

# Preparation and structure–chiroptical relationships of tartaric acid-based layer-block chiral dendrimers

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Two optically active, diastereoisomeric, first generation layer-block dendrimers **1** and **2** have been prepared by a convergent synthetic procedure. These chiral, layer-block dendrimers utilize 4-*tert*-butylphenoxy moieties as the surface groups and phloroglucinol as the branching junctures. Two different chiral units, which are derivatives of (D)- and (L)-tartaric acid, serve as the chiral linkers between the surface group and the branching juncture, or between two branching junctures. The first layer-block dendrimer **1** has an outer chiral layer made up of six (L)-tartrate derived units and an inner chiral layer of three (D)-tartrate derived units. The second layer-block dendrimer **2** has an outer shell consisting of three (D)- and three (L)-chiral units and an inner shell of three (D)-chiral units. The molar rotation of these structurally flexible, low generation dendritic compounds is proportional to the number of chiral tartrate units in excess, with the chiroptical effect of a (D)-tartrate derived chiral unit cancelling that of an (L)-tartrate derived unit on a 1:1 basis. Circular dichroism studies, however, reveal that this cancellation effect is more effective when both the (D)- and (L)-chirons are situated within the same layer.

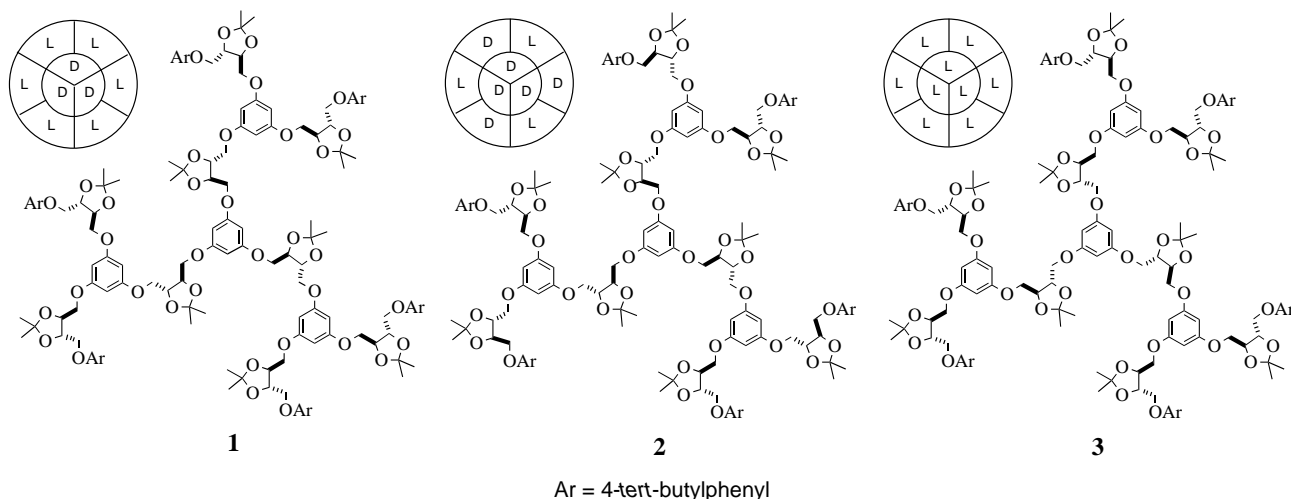
Dendrimer chemistry has become a rapidly growing research area serving as the bridge between conventional organic chemistry and polymer science.<sup>1</sup> Within this context, the preparation of optically active dendrimers for use as chiral hosts for enantiomeric recognition and as catalysts for asymmetric synthesis is of current interest. Although the use of optically active, naturally occurring biological molecules, such as carbohydrates and amino acids, as monomeric units for the construction of bio-dendrimers is well documented,<sup>2</sup> the relationship between the overall chiroptical properties of a chiral dendrimer and the stereo-spatial arrangement of its constituent chiral elements has been little investigated. Recently, Seebach<sup>3</sup> and we<sup>4</sup> independently reported that the optical activity of low generation dendrimers containing multiple chiral units was roughly proportional to the number of repeating chiral elements inside the dendritic structure. In contrast, Meijer suggested that sterically congested dendrimers with optically active units located on the surface sector displayed little or a diminishing level of optical rotatory activity.<sup>2i</sup> Since most chiral dendrimers reported so far have been made up of a single type of chiral element, it was of interest to prepare chiral dendritic copolymers bearing more than one single type of chiral unit and to study the effect of the different chiral units on the overall chiroptical activity. In a preliminary communication,<sup>5</sup> we

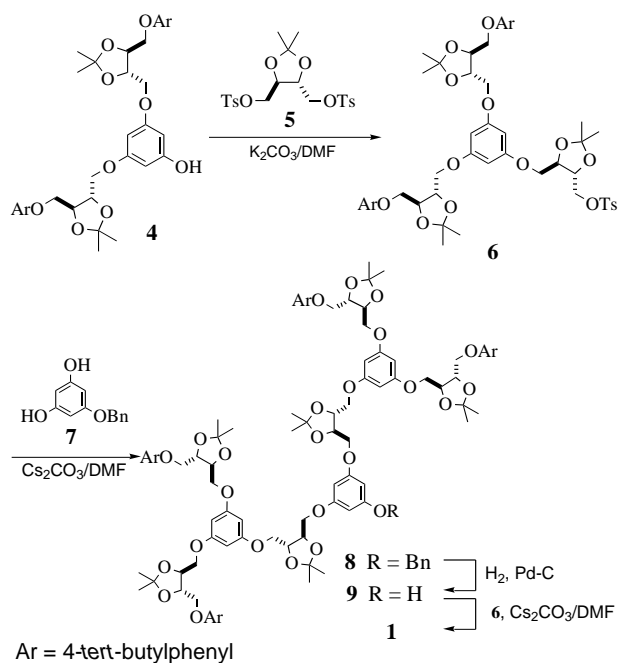
reported the synthesis and chiroptical properties of two different layer-block chiral dendrimers **1** and **2** containing two different chiral elements which were derivatives of (D)- and (L)-tartaric acid. In this article, we disclose the details of the synthesis and optical activity properties of these compounds. In order to gain further insight into the chiroptical properties of this series of dendrimer, the circular dichroism (CD) spectra of these compounds are also reported and compared to that of the all (L)-tartaric acid derived chiral dendrimer **3** previously synthesized.<sup>4</sup>

## Results and discussion

### Synthesis

An iterative, convergent synthetic strategy<sup>6</sup> was used to prepare these novel layer-block dendrimers. As for the all-(L)-tartrate derived chiral dendrimer **3** prepared by us earlier, the surface group chosen was a 4-*tert*-butylphenoxy moiety and the branching juncture was a phloroglucinol unit. However, two different chiral units, which were derivatives of (D)- and (L)-tartaric acid, were used as the chiral linker branches. The first layer-block dendrimer **1** consisted of an outer chiral layer having six (L)-tartrate derived units and an inner chiral layer having three antipodal (D)-chiral elements. The second



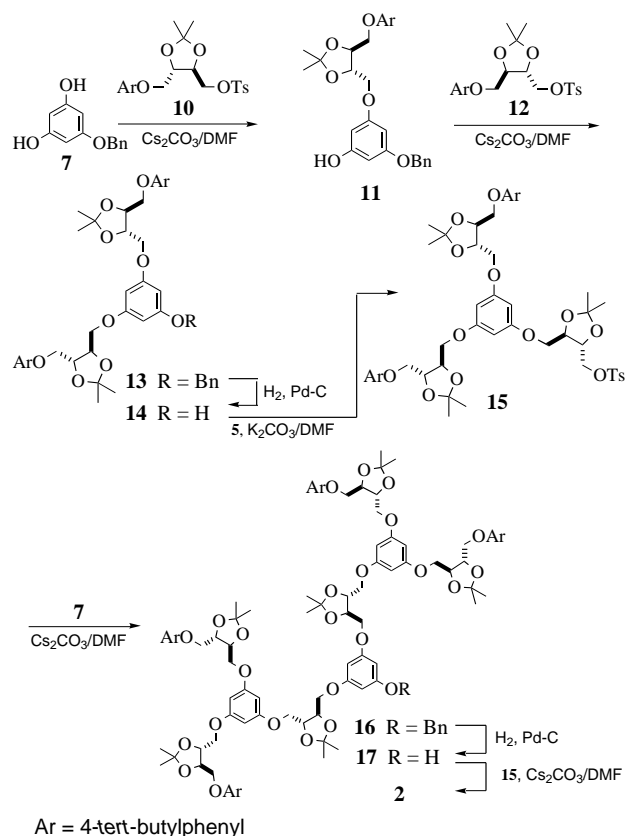


layer-block dendrimer **2**, however, had an outer shell of three (D)- and three (L)-chiral units and an inner shell of three (D)-chiral units.

The starting material for the synthesis of dendrimer **1** began with the  $C_2$ -symmetric phenol **4**.<sup>4</sup> Treatment of 2 mol equiv. of (2*R*,3*R*)-(+)-2,3-*O*-isopropylidene-1,4-di-*O*-tosyl-(D)-threitol **5** with phenol **4** in the presence of potassium carbonate in dimethylformamide (DMF) gave the tosyl compound **6** (57%) as an oil. Bis-*O*-alkylation of 5-benzyloxyresorcinol **7** with 2.1 mol equiv. of compound **6** under similar conditions ( $\text{Cs}_2\text{CO}_3$  in DMF, 110 °C) afforded the  $C_2$ -symmetric benzyl ether **8** (55%). All the isopropylidene methyl groups in compound **8**, regardless of the absolute configurations of their neighbouring chiral centres, had identical chemical shift values in their  $^1\text{H}$  ( $\delta$  1.48) and  $^{13}\text{C}$  ( $\delta$  27.0) NMR spectra. The central phloroglucinol protons, however, appeared at a slightly different position ( $\delta$  6.20) as compared to the peripheral phloroglucinol protons ( $\delta$  6.16) in the  $^1\text{H}$  NMR spectrum. The benzyl protecting group was then removed by treatment with 10% palladium-on-charcoal under hydrogen to give the  $C_2$ -symmetric phenol **9** (70%). Finally, attachment of a third sector **6** to the resulting phenol **9** ( $\text{Cs}_2\text{CO}_3$  in DMF, 100 °C) furnished the layer-block dendrimer **1** (65%) as a syrup.

This first generation layer-block dendrimer **1** contains six (L)-tartrate and three (D)-tartrate chiral units and has a  $C_3$  symmetry. Similar to the benzyl ether **8**, all the isopropylidene methyl groups in compound **1** have identical chemical shift values in both their  $^1\text{H}$  NMR and  $^{13}\text{C}$  NMR spectra. The core and peripheral phloroglucinol protons are again slightly different, as they display different chemical shift values ( $\delta$  6.16 and 6.17 respectively) in the  $^1\text{H}$  NMR spectrum. Most interestingly, this layer-block dendrimer **1** has nearly identical  $^1\text{H}$  NMR and  $^{13}\text{C}$  NMR spectra to those of the all (L)-tartrate dendrimer **3** reported previously.<sup>4</sup> This result suggests that each chiral unit appears as an isolated non-communicating chiron residing in the dendritic matrix.

The synthesis of the other layer-block dendrimer **2** proved to be problematic. The bottleneck was an inefficient mono-*O*-alkylation ( $\text{Cs}_2\text{CO}_3$  in DMF, 90 °C) of 5-benzyloxyresorcinol **7** with the (L)-tartrate derived tosyl compound **10**<sup>4</sup> to give the mono-*O*-alkylated product **11**. Under all the conditions tried, the bis-*O*-alkylated compound was always the predominant product even when a large excess of **7** was employed. We speculated that this problem arose as a result of the poor solubility of the anion of 5-benzyloxyresorcinol compared to that of com-



ound **11** in the reaction medium. Thus, as soon as **11** was generated, it underwent a second *O*-alkylation at a far faster rate than compound **7**. Finally, after optimization, we were able to obtain the desired product **11** (34%) together with the bis-*O*-alkylated side product (28%). It is of interest to note that the phloroglucinol protons in the mono-*O*-alkylated benzyl ether **11** appear as three distinctive triplet signals at  $\delta$  6.05, 6.11 and 6.17 in the  $^1\text{H}$  NMR spectrum, a unique characteristic of its inherently unsymmetrical nature. Phenol **11** was then *O*-alkylated with the (D)-tartrate derived tosyl compound **12**<sup>8</sup> under similar conditions ( $\text{Cs}_2\text{CO}_3$  in DMF, 100 °C) to afford the  $C_2$ -symmetric benzyl ether **13** as a white foam (89%). The benzyl group was again deprotected by catalytic hydrogenolysis (10% Pd-C, EtOH-EtOAc) to give the phenol **14** (85%). In a procedure similar to that described for the diastereoisomeric phenol **4**, compound **14** could be converted into the tosyl compound **15** (73%) by treatment with an excess of the (D)-tartrate derived ditosyl compound **5**. The dendritic 'wedge' **15** (2 mol equiv.) was then treated with 5-benzyloxyresorcinol **7** to give the benzyl ether **16** as an oil, subsequent debenzoylation of which afforded the phenol **17**. Attachment of the final dendritic 'wedge' **15** to this then furnished the first generation layer-block dendrimer **2**.

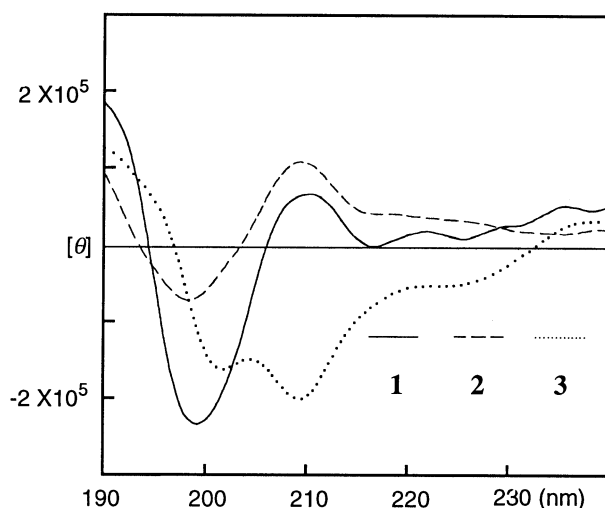
The structural identities of the layer-block dendrimers **1** and **2** were confirmed from their  $^1\text{H}$  and  $^{13}\text{C}$  NMR spectra and by mass spectroscopic analysis. Most interestingly, both the  $^1\text{H}$  and  $^{13}\text{C}$  NMR spectra of **1** and **2** as well as that of the all (L)-tartrate derived dendrimer **3** are almost superimposable. This suggested that the central as well as the peripheral phloroglucinol rings in different dendrimers have nearly the same chemical microenvironment, irrespective of absolute configurations of the chiral branches around them.

Attempts to prepare higher generation analogues of this series of layer-block dendrimers by this iterative reaction sequence were unsuccessful. We believe that the steric bulkiness of the isopropylidene protecting group in the chiral tartrate branch inhibits further growth of the dendritic sector, since a previously reported<sup>9</sup> non-chiral dendritic series using a

**Table 1** Specific and molar rotations of dendritic molecules (23 °C in CHCl<sub>3</sub>, D-line)

Compound	No. of (D)-tartrate units	No. of (L)-tartrate units	No. of (D)-units in excess <sup>a</sup>	Specific rotation [ $\alpha$ ] <sup>b</sup>	Molar rotation <sup>b</sup>	Molar rotation per tartrate unit <sup>c</sup>
<b>1</b>	3	6	-3	-16.2 ( <i>c</i> 1.71)	-411	-137
<b>2</b>	6	3	3	+22.8 ( <i>c</i> 1.07)	+579	+193
<b>3</b>	0	9	-9	-69.7 ( <i>c</i> 0.37) <sup>d</sup>	-1769	-197
<b>4</b>	0	2	-2	-52.4 ( <i>c</i> 0.53) <sup>d</sup>	-355	-178
<b>6</b>	1	2	-1	-29.5 ( <i>c</i> 1.64)	-288	-288
<b>8</b>	2	4	-2	-16.7 ( <i>c</i> 2.80)	-304	-152
<b>9</b>	2	4	-2	-21.9 ( <i>c</i> 2.10)	-379	-190
<b>11</b>	0	1	-1	-33.4 ( <i>c</i> 1.30)	-164	-164
<b>13</b>	1	1	0	-2.9 ( <i>c</i> 4.30)	-25	—
<b>14</b>	1	1	0	-3.3 ( <i>c</i> 1.36)	-22	—
<b>15</b>	2	1	1	+7.9 ( <i>c</i> 1.52)	+75	+75
<b>16</b>	4	2	2	+17.6 ( <i>c</i> 0.44)	+314	+157
<b>17</b>	4	2	2	+18.2 ( <i>c</i> 1.00)	+316	+158

<sup>a</sup> Negative values denote (L)-tartrate unit(s) is in excess. <sup>b</sup> In units of 10<sup>-1</sup> deg cm<sup>2</sup> g<sup>-1</sup>. <sup>c</sup> Negative and positive values denote contributions from (L)- and (D)-tartrate unit(s), respectively. <sup>d</sup> Ref. 4.

**Fig. 1** Circular dichroism spectra of dendrimers 1–3

three-carbon spacer branch could be prepared up to the fourth generation.

#### Structure–optical rotation relationships

The specific and molar rotations of the two layer-block dendrimers and their immediates are shown in Table 1. Upon first examination, it was noticed that the chiroptical effect of the (L)-tartrate chiral unit cancelled that of the (D)-tartrate unit on a one to one basis. As a consequence, the overall molar rotation of the dendritic fragment was proportional to the number of (D)- or (L)-tartrate units in excess. Hence, dendritic fragments with an excess of (D)-tartrate units consistently gave positive optical rotation values and those with an excess of (L)-tartrate units had negative values. Based on those compounds with an excess of (D)-chirons, the average contribution per (D)-tartrate unit towards the overall molar rotation was +146. In absolute terms this was slightly less than the average contribution from an (L)-chiron, which was previously reported to be -185.<sup>4</sup> Although compounds **13** and **14**, having *C*<sub>2v</sub> symmetry, should be devoid of optical activity, they did have very small specific rotational values. This could be due to the presence of a very small amount of optically active impurities.

The circular dichroism spectra revealed findings which were not apparent from polarimetry studies (Fig. 1). Amongst the three G1 dendrimers, the all (L)-tartrate-derived homo dendrimer **3** gave two negative Cotton effects at 200 and 210 nm with large molar ellipticities. Due to the cancellation effect of having both enantiomeric (D)- and (L)-chirons in the same outer layer in the layer-block dendrimer **2**, this compound failed to show any large Cotton effects at either transition, as compared to dendrimers **1** and **3**. On the other hand, the layer-block den-

dimer **1** with six (L)-tartrate-derived units in the outer shell and three (D)-chiral units in the inner shell, still exhibited a significantly large negative Cotton effect at 200 nm, although the positive Cotton effect at 210 nm was less prominent. This result suggested that the chiroptical effect of an (L)-chiral unit in the outer shell did not exactly eliminate that of a (D)-chiral unit in the inner shell, thus still leaving a significant absorption at 200 nm. It was therefore concluded that chiroptically, the outer chiral layer was slightly different from the inner layer.

#### Conclusions

This paper describes the syntheses of two diastereoisomeric, optically active layer-block dendrimers **1** and **2**, both of which contain two different types of chiral elements. It was discovered that the molar rotation of these lower generation dendrimers was proportional to the number of chiral units in excess. In other words, the chiroptical effect of a (D)-tartrate chiron cancels out that of an antipodal (L)-tartrate unit. Circular dichroism studies, however, pointed out that this cancellation effect was more effective when both the (D)- and (L)-chirons were deposited within the same layer. This finding was different from that observed for sterically congested chiral dendrimers with optically active units located on the surface sector, where they were devoid of any significant optical rotational activity.<sup>2i</sup>

## Experimental

#### General

IR spectra were recorded on a Nicolet (205) FT-IR spectrophotometer as neat films on KBr disks. <sup>1</sup>H NMR spectra were recorded on a Bruker Cryospec WM 250 (250 MHz) spectrometer in CDCl<sub>3</sub> solution with tetramethylsilane as internal standard. Chemical shifts are reported as ppm in the  $\delta$  scale downfield from SiMe<sub>4</sub> and coupling constants (*J*) are reported in Hz. <sup>13</sup>C NMR spectra were obtained on a Bruker WM 250 spectrometer at 62.9 MHz. Mass spectra were recorded on a VG Micromass 7070F or a Bruker APEX 47e FT-MS spectrometer. Optical rotations were measured with sodium D light on a Perkin-Elmer polarimeter 341 at 23 °C; they are recorded 10<sup>-1</sup> deg cm<sup>2</sup> g<sup>-1</sup>. Circular dichroism measurements were carried out on a JASCO J-720 Spectropolarimeter at 25 °C. Elemental analyses were carried out by Medac Ltd, Uxbridge, UK.

#### Mono-*O*-alkylated benzyl ether 11

A mixture of 5-benzyloxyresorcinol **7** (1.00 g, 4.63 mmol), mono-*O*-arylated tosyl ester **10** (1.50 g, 3.35 mmol) and caesium carbonate (0.80 g, 2.45 mmol) in DMF (50 cm<sup>3</sup>) was stirred at 90 °C under nitrogen for 2 d. The reaction mixture was cooled and evaporated under reduced pressure. The residue was partitioned between ethyl acetate (30 cm<sup>3</sup>) and water (30 cm<sup>3</sup>). The aqueous layer was extracted with ethyl acetate (3 × 15 cm<sup>3</sup>) and

the combined organic layers were washed with brine, dried ( $\text{Na}_2\text{SO}_4$ ) and filtered. The filtrate was concentrated, and purified by flash chromatography on silica gel with hexane–ethyl acetate (5:1) as eluent to give *mono-O-alkylation product 11* (0.55 g, 34%) as a white solid,  $R_f$  0.29 (3:1, hexane–ethyl acetate); mp 107–108 °C (Found: C, 73.2; H, 7.4.  $\text{C}_{30}\text{H}_{36}\text{O}_6$  requires C, 73.2; H, 7.4%);  $\nu_{\text{max}}/\text{cm}^{-1}$  3390 (OH);  $\delta_{\text{H}}$  1.29 (9 H, s, Bu<sup>1</sup>), 1.49 (6 H, s, 2 × Me), 4.10–4.30 (4 H, m, 2 OCH<sub>2</sub>), 4.30–4.40 (2 H, m, OCH), 4.97 (2 H, s, PhCH<sub>2</sub>), 5.34 (1 H, br s, OH), 6.05 (1 H, t, *J* 2.1, ArH), 6.11 (1 H, t, *J* 2.1, ArH), 6.17 (1 H, t, *J* 2.1, ArH), 6.86 (2 H, d, *J* 8.9, ArH), 7.29 (2 H, d, *J* 8.9, ArH) and 7.30–7.45 (5 H, m, PhCH<sub>2</sub>);  $\delta_{\text{C}}$  27.0, 31.5, 34.0, 68.7, 70.1, 77.1, 94.7, 95.5, 96.0, 110.5, 114.2, 126.3, 127.4, 127.9, 128.5, 136.9, 144.1, 156.2, 157.8, 160.5 and 160.8;  $m/z$  (EI) 492 (M<sup>+</sup>, 8%), 342 (M<sup>+</sup> – 2C<sub>7</sub>H<sub>7</sub>O – 2CH<sub>3</sub>, 18), 197 (28), 91 (100) and 65 (24).

### Bis-*O*-alkylated dendritic benzyl ether 13

A mixture of mono-*O*-alkylated benzyl ether **11** (0.50 g, 1.02 mmol), mono-*O*-arylated tosyl ester **12** (0.50 g, 1.12 mmol) and caesium carbonate (0.40 g, 1.23 mmol) in DMF (25 cm<sup>3</sup>) was stirred at 100 °C under nitrogen for 2.5 h. The reaction mixture was cooled and evaporated under reduced pressure. The residue was taken up in ethyl acetate and filtered. The filter cake was washed with ethyl acetate and the combined filtrates were concentrated and purified by flash chromatography on silica gel with hexane–ethyl acetate (10:1) as eluent to afford the *benzyl ether 13* (0.70 g, 89%) as a white foam,  $R_f$  0.42 (5:1, hexane–ethyl acetate) (Found: C, 72.6; H, 7.9.  $\text{C}_{47}\text{H}_{60}\text{O}_9$  requires C, 73.4; H, 7.9%);  $\delta_{\text{H}}$  1.28 (18 H, s, 2 × Bu<sup>1</sup>), 1.49 (12 H, s, 4 × Me), 4.05–4.25 (8 H, m, OCH<sub>2</sub>), 4.25–4.40 (4 H, m, OCH), 4.97 (2 H, s, PhCH<sub>2</sub>), 6.15–6.25 (1 H, m, ArH), 6.25–6.30 (2 H, m, ArH), 6.86 (4 H, d, *J* 8.5, ArH), 7.29 (4 H, d, *J* 8.6, ArH) and 7.30–7.45 (5 H, m, PhCH<sub>2</sub>);  $\delta_{\text{C}}$  27.0, 31.4, 34.0, 68.6, 68.7, 70.0, 76.7, 94.4, 94.9, 110.3, 114.0, 126.1, 127.4, 127.9, 128.4, 136.7, 143.8, 156.1, 160.3 and 160.6;  $m/z$  (+L-SIMS) 769.4 (M + H<sup>+</sup>, 100%).

### Dendritic phenol 14

A mixture of the benzyl ether **13** (0.65 g, 0.85 mmol) and 10% palladium-on-charcoal (60 mg) in absolute ethanol–ethyl acetate (20:20 cm<sup>3</sup>) was stirred at room temperature under an atmospheric pressure of hydrogen. After 6 h, the suspension was filtered through a pad of silica gel and the filtrate was concentrated. The residue was purified by flash chromatography on silica gel with hexane–ethyl acetate (4:1) as eluent to furnish the *dendritic phenol 14* (0.49 g, 85%) as a white glassy substance,  $R_f$  0.18 (5:1, hexane–ethyl acetate) (Found: C, 70.5; H, 8.1.  $\text{C}_{40}\text{H}_{54}\text{O}_9$  requires C, 70.8; H, 8.0%);  $\nu_{\text{max}}/\text{cm}^{-1}$  3600–3200 (OH);  $\delta_{\text{H}}$  1.29 (18 H, s, 2 × Bu<sup>1</sup>), 1.49 (12 H, s, 4 × Me), 4.10–4.30 (8 H, m, OCH<sub>2</sub>), 4.30–4.45 (4 H, m, OCH), 5.08 (1 H, br s, OH), 6.06 (2 H, d, *J* 2.1, ArH), 6.13 (1 H, t, *J* 2.0, ArH), 6.86 (4 H, d, *J* 8.8, ArH) and 7.30 (4 H, d, *J* 8.9, ArH);  $\delta_{\text{C}}$  27.0, 31.5, 34.1, 68.6, 68.7, 76.7, 94.3, 95.4, 110.5, 114.0, 126.3, 144.0, 156.2, 157.4 and 160.5;  $m/z$  (+L-SIMS) 679.3 (M + H<sup>+</sup>, 100%).

### General procedure for the synthesis of layer-block dendritic tosyl ester 6 or 15

A mixture of the phenol **4** or **14** (1.0 mol equiv.), di-*O*(+)-tosyl ester **5** (2.0 mol equiv.) and potassium carbonate (1.5 mol equiv.) in DMF was stirred at 90 °C under nitrogen for 3 h. The reaction mixture was cooled to room temperature and evaporated under reduced pressure. The residue was taken up in ethyl acetate and suction filtered. The filter cake was washed with ethyl acetate and the combined filtrates concentrated and purified as described below:

**Compound 6.** This compound was prepared from the phenol **4** and purified by flash chromatography on silica gel with hexane–ethyl acetate (5:1) as eluent to provide the *tosyl compound 6* (57%) as a white glassy substance,  $R_f$  0.25 (4:1, hexane–ethyl acetate) (Found: C, 66.6; H, 7.5.  $\text{C}_{54}\text{H}_{72}\text{O}_{14}\text{S}$  requires C, 66.4; H, 7.4%);  $\nu_{\text{max}}/\text{cm}^{-1}$  1177 (SO<sub>2</sub>);  $\delta_{\text{H}}$  1.29 (18 H, s, 2 × Bu<sup>1</sup>), 1.37 (3 H,

s, Me), 1.39 (3 H, s, Me), 1.50 (12 H, s, 4 × Me), 2.42 (3 H, s, OSO<sub>2</sub>ArCH<sub>3</sub>), 3.90–4.40 (18 H, m, OCH and OCH<sub>2</sub>), 6.11 (2 H, d, *J* 2.0, ArH), 6.15–6.20 (1 H, m, ArH), 6.86 (4 H, d, *J* 8.9, ArH), 7.29 (4 H, d, *J* 8.8, ArH), 7.31 (2 H, d, *J* 8.0, OSO<sub>2</sub>ArH) and 7.79 (2 H, d, *J* 8.3, OSO<sub>2</sub>ArH);  $\delta_{\text{C}}$  21.5, 26.7, 26.8, 26.9, 31.4, 33.9, 68.0, 68.4, 68.6, 68.9, 75.5, 76.0, 76.9, 94.5, 94.6, 110.2, 110.4, 113.9, 126.1, 127.8, 129.7, 132.5, 143.8, 144.9, 156.0, 160.0 and 160.2;  $m/z$  (+L-SIMS) 977.5 (M + H<sup>+</sup>, 100%).

**Compound 15.** This compound was prepared from the phenol **14** and purified by flash chromatography on silica gel with hexane–ethyl acetate (5:1) as eluent to afford the *tosyl compound 15* (73%) as a white glassy substance,  $R_f$  0.25 (4:1, hexane–ethyl acetate) (Found: C, 66.8; H, 7.7.  $\text{C}_{54}\text{H}_{72}\text{O}_{14}\text{S}$  requires C, 66.4; H, 7.4%);  $\nu_{\text{max}}/\text{cm}^{-1}$  1177 (SO<sub>2</sub>);  $\delta_{\text{H}}$  1.29 (18 H, s, 2 × Bu<sup>1</sup>), 1.37 (3 H, s, Me), 1.39 (3 H, s, Me), 1.50 (12 H, s, 4 × Me), 2.42 (3 H, s, OSO<sub>2</sub>ArCH<sub>3</sub>), 3.90–4.40 (18 H, m, OCH and OCH<sub>2</sub>), 6.11 (2 H, d, *J* 2.0, ArH), 6.18 (1 H, t, *J* 1.9, ArH), 6.86 (4 H, d, *J* 8.8, ArH), 7.30 (4 H, d, *J* 8.8, ArH), 7.31 (2 H, d, *J* 8.2, OSO<sub>2</sub>ArH) and 7.78 (2 H, d, *J* 8.3, OSO<sub>2</sub>ArH);  $\delta_{\text{C}}$  21.6, 26.9, 27.0, 27.2, 31.5, 34.1, 68.4, 68.9, 69.1, 69.2, 76.0, 77.3, 95.1, 95.2, 110.4, 110.7, 114.3, 126.3, 128.0, 129.9, 133.2, 144.2, 145.0, 156.4, 160.3 and 160.6;  $m/z$  (+L-SIMS) 977.5 (M + H<sup>+</sup>, 100%).

### General procedure for the synthesis of layer-block dendritic benzyl ether 8 or 16

A mixture of 5-benzoyloxyresorcinol **7** (1.0 mol equiv.), the appropriate tosyl compound **6** or **15** (2.1 mol equiv.) and caesium carbonate (3.0 mol equiv.) in DMF was stirred under nitrogen at 110 °C. The reaction time required was 1.5 and 1 d for compounds **8** and **16**, respectively. The reaction mixture was cooled to room temperature and evaporated under reduced pressure. The residue was taken up in ethyl acetate and suction filtered. The filter cake was washed with ethyl acetate and the combined filtrates were concentrated and purified as described in the following text.

**Compound 8.** This compound was prepared from the tosyl compound **6** and purified by flash chromatography on silica gel with hexane–ethyl acetate (5:1) as eluent to provide the *benzyl ether 8* (55%) as a white foam,  $R_f$  0.23 (4:1 hexane–ethyl acetate) (Found: C, 70.7; H, 8.0.  $\text{C}_{107}\text{H}_{140}\text{O}_{25}$  requires C, 70.4; H, 7.7%);  $\delta_{\text{H}}$  1.28 (36 H, s, 4 × Bu<sup>1</sup>), 1.48 (36 H, s, 12 × Me), 3.95–4.20 (24 H, m, OCH<sub>2</sub>), 4.20–4.40 (12 H, m, OCH), 4.96 (2 H, s, PhCH<sub>2</sub>), 6.16 (6 H, s, ArH), 6.20 (3 H, br s, ArH), 6.85 (8 H, d, *J* 8.7, ArH), 7.29 (8 H, d, *J* 8.8, ArH) and 7.29–7.40 (5 H, m, PhCH<sub>2</sub>);  $\delta_{\text{C}}$  27.0, 31.5, 34.1, 68.6, 68.7, 70.1, 76.7, 94.4, 94.6, 94.9, 110.4, 114.0, 126.3, 127.5, 128.0, 128.6, 136.6, 143.9, 156.2, 160.3 and 160.6;  $m/z$  (+L-SIMS) 1825.8 (M + H<sup>+</sup>, 10%).

**Compound 16.** This compound was prepared from the tosyl compound **15** and purified by flash chromatography on silica gel with hexane–ethyl acetate (5:1) as eluent to provide the *benzyl ether 16* (51%) as a white foam,  $R_f$  0.55 (3:1 hexane–ethyl acetate) (Found: C, 70.4; H, 7.7.  $\text{C}_{107}\text{H}_{140}\text{O}_{25}$  requires C, 70.4; H, 7.7%);  $\delta_{\text{H}}$  1.28 (36 H, s, 4 × Bu<sup>1</sup>), 1.48 (36 H, s, 12 × Me), 4.00–4.25 (24 H, m, OCH<sub>2</sub>), 4.25–4.40 (12 H, m, OCH), 4.96 (2 H, s, PhCH<sub>2</sub>), 6.17 (6 H, s, ArH), 6.19 (3 H, s, ArH), 6.85 (8 H, d, *J* 8.6, ArH), 7.29 (8 H, d, *J* 8.5, ArH) and 7.30–7.40 (5 H, m, PhCH<sub>2</sub>);  $\delta_{\text{C}}$  27.0, 31.5, 34.1, 68.6, 68.8, 70.1, 76.7, 94.6, 94.9, 110.4, 114.0, 126.3, 127.5, 128.0, 128.5, 136.6, 143.9, 156.2, 160.3 and 160.6.

### General procedure for the synthesis of layer-block dendritic phenol 9 or 17

A suspension of the appropriate compound **8** or **16** (0.10 g) and 10% palladium-on-charcoal (10 mg) in absolute ethanol–ethyl acetate (12:6 cm<sup>3</sup>) was stirred at room temperature under an atmospheric pressure of hydrogen for 5 h. The suspension was filtered through a pad of silica gel and the filtrate concentrated. The crude product was purified as described in the following text.

**Compound 9.** This compound was prepared from compound **8** and purified by flash chromatography on silica gel with hexane–ethyl acetate (3:1) as eluent to give the *phenol 9* (70%) as a white foam,  $R_f$  0.24 (3:1, hexane–ethyl acetate) (Found: C, 69.1; H, 7.9.  $C_{100}H_{134}O_{25}$  requires C, 69.2; H, 7.8%);  $\nu_{\max}/\text{cm}^{-1}$  3500–3200 (OH);  $\delta_H$  1.28 (36 H, s, 4 × Bu<sup>t</sup>), 1.48 (12 H, s, 4 × Me), 1.49 (24 H, s, 8 × Me), 4.00–4.20 (24 H, m, OCH<sub>2</sub>), 4.20–4.40 (12 H, m, OCH), 6.06 (2 H, d, *J* 1.9, ArH), 6.10 (1 H, t, *J* 2.0, ArH), 6.11 (1 H, s, OH), 6.17 (6 H, s, ArH), 6.86 (8 H, d, *J* 8.7, ArH) and 7.29 (8 H, d, *J* 8.8, ArH);  $\delta_C$  27.0, 31.5, 34.1, 68.6, 68.7, 76.6, 93.7, 94.6, 94.8, 95.6, 110.4, 114.0, 126.3, 144.0, 156.1, 157.8 and 160.3;  $m/z$  (+L-SIMS) 1735.9 (M + H<sup>+</sup>, 35%).

**Compound 17.** This compound was prepared from compound **16** and purified by flash chromatography on silica gel with hexane–ethyl acetate (3:1) as eluent to give the *phenol 17* (81%) as a white foam,  $R_f$  0.22 (3:1, hexane–ethyl acetate) (Found: C, 68.9; H, 7.8.  $C_{100}H_{134}O_{25}$  requires C, 69.2; H, 7.8%);  $\nu_{\max}/\text{cm}^{-1}$  3379 (OH);  $\delta_H$  (OH not observed) 1.28 (36 H, s, 4 × Bu<sup>t</sup>), 1.47 (12 H, s, 4 × Me), 1.49 (24 H, s, 8 × Me), 4.00–4.20 (24 H, m, OCH<sub>2</sub>), 4.20–4.40 (12 H, m, OCH), 6.05–6.10 (3 H, m, ArH), 6.18 (6 H, s, ArH), 6.86 (8 H, d, *J* 8.7, ArH) and 7.29 (8 H, d, *J* 8.8, ArH);  $\delta_C$  27.1, 31.5, 34.1, 68.7, 68.8, 76.7, 77.1, 93.9, 94.8, 95.0, 95.7, 110.4, 114.1, 126.3, 144.1, 156.3, 157.8, 160.4 and 160.5;  $m/z$  (+L-SIMS) 1736.0 (M + H<sup>+</sup>, 23%).

#### General procedure for synthesis of first generation layer-block dendrimer 1 or 2

A mixture of the appropriate phenol **9** or **17** (1.0 mol equiv.), corresponding dendritic wedge **6** or **15** respectively (1.5 mol equiv.) and caesium carbonate (1.3 mol equiv.) in DMF was stirred under nitrogen at 100 °C for 15 h. The reaction mixture was cooled to room temperature and evaporated under reduced pressure. The residue was taken up in ethyl acetate and the solution filtered. The filter cake was washed with ethyl acetate and the combined filtrates were concentrated and purified as described below.

**Dendrimer 1.** This compound was prepared from the phenol **9** and the tosyl compound **6** and purified by flash chromatography on silica gel using hexane–ethyl acetate (4:1) as eluent to afford *G1 layer-block dendrimer 1* (65%) as a white foam,  $R_f$  0.34 (3:1, hexane–ethyl acetate) (Found: C, 69.8; H, 8.0.  $C_{147}H_{198}O_{36}$  requires C, 69.5; H, 7.85%);  $\delta_H$  1.28 (54 H, s, 6 × Bu<sup>t</sup>), 1.48 (54 H, s, 18 × Me), 4.05–4.25 (36 H, m, OCH<sub>2</sub>), 4.25–4.40 (18 H, m, OCH), 6.16 (3 H, s, core ArH), 6.17 (9 H, s, ArH), 6.85 (12 H, d, *J* 8.9, ArH) and 7.28 (12 H, d, *J* 8.9, ArH);  $\delta_C$  27.0, 31.5, 34.0, 68.8, 68.9, 76.8, 77.1, 95.0, 110.3, 114.2, 126.2, 144.0, 156.3 and 160.5;  $m/z$  (+L-SIMS) 2540.5 (M + H<sup>+</sup>, 5%).

**Dendrimer 2.** This compound was prepared from the phenol **17** and the tosyl compound **15** and purified by flash chromatography on silica gel with hexane–ethyl acetate (4:1) as eluent to afford the *G1 layer-block dendrimer 2* (34%) as a white foam,  $R_f$  0.34 (3:1, hexane–ethyl acetate) (Found: C, 69.7; H, 8.1.

$C_{147}H_{198}O_{36}$  requires C, 69.5; H, 7.85%);  $\delta_H$  1.29 (54 H, s, 6 × Bu<sup>t</sup>), 1.48 (54 H, s, 18 × Me), 4.05–4.25 (36 H, m, OCH<sub>2</sub>), 4.25–4.40 (18 H, m, OCH), 6.15 (3 H, s, core ArH), 6.16 (9 H, s, ArH), 6.85 (12 H, d, *J* 8.8, ArH) and 7.28 (12 H, d, *J* 9.0, ArH);  $\delta_C$  27.1, 31.5, 34.1, 68.7, 68.9, 76.8, 76.9, 94.8, 110.4, 114.1, 126.3, 144.0, 156.3 and 160.4;  $m/z$  (+L-SIMS) 2540.5 (M + H<sup>+</sup>, 1%).

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