBr) ν 3257, 3123 (NH), 2239 (C≡N), 1687 (C=O), 1399, 1367, 1164 cm^{-1}; MS, m/e calcd for $C_{13}H_{18}N_2O_2$: 234.1368. Found: 234.1359.

Preparation of 7-*syn*-Aminobicyclo[2.2.1]hept-5-ene-2-*exo*,3-*exo*-dicarbonitrile (7, R^1 = R^2 = CN, R^3 = R^4 = H). A solution of carbamate **6**, R^1 = R^2 = CN, R^3 = R^4 = H (38.7 mg, 0.15 mmol), and *p*-toluenesulfonic acid (36.2 mg, 0.19 mmol) in acetonitrile (20 mL) was stirred at ambient temperature for 15 h. The reaction mixture was dissolved in dichloromethane (25 mL), washed with a saturated aqueous sodium bicarbonate solution, dried over anhydrous magnesium sulfate, filtered through Celite, and concentrated under reduced pressure. The crude product was recrystallized from dichloromethane–hexanes, yielding amine **7**, R^1 = R^2 = CN, R^3 = R^4 = H, as a white solid (22.4 mg, 94%): mp 129–131 °C; ^1H NMR ($CDCl_3$, 250 MHz) δ 6.23 (br s, 2, CH=), 3.75 (br s, 1, H7-*anti*), 3.20 (br s, 2, H1, H4), 2.60 (s, 2, H2-*endo*, H3-*endo*), 1.35 (m, s, N*H*); IR (KBr) ν 3388, 3326 (NH_2), 2240 (C≡N), 1260 cm^{-1}; MS, m/e calcd for $C_9H_9N_3$: 159.0798. Found: 159.0783.

Preparation of 7-*syn*-Aminobicyclo[2.2.1]hept-5-ene-2-*endo*,3-*endo*-dicarbonitrile (7, R^1 = R^2 = H, R^3 = R^4 = CN). A solution of carbamate **6**, R^1 = R^2 = H, R^3 = R^4 = CN (14.7 mg, 0.057 mmol), and *p*-toluenesulfonic acid (26.4 mg, 0.14 mmol) in acetonitrile (10 mL) was stirred at room temperature for 15 h. The reaction mixture was dissolved in dichloromethane (25 mL), washed with a saturated aqueous sodium bicarbonate solution, dried over anhydrous magnesium sulfate, filtered through Celite, and concentrated under reduced pressure. The crude product was recrystallized from dichloromethane–hexanes yielding amine **7**, R^1 = R^2 = H, R^3 = R^4 = CN, as a white solid (7.6 mg, 84%): mp 146–147 °C; ^1H NMR ($CDCl_3$, 250 MHz) δ 6.49 (br s, 2, CH=), 3.31 (dd, 2, J = 1.9, 1.25 Hz, H2-*exo*, H3-*exo*), 3.21 (br s, 2, H1, H4), 3.07 (br s, 1, H7-*anti*), 1.45 (br s, NH_2); IR (KBr) ν 3368, 3315 (NH_2), 2240 (C≡N), 1590, 1355, 1271, 1144, 990, 932, 878, 780, 762 cm^{-1}; MS, m/e calcd for $C_9H_9N_3$: 159.0798. Found: 159.0781.

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Synthesis of Spherands with Functional Groups at the Outer Sphere

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Three novel spherands (**10a–c**) have been synthesized by the oxidative coupling reaction of the corresponding dilithioterphenyls in yields of 12–17%. The compounds have been isolated as the corresponding LiCl complexes. Two of these spherands (**10a** and **10b**) have two functional groups at the outer sphere (OCH_3 or OCH_2OCH_3), whereas the third compound (**10c**) has two reactive positions that allow further reaction in the outer sphere. A spherand with two *N*,*N*-dibenzyl groups at the outer sphere (**10d**) was obtained in low yield. The starting terphenyls (**8c,d,f,h**) were prepared from a common intermediate (**7a**) by the appropriate modification of the nitro group and methylation of the hydroxyl group. Compound **7a** was synthesized in nine steps from 4-methylanisole (**2**) via the condensation of nitromalondialdehyde with the 1,3-diphenyl-2-propanone (**6b**). The spherand–lithium chloride complexes were characterized by ^1H and ^{13}C NMR spectroscopy and mass spectrometry.

Introduction

In 1979 Cram et al.[1] reported the synthesis of a novel class of macrocyclic host molecules that have rigid pre organized cavities and are composed of at least six anisyl units. These so-called spherands form very stable complexes with small alkaline cations (Li^+, Na^+). The high thermodynamic stabilities ($K_a > 10^{14}$ L mol^{-1}) are due to the rigidity of the molecular framework which enforces a high electron density in the cavity, which is composed of the anisyl moieties. Upon complexation the electron–electron repulsion of neighboring oxygen lone pairs is relieved. This is a fundamentally different concept compared with the complexation of cations by flexible macrocyclic polyligands,[2] that requires reorganization of the ligand prior to or during complexation, although also in the complexation of cations by crown-ethers, relief of oxygen–oxygen repulsions may contribute.[3] In a series of papers[4] the concept of preorganization was further ex-

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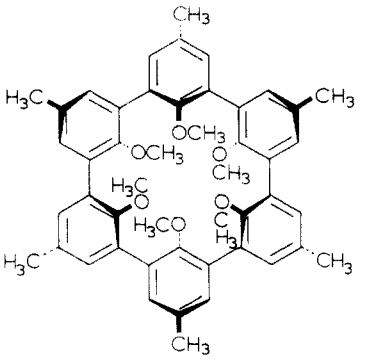
tended by Cram and his group, e.g., by variation of the ring size and by substitution of one or more anisyl units by methoxycyclohexyl or urea subunits. Cram et al. have shown that for a number of spherands the complexes with Li^+ and Na^+ are kinetically very stable with rate constants of decomplexation (picrate salts, in deuteriochloroform saturated with water) as low as 10^{-9} s^{-1}. Host 1, which is



1

the prototype of the spherands was prepared by Cram et al.[4j] from substituted mono-, di-, and trimeric anisyl units. These reactions involve halogen–lithium exchange and subsequently the oxidative coupling of the in situ generated aryllithiums with iron(III) acetylacetonate ($Fe(acac)_3$) under high dilution conditions. The highest yields of spherand 1 were obtained by *dimerization* of the 1,1′:3′,1″-terphenyls; in the other reactions both the cyclic hexamer and the octamer were obtained. The methyl group in the para position serves as a blocking group to prevent undesired substitution reactions at that position during the synthesis of the starting materials. The same method was applied to spherands containing 1,3-aryl or 2-methoxycyclohexyl units.[4] For these ligands severe reduction of free energies of complexation was found. This is attributed to the loss of (a) binding site(s) and to less complete desolvation than in complexes of spherands that have only anisyl units. Besides, the methyl group of the methoxycyclohexyl units may partly occupy the cavity, and this is also unfavorable for complexation. In spherands composed of both cyclic urea units and anisyl units, preorganization before complexation has also been found. Apart from their binding selectivities these spherands also differ in the rates of complexation and decomplexation.[4i,5] Although the urea oxygen is a better ligating site than an anisyl oxygen, spherand 1 is a better ligand for small alkali cations than any of the spherands containing urea units because of its higher degree of preorganization and the shielding of the cavity for solute molecules.

We are currently interested in using such ligands in biological systems, e.g., for the specific transport of radioactive isotopes of alkali cations in living systems for diagnostic purposes.[6] For this application the complexes with radioactive cations should be kinetically "stable" on the human time scale. Spherands such as 1 fulfill this prerequisite viz. strong and almost irreversible complexation of cations such as Li^+ or Na^+. However, they lack a chemical anchoring point for binding the ligand to biological carriers such as proteins. The general synthesis of spherand 1 involves the generation and oxidative coupling of 3,3″-dilithio-1,1′:3′,1″-terphenyls. As a consequence of the method used, there may be severe limitations to substituents that can be tolerated in these aryl–aryl radical coupling reactions.

In this paper we describe a route to spherands modified at specific positions in the outer sphere starting from substituted 1,1′:3′,1″-terphenyls, via lithiation and subsequent oxidative coupling to spherands.[7]

Results and Discussion

In order to prepare spherands like 1, with the same complexing abilities towards the alkali cations lithium and sodium, but with modified outer spheres, we needed an alternative route for the synthesis of the corresponding substituted 1,1′:3′,1″-terphenyls. The oxidative coupling of phenols as was used in the synthesis of the precursor for spherand 1 is only applicable if the phenol has an *alkyl* substituent at the 4-position and therefore it only leads to symmetrical 1,1′:3′,1″-terphenyls with alkyl substituents at positions 5, 5′, and 5″, respectively.[8,9] The synthesis requires a *symmetrical* terphenyl in order to avoid the formation of more than one isomer in the oxidative coupling to spherands. In the literature the synthesis of 1,1′:3′,1″-terphenyls has been approached by two different routes. One route starts from the central aromatic ring, and in a second route the central aromatic ring is constructed in the synthesis from phenyl-substituted acyclic precursors.

Starting from the central aromatic ring 1,1′:3′,1″-terphenyls have been obtained by photochemical reactions of 3,5-diiodo-4-hydroxybenzaldehydes or benzonitriles with benzene in low to moderate yields.[10] By this method the 2′-hydroxyl group and a functional group at the 5′-position can be introduced, but similar reactions with substituted benzenes have not been described. In principle a 1,4-benzoquinone would be a suitable precursor of the central aromatic ring but arylation of 1,4-benzoquinones leads to 2,5-substituted products.[11]

The second method in which the central aromatic ring is constructed during synthesis was reported by Betts and Davey.[12] 2,4-Diphenylcyclohexane-1,3-dione, prepared by Robinson's modification of the Michael reaction starting from 1,3-diphenylpropanone and diethyl malonate, can be converted into different types of 2′-hydroxy-1,1′:3′,1″-terphenyls. Dana and Hay[13] improved this method for the synthesis of 2,6-diphenylcyclohexanones by reacting propanones and 1,3-dibromopropane under phase-transfer conditions. Subsequent dehydrogenation gave the corresponding phenols. These terphenyls have at the 5′-position a reactive site for electrophilic aromatic substitution, or they may be oxidized to the corresponding 1,4-benzoquinones, which after reduction gives a hydroxyl function at the 5′-position. A more direct way to 4-substituted phenols involves the reaction of malondialdehydes with 2-propanones. Generally, substituted malondialdehydes are versatile three-carbon building blocks for the preparation of linear, carbocyclic, and heterocyclic compounds

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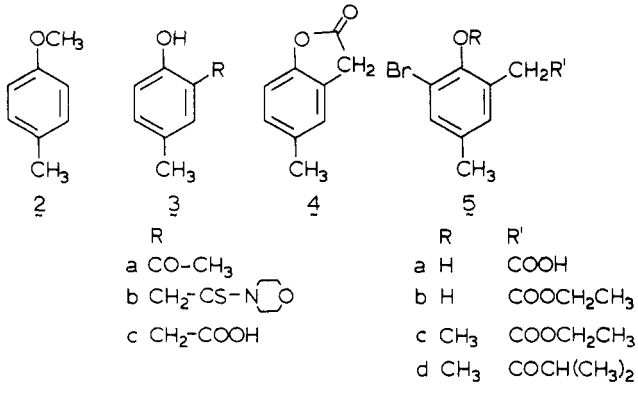
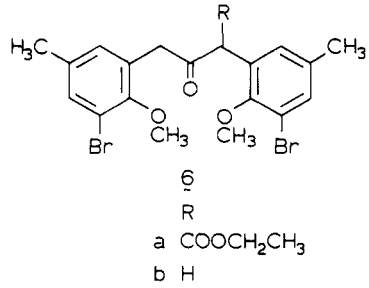
via reactions with nucleophiles.[14] In particular the condensation of malondialdehydes carrying electron-withdrawing substituents received attention because of the higher reactivity towards nucleophiles. Thus, 5′-nitro-1,1′:3′,1″-terphenyl-2′-ol was obtained from the condensation of 1,3-diphenylpropanone and 2-nitromalondialdehyde.[15]

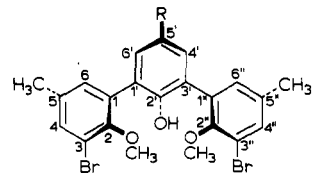
This synthesis has been extended to 1,3-diphenylpropanones with methyl, methoxy, or chloro substituents.[16] However, there are restrictions on the use of these 2-substituted malondialdehydes in the reaction with 1,3-diaryl substituted propanones to obtain 4-substituted phenols. Except for 2-nitromalondialdehyde no examples are known in the literature for similar conversions to 1,1′:3′,1″-terphenyls, although many 2-substituted malondialdehydes react with the more activated diethyl acetonedicarboxylate to the 4-substituted phenols.[17] Nevertheless, the nitro group is a versatile functional group with many possibilities for further conversions, e.g., to an amino, a hydroxyl, or a cyano group. Because there are numerous possibilities for the synthesis of 1,3-diarylpropanones, this reaction with nitromalondialdehyde seemed to be a proper choice because it provides a route to construct *symmetrical 1,1′:3′,1″-terphenyls* both with the 2′-hydroxyl (methoxy) group and a functional group at the 5′-position. Therefore our first target molecule was **6b** because it is prefunc-



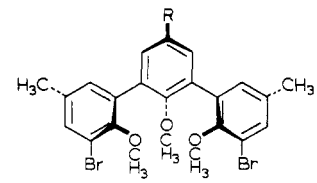


tionalized in the aryl groups and it has the potential to react with nitromalondialdehyde to yield the 3,3″-dibromo-2,2″-dimethoxy-5,5″-dimethyl-5′-nitro-1,1′:3′,1″-terphenyl-2′-ol (**7a**), which is suitable for further conversions.

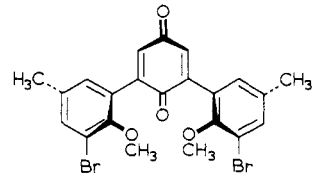
2-Hydroxy-5-methylacetophenone (**3a**) was obtained by reaction of 4-methylanisole (**2**) with $AlCl_3$ and acetyl chloride in 93% yield.[18] The Willgerodt–Kindler reaction as previously described yielded **3b**, which upon base-catalyzed hydrolysis gave the benzeneacetic acid **3c** in 52% overall yield.[19] Bromination of **3c** at the 3-position with molecular bromine did not give the expected **5a** but the lactone **4** due to the strongly acidic medium that is created during the bromination. Compound **4** showed a carbonyl stretching frequency at 1810 cm^{-1} which is characteristic for these lactones. Bromination of **3c** with *N*-bromosuccinimide in dry *N*,*N*-dimethylformamide was successful and **5a**, mp 132–133 °C, was obtained in 89% yield after recrystallization from benzene. Esterification of **5a** with ethanol and a catalytic amount of sulphuric acid gave **5b** in 88% yield; subsequent methylation of the hydroxyl group in **5b** with methyl iodide in acetone and K_2CO_3 as a base gave ethyl 3-bromo-2-methoxy-5-methylbenzeneacetate (**5c**) in 95% yield. The substitution pattern in **5c** was proven by the ^1H NMR spectrum which showed absorptions for the aromatic protons at δ 7.00 and δ 7.29 with a coupling constant of 1.5 Hz which is characteristic for a 1,3-relationship. The Claisen condensation of the ethyl benzeneacetate **5c** to the β-oxo ester **6a** with sodium ethanolate or sodium hydride in tetrahydrofuran resulted in low yields of impure **6a**. Conant and Blatt[20] found that when ethyl benzeneacetate was added to isopropylmagnesium bromide, a high yield of the ethyl 3-oxo-2,4-diphenylbutanoate could be obtained. The use of a bulky Grignard reagent obviously effected enolization of the acetic acid ester and subsequent condensation. When this method was applied to **5c**, we did not obtain **6a** but mainly **5d** which is formed by a normal Grignard reaction. The formation of **5d** could strongly be reduced by reverse addition, but it was never inhibited completely. Because **5d** and **6a** were difficult to separate, the mixture was subjected to a decarboxylation reaction in a mixture of dioxane and diluted hydrochloric acid. After chromatographic separation, **6b** was obtained in a 78% overall yield as a crystalline compound, mp 67–70 °C. The ^1H NMR spectrum clearly proved the symmetrical structure of **6b**. Apart from the aromatic protons the spectrum shows only two singlets at δ 2.25 (CH_3) and δ 3.74 (coinciding OCH_3 and CH_2 protons). Reaction of **6b**, with the sodium salt of nitromalondialdehyde in water gave the 3,3″-dibromo-2,2″-dimethoxy-5,5″-dimethyl-5′-nitro-1,1′:3′,1″-terphenyl-2′-ol (**7a**), mp 168–169 °C. The nonsplitting of the ^1H NMR absorptions of the aromatic H-atoms in the 3′- and 5′-position at δ 8.27 and also the singlets for methoxy (δ 3.62) and methyl substituents (δ 2.37) proved the symmetry of the product. Excellent yields up to 93% were obtained



7
R
a NO_2
b NH_2
c OH



8
R
a NO_2
b NH_2
c $N(CH_2\phi)_2$
d H
R
e SH
f OCH_3
g OH
h OCH_2OCH_3
i CH_3



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when the reaction was carried out at 48 °C. Compound **7a** was used as the starting material in the synthesis of other terphenyls, which could be used in the synthesis of functionalized spherands.

However, the nitro and many other functional groups at the 5′-position of the terphenyl will not survive the action of strong bases such as *sec*-butyllithium or *tert*-butyllithium used for bromo–lithium exchange and of the aryl radicals that result from oxidation of the corresponding aryllithium compounds in the coupling reaction to spherands. Therefore, the nature of the functional groups at the 5′-position of the terphenyl is limited by the conditions used in the spherand synthesis. In order to investigate the scope of the reaction we have introduced different groups or a H atom at the 5′-position of the terphenyl. Terphenyl **7a** was first methylated with methyl iodide and K_2CO_3 as a base to give **8a** in 97% yield. Reduction of the nitro group was best achieved by the action of titanium tetrachloride and amalgamated magnesium in tetrahydrofuran[21] (THF) to give **8b** in 87% yield. Prolonged hydrolysis of the reaction mixture afforded clear solutions, which gave this method an advantage over the reduction with tin and ethanol. Although this method gave **8b** in good yields, the salts formed in the reaction are difficult to separate. Because of the bromo substituents present in the 3- and 3″-positions, the protection of the amino group[22] by a trimethylsilyl group was not possible because it is introduced by treatment with ethylmagnesium bromide and subsequent reaction with trimethylsilyl chloride.[23] Therefore the amino group was dialkylated with benzyl bromide and diisopropylethylamine as a base to give **8c** in 75% yield.

The replacement of the nitro group by a hydrogen atom would be important because other functional groups may be introduced in the resulting terphenyl or in the corresponding spherand by electrophilic aromatic substitution. Diazotization of **8b** with sodium nitrite in acetic acid and subsequent reaction with an excess of hypophosphorous acid gave **8d**, mp 144–145 °C, in 52% yield after chromatographic separation and recrystallization from ethanol. The ^1H NMR spectrum of **8d** displayed a distinct AB_2 system for the hydrogen atoms of the central aromatic ring ($\Delta\nu$ = 9.0, J = 10.2 Hz) at δ 7.29. Introduction of a sulfur atom at the 5′-position via the diazo compound was not possible. Neither reaction with potassium ethyl xanthate[24] or with (methylthio)copper[25] were successful. The introduction of an oxygen substituent was possible via the 2,6-diphenyl-substituted 1,4-benzoquinone **9**. This quinone was obtained by oxidation of **7b** with potassium dichromate. Compound **7b** was obtained from the reduction of **7a** with amalgamated magnesium and titanium tetrachloride in THF in a yield of 35%, mp 224–226 °C. The quinone **9** could also be synthesized from **7a** by oxidation with lead(IV) acetate, a method described by Jones and Kenner.[16a] The orange-colored crystals, obtained in 75% yield, were purified by repeated recrystallization. Reduction of **9** with zinc in acetic acid gave the hydroquinone **7c** in 86% yield. The ^1H NMR spectrum showed two separate phenolic hydrogen atoms at δ 4.90 (5′-OH) and δ 6.51 (2′-OH). Despite several attempts this hydroquinone derivative gave a slightly deviating elemental analysis. Therefore compound **7c** was further characterized by

Table I. Alkyllithium Reagent Used and Yields of Spherand–Lithium Chloride Complexes

	reagent[a]	product[b]	yield, %[b]
8f	*n*-BuLi	**10a**·LiCl	12
8h	*t*-BuLi	**10b**·LiCl	17
8d	*sec*-BuLi	**10c**·LiCl	12
8c	*t*-BuLi	**10d**·LiCl	0–2

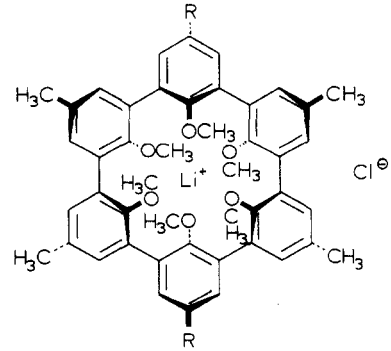
[a] *n*-Butyllithium, 1.5 M in *n*-hexane; *sec*-butyllithium, 1.3 M in cyclohexane; *tert*-butyllithium, 1.5 M in *n*-pentane. [b] After anion exchange (see Experimental Section).

Table II. Chemical Shifts (δ) in ^1H NMR Spectra (200 MHz, $CDCl_3$)

compd	$ArCH_3$	$ArOCH_3$	ArH substituents
10a·LiCl	2.50 (s, 12 H)	3.07 (s, 6 H)	7.04 (s, 4 H), 3.93 (s, 6 H, OCH_3)
		3.10 (s, 12 H)	7.34 (s, 8 H),
10b·LiCl	2.50 (s, 12 H)	3.08 (s, 6 H)	7.20 (s, 4 H), 3.58 (s, 6 H, OCH_3)
		3.10 (s, 12 H)	7.33 (s, 8 H), 5.27 (s, 4 H, OCH_2O)
10c·LiCl	2.51 (s, 12 H)	3.08 (s, 12 H)	7.35 (s, 8 H),
		3.12 (s, 6 H)	7.41–7.57 (A_2B, 6 H) δ_A 7.55 δ_b 7.45 J_{AB} = 11.5 Hz

methylation with methyl iodide and K_2CO_3 as a base to give 3,3″-dibromo-2,2′,5′,2″-tetramethoxy-5,5″-dimethyl-1,1′:3′,1″-terphenyl (**8f**) in 94% yield. The exclusive introduction of O-protecting groups at the 5′-position of the terphenyls by selective alkylation at that position was not possible. Mixtures of mono- and disubstituted products were obtained, and these could not be separated. These problems were solved when **8b** was diazotated and converted into **8g** in diluted sulphuric acid in 73% yield. Methoxymethylation with chloromethyl methyl ether in DMF and sodium hydride as a base gave **8h** in 63% yield.

We have repeated the synthesis of **1** by lithiation of **8i** with *sec*-butyllithium and oxidation of the diaryllithium compound by reaction with $Fe(acac)_3$, which had turned out to be the best reagent,[4j] and yields up to 18% were obtained. The yields are extremely sensitive to minor impurities, reaction conditions, and experimental skill. We found that substantial amounts of alkylated products were obtained when *n*-butyllithium was used in the preparation of the diaryllithium compound from **8i**, and this decreased the yield of spherand **1** to about 5%. The synthesis of spherands **10a–c**·LiCl was carried out in several different experiments in which either *n*-, *sec*-, or *tert*-butyllithium



10

R

a OCH_3
b OCH_2OCH_3
c H
d $N(CH_2\phi)_2$

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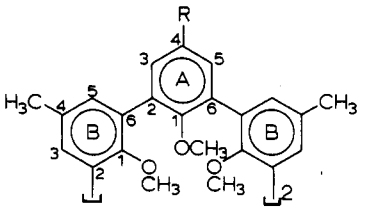
Table III. Chemical Shifts (δ) in ^{13}C NMR Spectra (200 MHz, $CDCl_3$)



compd	A1	A2,6	A3,5[a]	A4	B1	B2,6	B3,5[a]	B4	OCH_3[b]	CH_3[b]	R
1·LiCl	154.0	130.6	129.8	135.9	154.0	130.6	129.8	135.9	63.1	21.2	21.2 (CH_3)[b]
10a·LiCl	149.1	131.7	114.3	157.3	154.0	130.5[d]	129.8[d]	136.0	63.1	21.2	55.9 (OCH_3)[b]
						130.7[d]	130.0[d]		63.2		
10b·LiCl	150.6	131.7	116.8	155.1	153.9	130.4[d]	129.8[d]	136.0	63.1	21.2	56.4 (OCH_3)[b]
						130.7[d]	130.0[d]		63.2		95.2 (OCH_2O)[c]
10c·LiCl	156.0	131.0	129.5	126.3	153.9	130.5[d]	129.9[d]	136.1	63.1	21.2	
						130.6[d]	130.0[d]				

[a] Doublet. [b] Quartet. [c] Triplet. [d] Not unambiguously assigned.

were used for the preparation of the diaryllithium compounds from **8d**, **8f**, and **8h**. The organometallic reagent that gave the highest yield and the yields of the spherands **10a–c**·LiCl are given in Table I; they are the average values of at least six experiments.

The ^1H NMR spectra ($CDCl_3$, 200 MHz) of the spherands **10a–c**·LiCl clearly showed the C_{2h} symmetry of the complexes (Table II). Relative to the hydrogen atoms of the methyl-substituted aromatic rings (δ 7.33) the aromatic hydrogen atoms of the other rings are shifted upfield in **10a**·LiCl and **10b**·LiCl to δ 7.04 and δ 7.20, respectively, whereas in the spectrum of **10c**·LiCl an A_2B system with $\Delta\nu$ = 19.0 Hz and J = 11.5 Hz is present downfield at $\delta \sim 7.50$. Only minor differences due to different substituents are found for the chemical shifts of the inner sphere methoxy hydrogen atoms.

The ^{13}C NMR spectrum ($CDCl_3$, 200 MHz) of spherand 1·LiCl gave the expected six signals according to its D_{3d} symmetry. The signals were assigned by comparing this spectrum with the spectra of **10a**·LiCl and **10c**·LiCl (Table III) and the additive increments known for aromatic carbon atoms by different substituents. A separate absorption for the quaternary aryl carbon atoms (B4) is found at δ 136. The quaternary aryl carbon atoms (A2,6 and B2,6) of 1·LiCl give an absorption at δ 130.6, and these carbon atoms are differentiated by the introduction of different substituents at A4, which is also found for the aryl carbon atoms B3,5. The methoxy-substituted aryl carbon atoms (A1 and B1) of 1·LiCl are found at δ 154.0. In **10a**·LiCl the absorption of A1 is shifted upfield to δ 149.1, and in **10c**·LiCl this carbon atom is shifted downfield to δ 156.0.

The mass spectra of the spherands **10a–c**·LiCl and 1·LiCl (70 eV, 180 °C) all gave a molecular ion peak corresponding to the lithium salt of the mono demethylated ion as is also found in 1·LiBr.[4j] The fragmentation pattern of the spherands showed a minor peak for the demethylated Li^+-free molecules at $M^+ - 6$. In all spectra a substantial peak is found that corresponds with a demethoxylation reaction ($M^+ - 31$). The spherand **10d**·LiCl could only be obtained in very low yield (<1%) and was characterized by its mass spectrum (70 eV, 250 °C). It showed a molecular ion at m/e 1074 corresponding to mono demethylation, as is found in the other spherands. As expected, a substantial peak at m/e 711 was found and is attributed to the removal of the four benzyl groups from the molecular ion.

Although the method used for the introduction of functional groups at the 5′-position of the 1,1′:3′,1″-terphenyls is general, the synthesis of outer sphere functionalized spherands is largely limited by the reaction conditions needed in the oxidative coupling of the 1,1′:3′,1″-terphenyls. Currently we are investigating the problem of decomplexation of the lithium chloride complexes and further modifications of outer sphere modified spherands as well as the coupling reactions with biologically active molecules.

Experimental Section

Melting points were determined with a Reichert melting point apparatus and are uncorrected. ^1H NMR spectra ($CDCl_3$) were recorded with a Bruker WP-80 spectrometer and ^{13}C NMR spectra ($CDCl_3$) were recorded with a Nicolet MT 200 spectrometer (Me_4Si as an internal standard). Mass spectra were obtained with a Varian MAT 311A spectrometer and IR spectra with a Perkin-Elmer 257 spectrophotometer. Elemental analyses are carried out by E. Hoogendam of the Laboratory of Chemical Analysis of the Twente University of Technology.

Tetrahydrofuran (THF) and benzene were freshly distilled from sodium benzophenone ketyl and calcium hydride, respectively, whereas *N*,*N*-dimethylformamide (DMF) and diethyl ether were dried on molecular sieves 4Å. All reactions in which dry solvents were used were carried out in a nitrogen atmosphere. Nitromalondialdehyde sodium salt was prepared from mucobromic acid.[26] All mass spectra were calculated for ^{79}Br.

3-Bromo-2-hydroxy-5-methylbenzeneacetic Acid (5a). *N*-Bromosuccinimide (11.0 g, 61 mmol) in 40 mL of DMF was added dropwise to a solution of **3c** (10.0 g, 60 mmol) in 40 mL of DMF at 0 °C. The reaction mixture was stirred for 18 h at room temperature, poured into water (200 mL), and subsequently extracted with dichloromethane (3 × 50 mL). The combined organic layers were washed with water, dried with $MgSO_4$, and evaporated under reduced pressure to give a residue which was crystallized by the addition of water. Recrystallization from benzene gave pure **5a**: yield 89%; mp 132–133 °C; mass spectrum, m/e 243.973 (M^+, calcd, 243.973); ^1H NMR δ 10.27 (br s, 1 H, COOH), 7.21 (d, 1 H, Ar H), 6.91 (d, 1 H, Ar H), 5.80 (br s, 1 H, OH), 3.68 (s, 2 H, CH_2), 2.24 (s, 3 H, CH_3). Anal. Calcd for $C_9H_9BrO_3$: C, 44.11; H, 3.70. Found: C, 43.95; H, 3.47.

Ethyl 3-Bromo-2-hydroxy-5-methylbenzeneacetate (5b). A solution of **5a** (75.0 g, 0.31 mol) in 1 L of ethanol and 14 mL of H_2SO_4 was refluxed for 16 h. Upon cooling to room temperature, the mixture was neutralized with 10% $NaHCO_3$, and the solvent was evaporated under reduced pressure to a small volume. The residue was diluted with water and extracted with diethyl ether (3 × 250 mL). The combined organic layers were dried ($MgSO_4$) and concentrated under reduced pressure. The residue was distilled to give **5b** as a colorless oil: yield 88%; bp 110–112 °C (0.05 mmHg); mass spectrum, m/e 272.002 (M^+, calcd for $C_{11}H_{13}BrO_3$, 272.005); ^1H NMR δ 7.20 (d, 1 H, Ar H), 6.91 (d, 1 H, Ar H), 6.31 (s, 1 H, OH), 4.18 (q, 2 H, OCH_2), 3.63 (s, 2 H, CH_2), 2.23 (s, 3 H, CH_3), 1.26 (t, 3 H, CH_3); ^{13}C NMR δ 172.1 (s, C=O),

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148.7 (s, Ar C-2), 131.6, 131.1 (d, aromatic C–H), 131.0 (s, Ar C-5), 121.8 (s, Ar C-1), 110.7 (s, Ar C-3), 61.3 (t, Ar CH_2), 36.9 (t, CH_2), 20.2 (q, Ar CH_3), 14.1 (q, CH_3).

Ethyl 3-Bromo-2-methoxy-5-methylbenzeneacetate (5c). A mixture of **5b** (8.8 g, 32.0 mmol), K_2CO_3 (5.1 g, 36.4 mmol), and methyl iodide (14.8 g, 104 mmol) in 180 mL of dry acetone (K_2CO_3) was stirred at room temperature for 20 h. The solvent and excess methyl iodide were removed under reduced pressure. After addition of water (80 mL) and HCl (7 mL) the mixture was extracted with diethyl ether (3 × 50 mL). The combined organic layers were washed with water, a saturated Na_2CO_3 solution, and water and dried with $MgSO_4$. After removal of the solvent under reduced pressure, the resulting oil was distilled to give **5c** as a pale yellow oil: yield 95%; bp 99–101 °C (0.04 mmHg); mass spectrum, *m/e* 286.021 (M^+, calcd for $C_{12}H_{15}BrO_3$, 286.019); ^1H NMR δ 7.29 (d, 1 H, Ar H), 7.00 (d, 1 H, Ar H), 4.16 (q, 2 H, OCH_2), 3.80 (s, 3 H, OCH_3), 3.64 (s, 2 H, Ar CH_2), 2.27 (s, 3 H, Ar CH_3), 1.26 (t, 3 H, CH_3); ^{13}C NMR δ 171.2 (s, C=O), 153.2 (s, Ar C-2), 135.1 (s, Ar C-5), 133.0, 131.0 (d, aromatic CH), 129.3 (s, Ar C-1), 116.7 (s, Ar C-3), 60.9 (q, t, OCH_3, CH_2), 35.9 (t, Ar CH_2), 20.4 (q, Ar CH_3), 14.2 (q, CH_3).

1,3-Bis(3-bromo-2-methoxy-5-methylphenyl)-2-propanone (6b). An ice-cold and through-glass-wool-filtered solution of isopropylmagnesium bromide (46.7 g, 0.32 mol) in 260 mL of dry diethyl ether was added slowly to a solution of **5c** (45.5 g, 0.16 mol) in 210 mL of dry diethyl ether at 0 °C. The reaction mixture was stirred for 20 h at room temperature and poured on 600 g of ice. After acidification with concentrated sulfuric acid, the products were extracted with diethyl ether (2 × 200 mL). The combined organic layers were dried with $MgSO_4$, and the solvent was removed under reduced pressure to give a yellow oil (42.0 g). To this oil 690 mL of dioxane and 610 mL of 6 M HCl were added, and the resulting mixture was stirred under reflux for 24 h. The reaction mixture was poured into 1 L of water and extracted with diethyl ether (3 × 300 mL). The combined organic layers were thoroughly washed with water and dried with $MgSO_4$. After removal of the solvent under reduced pressure, the resulting yellow oil was fractionated by chromatography (silica gel, dichloromethane) to give a pale yellow oil which slowly crystallized from petroleum ether (bp 40–60 °C) at −20 °C to afford **6b** which was recrystallized from the same solvent to give white crystals: yield 78%; mp 67–70 °C; mass spectrum, *m/e* 453.978 (M^+, calcd 453.976); ^1H NMR δ 7.25 (d, 2 H, Ar H), 6.86 (d, 2 H, Ar H), 3.74 (s, 10 H, OCH_3, CH_2), 2.25 (s, 6 H, CH_3).

Anal. Calcd for $C_{19}H_{20}Br_2O_3$: C, 50.03; H, 4.42. Found: C, 50.13; H, 4.44.

3,3″-Dibromo-2,2″-dimethoxy-5,5″-dimethyl-5′-nitro-1,1′:3′,1″-terphenyl-2′-ol (7a). A solution of **6b** (50.0 g, 0.11 mol) in 150 mL of ethanol was added to a solution of nitromalondialdehyde sodium salt (25.0 g, 0.16 mol) in 60 mL of water. Subsequently a solution of NaOH (18.0 g, 0.45 mol) in 30 mL of water was added dropwise at 30 °C. The reaction mixture was stirred at 48 °C for 16 h. The reaction mixture was concentrated under reduced pressure and acidified with concentrated HCl at 0 °C. The reaction product was extracted with diethyl ether (3 × 150 mL), and the combined organic layers were dried with $MgSO_4$. The solvent was removed under reduced pressure to give a yellow residue, which was crystallized from ethanol to give pure **7a**: yield 93%; mp 168–169 °C; mass spectrum, *m/e* 534.963 (M^+, calcd, 534.963); ^1H NMR δ 8.27 (s, 2 H, Ar H), 7.70 (s, 1 H, OH), 7.48 (d, 2 H, Ar H), 7.13 (d, 2 H, Ar H), 3.62 (s, 6 H, OCH_3), 2.37 (s, 6 H, CH_3).

Anal. Calcd for $C_{22}H_{19}Br_2NO_5$: C, 49.19; H, 3.57; N, 2.61. Found: C, 49.49; H, 3.50; N, 2.78.

3,3″-Dibromo-2,2″-dimethoxy-5,5″-dimethyl-1,1′:3′,1″-terphenyl-2′,5′-diol (7c). A mixture of **9** (30 g, 6 mmol) and zinc powder (1.0 g, 15 mmol) in 25 mL of glacial acetic acid was heated at 50 °C for 3 h. The reaction mixture was poured into ice-water (100 mL) and extracted with diethyl ether (3 × 50 mL). The combined extracts were washed with water, 10% $NaHCO_3$, and dried with $MgSO_4$. The solvent was removed under reduced pressure, and the residue was crystallized from ethanol to give **7c** as white crystals: yield 86%; mp 191–192 °C; mass spectrum, *m/e* 505.972 (M^+, calcd for $C_{22}H_{20}Br_2O_4$ 505.973); ^1H NMR δ 7.38 (d, 2 H, Ar H), 7.06 (d, 2 H, Ar H), 6.82 (s, 2 H, Ar H), 6.51 (br s, 1 H, 2′-OH), 4.90 (br s, 1 H, 5′-OH), 3.58 (s, 6 H, OCH_3), 2.33 (s, 6 H, CH_3); ^{13}C NMR δ 151.4 (s, 2,2″), 149.1 (s, 5′), 144.4 (s, 2′), 135.6 (s, 5,5″), 133.3 and 131.9 (d, aromatic CH), 133.0 (s, 1′,3′), 128.0 (s, 1,1″), 117.6 (d, 4′,6′), 117.1 (s, 3,3″), 61.0 (q, OCH_3), 20.5 (q, CH_3).

3,3″-Dibromo-2,2′,2″-trimethoxy-5,5″-dimethyl-5′-nitro-1,1′:3′,1″-terphenyl (8a). A mixture of **7a** (6.0 g, 11.2 mmol), K_2CO_3 (3.9 g, 28.0 mmol), and methyl iodide (4.7 g, 33.0 mmol) in dry acetone (60 mL) was heated under reflux for 8 h. The solvent and excess methyl iodide were removed under reduced pressure whereupon 100 mL of diethyl ether and 100 mL of 2 M HCl were added to the residue. After extraction of the aqueous layer with another 100 mL of diethyl ether, the combined organic layers were dried ($MgSO_4$) and the solvent was removed under reduced pressure. The solid residue was recrystallized from ethanol to give pure **8a**: yield 97%; mp 152–153 °C; mass spectrum, *m/e* 548.980 (M^+, calcd, 548.979); ^1H NMR δ 8.23 (s, 2 H, Ar H), 7.45 (d, 2 H, Ar H), 7.13 (d, 2 H, Ar H), 3.60 (s 6 H, OCH_3), 3.35 (s, 3 H, 2′-OCH_3), 2.35 (s, 6 H, CH_3).

Anal. Calcd for $C_{23}H_{21}Br_2NO_5$: C, 50.11; H, 3.84; N, 2.54. Found: C, 50.07; H, 3.78; N, 2.54.

3,3″-Dibromo-2,2′,2″-trimethoxy-5,5″-dimethyl-1,1′:3′,1″-terphenyl-5′-amine (8b). Magnesium (2.1 g, 84.5 mmol) was added to a solution of $HgCl_2$ (1.4 g, 5.2 mmol) in 60 mL of dry THF. The resulting amalgamated magnesium was washed with another two portions of dry THF. To the suspension of the amalgamated magnesium in dry THF (115 mL) was added successively $TiCl_4$ (4.7 mL, 42.3 mmol), a solution of **8a** (7.8 g, 14.1 mmol) in dry THF (50 mL), and finally *tert*-butyl alcohol (32 mL), the temperature being kept between −15 and −5 °C. The reaction mixture was stirred at 0 °C for 2 h and then treated with water under vigorous stirring for 20 h. The mixture was extracted with chloroform (3 × 75 mL). The combined organic layers were washed with water and dried with $MgSO_4$, and the solvent was evaporated under reduced pressure to give a residue which was recrystallized from ethanol to afford **8b** as pale yellow crystals: yield 87%; mp 225–226 °C; mass spectrum, *m/e* 519.007 (M^+, calcd, 519.005); ^1H NMR δ 7.35 (d, 2 H, Ar H), 7.12 (d, 2 H, Ar H), 6.67 (s, 2 H, Ar H), 3.59 (s, 6 H, 2,2″-OCH_3), 3.39 (br s, 2 H, NH_2), 3.17 (s, 3 H, 2′-OCH_3), 2.30 (s, 6 H, CH_3).

Anal. Calcd for $C_{23}H_{23}Br_2NO_3$: C, 53.00; H, 4.45; N, 2.69. Found: C, 52.90; H, 4.43; N, 2.78.

***N,N*-Bis(phenylmethyl)-3,3″-dibromo-2,2′,2″-trimethoxy-5,5″-dimethyl-1,1′:3′,1″-terphenyl-5′-amine (8c).** A mixture of **8b** (5.0 g, 9.6 mmol), diisopropylethylamine (2.5 g, 19.2 mmol), and benzyl bromide (3.3 g, 19.2 mmol) in 150 mL of dry toluene was heated under reflux for 18 h. Upon cooling to 0 °C and filtration, the solvent was removed under reduced pressure. The residue was crystallized upon the addition of petroleum ether (bp 40–60 °C) and recrystallized from ethanol to give **8c** as white crystals: yield 75%; mp 156–157 °C; mass spectrum, *m/e* 699.098 (M^+, calcd, 699.096); ^1H NMR δ 7.34–7.24 (m, 12 H, Ar H), 7.07 (d, 2 H, Ar H), 6.75 (s, 2 H, Ar H), 4.57 (s, 4 H, NCH_2), 3.44 (s, 6 H, 2,2″-OCH_3), 3.13 (s, 3 H, 2′-OCH_3), 2.28 (s, 6 H, CH_3).

Anal. Calcd for $C_{35}H_{35}Br_2NO_3$: C, 63.34; H, 5.03; N, 2.00. Found: C, 63.11, H, 4.92; N, 1.83.

3,3″-Dibromo-2,2′,2″-trimethoxy-5,5″-dimethyl-1,1′:3′,1″-terphenyl (8d). A solution of $NaNO_2$ (1.0 g, 14.5 mmol) in 1 mL of water was added to a clear solution of **8b** (5.0 g, 9.6 mmol) in 70 mL of glacial acetic acid, 3 mL of sulfuric acid, and 25 mL of water (obtained by heating to reflux and slowly cooling to 5 °C) at such a rate, that the temperature did not exceed 5 °C. The reaction mixture was stirred for 15 min at 0 °C whereupon sulfamic acid was added to destroy excess $NaNO_2$. H_3PO_2 (13.0 g, 96.5 mmol) was added to the diazonium solution, and the reaction mixture was quickly heated to reflux which temperature was maintained for 15 min. Upon cooling to room temperature, the solution was extracted with chloroform (3 × 25 mL). The combined organic layers were washed with water, 10% $NaHCO_3$, and water and dried with $MgSO_4$. After evaporation of the solvent under reduced pressure, the resulting red oil was purified by chromatography [silica gel, chloroform/petroleum ether (bp 60–80 °C), 1/1] followed by crystallization from ethanol to afford pure **8d**: yield 52%; mp 144–145 °C; mass spectrum, *m/e* 503.991 (M^+, calcd, 503.994); ^1H NMR δ 7.38 (d, 2 H, Ar H), 7.29 (AB_2 system, $\delta\nu$ = 9.0, J = 10.2 Hz, 3 H, Ar H), 7.13 (d, 2 H, Ar H), 3.55 (s, 6 H, 2,2″-OCH_3), 3.25 (s, 3 H, 2′-OCH_3), 2.32 (s, 6 H, CH_3).

Anal. Calcd for $C_{23}H_{22}Br_2O_3$: C, 54.55; H, 4.38. Found: C, 54.70; H, 4.27.

3,3″-Dibromo-2,2′5′,2″-tetramethoxy-5,5″-dimethyl-1,1′:3′,1″-terphenyl (8f). A mixture of **7c** (4.5 g, 8.9 mmol), methyl iodide (3.5 g, 24.6 mmol), and K_2CO_3 (2.8 g, 20.0 mmol) in 100 mL of dry acetone (K_2CO_3) was stirred and heated under reflux for 48 h. The solvent and excess methyl iodide were removed under reduced pressure. To the residue diethyl ether (100 mL) and 2 M HCl (100 mL) were added. After extraction of the aqueous layer with another 100 mL of diethyl ether, the combined organic layers were dried ($MgSO_4$) and the solvent was removed under reduced pressure to give a solid which was recrystallized from benzene to give pure **8f** as white crystals: yield 94%; mp 94–96 °C; mass spectrum, *m/e* 534.002 (M^+, calcd, 534.004); ^1H NMR δ 7.38 (d, 2 H, Ar H), 7.14 (d, 2 H, Ar H), 6.88 (s, 2 H, Ar H), 3.80 (s, 3 H, 5′-OCH_3), 3.59 (s, 6 H, 2,2″-OCH_3), 3.19 (s, 3 H, 2′-OCH_3), 2.32 (s, 6 H, CH_3).

Anal. Calcd for $C_{24}H_{24}Br_2O_4$: C, 53.75; H, 4.51. Found: C, 53.55; H, 4.52.

3,3″-Dibromo-2,2′,2″-trimethoxy-5,5″-dimethyl-1,1′:3′,1″-terphenyl-2′-ol (8g). A diazonium salt solution as described for **8d** was added to a refluxing solution of 19 mL of concentrated sulfuric acid in 125 mL of water. Reflux was continued for 15 min. After extraction with diethyl ether (3 × 100 mL), the combined organic layers were dried ($MgSO_4$) and the solvent was removed under reduced pressure. The resulting viscous oil was purified by chromatography (silica gel, $CHCl_3$) to give an oil which was crystallized from *n*-heptane to afford pure **8g**: yield 73%; mp 177–178 °C; mass spectrum, *m/e* 519.990 (M^+, calcd, 519.989); ^1H NMR δ 7.38 (d, 2 H, Ar H), 7.12 (d, 2 H, Ar H), 6.82 (s, 2 H, Ar H), 4.91 (br s, 1 H, OH), 3.58 (s, 6 H, 2,2″-OCH_3), 3.18 (s, 3 H, 2′-OCH_3), 2.31 (s, 6 H, CH_3).

Anal. Calcd for $C_{23}H_{22}Br_2O_4$: C, 52.90; H, 4.25. Found: C, 53.24; H, 4.02.

3,3″-Dibromo-2,2′,2″-trimethoxy-5′-(methoxymethoxy)-5,5″-dimethyl-1,1′:3′,1″-terphenyl (8h). Sodium hydride (0.20 g, 8.4 mmol) was slowly added to a solution of **8g** (4.0 g, 7.6 mmol) in 50 mL of dry DMF. After stirring for 15 min at room temperature chloromethyl methyl ether (0.71 g, 8.4 mmol) was added dropwise to the resulting suspension whereupon stirring was continued for 2 h. After hydrolysis the aqueous layer was extracted with chloroform (3 × 50 mL). The combined organic layers were washed with water and dried with $MgSO_4$, and the solvent was evaporated under reduced pressure. The residue was crystallized from methanol and recrystallized from the same solvent to give pure **8h** as white crystals: yield 63%; mp 105–106 °C; mass spectrum, *m/e* 564.015 (M^+, calcd, 564.015); ^1H NMR δ 7.33 (d, 2 H, Ar H), 7.13 (d, 2 H, Ar H), 7.02 (s, 2 H, Ar H), 5.15 (s, 2 H, OCH_2O), 3.59 (s, 6 H, 2,2″-OCH_3), 3.48 (s, 3 H, OCH_3), 3.19 (s, 3 H, 2′-OCH_3), 2.32 (s, 6 H, CH_3).

Anal. Calcd for $C_{25}H_{26}Br_2O_5$: C, 53.03; H, 4.63. Found: C, 52.81; H, 4.74.

2,6-Bis(3-bromo-2-methoxy-5-methylphenyl)-1,4-benzoquinone (9). Lead(IV) acetate (2.0 g, 4.5 mmol) was added to a suspension of **7a** (4.5 g, 8.4 mmol) in 70 mL of glacial acetic acid. The reaction mixture was heated to 50 °C, and after 2 h an additional portion of lead(IV) acetate (2.0 g) was added. Heating was continued for another 2 h. The reaction mixture was poured into ice-water (100 mL) and extracted with chloroform (3 × 100 mL). The combined extracts were washed with water (2 × 100 mL), 2 M NaOH (50 mL), water, and 2 M HCl (50 mL). After drying with $MgSO_4$, the solvent was evaporated under reduced pressure to give a solid which was recrystallized from ethanol to afford **9**: yield 75%; mp 119–121 °C; mass spectrum, *m/e* 503.959 (M^+, calcd, 503.957); ^1H NMR δ 7.43 (d, 2 H, Ar H), 6.94 (d, 2 H, Ar H), 6.87 (s, 2 H, quinone H), 3.52 (s, 6 H, OCH_3), 2.32 (s, 6 H, CH_3).

Anal. Calcd for $C_{22}H_{18}Br_2O_4$: C, 52.20; H, 3.58. Found: C, 51.82; H, 3.62.

Synthesis of Spherands 10a–c·LiCl. General Procedure. The appropriate butyllithium (2.0 mmol, see Table I) was added to a solution of **8d**, **8f**, or **8h** (1.0 mmol) in 20 mL of dry THF at −78 °C. The mixture was stirred for 10 min and cannulated through a steel needle to a vigorously stirred and boiling solution of dry benzene containing ferric acetylacetonate (1.58 g, 4.4 mmol). The resulting mixture was refluxed for 1 h and cooled to room temperature. To this mixture a solution of ferric chloride (0.55 g, 2.0 mmol) in 50 mL of 2 M HCl was added. After stirring for 14 h the layers were separated. The organic solvents were removed under reduced pressure to give an orange foam which crystallized upon adding 15 mL of diethyl ether and heating to reflux. The resulting crystals were washed with benzene and pentane and were recrystallized from a mixture of 25 mL of dichloromethane and 15 mL of glacial acetic acid. Anion exchange to the lithium chloride complexes was performed by washing a dichloromethane solution of **10a–c·LiFeCl$_4$** (0.1 g) twice with a saturated EDTA solution containing 0.24 M LiCl and once with deionized water. Recrystallization from a mixture of toluene/dichloromethane (1:1) by evaporation under reduced pressure gave the corresponding spherands **10a–c·LiCl** which were fully characterized by ^1H and ^{13}C NMR spectroscopy (Table II–III) and by mass spectrometry.

4,19,31,32,33,34,35,36-Octamethoxy-9,14,24,29-tetramethylheptacyclo[25.3.1.1^{2,6}.1^{7,11}.1^{12,16}.1^{17,21}.1^{22,26}]hexatriaconta-1(31),2,4,6(36),7,9,11(35),12,14,16(34),17,19,21(33),22,24,26(32),27,29-octadecaene–Lithium Chloride (10a·LiCl). Mass spectrum: *m/e* 744.331 ($M^+ - CH_3Cl$, calcd for $C_{47}H_{45}O_8Li$ 744.337).

31,32,33,34,35,36-Hexamethoxy-4,19-bis(methoxymethoxy)-9,14,24,29-tetramethylheptacyclo[25.3.1.1^{2,6}.1^{7,11}.1^{12,16}.1^{17,21}.1^{22,26}]hexatriaconta-1(31),2,4,6(36),7,9,11(35),12,14,16(34),17,19,21(33),22,24,26(32),27,29-octadecaene–Lithium Chloride (10b·LiCl). Mass spectrum: *m/e* 804.345 ($M^+ - CH_3Cl$, calcd for $C_{49}H_{49}O_{10}Li$ 804.348).

31,32,33,34,35,36-Hexamethoxy-9,14,24,29-tetramethylheptacyclo[25.3.1.1^{2,6}.1^{7,11}.1^{12,16}.1^{17,21}.1^{22,26}]hexatriaconta-1(31),2,4,6(36),7,9,11(35),12,14,16(34),17,19,21(33),22,24,26(32),27,29-octadecaene–Lithium Chloride (10c·LiCl). Mass spectrum: *m/e* 684.309 ($M^+ - CH_3Cl$, calcd for $C_{45}H_{41}O_6Li$ 684.310).

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