Medium-size cyclophanes, 68[1]. Synthesis and bromination of 1,2-dimethyl[2.3]metacyclophan-1-enes

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McMurry cyclisation of 1,3-bis(3-acetyl-5-*tert*-butyl-2-methoxyphenyl)propane (**4**) afforded *anti*- and *syn*-1,2-dimethyl[2.3]metacyclophan-1-enes **5**, which were converted to the corresponding 1,2-bisbromomethyl[2.3]metacyclophan-1-enes (**8**) by treatment with excess BTMA Br_3.

Keywords: cyclophanes, [2.3]metacyclophan-1-enes, McMurry reaction, conformation, strained molecules

For many years various research groups have been attracted by the chemistry and spectral properties of the [2.2]MCP-1-enes (MCP = metacyclophane) skeleton.[2,3] Many attempts have been made directly to introduce functional groups into the bridged double bonds of [2.2]MCP-1-enes, but these have failed because of the deviation of the benzyl carbon atom from the plane of the benzene ring as well as the novel transannular reaction arising from the electronic interaction between two benzene rings, the proximity of the 8,16-positions and the release of the considerable strain energy to form the more stable annulene π-electron system, 10b,10c-dihydropyrene.[4,5] Thus, there is substantial interest in the developing a convenient preparation of 1,2-disubstituted [2.*n*]MCP-1-enes.

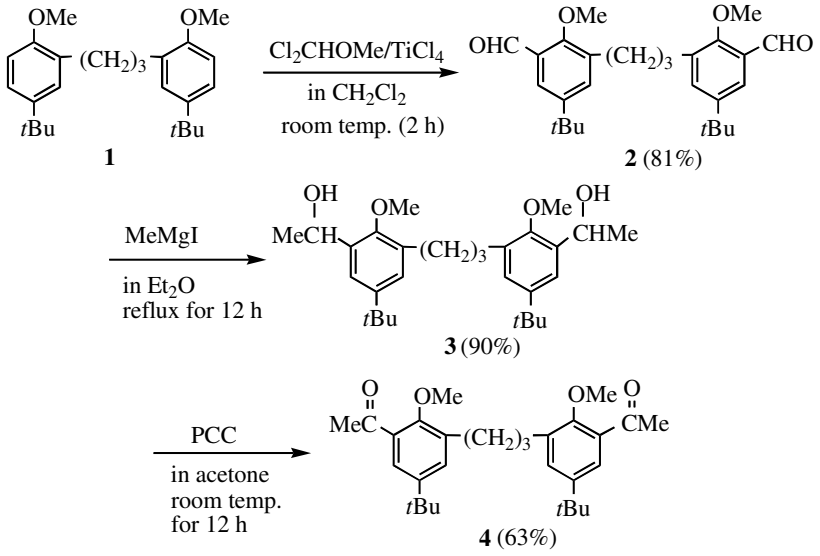
On the other hand, in cyclophane chemistry, the reductive coupling of carbonyl compounds by low-valent titanium, the McMurry reaction, has been used before by Mitchell *et al.*[6] to synthesise cyclophanes with glycol units as bridges, by Tanner and Wennerström,[7] and recently by Hopf *et al.*[8] and Grützmacher *et al.*[9] for a cyclisation of suitable dialdehydes to yield unsaturated cyclophanes. We report here on a convenient preparation of *syn*- and *anti*-1,2-dimethyl[2.3]MCP-1-enes **5** by McMurry reaction[10,11] and conversion to 1,2-disubstituted [2.3]MCP-1-enes.

Results and discussion

The starting compound 1,3-bis(5-*tert*-butyl-2-methoxylphenyl) propane (**1**) has been prepared according our previous paper by using the *tert*-butyl group as a positional protective group on the aromatic ring.[12] In contrast, the $TiCl_4$-catalysed formylation of compound **1** with dichloromethyl methyl ether at 20°C for 2 h led to complete two-fold regioselective formylation at the meta positions of the 1,3-diphenylpropane affording the desired 1,3-bis(5-*tert*-butyl-3-formyl-2-methoxylphenyl)propane **2** in 81% yield. The bisformylated compound **2** was converted to the bisalcohol derivative **3** in 90% yield by the Grignard reaction of **2** with MeMgI in ether. Oxidation of **3** with PCC afforded bisacetyl derivative **4** in 63% yield.

1,3-Bis(3-acetyl-5-*tert*-butyl-2-methoxylphenyl)propane (**4**) was subjected to reductive coupling by the McMurry reaction following the improved Grützmacher's procedure[9] (Scheme 2). Thus, the reductive coupling reaction of **4** carried out using $TiCl_4$–Zn in refluxing THF under the high dilution conditions afforded the desired compound *anti*- (*anti*-**5**) and *syn*-5,14-di-*tert*-butyl-8,17-dimethoxy-1,2-dimethyl[2.3]MCP-1-ene (*syn*-**5**) in 17 and 13 % yields, respectively.

The structures of **5** were elucidated based on their elemental analyses and spectral data. Especially, the mass spectral data for **5** (M^+ = 420) strongly supports the cyclic structure. The structures *anti*-**5** and *syn*-**5** were readily apparent from their ^{1}H NMR spectra. Thus, the internal methoxy protons show an upfield shift due to the ring current of the opposite benzene ring.[2,13] The ^{1}H NMR spectrum of conformer *anti*-**5** and *syn*-**5** respectively shows the methoxy protons at δ 3.16 and 3.67 ppm. The aromatic protons of conformer *syn*-**5** are observed much higher field (δ 6.17, 6.55 ppm) than those of conformer *anti*-**5** at δ 6.88 and 6.91 ppm. The above data show



Scheme 1

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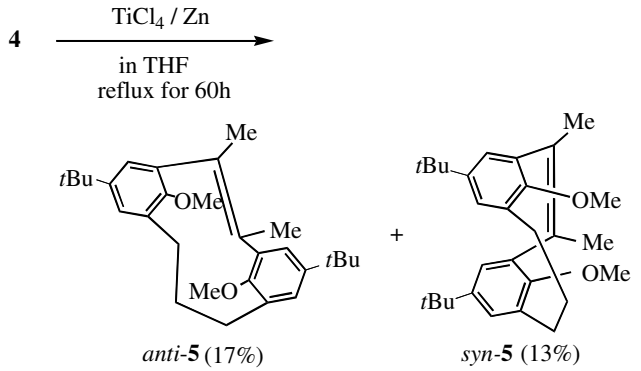


Scheme 2

that the structure of *anti*-**5** is the *anti*-conformer, whereas the structure of *syn*-**5** is the *syn*-conformer. And in both *anti*-**5** and *syn*-**5** the double bond stereochemistry adopts *Z*-geometry.

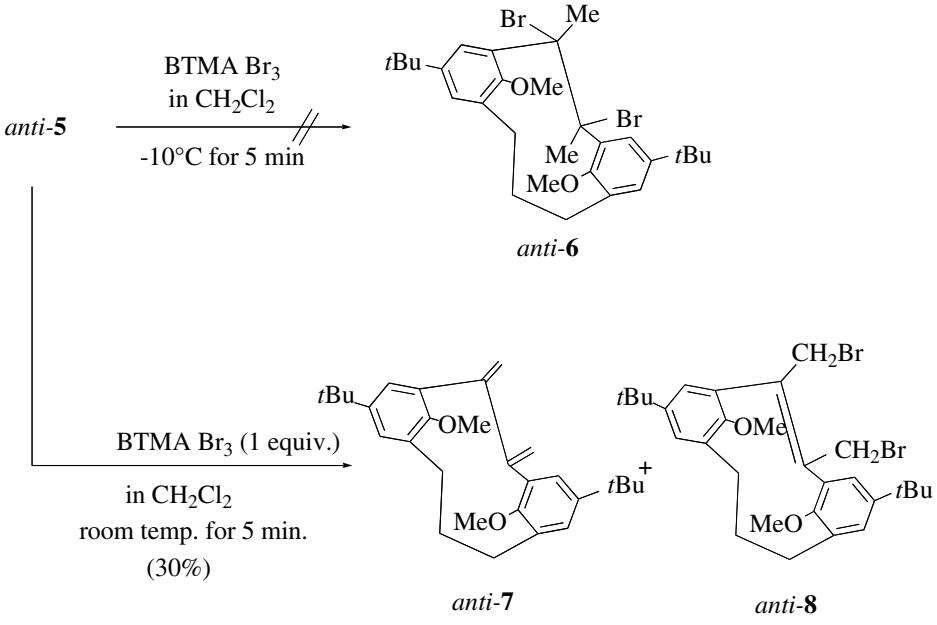
Bromination of *anti*-5,14-di-*tert*-butyl-8,17-dimethoxy-1,2-dimethyl[2.3]MCP-1-ene (*anti*-**5**) with 1 equiv. of benzyltrimethylammonium tribromide (BTMA Br_3)[14] in dichloromethane solution at room temperature for 5 min afforded a mixture of the corresponding 1,2-dimethylene [2.3]MCP (*anti*-**7**) and 1,2-bis(bromomethyl)[2.3]MCP (*anti*-**8**) in 30% yield (7:3 ratio determined by ^{1}H NMR in $CDCl_3$) along with a recovery of the starting compound. The former transformation probably occurred by addition of bromine to the double bond followed by the two-fold dehydrobromination to diene *anti*-**7**. In fact, the same treatment of *anti*-**5** at –10°C afforded a trace amount of diene *anti*-**7** along with a recovery of the starting compound. No formation of the adducts to the bridging double bond was observed. This result is quite different from the bromination of the corresponding *anti*-5,14-di-*tert*-butyl-8,17-dimethoxy[2.3]MCP-1-ene which afforded the *cis*-addition product to the bridging double bond.[15] Although the detailed mechanism of formation of 1,2-dimethylene[2.3]MCP (*anti*-**7**) is not clear in the present stage, one might assume the reaction pathway as shown in Scheme 4 like the bromination of octamethylcyclopentene to afford 1,2-dimethylene-3,3,4,4,5,5-hexamethylcyclopentene by a bromination elimination sequence.[16] It seems to assume that the initial formation of the bromonium ion **A** might take place in accordance with the behaviour of the sterically hindered alkenes.[17] Successive deprotonation yields the tertiary allylic bromide **B**, from which the HBr elimination may yield diene *anti*-**7**. The compound *anti*-**5** was treated with 4 equiv. of BTMA Br_3 at room temperature for 12 h afforded 1,2-bis(bromomethyl)[2.3]MCP-1-ene (*anti*-**8**) in 90% yield. It was also found that the bromination of 1,2-dimethylene[2.3]MCP (*anti*-**7**) with an equimolar of BTMA Br_3 at room temperature for 5 min. afforded 1,2-bis(bromomethyl)[2.3]MCP-1-ene (*anti*-**8**) in quantitative yield. This result strongly suggests that the 1,2-dimethylene[2.3]MCP (*anti*-**7**) could be an intermediate of formation of 1,2-bis(bromomethyl)[2.3]MCP-1-ene (*anti*-**8**) in the bromination of 1,2-dimethyl[2.3]MCP (*anti*-**5**). In contrast, compound *syn*-**5** was treated with an equimolar amount of BTMA Br_3 under the same conditions above afforded intractable mixtures of products. No formation of bromine adducts to the double bond and the corresponding diene (*syn*-**7**) was detected under the conditions used.

The 300 MHz ^{1}H NMR spectrum of *anti*-**8** showed a singlet of the methoxy protons at δ 3.22 ppm in addition to the resonances at δ 6.99 and 7.19 ppm (*J*= 2.4 Hz) for the two protons of the aromatic rings. The methylene protons of the bromomethyl group were observed as a doublet at δ 4.69 and 4.81ppm (*J* = 10.5 Hz), which is not imerged even at 130°C in $CDBr_3$. Thus, the introduction of bromo group to methyl group at the ethenobridge might inhibit the rotation around the single bond of C–CH_2Br, which makes the methylene protons diasterotopic enviroment.

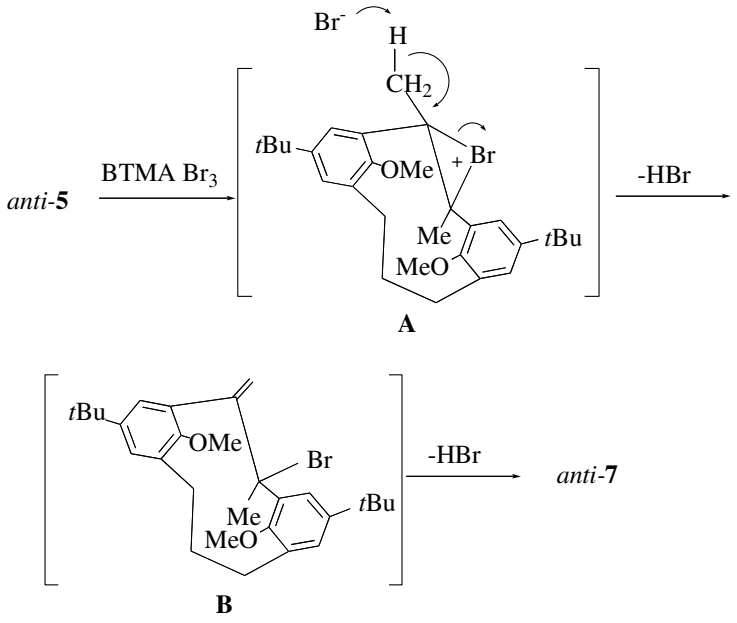
Treatment of 1,2-bis(bromomethyl)[2.3]MCP-1-ene (*anti*-**8**) with silver acetate in acetic acid at 80°C for 12 h afforded the corresponding acetate (*anti*-**9**) in 90% yield. Compound *anti*-**9** was further converted to 1,2-bis(hydroxymethyl) derivative (*anti*-**10**) in quantitative yield. An attempted oxidation of the diol *anti*-**10** to the dialdehyde (*anti*-**11**) with Swern oxidation[18] carried out in a dichloromethane solution according to the reported procedure failed. Only the cleavage reaction product, the diacetyl compound **4**, was obtained in a quantitative yield. This finding seems to support the strained nature of the diol *anti*-**10**.

Conclusions

We have demonstrated a convenient preparation of *syn*- and *anti*-1,2-dimethyl[2.3]MCP-1-enes **5** by McMurry reaction



Scheme 3



Scheme 4

of 1,3-bis(3-acetyl-5-*tert*-butyl-2-methoxyphenyl)propane (**4**). Bromination of *anti*-1,2-dimethyl[2.3]MCP-1-ene with BTMA Br_3 afforded 1,2-dimethylene- [2.3]MCP and 1,2-[bis(bromo methyl)[2.3]MCP depending on the amount of bromination reagent. Also, 1,2-bis(bromomethyl) derivative is converted to the corresponding 1,2-disubstituted [2.3]MCP-1-enes. Further studies on the chemical properties of 1,2-dimethylene[2.*n*]MCPs and 1,2-[bis(bromomethyl)[2.*n*]MCPs are now in progress.

Experimental

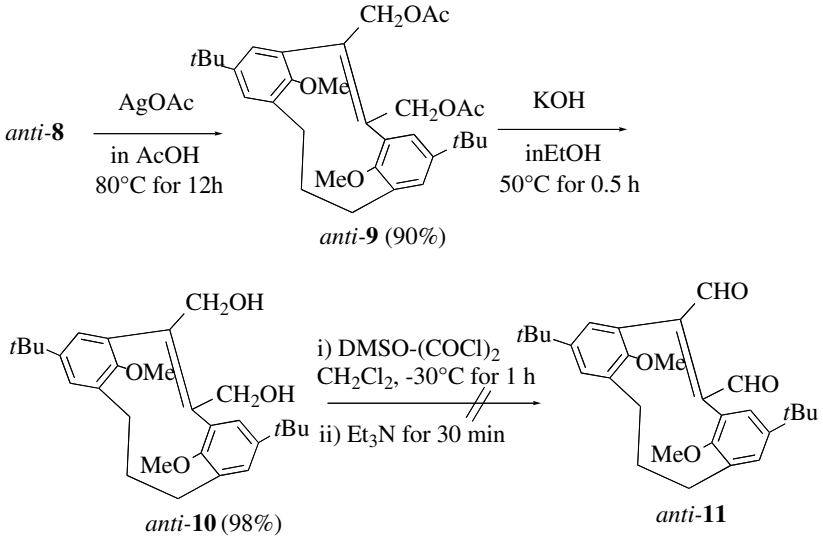
^{1}H NMR spectra were recorded at 300 MHz on a Nippon Denshi JEOL FT-300 NMR spectrometer in deuteriochloroform with Me_4Si as an internal reference. IR spectra were measured as KBr pellets on a Nippon Denshi JIR-AQ2OM spectrometer. Mass spectra were obtained on a Nippon Denshi JMS-01SA-2 spectrometer at 75 eV using a direct-inlet system.

Materials

Preparation of 1,3-bis(5-*tert*-butyl-2-methoxylphenyl)propane (**1**) was previously described.[12]

Preparation of 1,3-bis(5-tert-butyl-3-formyl-2-methoxyphenyl) propane **(2):** To a solution of 1,3-bis(5-*tert*-butyl-2-methoxylphenyl) propane (**1**)[12] (3.19 g, 9.0 mmol) and Cl_2CHOCH_3 (2.28 cm^3, 25.2 mmol) in CH_2Cl_2 (20 cm^3) was added a solution of $TiCl_4$ (6.0 cm^3, 54.5 mmol) in CH_2Cl_2 (20 cm^3) at 0°C. After the reaction mixture was stirred at room temp. for 2 h, it was poured into a large amount of ice/water (200 cm^3) and extracted with CH_2Cl_2 (100 cm^3 × 2). The combined extracts were washed with water, dried with Na_2SO_4 and concentrated. The residue was chromatographed over silica gel (Wako C-300, 200 g) with $CHCl_3$ as eluent to give crude 1,3-bis(5-*tert*-butyl-3-formyl-2-methoxyphenyl)propane (**2**) (3.09 g, 81%) as colourless oil; ν_{max} (NaCl)/cm^{-1} 1688 (C=O); δ_H ($CDCl_3$) 1.32 (18H, s, *t*Bu), 1.94–2.04 (2H, m, $ArCH_2CH_2CH_2Ar$), 2.73–2.79 (4H, m, $ArCH_2CH_2CH_2Ar$), 3.84 (6H, s, O*Me*), 7.50 (2H, d, *J* = 2.6, Ar–*H*), 7.72 (2H, d, *J* = 2.6, Ar–*H*), 10.35 (2H, s, C*H*O); *m/z* 424 (M^+) (Found C, 76.60; H, 8.63. $C_{27}H_{36}O_4$ (424.57) requires C, 76.38; H, 8.55%).

Preparation of 1,3-bis[5-tert-butyl-3-(1-hydroxyethyl)-2-methoxyl-phenyl]propane **(3):** To a solution of methylmagnesium bromide [prepared from methyl iodide (14.4 g, 101 mmol) and magnesium (2.05 g, 84.3 mmol)] in Et_2O (45 cm^3) was added a solution of **2** (8.85 g, 20.9 mmol) in tetrahydrofuran (100 cm^3) dropwise under the conditions of gentle refluxing. After the reaction mixture was refluxed for an additional 12 h, it was quenched with 10%



Scheme 5

ammonium chloride (100 cm^3) and extracted with Et_2O (100 $cm^3 \times 3$). The extract was washed with water (100 cm^3 × 2), dried over Na_2SO_4, and concentrated *in vacuo*. The residue was recrystallised from hexane to afford 1,3-bis[5-*tert*-butyl-3-(1-hydroxyethyl)-2-methoxyphenyl]propane (**3**) (8.57 g, 90%) as pale yellow oil; ν_{max} (NaCl)/cm^{-1} 3418, 2924, 2856, 1480, 1463, 1363, 1204, 1033, 1011; δ_H ($CDCl_3$) 1.30 (18H, s, *t*Bu), 1.50 (6H, d, *J* = 6.4, CH(OH)*Me*), 1.97–2.01 (2H, m, $ArCH_2CH_2CH_2Ar$), 2.68 (2H, s, O*H*), 2.71–2.73 (4H, m, $ArCH_2CH_2CH_2Ar$), 3.71 (6H, s), 5.17 (2H, q, *J* = 6.4 Hz, C*H*(OH)Me), 7.15 (2H, d, *J* = 2.2, Ar-*H*), 7.30 (2H, d, *J* = 2.2, Ar–*H*); *m/z*: 456 (M^+–H_2O) (Found C, 76.23; H, 9.90. $C_{29}H_{44}O_4$ (456.67) requires C, 76.27; H, 9.72%).

Preparation of 1,3-bis(3-acetyl-5-tert-butyl-2-methoxylphenyl) propane **(4):** To a solution of $C_5H_5NH^+CrO_3Cl^-$ (31.0 g, 144 mmol) in acetone (300 cm^3) was added a solution of 1,3-bis[5-*tert*-butyl-3-(1-hydroxyethyl)-2-methylphenyl]propane (**3**) (10.62 g, 23.3 mmol) in acetone (100 cm^3) dropwise at 0°C. The reaction mixture was stirred at room temperature for 12 h. The reaction mixture was filtered and the filtrate was concentrated. The residue was subjected to silica-gel (Wako, C-300; 500 g) column chromatography using as eluent $CHCl_3$ to afford 1,3-bis(3-acetyl-5-*tert*-butyl-2-methoxyphenyl)propane (**4**) (6.64 g, 63 %) as a pale yellow oil; ν_{max} (NaCl)/cm^{-1}: 2944, 1696 (C=O), 1465, 1358, 1229, 1115, 1008, 890, 809; δ_H ($CDCl_3$): 1.31 (18H, s, *t*Bu), 1.93–2.03 (2H, m, $ArCH_2CH_2CH_2Ar$), 2.64 (6H, s, CO*Me*), 2.72–2.77 (4H, m, $ArCH_2CH_2CH_2Ar$), 3.71 (6H, s, O*Me*), 7.37 (2H, d, *J* = 2.4, Ar-*H*), 7.44 (2H, d, *J* = 2.4, Ar-*H*); *m/z*: 452 (M^+) (Found C, 76.73; H, 8.70. $C_{29}H_{40}O_4$ (452.63) requires C, 76.95; H, 8.91%).

McMurry coupling reaction of **4**: The McMurry reagent was prepared from $TiCl_4$ (13.75 cm^3, 125 mmol) and Zn powder (18 g, 275 mmol) in dry THF (500 cm^3), under nitrogen. A solution of 1,3-bis(3-acetyl-5-*tert*-butyl-2-methoxylphenyl)propane (**4**) (3.4 g, 7.5 mmol) and pyridine (22.8 cm^3, 0.2 mol) in dry THF (250 cm^3)was added within 60 h to the black mixture of the McMurry reagent by using a high-dilution technique with continuous refluxing and stirring. The reaction mixture was refluxed for additional 8 h, cooled to room temperature, and hydrised with aqueous 10% K_2CO_3 (200 cm^3) at 0°C. The reaction mixture was extracted with CH_2Cl_2 (200 $cm^3 \times 3$). The combined extracts were washed with water, dried with Na_2SO_4 and concentrated. The residue was chromatographed over silica gel (Wako C-300, 300 g) with hexane:benzene, 1:1 and benzene as eluents to give *anti*-**5** and *syn*-**5** as a colourless solid. Each eluents were recrystallised from hexane to afford *anti*-**5** (537mg, 17%) and *syn*-**5** (411 mg, 13%), respectively.

anti-5,14-Di-*tert*-butyl-8,17-dimethoxy-1,2-dimethyl[2.3] metacyclophan-1-ene (*anti*-**5**) was obtained as colourless prisms (hexane); m.p. 170–171°C; ν_{max} (KBr)/ cm^{-1} 2951, 1475, 1256, 1240, 1116, 1030, 896; δH($CDCl_3$) 1.31 (18H, s, *t*Bu), 1.78–1.89 (2H, m, $ArCH_2CH_2CH_2Ar$), 2.24 (6H, s, *Me*), 2.21–2.30 (2H, m, $ArCH_2CH_2CH_2Ar$), 2.49–2.60 (2H, m, $ArCH_2CH_2CH_2Ar$), 3.16 (6H, s, O*Me*), 6.88 (2 H, d, *J* = 2.4, Ar–*H*), 6.91 (2H, d, *J* = 2.4, Ar–*H*); δ_C($CDCl_3$) 19.1, 22.2, 23.6, 31.6, 33.9, 59.0, 122.3, 125.4, 129.1, 130.5, 131.9, 143.3, 155.5; *m/z* 420 (M^+) (Found C, 82.53; H, 9.61. $C_{29}H_{40}O_2$ (420.64) requires C, 82.81; H, 9.59%).

syn-5,14-Di-*tert*-butyl-8,17-dimethoxy-1,2-dimethyl[2.3] metacyclophan-1-ene (*syn*-**5**) was obtained as colourless prisms (hexane); m.p. 142–143°C; ν_{max} (KBr)/ cm^{-1} 2950, 1475, 1359, 1214, 1120, 1025, 859; δ_H($CDCl_3$) 1.10 (18 H, s, *t*Bu), 2.14–2.20 (1 H, m, $ArCH_2CH_2CH_2Ar$), 2.24–2.28 (1H, m, $ArCH_2CH_2CH_2Ar$), 2.25 (6H, s, *Me*), 2.44–2.50 (2H, m, $ArCH_2CH_2CH_2Ar$), 3.05–3.15 (2H, m, $ArCH_2CH_2CH_2Ar$), 3.67 (6H, s, O*Me*), 6.17 (2H, d, *J* = 2.4, Ar–*H*), 6.55 (2H, d, *J* = 2.4, Ar–*H*); δ_C($CDCl_3$) 19.6, 28.9, 31.4, 33.6, 60.6, 77.2, 123.5, 123.9, 130.7, 132.4, 133.3, 141.6, 156.9; *m/z* 420 (M^+) (Found C, 82.63; H, 9.65. $C_{29}H_{40}O_2$ (420.64) requires C, 82.81; H, 9.59%).

Bromination of *anti*-5,14-di-tert-butyl-8,17-dimethoxy-1,2-dimethyl [2.3]metacyclophan-1-ene (*anti*-**5**) with BTMA Br_3 in CH_2Cl_2 at room temperature: A solution of *anti*-**5** (185 mg, 0.44 mmol) in CH_2Cl_2 (24 cm^3) was added BTMA Br_3 (170.3 mg, 0.44 mmol) at room temperature. After the reaction mixture was stirred for 5 min, it was poured into water (20 cm^3). The organic layer was extracted with CH_2Cl_2 (10 cm^3, 2 times). The extract was washed with 10% aqueous sodium thiosulfate (10 cm^3) and water (10 cm^3), dried (Na_2SO_4), and concentrated. The residue was column chromatographed over silica gel with hexane and hexane:benzene, 1:1 as eluents to give a mixture of *anti*-**7** and *anti*-**8** [42 mg, 30%, (7:3 ratio determined by ^1H NMR in $CDCl_3$)] and *anti*-**5** (130 mg, 70 %) as colourless solid, respectively. Recrystallisation of the former eluents from hexane gave *anti*-5,14-di-*tert*-butyl-8,17-dimethoxy-1,2-dimethylene[2.3]metacyclophan-1-ene (*anti*-**7**) as colourless prisms (hexane); 148–149 °C; ν_{max} (KBr)/ cm^{-1} 2959, 1472, 1258, 1096, 1019, 871, 809, 702; δ_H($CDCl_3$) 1.31 (18H, s, tBu), 1.90–1.97 (2H, m, $ArCH_2CH_2CH_2Ar$), 2.31–2.37 (2H, m, $ArCH_2CH_2CH_2Ar$), 2.53–2.59 (2H, m, $ArCH_2CH_2CH_2Ar$), 3.11 (6H, s, OMe), 5.14 (2H, d, *J* = 1.8, $=CH_2$), 5.72 (2H, d, *J* = 1.8, $=CH_2$), 6.94 (2H, d, *J* = 2.4, Ar–H), 7.02 (2H, d, *J* = 2.4, Ar–H); m/z 418 (M^+) (Found C, 82.36; H, 9.61. $C_{29}H_{38}O_2$ (418.61) requires C, 83.21; H, 9.15%).

Similarly, bromination of *anti*-**5** with 4 equiv. of BTMA Br_3 was carried out at room temperature for 12 h to afford *anti*-1,2-bis(bromomethyl)-5,14-di-*tert*-butyl-8,17-dimethoxy[2.3] metacyclophan-1-ene (*anti*-**8**) in 90% yield as colourless prisms (hexane); 161–162 °C; ν_{max} (KBr)/ cm^{-1} 2959, 1461, 1255, 1100, 1048, 1015, 860, 809; δ_H($CDCl_3$) 1.32 (18H, s *t*Bu), 1.78–1.88 (2H, m, $ArCH_2CH_2CH_2Ar$), 2.25–2.34 (2H, m, $ArCH_2CH_2CH_2Ar$), 2.44–2.56 (2H, m, $ArCH_2CH_2CH_2Ar$), 3.22 (6H, s, O*Me*), 4.69 (2H, d, *J* = 10.5, CH_2Br), 4.81 (2H, d, *J* = 10.5, CH_2Br), 6.99 (2H, d, *J* = 2.4, Ar–*H*), 7.19 (2H, d, *J* = 2.4, Ar–*H*); *m/z* 576, 578, 580 (M^+) (Found C, 82.36; H, 9.61. $C_{29}H_{38}O_2Br_2$ (578.43) requires C, 60.22; H, 6.62%).

*Preparation of anti-5,14-di-tert-butyl-8,17-dimethoxy-1,2-bis (acetoxymethyl)[2.3]metacyclophan-1-ene (anti-***9**): A solution of *anti*-**8** (60 mg, 0.104 mmol) in glacial acetic acid (4 cm^3) containing silver acetate (519 mg, 3.11 mmol) was heated at 80°C for 12 h. The resulting suspension was concentrated and then extracted with CH_2Cl_2 (20 $cm^3 \times 3$). The combined extracts were washed with a 10% aqueous $NaHCO_3$ solution (10 cm^3 × 2), water (10 cm^3 × 2), and brine (10 cm^3), dried with Na_2SO_4, and concentrated *in vacuo*. The residue was chromatographed over silica gel (Wako C-300, 300 g) with hexane:$CHCl_3$, 1:1 as eluents to give *anti*-**9** as a colourless solid. Recrystallisation from methanol gave *anti*-1,2-bis(acetoxymethyl)5,14-di-*tert*-butyl-8,17-dimethoxy-[2.3]metacyclophan-1-ene (*anti*-**9**) (50 mg, 90%) as colourless prisms, m.p. 127–128 °C; ν_{max} (KBr) /cm^{-1} 1740 (C=O); δ_H (CDCl3) 1.17 (18H, s, *t*Bu), 1.61–1.72 (2H, m, $ArCH_2CH_2CH_2Ar$), 1.87 (6H, s, *Me*), 2.10–2.23 (2H, m, $ArCH_2CH_2CH_2Ar$), 2.31–2.43 (2H, m, $ArCH_2CH_2CH_2Ar$), 3.04 (6H, s, O*Me*), 5.12 (2H, d, *J* = 12.6, CH_2OAc), 5.19 (2H, d, *J* = 12.6, CH_2OAc), 6.83 (2H, d, *J* = 2.4, Ar–*H*) 6.92 (2H, d, *J* = 2.4 , Ar–*H*); *m/z* 536 (M^+) (Found: C, 73.71; H, 8.42. $C_{33}H_{44}O_6$ requires C, 73.85; H, 8.26%).

*Preparation of anti-5,14-di-tert-butyl-1,2-bis(hydroxymethyl)-8,17-dimethoxy-[2.3]metacyclophan-1-ene (anti-***10**): To a solution of *anti*-**9** (29 mg, 0.047 mmol) in EtOH (2.5 cm^3) was added a solution of KOH (50 mg, 0.891 mmol) in water (0.2 cm^3) at room temperature. After the reaction mixture had been heated at 50 °C for 30 min, it was condensed under reduced pressure, and extracted with CH_2Cl_2 (10 $cm^3 \times 3$). After the dichloromethane solution had been washed successively with water, the extract was dried over anhydrous sodium sulfate and concentrated to afford *anti*-**10** (21 mg, 98%) as a colourless solid. Recrystallisation from methanol gave *anti*-5,14-di-*tert*-butyl-8,17-dimethoxy-1,2-bis(hydroxymethyl)[2.3]metacyclophan-1-ene (*anti*-**10**) as colourless prisms, m.p. 143–144 °C ν_{max} (KBr) /cm^{-1} 3240 (OH); δ_H ($CDCl_3$) 1.32 (18H, s, *t*Bu), 1.81–1.92 (2H, m, $ArCH_2CH_2CH_2Ar$), 2.26–2.37 (2H, m, $ArCH_2CH_2CH_2Ar$), 2.43–2.55 (2H, m, $ArCH_2CH_2CH_2Ar$), 3.22 (6H, s, O*Me*), 4.81 (2H, d, *J* = 12.6, CH_2OH), 4.87 (2H, d, *J* = 12.6, CH_2OH), 6.96 (2H, *J* = 2.4, Ar–*H*), 7.04 (2H, d, *J* = 2.4, Ar–*H*); *m/z* 452 (M^+) (Found: C, 76.81; H, 8.82. $C_{29}H_{40}O_4$ requires C, 76.95; H, 8.91%).

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