ONE-STEP SYNTHESIS OF DISACCHARIDE MIMETICS *VIA* TANDEM REARRANGEMENT OF UNSATURATED DISACCHARIDES

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Abstract—The unsaturated thioglycoside disaccharide (**4**) undergoes stereoselective tandem reductive rearrangement with TIBAL (triisobutylaluminium) to afford the (1→4) ether-linked disaccharide mimetics (**1-3**).

INTRODUCTION

The pyranose-to-cyclohexane transformation provides an expedient route to the synthesis of highly functionalised cyclohexane derivatives from readily available sugar precursors. For example, we reported[1] that perbenzylated α-methyl or benzyl 6-deoxyhex-5-enopyranosides undergo smooth reductive rearrangement with TIBAL (triisobutylaluminium) to afford substituted cyclohexane derivatives with retention of anomeric stereochemical information (Figure 1).

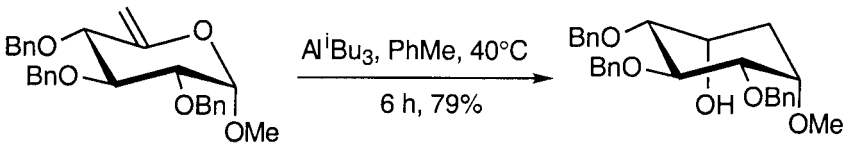


Figure 1

In contrast to the classical Ferrier-II[2] carbocyclisation reaction, the aglycon moiety is also retained during the TIBAL promoted rearrangement due to initial *endo*-glycosidic cleavage. We exploited this observation and more recently reported[3] that (6-deoxy-hex-5-enopyranosyl)glycosides smoothly undergo this transformation, thereby providing a direct synthesis of 5'a-carbadisaccharide precursors (Figure 2). Carbadisaccharides in which two carba-sugar rings are connected through a stable ether linkage are of potential interest as substrate analogues for glycosyltransferases.[4] In light of this, we now report the extension of our methodology to the expedient and stereoselective synthesis of ether-linked disaccharide mimetics (**1-3**) from the readily prepared bis-(hex-5-enopyranoside) (**4**) (Figure 3). This tandem reductive rearrangement represents the first step towards our evaluation of the cascade rearrangement of polyunsaturated systems.

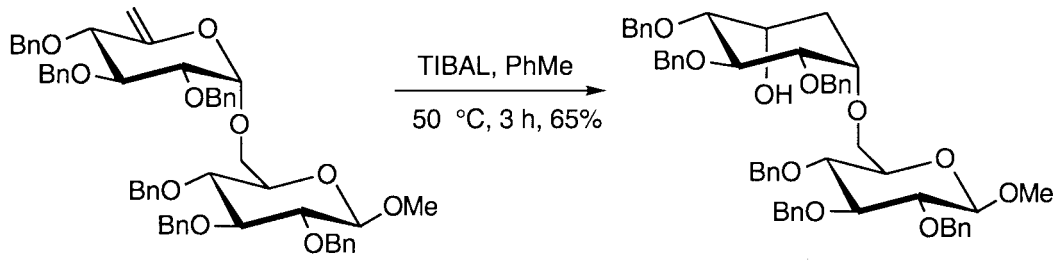
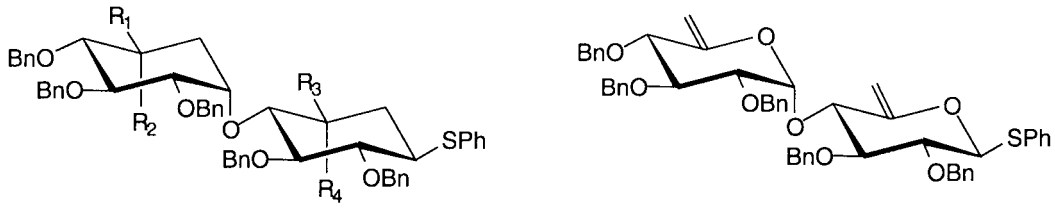


Figure 2



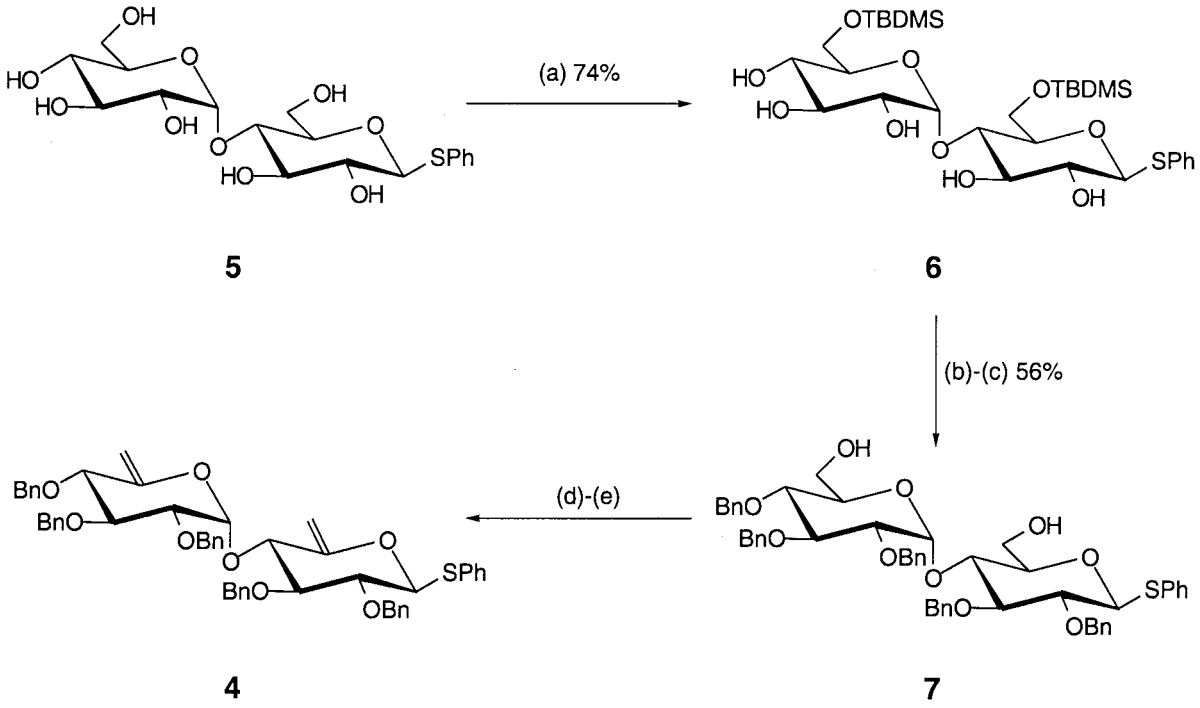
1: R_1=H, R_2=OH, R_3=OH, R_4=H
2: R_1=OH, R_2=H, R_3=OH, R_4=H
3: R_1=OH, R_2=H, R_3=H, R_4=OH

4

Figure 3

RESULTS AND DISCUSSION

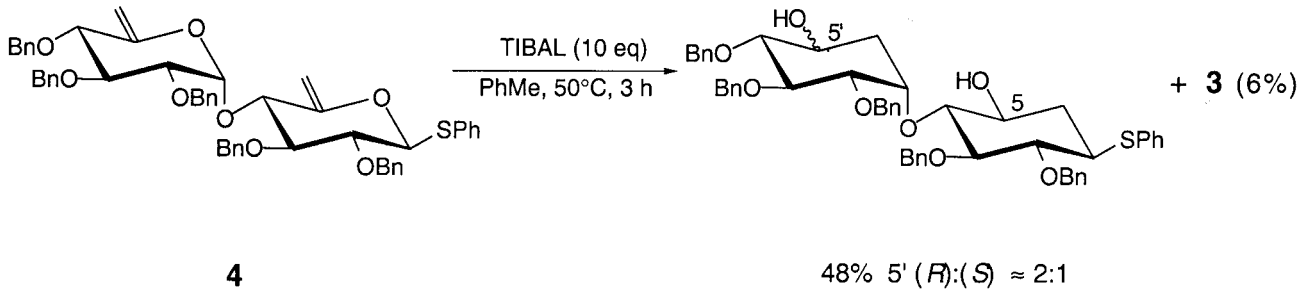
Silylation of phenyl 1-thio-β-D-maltoside (**5**)[5] with *tert*-butyldimethylsilyl chloride in dry DMF, containing triethylamine and catalytic 4-dimethylaminopyridine afforded the 6,6'-di-protected thiomaltoside (**6**) (74%). Perbenzylation of **6** with benzyl bromide and sodium hydride in dry DMF, followed by desilylation with tetrabutylammonium fluoride in THF gave the diol (**7**) (56% from **6**). Iodination of diol (**7**) using Garegg's conditions[6] gave the corresponding bis-iodide (64%) which was unstable and therefore immediately subjected to elimination with sodium hydride in dry DMF, to give the desired bis-unsaturated β-thiophenyl maltoside (**4**), as summarised in Scheme 1. Structural assignment of **4** was supported by ^{13}C-NMR which showed clear signals (δ = 154.4, 153.4, 2 x s, C-5, C-5' and δ = 98.2, 97.3, 2 x t, C-6', C-6) due to the exocyclic double bonds.



Reagents and Conditions: (a) TBDMSCl, DMF, Et_3N, cat DMAP; (b) NaH, BnBr, DMF; (c) TBAF.$3H_2O$, THF, rt; (d) Ph_3P, I_2, Im, PhMe, 70 °C, 64%; (e) NaH, BnBr, DMF, rt, 79%

Scheme 1

As shown in Scheme 2, reaction of the bis-unsaturated β-thiophenyl maltoside (**4**) with excess TIBAL at 50 °C resulted in the tandem transposition of both oxygens of the pyranose rings with the corresponding exocyclic carbon atoms as expected, to afford the (1→4) ether-linked disaccharide mimetics (**1**) (31%), (**2**) (17%) and (**3**) (6%). Overall high stereoselectivity at C-5 (8:1 S:R) was observed and although only moderate diastereoselectivity was observed at C-5' it is noteworthy that complete retention of stereochemical information at both anomeric centres was obtained.



Scheme 2

In summary, we have demonstrated the first tandem triisobutylaluminium-assisted reductive rearrangement of bis-unsaturated disaccharides. This methodology provides direct and efficient access to highly functionalised ether-linked cyclohexane derivatives from disaccharide precursors.

ACKNOWLEDGEMENTS

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EXPERIMENTAL SECTION

General: Melting points: Büchi 510 apparatus and were uncorrected. -IR: Nicolet Impact 400D. -Optical rotations: Perkin Elmer 241 digital polarimeter. -MS: Nermag R10-10 spectrometer, C.I.(ammonia). -Elemental analyses: performed by Service d'Analyse de l'Université Pierre et Marie Curie, 75252 Paris Cedex 05, France. -NMR: Brüker AM-400 (400 MHz and 100.6 MHz, for ^{1}H and ^{13}C, respectively), TMS as internal standard. -TLC: silica gel 60 F_{254} (Merck) and detection by charring with conc. H_2SO_4. -Flash column chromatography: silica gel 60 (230-400 mesh, Merck).

Phenyl 6,6'-di-O-tert-butyldimethylsilyl-1-thio-β-D-maltoside (**6**): Triethylamine (1.63 mL, 11.67 mmol), DMAP (48.0 mg, 0.39 mmol) and then TBDMSCl (1.75 g, 11.63 mmol) were added to a stirred solution of phenyl 1-thio-β-D-maltoside (**5**)[5] (1.70 g, 3.92 mmol) in anhydrous DMF (30 mL) at 0 °C under argon. The mixture was immediately warmed to rt and stirred for 14 h, when TLC (DCM/MeOH, 6:1) indicated no starting material (R_f 0.1) and product (R_f 0.6). Methanol (10 mL) was added and the solvent was removed *in vacuo*. The residue was purified by flash chromatography (eluent gradient, 40-50% acetone in DCM) to afford **6** (1.93 g, 74%), as a colourless foam, mp 57-58 °C. - $[\alpha]_D^{21}$ +37.3° (*c* 1.0 in $CHCl_3$). - ^{1}H NMR ($CDCl_3$): δ = 7.58-7.28 (m, 5 H, arom. H), 6.01 (br s, 1 H, OH), 5.45 (br d, *J* 6.1 Hz, 1 H, OH), 5.02 (br s, 1 H, OH), 5.00 (d, $J_{1',2'}$ 3.4 Hz, 1 H, 1'-H), 4.50 (d, $J_{1,2}$ 9.7 Hz, 1 H, 1-H), 4.13 (br s, 1 H, OH), 3.87-3.35 (m, 12 H), 2.20 (br s, 1 H, OH), 0.93 (s, 9 H, $(CH_3)_3C$), 0.91 (s, 9 H, $(CH_3)_3C$), 0.11 (s, 3 H, Si-CH_3), 0.09 (s, 9 H, 3 x Si-CH_3). - ^{13}C NMR ($CDCl_3$): δ = 132.4 (d, Ph), 132.3 (s, C-arom. quat.), 128.8, 127.7 (2 x d, Ph), 101.6 (C-1'), 87.3 (C-1), 79.8, 79.8, 77.4, 74.0, 72.9, 72.0, 71.7, 71.1 (8 x d, *C*H), 63.6, 62.2 (2 x t, C-6, C-6'), 25.9 (2 x q, 2 x $(CH_3)_3C$), 18.3 (2 x s, 2 x $(CH_3)_3C$), -5.19, -5.29, -5.37, -5.39 (4 x q, 4 x Si-CH_3). - MS (CI); *m/z* (%): 680 (100) $[MNH_4^+]$.
- *Anal.* Calcd for $C_{30}H_{54}O_{10}SSi_2$: C, 54.34; H, 8.21. Found: C, 54.20; H, 8.28.

Phenyl 2,3,2',3',4'-penta-O-benzyl-1-thio-β-D-maltoside (**7**): Sodium hydride (660 mg, 16.5 mmol, 60% in mineral oil) was added to a stirred solution of **6** (1.09 g, 1.65 mmol) in anhydrous DMF (10 mL) and benzyl bromide (1.47 mL, 12.4 mmol) at 0 °C. The mixture was stirred at rt for 4 h when TLC

(EtOAc/cyclohexane, 3:7) indicated no starting material (R_f 0.0) and product (R_f 0.9). The mixture was cooled to 0 °C and anhydrous methanol (10 mL) was added dropwise. The reaction mixture was then warmed to rt, the solvent was removed *in vacuo* and the resulting residue was partitioned between DCM (150 mL) and water (150 mL). The aqueous layer was extracted with DCM (2 x 100 mL) and combined extracts were dried ($MgSO_4$), filtered and the solvent was removed *in vacuo*. The residue was dissolved in THF (15 mL) and stirred at rt. TBAF.3H20 (1.56 g, 4.94 mmol) was added and after stirring for 45 min, the solvent was removed *in vacuo*. The residue was partitioned between DCM (100 mL) and water (50 mL). The aqueous layer was extracted with DCM (3 x 50 mL) and combined extracts were dried ($MgSO_4$), filtered and the solvent was removed *in vacuo*. The residue was purified by flash chromatography (eluent gradient, 30-45% EtOAc in cyclohexane) to afford **7** (807 mg, 56%), as a colorless foam, mp 52.5-53.0 °C. - $[\alpha]_D^{21}$ +32.0° (*c* 1.0 in $CHCl_3$). - ^{1}H NMR ($CDCl_3$): δ = 7.55-7.20 (m, 30 H, arom. H), 5.73 (d, $J_{1',2'}$ 3.9 Hz, 1 H, 1'-H), 4.98 (d, *J* 11.9 Hz, 1 H, C*H*Ph), 4.92-4.83 (m, 5 H, 5 x C*H*Ph), 4.78 (d, $J_{1,2}$ 9.8 Hz, 1 H, 1-H), 4.66 (d, *J* 11.9 Hz, 1 H, C*H*Ph), 4.64 (d, *J* 11.0 Hz, 1 H, C*H*Ph), 4.63 (d, *J* 10.1 Hz, 1 H, C*H*Ph), 4.50 (d, *J* 11.8 Hz, 1 H, C*H*Ph), 4.12 (dd, $J_{3,4} = J_{4,5}$ 9.3 Hz, 1 H, 4-H), 3.97 (dd, $J_{2',3'} = J_{3',4'}$ 9.3 Hz, 1 H, 3'-H), 3.96-3.89 (m, 3 H, 6-Ha, 6-Hb, 6'-Ha), 3.88 (dd, $J_{2,3} = J_{3,4}$ 9.3 Hz, 1 H, 3-H), 3.76 (ddd, $J_{4',5'}$ 9.8, $J_{5',6'b}$ 5.5, $J_{5',6'a}$ 2.1 Hz, 1 H, 5'-H), 3.70-3.64 (br m, 1 H, 6'-Hb), 3.56 (dd, $J_{1,2}$ 9.8, $J_{2,3}$ 9.3 Hz, 1 H, 2-H), 3.53 (m, 1 H, 5-H), 3.50 (dd, $J_{2',3'}$ 9.3, $J_{1',2'}$ 3.9 Hz, 1 H, 2'-H), 3.46 (dd, $J_{4',5'}$ 9.8, $J_{3',4'}$ 9.3 Hz, 1 H, 4'-H), 2.26-2.20 (br m, 2 H, 2 x OH). - ^{13}C NMR ($CDCl_3$): δ = 138.5, 138.4, 137.8, 137.7, 137.5, 133.5 (6 x s, C-arom. quat.), 131.7-126.1 (30 x d, Ph), 97.0 (C-1'), 87.5 (C-1), 86.5 (C-3), 81.8 (C-3'), 81.2 (C-2), 79.1 (C-2'), 78.6 (C-5), 78.0 (C-4'), 75.4, 75.3, 75.1, 74.1, 73.5 (5 x t, CH_2Ph), 72.2 (C-5'), 71.5 (C-4), 61.9 (C-6'), 61.3 (C-6). - MS (CI); *m/z* (%): 902.5 (100) [MNH_4^+].

- *Anal.* Calcd for $C_{53}H_{56}O_{10}S$: C, 71.92; H, 6.38. Found: C, 71.74; H, 6.56.

Phenyl 2,3,2',3',4'-penta-O-benzyl-6,6'-dideoxy-6,6'-di-iodo-1-thio-β-D-maltoside: Triphenylphosphine (4.54 g, 17.3 mmol), imidazole (3.07 g, 45.1 mmol) and iodine (4.39 g, 17.3 mmol) were added to a stirred solution of **7** (6.65 g, 7.52 mmol) in anhydrous toluene (200 mL) at rt under argon. The mixture was heated at 70 °C for 0.5 h, when TLC (15% EtOAc in cyclohexane) indicated no starting material (R_f 0.0) and product (R_f 0.4). The reaction mixture was cooled to rt and saturated sodium thiosulfate (100 mL) was added. After 15 min the aqueous layer was extracted with EtOAc (200 mL) and combined extracts were dried ($MgSO_4$), filtered and the solvent was removed *in vacuo*. The residue was purified by flash chromatography (15% EtOAc in cyclohexane) to afford *the title compound* (5.32 g, 64%), as a colourless unstable foam, which was used immediately without further purification. - ^{1}H NMR ($CDCl_3$): δ = 7.77-7.28 (m, 30 H, arom. H), 5.65 (d, $J_{1',2'}$ 3.8 Hz, 1 H, 1'-H), 5.00 (d, *J* 10.8 Hz, 1 H, C*H*Ph), 4.94 (d, *J* 11.2 Hz, 1 H, C*H*Ph), 4.92 (s, 2 H, CH_2Ph), 4.90 (d, *J* 8.0 Hz, 1 H, C*H*Ph), 4.85 (d, *J* 10.8 Hz, 1 H, C*H*Ph), 4.79 (d, *J* 11.3 Hz, 1 H, C*H*Ph), 4.79 (d, $J_{1,2}$ 10.0 Hz, 1 H, 1-H), 4.72 (d, *J* 11.9 Hz, 1 H, C*H*Ph), 4.63 (d, *J* 10.1 Hz, 1 H, C*H*Ph), 4.55 (d, *J* 11.9 Hz, 1 H, C*H*Ph), 4.03 (dd, $J_{2',3'} = J_{3',4'}$ 9.0 Hz, 1 H, 3'-H), 3.92 (dd, $J_{3,4} = J_{4,5}$ 8.6 Hz, 1 H, 4-H), 3.87 (dd, $J_{2,3} = J_{3,4}$ 8.6 Hz, 1 H, 3-H), 3.76 (dd, $J_{6a,6b}$ 10.7, $J_{5,6a}$ 2.8 Hz, 1 H, 6-Ha), 3.64 (dd, $J_{6'a,6'b}$ 8.8, $J_{5',6'a}$ 2.0 Hz, 1 H, 6'-Ha), 3.60 (dd,

$J_{1,2}$ 10.0, $J_{2,3}$ 8.6 Hz, 1 H, 2-H), 3.56 (dd, $J_{6a,6b}$ 10.7, $J_{5,6b}$ 6.4 Hz, 1 H, 6-Hb), 3.55 (dd, $J_{2',3'}$ 9.0, $J_{1',2'}$ 3.8 Hz, 1 H, 2'-H), 3.49-3.43 (m, 3 H, 4'-H, 5'-H, 6'-Hb), 3.40 (ddd, $J_{4,5}$ 8.6, $J_{5,6b}$ 6.4, $J_{5,6a}$ 2.8 Hz, 1 H, 5-H). - ^{13}C NMR ($CDCl_3$): δ = 138.4, 138.2, 137.7, 137.7, 137.6 (5 x s, C-arom. quat.), 129.0-127.0 (30 x d, Ph), 97.0 (C-1'), 87.1 (C-1), 85.7 (C-3), 81.4 (C-4'), 81.2 (C-3'), 80.5 (C-2), 79.4 (C-2'), 77.2 (C-5), 77.15 (C-4), 75.5, 75.5, 75.2, 74.1, 73.7 (5 x t, CH_2Ph), 70.3 (C-5'), 8.3 (C-6'), 7.7 (C-6). - MS (CI); *m/z* (%): 1122 (10) [MNH_4^+], 994.5 (100).
- *Anal.* Calcd for $C_{53}H_{54}O_8I_2S$: C, 57.61; H, 4.93. Found: C, 57.48; H, 5.09.

Phenyl 2,3-di-O-benzyl-6-deoxy-4-O-(2,3,4-tri-O-benzyl-6-deoxy-α-D-xylo-hex-5-enopyranosyl)-1-thio-β-D-xylo-hex-5-enopyranoside (**4**): Sodium hydride (296 mg, 7.40 mmol, 60% in mineral oil) was added to a stirred solution of phenyl 2,3,2',3',4'-penta-*O*-benzyl-6,6'-dideoxy-6,6'-di-iodo-1-thio-β-D-maltoside (408 mg, 0.37 mmol) in anhydrous DMF (15 mL) at rt. After 6 h the reaction mixture was cooled to 0 °C and methanol (10 mL) was added dropwise. The solvent was removed *in vacuo* and the residue was partitioned between DCM (50 mL) and water (50 mL). The aqueous layer was extracted with DCM (2 x 50 mL) and combined extracts were washed with brine (50 mL), dried ($MgSO_4$), filtered and the solvent was removed *in vacuo*. The residue was purified by flash chromatography (10% EtOAc in cyclohexane) to afford **4** (247 mg, 79%), as a colourless oil. - $[\alpha]_D^{21}$ -45.8° (*c* 1.0 in $CHCl_3$). - IR (film): ν = 1663 cm^{-1} (C=C), 1092 (C-O). - ^{1}H NMR ($CDCl_3$): δ = 7.61-7.15 (m, 30 H, arom. H), 5.56 (d, $J_{1',2'}$ 3.5 Hz, 1 H, 1'-H), 5.05 (d, $J_{1,2}$ 8.6 Hz, 1 H, 1-H), 4.95 (d, *J* 10.9 Hz, 1 H, C*H*Ph), 4.91 (d, *J* 10.9 Hz, 1 H, C*H*Ph), 4.90 (m, 1 H, 6'-Ha), 4.87 (d, *J* 10.6 Hz, 1 H, C*H*Ph), 4.86 (s, 2 H, CH_2Ph), 4.82 (br s, 4 H, CH_2Ph, 6-Ha, 6-Hb), 4.71 (m, 1 H, 6'-Hb), 4.70 (d, *J* 11.9 Hz, 1 H, C*H*Ph), 4.66 (d, *J* 10.6 Hz, 1 H, C*H*Ph), 4.61 (d, *J* 11.9 Hz, 1 H, C*H*Ph), 4.58 (ddd, $J_{3,4}$ 8.3, $J_{4,6a} = J_{4,6b}$ 1.2 Hz, 1 H, 4-H), 4.07 (dd, $J_{2',3'} = J_{3',4'}$ 9.3 Hz, 1 H, 3'-H), 3.98 (ddd, $J_{3',4'}$ 9.3, $J_{4',6'a} = J_{4',6'b}$ 1.9 Hz, 1 H, 4'-H), 3.85 (dd, $J_{3,4}$ 8.3, $J_{2,3}$ 7.7 Hz, 1 H, 3-H), 3.73 (dd, $J_{1,2}$ 8.6, $J_{2,3}$ 7.7 Hz, 1 H, 2-H), 3.68 (dd, $J_{2',3'}$ 9.3, $J_{1',2'}$ 3.5 Hz, 1 H, 2'-H). - ^{13}C NMR ($CDCl_3$): δ = 154.4, 154.4 (2 x s, C-5, C-5'), 138.5, 138.3, 137.8, 137.7, 137.5, 133.9 (6 x s, C-arom. quat.), 131.8-126.5 (30 x d, Ph), 98.2 (C-6'), 98.0 (C-1'), 97.3 (C-6), 87.4 (C-1), 84.3 (C-3), 80.9 (C-2 + C-3'), 79.6 (C-4'), 78.6 (C-2'), 75.5, 74.6, 74.4, 73.7 (4 x t, CH_2Ph), 73.4 (C-4), 73.3 (t, CH_2Ph). - MS (CI); *m/z* (%): 866 (15) [MNH_4^+], 358.0 (100).
- *Anal.* Calcd for $C_{53}H_{52}O_8S$: C, 74.97; H, 6.17. Found: C, 74.43; H, 6.36.

1L-(1,3,5/2,4)-2,3-di-O-benzyl-4-O-[1D-(1,2,4,5/3)-2,3,4-tri-O-benzyl-1,2,3,4,5-pentahydroxy-cyclohexyl]-1-thiophenyl-2,3,4,5-tetrahydroxy-cyclohexane (**1**), *1L-(1,3,5/2,4)-2,3-di-O-benzyl-4-O-[1D-(1,2,4/3,5)-2,3,4-tri-O-benzyl-1,2,3,4,5-pentahydroxy-cyclohexyl]-1-thiophenyl-2,3,4,5-tetrahydroxy-cyclohexane* (**2**) and *1L-(1,3/2,4,5)-2,3-di-O-benzyl-4-O-[1D-(1,2,4/3,5)-2,3,4-tri-O-benzyl-1,2,3,4,5-pentahydroxy-cyclohexyl]-1-thiophenyl-2,3,4,5-tetrahydroxy-cyclohexane* (**3**): TIBAL (0.42 mL, 0.42 mmol, 1M in toluene) was added to a stirred solution of **4** (36 mg, 0.04 mmol) in anhydrous toluene (1 mL) at rt under argon. The reaction mixture was heated at 50 °C for 2.75 h, when TLC (EtOAc/cyclohexane, 2:3) indicated no starting material (R_f 0.9), formation of a major component (R_f 0.5) and minor components (R_f 0.3 and 0.25). The mixture was cooled to 0 °C and ice-water (5 mL) was

added. The mixture was stirred (15 min) then filtered into a separating funnel, washing with EtOAc (5 mL) and the aqueous layer was extracted with EtOAc (3 x 10 mL). Combined extracts were dried ($MgSO_4$), filtered and the solvent was removed *in vacuo*. The residue was purified by flash chromatography (eluent gradient, 30-50%) to afford **1** (11 mg, 31%), as a colourless oil. - $[\alpha]_D^{22}$ +6.8° (*c* 1.1 in $CHCl_3$). - ^1H NMR ($CDCl_3$): δ = 7.50-7.11 (m, 30 H, arom. H), 5.50 (br s, 1 H, OH), 4.99 (d, *J* 12.0 Hz, 1 H, C*H*Ph), 4.91-4.67 (m, 8 H, 8 x C*H*Ph), 4.67-6.64 (m, 1 H, 1'-H), 4.45 (d, *J* 12.0 Hz, 1 H, C*H*Ph), 4.27 (dd, $J_{2',3'}$ 9.8, $J_{3',4'}$ 9.1 Hz, 1 H, 3'-H), 4.16-4.13 (br m, 1 H, 5'-H), 3.66 (dd, $J_{2,3} = J_{3,4}$ 9.0 Hz, 1 H, 3-H), 3.61 (ddd, $J_{5,5a(ax)}$ 11.7, $J_{4,5}$ 9.0, $J_{5,5a(eq)}$ 4.6 Hz, 1 H, 5-H), 3.51 (dd, $J_{1,2}$ 10.7, $J_{2,3}$ 9.0 Hz, 1 H, 2-H), 3.45 (dd, $J_{3',4'}$ 9.1, $J_{4',5'}$ 3.6 Hz, 1 H, 4'-H), 3.42 (dd, $J_{3,4} = J_{4,5}$ 9.0 Hz, 1 H, 4-H), 3.34 (dd, $J_{2',3'}$ 9.8, $J_{1',2'}$ 3.3 Hz, 1 H, 2'-H), 3.23 (ddd, $J_{1,5a(ax)}$ 13.0, $J_{1,2}$ 10.7, $J_{1,5a(eq)}$ 3.8 Hz, 1 H, 1-H), 3.15 (br s, 1 H, OH), 2.56 (br d, $J_{gem'}$ 15.7 Hz, 1 H, 5'a-Heq), 2.28 (ddd, J_{gem} 13.0, $J_{5,5a(eq)}$ 4.6, $J_{1,5a(eq)}$ 3.8 Hz, 1 H, 5a-Heq), 1.53 (ddd, $J_{gem} = J_{1,5a(ax)}$ 13.0, $J_{5,5a(ax)}$ 11.7 Hz, 1 H, 5a-Hax), 1.37 (br d, $J_{gem'}$ 15.7 Hz, 1 H, 5'a-Hax). - ^{13}C NMR ($CDCl_3$): δ = 139.3, 138.7, 138.3, 137.85, 137.8, 134.0 (6 x s, C-arom. quat.), 132.7-125.9 (30 x d, Ph), 85.4 (C-2 + C-3), 82.7 (C-4'), 82.0 (C-4), 80.9 (C-2'), 78.3 (C-3'), 76.1 (C-1'), 75.9, 75.7, 73.65, 73.6, 73.1 (5 x t, CH_2Ph), 69.6 (C-5), 67.4 (C-5'), 47.1 (C-1), 36.2 (C-5a), 28.6 (C-5'a). - MS (CI); *m/z* (%): 870.2 (100) [MNH_4^+].
- *Anal.* Calcd for $C_{53}H_{56}O_8S$: C, 74.62; H, 6.62. Found: C, 74.57; H, 6.80.

(**2**) (6 mg, 17%): as a colourless oil. - $[\alpha]_D^{22}$ +22.5° (*c* 0.4 in $CHCl_3$). - ^1H NMR ($CDCl_3$): δ = 7.51-7.25 (m, 30 H, arom. H), 4.97 (d, *J* 11.3 Hz, 1 H, C*H*Ph), 4.96 (d, *J* 11.9 Hz, 1 H, C*H*Ph), 4.93 (d, *J* 10.0 Hz, 1 H, C*H*Ph), 4.88 (d, *J* 11.7 Hz, 1 H, C*H*Ph), 4.81 (d, *J* 10.9 Hz, 1 H, C*H*Ph), 4.75 (d, *J* 10.3 Hz, 1 H, C*H*Ph), 4.72 (d, *J* 12.0 Hz, 1 H, C*H*Ph), 4.69 (d, *J* 11.3 Hz, 1 H, C*H*Ph), 4.68 (d, *J* 10.9 Hz, 1 H, C*H*Ph), 4.63 (d, *J* 11.9 Hz, 1 H, C*H*Ph), 4.41 (m, 1 H, 1'-H), 4.01-3.94 (m, 1 H, 5'-H), 3.96 (dd, $J_{2',3'} = J_{3',4'}$ 9.2 Hz, 1 H, 3'-H), 3.65-3.52 (m, 4 H, 2-H, 3-H, 4-H, 5-H), 3.45 (dd, $J_{2',3'}$ 9.2, $J_{1',2'}$ 2.9 Hz, 1 H, 2'-H), 3.30 (dd, $J_{3',4'}$ 9.2, $J_{4',5'}$ 8.9 Hz, 1 H, 4'-H), 3.17 (ddd, $J_{1,5a(ax)}$ 13.0, $J_{1,2}$ 10.0, $J_{1,5a(eq)}$ 3.9 Hz, 1 H, 1-H), 2.95 (d, $J_{5,OH}$ 3.0 Hz, 1 H, 5-OH), 2.93 (ddd, $J_{gem'}$ 13.9, $J_{1',5'a(eq)} = J_{5',5'a(eq)}$ 4.5 Hz, 1 H, 5'a-Heq), 2.21 (ddd, J_{gem} 13.3, $J_{5,5a(eq)}$ 4.2, $J_{1,5a(eq)}$ 3.9 Hz, 1 H, 5a-Heq), 2.17 (d, $J_{5',OH}$ 2.7 Hz, 1 H, 5'-OH), 1.53 (ddd, J_{gem} 13.3, $J_{1,5a(ax)}$ 13.0, $J_{5,5a(ax)}$ 11.3 Hz, 1 H, 5a-Hax), 1.34-1.25 (m, 1 H, 5'a-Hax). - ^{13}C NMR ($CDCl_3$): δ = 138.7, 138.6, 138.5, 137.85, 137.8, 133.9 (6 x s, C-arom. quat.), 132.8-126.5 (30 x d, Ph), 86.1 (C-4'), 84.1 (C-2), 83.6 (C-3), 82.4 (C-2'), 81.4 (C-3'), 81.3 (C-4), 75.7, 75.3, 75.3, 73.4, 73.0 (5 x t, CH_2Ph), 71.8 (C-1'), 69.4 (C-5), 68.4 (C-5'), 47.4 (C-1), 36.6 (C-5a), 32.6 (C-5'a). - MS (CI); *m/z* (%): 870.1 (100) [MNH_4^+].
- *Anal.* Calcd for $C_{53}H_{56}O_8S$: C, 74.62; H, 6.62. Found: C, 74.23; H, 6.80.

(**3**) (2 mg, 6%): as a colourless oil. - ^1H NMR ($CDCl_3$): δ = 7.50-7.22 (m, 30 H, arom. H), 5.01-4.56 (m, 10 H, 5 x CH_2Ph), 4.15-4.13 (m, 1 H, 1'-H), 4.07-4.04 (m, 1 H, 5-H), 3.99-3.94 (m, 2 H, 3'-H, 5'-H), 3.94 (dd, $J_{3,4}$ 9.2, $J_{4,5}$ 3.3 Hz, 4-H), 3.81 (dd, $J_{2,3} = J_{3,4}$ 9.2 Hz, 1 H, 3-H), 3.67 (ddd, $J_{1,5a(ax)}$ 12.9, $J_{1,2}$ 10.4, $J_{1,5a(eq)}$ 4.0 Hz, 1 H, 1-H), 3.46-3.40 (m, 2 H, 2-H, 2'-H), 3.28 (dd, $J_{3',4'} = J_{4',5'}$ 9.0 Hz, 1 H, 4'-H), 2.76 (br s, 1 H, 5-OH), 2.34 (d, $J_{5',OH}$ 2.1 Hz, 1 H, 5'-OH), 2.31 (ddd, J_{gem} 14.4,

$J_{1,5a(eq)} = J_{5,5a(eq)}$ 4.0 Hz, 1 H, 5a-Heq), 2.15 (ddd, $J_{gem'}$ 14.1, $J_{1',5'a(eq)} = J_{5',5'a(eq)}$ 4.4 Hz, 1 H, 5'a-Heq), 1.44-1.36 (m, 2 H, 5a-Hax, 5'a-Hax). - MS (CI); *m/z* (%): 870.1 (100) [MNH_4^+].
- *Anal.* Calcd for $C_{53}H_{56}O_8S$: C, 74.62; H, 6.62. Found: C, 74.36; H, 6.91.

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