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New 2/2-type surfactants via anomeric *O*-alkylation of mannofuranose [1]

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Abstract

New 2/2-type surfactants were synthesized from 1,2-di-*O*-alkyl-4-*O*-benzyl-L-threitols and 1,3-di-*O*-alkyl-4-*O*-benzyl-D-threitols. Their transformation into trifluoromethanesulfonates and then reaction with 2,3:5,6-di-*O*-isopropylidene-D-mannofuranose gave, via anomeric *O*-alkylation, predominantly β-D-mannofuranosides of erythritol. Hydrogenolytic *O*-debenzylation furnished the 4-*O*-deprotected derivatives which, on reaction with sulfur trioxide–trimethylamine and then hydrolytic removal of the *O*-isopropylidene groups, afforded 2/2-type surfactants having a mannofuranose and a sulfate residue as head groups. The 4-*O*-deprotected derivatives were also transformed into the corresponding 4-tosylates and the 4-iodides as alkylating agents. Their reaction with tetraethylene glycol, diethyl malonate, and diethyl iminodiacetate and then removal of the protective groups furnished 2/2-type surfactants having a mannofuranose residue and a tetraethylene glycol, or a malonate, or an iminodiacetate residue, respectively, as head groups. Surface tension and critical micelle concentration measurements with these compounds exhibited interesting amphiphilic properties. © 1997 Elsevier Science Ltd.

Keywords: Amphiphiles; Detergents; Surface tension measurements; Erythritol derivatives; Sulfates

1. Introduction

Ionic and non-ionic surfactants generally possess one hydrophilic head group and one lipophilic tail. Long-chain alkyl glycosides possessing one hydrophilc sugar residue and one lipophilic alkyl chain, for example octyl β-D-glucopyranoside, have also gained wide interest as non-ionic surfactants and have become commercially available [1–3]. Of particular importance are the structurally related alkyl polyglucosides (general abbreviation: APG) which are now produced on a large scale [3–5].

Investigations aiming at the structure dependence of surfactant properties led us to the synthesis and evaluation not only of amphiphilic compounds containing one hydrophilic head group and one lipophilic alkyl chain (termed 1/1-type surfactants) [5,6], but also of those possessing other hydrophilic head group/lipophilic tail ratios, for instance, 1/2- [6], 2/1- [6–8], and 2/2-type [6] surfactants. Here we report on new 2/2-type surfactants which are based on threitols of the general structure **A** and **B** (Scheme

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[1] Anomeric *O*-Alkylation, Part 16. For Part 15, see ref. [8].

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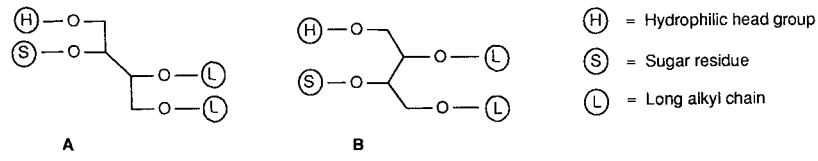


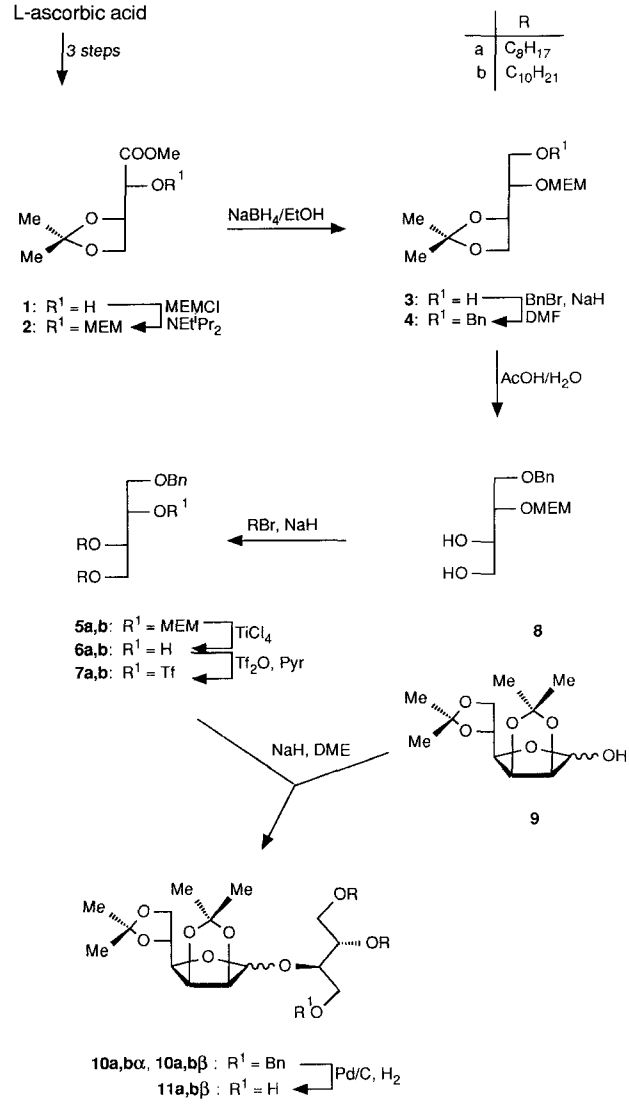
Scheme 1.

1) and which combine, in the hydrophilic head, a sugar residue and other typical head groups employed for non-ionic as well as for ionic surfactants. The D-mannofuranosyl residue was chosen as the sugar, because it can be readily attached via anomeric *O*-alkylation [7–10].

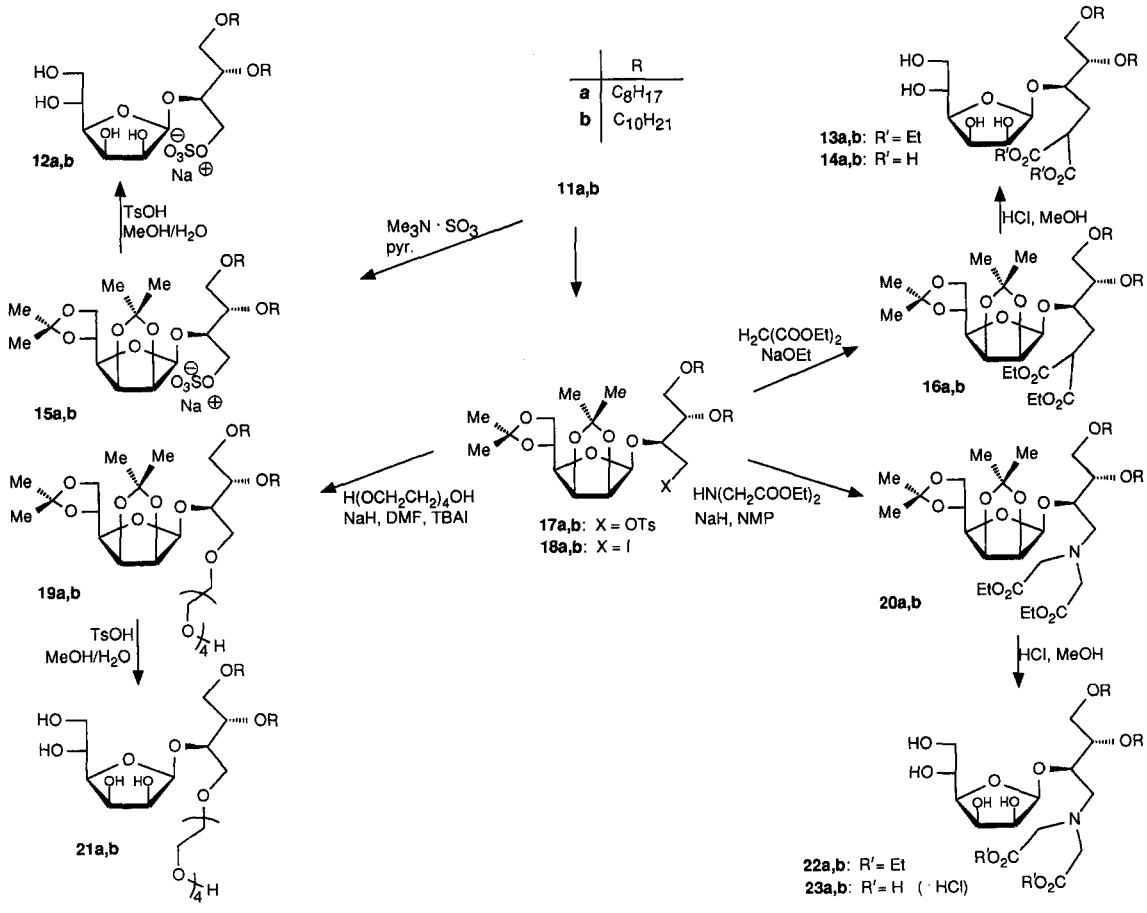
2. Results and discussion

For the synthesis of surfactants of structure **A** (Scheme 1), the required erythritol moiety **10** having 1,2-*O*-alkyl chains, a 3-*O*-glycosyl residue, and various other hydrophilic groups at O-4 was obtained from L-ascorbic acid (Scheme 2). L-Ascorbic acid was transformed, following a known procedure [11], into the methyl L-threonate derivative **1**. Reaction with methoxyethoxymethyl chloride (MEM-Cl) in the presence of Hünig's base afforded the 2-*O*-MEM protected derivative **2**. Reduction of the ester moiety with $NaBH_4$ in methanol afforded the L-threitol derivative **3**; treatment of **3** with benzyl bromide in the presence of NaH as base gave the 1-*O*-protected derivative **4**, which upon acid-catalyzed de-*O*-isopropylidenation furnished the 3,4-di-*O*-unprotected compound **8**. Reaction with octyl and decyl bromide, respectively, after deprotonation with NaH, led to the introduction of two alkyl chains, affording compounds **5a,b**. Selective removal of the MEM-group with titanium tetrachloride (→ **6a,b**) and then treatment with trifluoromethanesulfonic anhydride (Tf_2O) in pyridine gave the secondary trifluoromethanesulfonates (triflates) **7a,b**. Their reaction with 2,3:5,6-di-*O*-isopropylidene-D-mannofuranose (**9** [12]) with NaH as base in 1,2-dimethoxyethane (DME) gave, via direct anomeric *O*-alkylation, the α- and β-D-mannofuranosides **10a,b**α and **10a,b**β (α/β ≈ 1:2). Because of the low reactivity observed for cyclic secondary triflates in nonpolar solvents which favour β-glycoside bond formation [13], this result illustrates the good reactivity of acyclic secondary triflates as alkylating agents. Hydrogenolytic *O*-debenzylation of **10a,b**β led to isolation of target molecules **11a**β and **11b**β, which were then used for the attachment of other hydrophilic head groups.

For the introduction of a sulfate group, compounds **11a,b**β were treated with the sulfur trioxide–trimethylamine complex in pyridine, affording compounds **15a,b** (Scheme 3); acid-catalyzed removal of the *O*-isopropylidene groups furnished target molecules **12a,b**. For the alkylative ligation of **11a,b**β to other hydrophilic head groups their transformation into alkylating agents was required. To this aim, reaction of **11a,b**β with *p*-toluenesulfonyl chloride



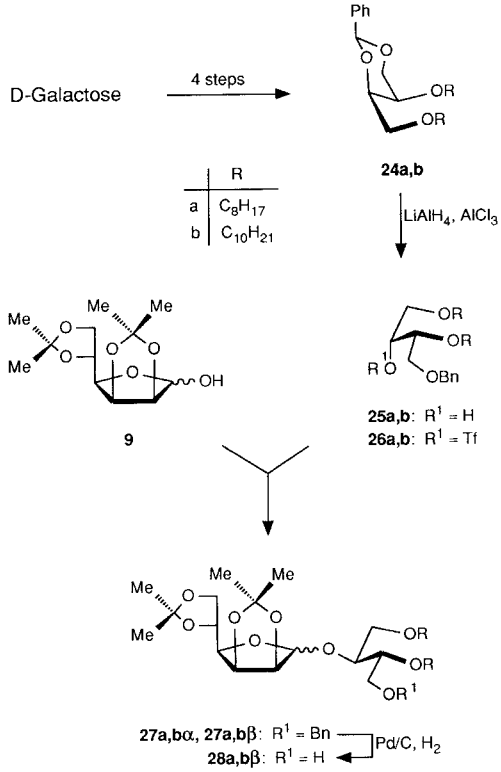
Scheme 2.



Scheme 3.

(TsCl) in pyridine was carried out, affording the tosylates **17a,b**. The corresponding iodides **18a,b** were obtained from **11a,b**β with triiodoimidazole and triphenylphosphine as reagents [14]. The introduction of the malonate group as a second hydrophilic head group was carried out with **17a,b** and sodium diethyl malonate leading to **16a,b**; acid-catalyzed de-*O*-isopropylidenation ($\rightarrow$ **13a,b**) and then base-promoted ester cleavage furnished diacids **14a,b** as target molecules. Other important hydrophilic head groups of surfactants are oligoethylene glycol residues. Therefore, reaction of **17a,b** with tetraethylene glycol (3,6,9-trioxaundecane-1,11-diol) in the presence of NaH as base and tetrabutylammonium iodide (TBAI) as catalyst was performed, yielding compounds **19a,b**; their acid-catalyzed de-*O*-isopropylidenation gave target molecules **21a,b**. The introduction of the iminodiacetic acid residue, also commonly employed as a hydrophilic head group and a good complexing agent for metal ions as well, was carried out with iodides **18a,b**; thus, with diethyl iminodiacetate in the presence of NaH as base in dry *N*-methylpyrrolidone (NMP) as solvent, compounds **20a,b** were obtained in good yields; acid-catalyzed de-*O*-isopropylidenation afforded compounds **22a,b** which were subjected to basic ester hydrolysis; addition of hydrochloric acid furnished hydrochlorides **23a,b** as target molecules.

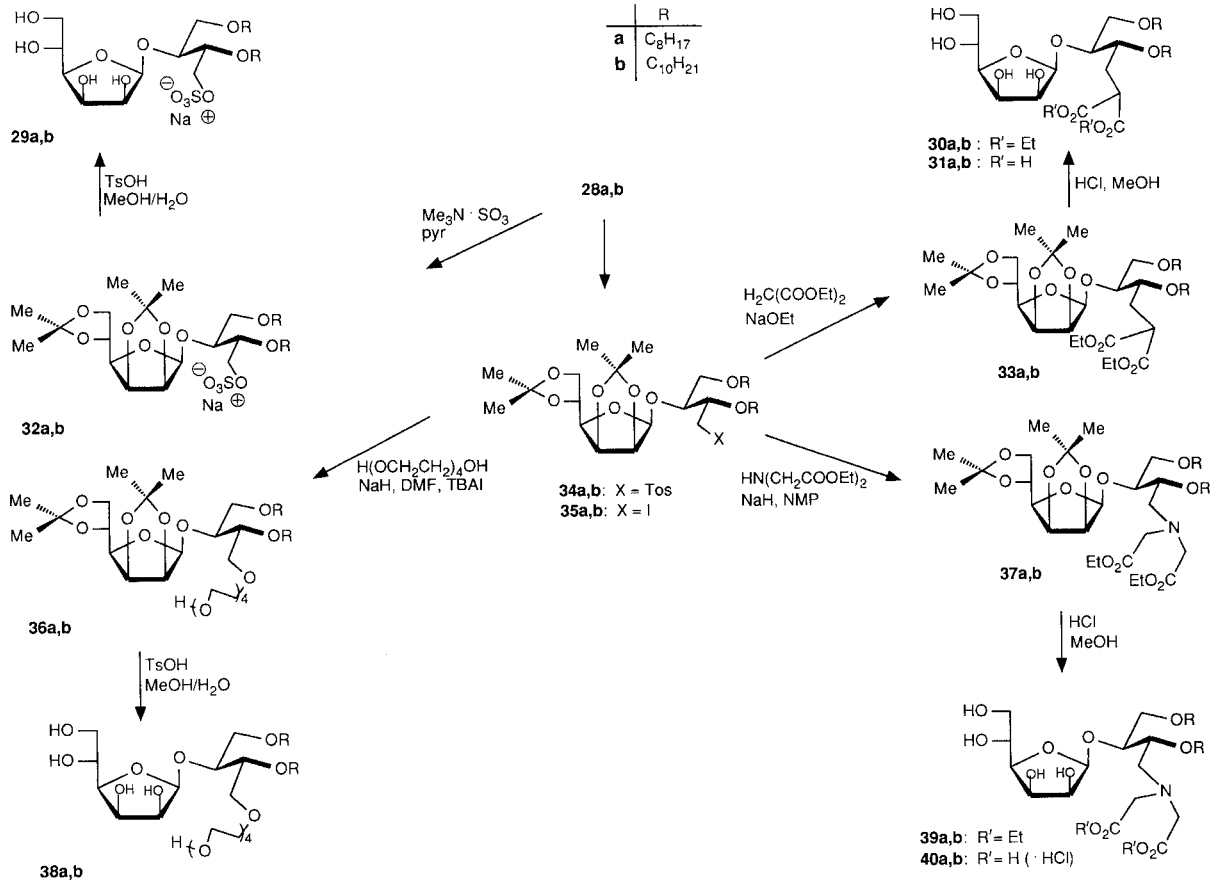
For the synthesis of surfactants of structure **B** (Scheme 1), the required threitol moiety was obtained from D-galactose which, following known procedures [15,16], was transformed into 1,3-di-*O*-alkyl-D-threitol derivatives **24a,b** [6] (Scheme 4). Reductive opening of the 1,3-dioxane ring with $LiAlH_4/AlCl_3$ led, as expected [17], to the 2-*O*-unprotected 4-*O*-benzyl derivatives **25a,b**. Treatment with Tf_2O in pyridine afforded triflates **26a,b** which were immediately used for the anomeric *O*-alkylation of **9**; thus, the α- and β-D-mannofuranosides **27a,b**α and **27a,b**β ($\alpha:\beta \approx$ 1:2) were obtained. Hydrogenolytic *O*-debenzylation of the β anomers **27a,b**β furnished the desired intermediates **28a**β and **28b**β which were used for the attachment of the above-mentioned hydrophilic head groups by employing the same procedures as



Scheme 4.

described for **11a,bβ**. Thus, the sulfated compounds **32a,b** were synthesized which gave target molecules **29a,b** (Scheme 5). Then transformation of **28a,bβ** into tosylates **34a,b** and iodides **35a,b** furnished the required alkylating agents for the formation of tetraethylene glycol derivatives **36a,b**, malonate derivatives **33a,b**, and iminodiacetate derivatives **37a,b**; their acid-catalyzed de-*O*-isopropylidenation afforded target molecules **38a,b**, and esters **30a,b** and **39a,b** which upon base-promoted hydrolysis and then treatment with acid led to target molecules **31a,b** and **40a,b**.

For all target molecules possessing two hydrophilic head groups and two lipophilic alkyl chains (i.e., compounds **12**, **14**, **21**, **23**, **29**, **31**, **38**, and **40**) the surface tension (σ_s, in mN/m) and the critical micelle concentration (cmc, in μmol/L) were measured in water. The results are compiled in Table 1. All compounds form micelles and some even at very low concentrations (for instance, the tetraethylene glycol derivatives **21b** and **38b**), thus exhibiting typical amphiphilic behaviour with little difference between corresponding **A**- and **B**-type compounds. Most interestingly, practically all the synthetic 2/2-type



Scheme 5.

Table 1
Surface tension and critical micelle concentration measurements

Compound	σ_s (mN/m)	cmc (μmol/L)	Compound	σ_s (mN/m)	cmc (μmol/L)
12a	32.0	278	**29a**	35.3	205
12b	29.2	18.1	**29b**	30.4	17.7
14a	25.9	89.1	**31a**	28.4	90.4
14b	28.9	13.6	**31b**	29.0	12.6
21a	30.2	21.2	**38a**	29.8	32.9
21b	32.6	0.25	**38b**	32.5	1.44
23a	27.9	70.2	**40a**	31.4	100
23b	30.2	25.6	**40b**	29.5	9.24

amphiphiles, which were also termed 'gemini' surfactants [6,18], exhibit technically interesting reductions of the surface tension of water (the σ_s-values range between 35 and 25 mN/m); however, again the corresponding **A**- and **B**-type compounds show only small differences with slightly lower σ_s-values for the **A**-type compounds.

3. Experimental

Solvents were purified in the usual way; the light petroleum used had a boiling range of 35–65 °C. Melting points are uncorrected. ^{1}H NMR spectra: Bruker AC 250 (250 MHz); internal standard, Me_4Si. Flash chromatography: Silica Gel 60 (Baker: particle size, 40 μm); BAKERBOND Reversed Phase, Octadecyl (C_{18}) (Baker: particle size 40 μm). Thin-layer chromatography (TLC): plastic sheets, Silica Gel 60 F_{254} (Merck; layer thickness, 0.2 mm); TLC plates RP-18 F_{254}s (Merck: layer thickness, 0.25 mm). Elemental analyses: Heraeus CHN–O-Rapid. Optical rotations: Perkin–Elmer polarimeter 241 MC; 1-dm cell; temperature, 20 °C.

Methyl 3,4-O-isopropylidene-2-O-(2-methoxyethoxymethyl)-L-threonate (**2**).—To a solution of methyl 3,4-*O*-isopropylidene-L-threonate [11] (**1**) (25.0 g, 132 mmol) and *N*,*N*-diisopropylethylamine (40.0 mL, 232 mmol) in dry CH_2Cl_2 (200 mL) was added 2-methoxyethoxymethyl chloride (26.0 mL, 228 mmol) dropwise at room temperature. After stirring for 24 h water (200 mL) was added. After adjusting to pH 7 with 1 M HCl the solution was extracted with CH_2Cl_2 (3 × 200 mL). The combined organic extracts were dried ($MgSO_4$) and concentrated in vacuo. Column chromatography (7:3 toluene–acetone) yielded **2** (33.8 g, 92%) as a colourless oil; TLC (7:3 toluene–acetone): R_f 0.55; $[\alpha]_D$ +30.5° (*c* 1, $CHCl_3$); ^{1}H NMR (250 MHz, $CDCl_3$): δ 1.31, 1.37 [2 s, 6 H, $C(CH_3)_2$], 3.33 (s, 3 H, OCH_3), 3.46–3.54 (m, 2 H, OCH_2CH_2O), 3.65–3.74 (m, 2 H, OCH_2CH_2O), 3.69 (s, 3 H, OCH_3), 3.89 (dd, $J_{4a,3}$ 6.3, $J_{4a,4b}$ 8.6 Hz, 1 H, H-4a), 3.98 (dd, $J_{4b,3}$ 6.3, 1 H, H-4b), 4.15 (d, *J* 6.1 Hz, 1 H, H-2), 4.33 (ddd, 1 H, H-3), 4.77 (s, 2 H, OCH_2O). Anal. Calcd for $C_{12}H_{22}O_7$ (278.3): C, 51.79; H, 7.97. Found: C, 51.30; H, 8.05.

1,2-O-Isopropylidene-3-O-(2-methoxyethoxymethyl)-L-threitol (**3**).—To a solution of **2** (21.7 g, 78.0 mmol) in dry EtOH (120 mL) was added $NaBH_4$ (2.50 g, 66.1 mmol) in several portions. When the reaction was completed, the solution was neutralized with 1 M HCl and concentrated in vacuo. Then water (60 mL) was added and the mixture was extracted with CH_2Cl_2 (6 × 50 mL). The combined organic extracts were dried ($MgSO_4$) and concentrated in vacuo. Flash chromatography (9:1 CH_2Cl_2–MeOH) of the residue yielded **3** (17.1 g, 87%) as a colourless oil; TLC (9:1 CH_2Cl_2–MeOH): R_f 0.30; $[\alpha]_D$ −6.5° (*c* 1, $CHCl_3$); ^{1}H NMR (250 MHz, $CDCl_3$): δ 1.33, 1.39 [2 s, 6 H, $C(CH_3)_2$], 3.36 (s, 3 H, OCH_3), 3.50–3.76 (m, 7 H, OCH_2CH_2O, CH_2OH, H-1a), 3.81–3.89 (m, 1 H, H-3), 4.01 (dd, $J_{1b,2}$ 6.6, $J_{1a,1b}$ 8.3 Hz, 1 H, H-1b), 4.20–4.28 (m, 1 H, H-2), 4.83, 4.88 (2 d, *J* 7.4 Hz, 2 H, OCH_2O). Anal. Calcd for $C_{11}H_{22}O_6$ (250.3): C, 52.78; H, 8.86. Found: C, 52.39; H, 8.80.

1-O-Benzyl-3,4-O-isopropylidene-2-O-(2-methoxyethoxymethyl)-L-threitol (**4**).—To a solution of **3** (17.0 g, 67.9 mmol) in dry DMF (80 mL) was added NaH (2.0 g, 83.3 mmol) at 0°C in several portions. Then benzyl bromide (9.0 mL, 75.8 mmol) was added dropwise at room temperature, and the mixture was stirred until the reaction was completed. Then MeOH (10 mL) was added and stirring was continued for 1 h. After addition of brine (250 mL), the mixture was extracted with EtOAc (150 mL). The combined organic extracts were dried ($MgSO_4$) and concentrated in vacuo. Column chromatography (7:3 light petroleum–EtOAc) of the residue yielded **4**

(17.6 g, 76%) as a colourless oil; TLC (4:1 light petroleum–EtOAc): R_f 0.13; $[\alpha]_D$ −7.5° (*c* 1, $CHCl_3$); ^1H NMR (250 MHz, $CDCl_3$): δ 1.33, 1.37 [2 s, 6 H, $C(CH_3)_2$], 3.35 (s, 3 H, OCH_3), 3.47–3.50 (m, 2 H, OCH_2CH_2O), 3.53–3.56 (m, 2 H, H-1a,1b), 3.70–3.82 (m, 3 H, H-4a, OCH_2CH_2O), 3.84 (mc, 1 H, H-2), 3.96 (dd, $J_{4b,3}$ 6.7, $J_{4b,4a}$ 8.4 Hz, 1 H, H-4b), 4.24 (ddd, $J_{3,2} = J_{3,4a} = J_{3,4b} = 6.7$ Hz, 1 H, H-3), 4.48, 4.50 (2 d, J_{gem} 12.0 Hz, 2 H, CH_2Ph), 4.86 (s, 2 H, OCH_2O), 7.22–7.35 (m, 5 H, Ph). Anal. Calcd for $C_{18}H_{28}O_6$ (340.5): C, 63.51; H, 8.29. Found: C, 63.28; H, 8.29.

*General procedure for the preparation of 1-*O*-benzyl-2-*O*-(2-methoxyethoxymethyl)-3,4-di-*O*-octyl-*L*-threitol* (**5a**) *and the homologous decyl compound* **5b**.—To a solution of **8** (22.0 g, 73.2 mmol) in dry DMF (180 mL) was added at 0 °C NaH (4.0 g, 167 mmol) in several portions. Then the alkyl bromide (155 mmol) was added and the mixture was stirred at 50 °C for 5 days. Then more alkyl bromide (17 mmol) and NaH (0.50 g, 21 mmol) were added, and stirring was continued for 3 days. After decomposition of the excess of NaH with MeOH, brine (500 mL) was added, and the mixture was extracted with light petroleum (5 × 250 mL). The combined organic extracts were dried ($MgSO_4$) and concentrated in vacuo. Flash chromatography (6:1 light petroleum–EtOAc) of the residue yielded **5a** (79%) or **5b** (88%) as a colourless oil; TLC (4:1 light petroleum–EtOAc): R_f 0.47 (**5a**), 0.54 (**5b**); $[\alpha]_D$ −8.5° (**5a**), −8.5° (**5b**) (*c* 1, $CHCl_3$); **5a,b**: ^1H NMR (250 MHz, $CDCl_3$): δ 0.87 (t, *J* 6.5 Hz, 6 H, CH_3), 1.26 (mc, 20/28 H, 10/14 CH_2), 1.53 (mc, 4 H, OCH_2CH_2), 3.35 (s, 3 H, OCH_3), 3.38–3.76 (m, 13 H, OCH_2CH_2O, H-4a,4b, H-3, H-1a,1b, 2 × OCH_2CH_2), 3.91–3.97 (m, 1 H, H-2), 4.50, 4.52 (2 d, J_{gem} 11.8 Hz, 2 H, CH_2Ph), 4.79, 4.84 (2 d, J_{gem} 7.0 Hz, 2 H, OCH_2O), 7.25–7.32 (m, 5 H, Ph). **5a**: Anal. Calcd for $C_{31}H_{56}O_6$ (524.8): C, 70.95; H, 10.76. Found: C, 71.13; H, 11.12. **5b**: Anal. Calcd for $C_{35}H_{64}O_6$ (580.9): C, 72.37; H, 11.11. Found: C, 72.49; H, 11.07.

*General procedure for the preparation of 1-*O*-benzyl-3,4-di-*O*-octyl-*L*-threitol* (**6a**) *and the homologous decyl compound* **6b**.—To a solution of **5a,b** (7.4 mmol) in dry CH_2Cl_2 (25 mL) was added $TiCl_4$ (2.5 mL, 22.8 mmol) dropwise at -20 °C. After stirring for 30 min the mixture was neutralized with 1 M aq NH_3 and extracted with CH_2Cl_2 (5 × 50 mL). The combined organic extracts were dried ($MgSO_4$) and concentrated in vacuo. Column chromatography (6:1 light petroleum–EtOAc) of the residue yielded **6a,b** (87%) as colourless oils; TLC (4:1 light petroleum–EtOAc): R_f 0.52 (**6a**), 0.57 (**6b**); $[\alpha]_D$ +12.0° (**6a**), +10.7° (**6b**) (*c* 1, $CHCl_3$); **6a,b**: ^1H NMR (250 MHz, $CDCl_3$): δ 0.86 (t, *J* 6.5 Hz, 6 H, CH_3), 1.25 (mc, 20/28 H, 10/14 CH_2), 1.52 (mc, 4 H, OCH_2CH_2), 2.65 (br s, 1 H, OH), 3.32–3.43 (m, 3 H, OCH_2CH_2), 3.45–3.61 (m, 5 H, H-4a,4b, H-3, CH_2OBn), 3.65 (ddd, $J_{vic} = J_{vic} = 6.5$, J_{gem} 9.2 Hz, 1 H, OCH_2CH_2), 3.84–3.90 (m, 1 H, *CH*OH), 4.54 (s, 2 H, CH_2Ph), 7.26–7.33 (m, 5 H, Ph). **6a**: Anal. Calcd for $C_{27}H_{48}O_4 \cdot 0.5H_2O$ (445.7): C, 72.76; H, 11.08. Found: C, 73.02; H, 11.08. **6b**: Anal. Calcd for $C_{31}H_{56}O_4 \cdot 0.25H_2O$ (497.3): C, 74.87; H, 11.45. Found: C, 74.90; H, 11.81.

*General procedure for the preparation of 1-*O*-benzyl-3,4-di-*O*-octyl-2-*O*-trifluoromethanesulfonyl-*L*-threitol* (**7a**), *the homologous decyl compound* **7b**, *and the isomeric 2,4-dialkyl compounds* **26a,b**.—A solution of **6a,b** or **25a,b** (22.8 mmol) and pyridine (1.9 mL, 23.6 mmol) in dry CH_2Cl_2 (35 mL) was added dropwise at 0 °C to a solution of Tf_2O (3.8 mL, 23.2 mmol) in dry CH_2Cl_2 (8 mL). When the reaction was completed water (30 mL) was added, and the mixture was extracted with CH_2Cl_2 (20 mL). The combined organic extracts were dried ($MgSO_4$) and concentrated in vacuo to yield **7a,b** or **26a,b** (95%) as yellow oils; TLC (9:1 light petroleum–EtOAc): R_f 0.72 (**7a**), 0.70 (**7b**), 0.67 (**26a**), 0.65 (**26b**); ^1H NMR (250 MHz, $CDCl_3$): **7a,b**: δ 0.86 (t, *J* 6.6 Hz, 6 H, CH_3), 1.24 (mc, 20/28 H, 10/14 CH_2), 1.47–1.58 (m, 4 H, OCH_2CH_2), 3.29–3.45 (m, 3 H, OCH_2CH_2), 3.46–3.72 (m, 6 H, H-4a,4b, 1/2 OCH_2CH_2, H-3, H-1a,1b), 4.45, 4.59 (2 d, J_{gem} 11.9 Hz, 2 H, CH_2Ph), 5.09 (mc, 1 H, H-2), 7.26–7.33 (m, 5 H, Ph); **26a,b**: δ 0.87 (t, *J* 6.5 Hz, 6 H, CH_3), 1.25 (mc, 20/28 H, 10/14 CH_2), 1.52 (mc, 4 H, OCH_2CH_2), 3.47–3.62 (m, 6 H, OCH_2CH_2, H-4a,4b), 3.66–3.81 (m, 3 H, H-2, H-1a,1b), 4.53, 4.56 (2 d, J_{gem} 12.0 Hz, 2 H, CH_2Ph), 5.10 (mc, 1 H, H-3), 7.28–7.37 (m, 5 H, Ph). The crude products **7a,b** and **26a,b** were used for the next step without purification because of their sensitivity to moisture.

*1-*O*-Benzyl-2-*O*-(2-methoxyethoxymethyl)-*L*-threitol* (**8**).—A solution of **4** (17.6 g, 51.7 mmol) in aq 70% AcOH was stirred at 35 °C, until the reaction was completed. Then the solvent was evaporated in vacuo, and the residue was coevaporated with toluene. Flash chromatography (9:1 CH_2Cl_2–MeOH) of the residue yielded **8** (14.8 g, 95%) as a colourless oil; TLC (9:1 CH_2Cl_2–MeOH): R_f 0.60; $[\alpha]_D$ −5.3° (*c* 1, $CHCl_3$); ^1H NMR (250 MHz, $CDCl_3$): δ 2.87 (br s, 2 H, OH), 3.35 (s, 3 H, OCH_3), 3.48–3.52 (m, 2 H,

OCH_2CH_2O), 3.53–3.71 (m, 5 H, H-1a, H-4a,4b, OCH_2CH_2O), 3.73–3.87 (m, 3 H, H-3, H-2, H-1b), 4.50, 4.52 (2 d, J_{gem} 12.0 Hz, 2 H, CH_2Ph), 4.76, 4.83 (2 d, J_{gem} 7.0 Hz, 2 H, OCH_2O), 7.25–7.34 (m, 5 H, Ph). Anal. Calcd for $C_{15}H_{24}O_6$ (300.3): C, 59.98; H, 8.05. Found: C, 59.90; H, 8.18.

General procedure for the preparation of 1-O-benzyl-2-O-(2,3:5,6-di-O-isopropylidene-α-D-mannofuranosyl)-3,4-di-O-octyl-L-erythritol (**10aα**), *the homologous decyl compound* **10bα**, *the corresponding β anomers* **10a, bβ**, *and the isomeric 2, 4 - dialkyl compounds* **27a,bα**, **27a,bβ**.—To a solution of 2,3:5,6-di-*O*-isopropylidene-D-mannofuranose [12] (**9**) (9.0 g, 34.6 mmol) in dry 1,2-dimethoxyethane (25 mL) was added NaH (0.80 g, 33.3 mmol) in several portions. After stirring for 30 min **7a,b** (22.7 mmol) was added. When the reaction was completed, brine (50 mL) was added, and the mixture was extracted with EtOAc (5 × 40 mL). The combined organic extracts were dried ($MgSO_4$) and concentrated in vacuo. Column chromatography (6:1 light petroleum–EtOAc) of the residue yielded the α anomers **10a,bα**, **27a,bα** (12%) and the β anomers **10a,bβ**, **27a,bβ** (27%) as colourless oils; TLC (6:1 light petroleum–EtOAc): R_f 0.58 (**10aα**), 0.18 (**10aβ**), 0.62 (**10bα**), 0.21 (**10bβ**), 0.58 (**27aα**), 0.18 (**27aβ**), 0.62 (**27bα**), 0.22 (**27bβ**); $[\alpha]_D$ +15.5° (**10aα**), −11.9° (**10aβ**), +14.5° (**10bα**), −10.0° (**10bβ**), +15.7° (**27aα**), −14.5° (**27aβ**), +13.8° (**27bα**), −12.3° (**27bβ**) (*c* 1, $CHCl_3$); ^1H NMR (250 MHz, $CDCl_3$): **10a,bα**: δ 0.86 (t, *J* 6.6 Hz, 6 H, CH_3), 1.24 (mc, 20/28 H, 10/14 CH_2), 1.30, 1.35, 1.40, 1.44 [4 s, 12 H, $C(CH_3)_2$], 1.53 (mc, 4 H, OCH_2CH_2), 3.33–3.64 (m, 9 H, H-4a,4b, OCH_2CH_2, H-3, H-1a,1b), 3.85–3.91 (m, 1 H, H-2), 3.94 (dd, $J_{3',4'}$ 3.6, $J_{4',5'}$ 7.9 Hz, 1 H, H-4′), 4.00 (dd, $J_{5',6'a}$ 3.9, $J_{6'a,6'b}$ 8.7 Hz, 1 H, H-6′a), 4.06 (dd, $J_{5',6'b}$ 6.1, $J_{6'a,6'b}$ 8.7 Hz, 1 H, H-6′b), 4.36 (mc, 1 H, H-5′), 4.47, 4.59 (2 d, J_{gem} 12.2 Hz, 2 H, CH_2Ph), 4.59 (d, $J_{2',3'}$ 6.0 Hz, 1 H, H-2′), 4.73 (dd, $J_{2',3'}$ 5.9, $J_{3',4'}$ 3.6 Hz, 1 H, H-3′), 5.24 (s, 1 H, H-1′), 7.26–7.32 (m, 5 H, Ph); **10a,bβ**: δ 0.85 (t, *J* 6.5 Hz, 3 H, CH_3), 1.24 (mc, 20/28 H, 10/14 CH_2), 1.30, 1.35, 1.42, 1.46 [4 s, 12 H, $C(CH_3)_2$], 1.46–1.51 (mc, 4 H, OCH_2CH_2), 3.36–3.45 (m, 4 H, OCH_2CH_2), 3.49 (dd, $J_{3',4'}$ 4.1, $J_{4',5'}$ 7.7 Hz, 1 H, H-4′), 3.53–3.70 (m, 5 H, H-1a,1b, H-3, H-4a,4b), 3.92 (mc, 1 H, H-2), 3.98–4.11 (m, 2 H, H-6′a, H-6′b), 4.40 (ddd, $J_{4',5'}$ 7.7, $J_{5',6'a}$ 5.2, $J_{5',6'b}$ 5.6 Hz, 1 H, H-5′), 4.49, 4.57 (2 d, J_{gem} 12.1 Hz, 2 H, CH_2Ph), 4.54 (dd, $J_{1',2'}$ 3.7, $J_{2',3'}$ 6.1 Hz, 1 H, H-2′), 4.59 (dd, $J_{2',3'}$ 6.1, $J_{3',4'}$ 3.9 Hz, 1 H, H-3′), 4.79 (d, $J_{1',2'}$ 3.7 Hz, 1 H, H-1′), 7.25–7.35 (m, 5 H, Ph). **27a,bα**: δ 0.87 (t, *J* 6.6 Hz, 6 H, CH_3), 1.24 (mc, 20/28 H, 10/14 CH_2), 1.30, 1.36, 1.39, 1.44 [4 s, 12 H, $C(CH_3)_2$], 1.46–1.58 (m, 4 H, OCH_2CH_2), 3.32–3.45 (m, 4 H, OCH_2CH_2), 3.47–3.61 (m, 5 H, H-4a,4b, H-1a,1b, H-4′), 3.84–3.88 (m, 1 H, H-2), 3.97–4.11 (m, 3 H, H-3, H-6′a, H-6′b), 4.35–4.38 (m, 1 H, H-5′), 4.49–4.58 (2 d, J_{gem} 12.1 Hz, 2 H, CH_2Ph), 4.60 (d, $J_{2',3'}$ 5.9 Hz, 1 H, H-2′), 4.77 (dd, $J_{2',3'}$ 5.9, $J_{3',4'}$ 3.6 Hz, 1 H, H-3′), 5.15 (s, 1 H, H-1′), 7.25–7.35 (m, 5 H, Ph); **27a,bβ**: δ 0.85 (t, *J* 6.5 Hz, 6 H, CH_3), 1.24 (mc, 20/28 H, 10/14 CH_2), 1.32, 1.35, 1.41, 1.49 [4 s, 12 H, $C(CH_3)_2$], 1.46–1.51 (m, 4 H, OCH_2CH_2), 3.39 (t, *J* 6.6 Hz, OCH_2CH_2), 3.45–3.52 (m, 2 H, H-4a,4b), 3.53–3.69 (m, 4 H, H-1a, H-2, OCH_2CH_2), 3.78 (dd, $J_{1b,2}$ 2.5, $J_{1a,1b}$ 10.4 Hz, 1 H, H-1b), 3.89–3.98 (m, 1 H, H-3), 4.02 (dd, $J_{5',6'a}$ 5.0, $J_{6'a,6'b}$ 8.7 Hz, 1 H, H-6′a), 4.06 (dd, $J_{5',6'b}$ 5.9, $J_{6'a,6'b}$ 8.7 Hz, 1 H, H-6′b), 4.37 (ddd, $J_{4',5'}$ 7.5, $J_{5',6'a}$ 5.0, $J_{5',6'b}$ 5.9 Hz, 1 H, H-5′), 4.50, 4.51 (2 d, J_{gem} 11.9 Hz, 2 H, CH_2Ph), 4.54 (dd, $J_{1',2'}$ 3.7, $J_{2',3'}$ 6.1 Hz, 1 H, H-2′), 4.63 (dd, $J_{2',3'}$ 6.1, $J_{3',4'}$ 3.7 Hz, 1 H, H-3′), 4.96 (d, $J_{1',2'}$ 3.7 Hz, 1 H, H-1′), 7.25–7.31 (m, 5 H, Ph). **10a**: Anal. Calcd for $C_{39}H_{66}O_9$ (678.9): C, 68.99; H, 9.80. Found: C, 69.54; H, 9.89. **10b**: Anal. Calcd for $C_{43}H_{74}O_9$ (735.0): C, 70.26; H, 10.15. Found: C, 70.50; H, 10.16. **27a**: Anal. Calcd for $C_{39}H_{66}O_6$ (678.9): C, 68.99; H, 9.80. Found: C, 69.01; H, 10.04. **27b**: Anal. Calcd for $C_{43}H_{74}O_9$ (735.0): C, 70.26; H, 10.15. Found: C, 70.00; H, 10.37.

General procedure for the preparation of 3-O-(2,3:5,6-di-O-isopropylidene-β-D-mannofuranosyl)-1,2-di-O-octyl-D-erythritol (**11aβ**), *the homologous decyl compound* **11bβ**, *and the isomeric 1, 3 - dialkyl compounds* **28a, bβ**.—A mixture of **10a,bβ** or **27a,bβ** (4.0 mmol) and Pd–C (150 mg) in dry 1:1:2 EtOAc–MeOH–acetone (60 mL) was stirred under H_2. When the reaction was completed, a little Na_2CO_3 was added and stirring was continued for 30 min. Then the mixture was filtered, and the organic solution was concentrated in vacuo. Column chromatography (6:4 light petroleum–EtOAc) yielded **11a,bβ** or **28a,bβ** (88%) as a colourless oil; TLC (6:4 light petroleum–EtOAc): R_f 0.26 (**11aβ**), 0.33 (**11bβ**), 0.25 (**28aβ**), 0.28 (**28bβ**); $[\alpha]_D$ +1.5° (**11aβ**), −0.5° (**11bβ**), −12.2° (**28aβ**), −10.4° (**28bβ**) (*c* 1, $CHCl_3$); ^1H NMR (250 MHz, $CDCl_3$): **11a,bβ**: δ 0.85 (t, *J* 6.5 Hz, 6 H, CH_3), 1.23 (mc, 20/28 H, 10/14 CH_2), 1.34, 1.35, 1.41, 1.52 [4 s, 12 H, $C(CH_3)_2$], 1.45–1.52 (m, 4 H, OCH_2CH_2), 3.33–3.48 (m, 5 H, 1.5 OCH_2CH_2, H-1a,1b), 3.50–

3.57 (m, 1 H, OCH_2CH_2), 3.59–3.66 (m, 3 H, H-4a,4b, H-4′), 3.70–3.77 (m, 2 H, H-2, H-3), 4.05 (d, $J_{5',6'}$ 5.3 Hz, 2 H, H-6′a,6′b), 4.40 (ddd, $J_{4',5'}$ 7.8, $J_{5',6'a} = J_{5',6'b} = 5.3$ Hz, 1 H, H-5′), 4.61 (dd, $J_{1',2'}$ 3.9, $J_{2',3'}$ 6.1 Hz, 1 H, H-2′), 4.73 (dd, $J_{2',3'}$ 6.1, $J_{3',4'}$ 4.0 Hz, 1 H, H-3′), 4.90 (d, $J_{1',2'}$ 3.9 Hz, 1 H, H-1′); **28a,bβ**: δ 0.85 (t, *J* 6.6 Hz, 6 H, CH_3), 1.23 (mc, 20/28 H, 10/14 CH_2), 1.32, 1.34, 1.41, 1.49 [4 s, 12 H, $C(CH_3)_2$], 1.47–1.55 (m, 4 H, OCH_2CH_2), 3.35–3.47 (m, 4 H, OCH_2CH_2), 3.58 (dd, $J_{3',4'}$ 3.8, $J_{4',5'}$ 7.8 Hz, 1 H, H-4′), 3.49–3.71 (m, 3 H, H-3, H-1a,1b), 3.74–3.76 (m, 2 H, CH_2OH), 3.82–4.03 (m, 1 H, H-2), 4.05–4.08 (m, 2 H, H-6′a,6′b), 4.42 (ddd, $J_{4',5'}$ 7.8, $J_{5',6'a}$ 4.7, $J_{5',6'b}$ 5.9 Hz, 1 H, H-5′), 4.62 (dd, $J_{1',2'}$ 3.8, $J_{2',3'}$ 6.1 Hz, 1 H, H-2′), 4.69 (dd, $J_{2',3'}$ 6.1, $J_{3',4'}$ 3.8 Hz, 1 H, H-3′), 5.03 (d, $J_{1',2'}$ 3.8 Hz, 1 H, H-1′). **11aβ**: Anal. Calcd for $C_{32}H_{60}O_9$ (588.8): C, 65.27; H, 10.27. Found: C, 65.10; H, 10.55. **11bβ**: Anal. Calcd for $C_{36}H_{68}O_9$ (644.9): C, 67.04; H, 10.63. Found: C, 66.87; H, 10.89. **28aβ**: Anal. Calcd for $C_{32}H_{60}O_9$ (588.8): C, 65.27; H, 10.27. Found: C, 65.42; H, 10.43. **28bβ**: Anal. Calcd for $C_{36}H_{68}O_9$ (644.9): C, 67.04; H, 10.63. Found: C, 66.71; H, 10.65.

*General procedure for the preparation of 2-O-(β-*D*-mannofuranosyl)-3,4-di-*O*-octyl-*L*-erythritol 1-(sodium sulfate)* (**12a**), *the homologous decyl compound* **12b**, *and the isomeric 2,4-dialkyl compounds* **29a,b**.—To a solution of **15a,b** or **32a,b** (0.13 mmol) in 5:1 MeOH–water (3 mL) was added *p*-toluenesulfonic acid (15 mg, 79 μmol). After stirring until the reaction was completed, the mixture was neutralized with solid $NaHCO_3$ and concentrated in vacuo. Column chromatography (4:1 CH_2Cl_2–MeOH) of the residue yielded **12a,b** or **29a,b** (88%) as a colourless oil; TLC (4:1 CH_2Cl_2–MeOH): R_f 0.28 (**12a**), 0.29 (**12b**), 0.24 (**29a**), 0.28 (**29b**); $[\alpha]_D$ −30.0° (**12a**), −28.5° (**12b**), −37.6° (**29a**), −36.9° (**29b**) (*c* 1, MeOH); ^{1}H NMR (250 MHz, $CDCl_3$): **12a,b**: δ 0.85 (t, *J* 6.7 Hz, 6 H, CH_3), 1.29 (mc, 20/28 H, 10/14 CH_2), 1.56 (mc, 4 H, OCH_2CH_2), 3.47 (t, *J* 6.6 Hz, 2 H, OCH_2CH_2), 3.52–3.73 (m, 6 H, OCH_2CH_2, H-3, H-4a,4b, H-6′a), 3.79 (dd, $J_{5',6'b}$ 3.0, $J_{6'a,6'b}$ 11.4 Hz, 1 H, H-6′b), 3.87 (dd, $J_{3',4'}$ 3.7, $J_{4',5'}$ 8.5 Hz, 1 H, H-4′), 3.92–4.01 (m, 2 H, H-2, H-5′), 4.11 (dd, $J_{1',2'} = J_{2',3'} = 4.9$ Hz, 1 H, H-2′), 4.21–4.26 (m, 3 H, H-1a,1b, H-3′), 5.15 (d, $J_{1',2'}$ 4.9 Hz, 1 H, H-1′); **29a,b**: δ 0.89 (t, *J* 6.6 Hz, 6 H, CH_3), 1.29 (mc, 20/28 H, 10/14 CH_2), 1.53–1.60 (m, 4 H, OCH_2CH_2), 3.40–3.56 (m, 3 H, OCH_2CH_2), 3.60–3.72 (m, 5 H, 1/2 OCH_2CH_2, H-2, H-4a,4b, H-6′a), 3.75-3.84 (m, 2 H, H-3, H-6′b), 3.91 (dd, $J_{3',4'}$ 3.9, $J_{4',5'}$ 8.0 Hz, 1 H, H-4′), 3.95–4.02 (m, 1 H, H-5′), 4.02 (dd, $J_{1',2'} = J_{2',3'} = 4.8$ Hz, 1 H, H-2′), 4.13 (dd, $J_{1a,2}$ 4.0, $J_{1a,1b}$ 11.0 Hz, 1 H, H-1a), 4.19 (dd, $J_{2',3'}$ 4.8, $J_{3',4'}$ 4.0 Hz, 1 H, H-3′), 4.28 (dd, $J_{1b,2}$ 3.0, $J_{1a,1b}$ 11.0 Hz, 1 H, H-1b), 5.16 (d, $J_{1',2'}$ 4.7 Hz, 1 H, H-1′). **12a**: Anal. Calcd for $C_{26}H_{51}O_{12}SNa \cdot H_2O$ (628.7): C, 49.66; H, 8.50. Found: C, 49.72; H, 8.90. **12b**: Anal. Calcd for $C_{30}H_{59}O_{12}SNa \cdot H_2O$ (684.9): C, 52.61; H, 8.98. Found: C, 52.40; H, 8.92. **29a**: Anal. Calcd for $C_{26}H_{51}O_{12}SNa \cdot H_2O$ (628.74): C, 49.66; H, 8.50. Found: C, 49.65; H, 8.74. **29b**: Anal. Calcd for $C_{30}H_{59}O_{12}SNa \cdot H_2O$ (684.9): C, 52.61; H, 8.98. Found: C, 52.44; H, 9.03.

*General procedure for the preparation of ethyl (4R,5S)-2-ethoxycarbonyl-4-(β-*D*-mannofuranosyloxy)-5,6-dioctyloxyhexanoate* (**13a**), *the homologous decyl compound* **13b**, *and the isomeric 4,6-dialkyl compounds* **30a,b**.—A solution of **16a,b** or **33a,b** (0.15 mmol) in MeOH (5 mL) and 1 M aq HCl (1 mL) was stirred until the reaction was completed. After neutralization with satd aq $NaHCO_3$ the MeOH was evaporated in vacuo. The remaining aqueous solution was extracted with EtOAc (5 × 10 mL). The combined organic extracts were dried ($MgSO_4$) and concentrated in vacuo. Column chromatography (9:1 CH_2Cl_2–MeOH) of the residue yielded **13a,b** or **30a,b** (66%) as a colourless oil; TLC (9:1 CH_2Cl_2–MeOH): R_f 0.45 (**13a**), 0.47 (**13b**), 0.49 (**30a**), 0.54 (**30b**); $[\alpha]_D$ −44.5° (**13a**), −42.2° (**13b**), −43.8° (**30a**), −40.9° (**30b**) (*c* 1, MeOH); ^{1}H NMR (250 MHz, $CDCl_3$): **13a**: δ 0.84 (t, *J* 6.6 Hz, 6 H, CH_3), 1.23 (mc, 26/34 H, 10/14 CH_2, OCH_2CH_3), 1.51 (mc, 4 H, OCH_2CH_2), 1.99–2.23 (m, 2 H, H-3a,3b), 3.25–3.48 (m, 4 H, OCH_2CH_2, H-6a,6b), 3.51–3.60 (m, 4 H, OCH_2CH_2, H-5, H-4), 3.71–3.87 (m, 3 H, H-2, H-6′a, H-6′b), 3.95–3.98 (m, 2 H, H-2′, H-4′), 4.02–4.10 (m, 1 H, H-5′), 4.12–4.24 (m, H-5′, OCH_2CH_3, H-3′), 4.91 (d, $J_{1',2'}$ 4.7 Hz, 1 H, H-1′); **30a,b**: δ 0.83 (t, *J* 6.6 Hz, 6 H, CH_3), 1.21 (mc, 26/34 H, 10/14 CH_2, OCH_2CH_3), 1.40–1.46 (m, 2 H, OCH_2CH_2), 1.51–1.56 (m, 2 H, OCH_2CH_2), 2.07–2.10 (m, 2 H, H-3a,3b), 3.31–3.49 (m, 5 H, OCH_2CH_2, H-4), 3.52–3.60 (m, 3 H, H-2, H-6a,6b), 3.74–3.82 (m, 3 H, H-5, H-6′a,6′b), 3.96 (dd, $J_{1',2'}$ 4.4, $J_{2',3'}$ 5.1 Hz, 1 H, H-2′), 4.00 (dd, $J_{3',4'} = J_{4',5'} =$ 5.1 Hz, 1 H, H-4′), 4.06 (mc, 1 H, H-5′), 4.10–4.28 (m, 4 H, OCH_2CH_3), 4.17 (dd, $J_{2',3'} = J_{3',4'} = 5.1$ Hz, 1 H, H-3′), 5.05 (d, $J_{1',2'}$ 4.4 Hz, 1 H, H-1′). **13a**: Anal. Calcd for $C_{33}H_{62}O_{12}$ (654.8): C, 60.52; H, 9.54. Found: C, 60.55; H, 9.62. **13b**: Anal. Calcd for $C_{37}H_{70}O_{12}$ (711.1): C, 62.48; H, 9.92. Found C,

62.41; H, 9.99. **30a**: Anal. Calcd for $C_{33}H_{62}O_{12}$ (654.8): C, 60.52; H, 9.52. Found: C, 60.58; H, 9.74. **30b**: Anal. Calcd for $C_{37}H_{70}O_{12}$ (711.1): C, 62.48; H, 9.92. Found: C, 62.93; H, 10.01.

General procedure for the preparation of (4R,5S)-2-carboxy-4-(β-D-mannofuranosyloxy)-5,6-dioctyloxyhexanoic acid (**14a**), *the homologous decyl compound* **14b**, *and the isomeric 4,6-dialkyl compounds* **31a,b**.—To a solution of **13a,b** or **30a,b** (0.20 mmol) in MeOH (3 mL) and water (1 mL) was added NaOH (0.30 g, 7.5 mmol). The mixture was stirred until the reaction was completed. After evaporation of the MeOH in vacuo, 4 M HCl was added to the solution in order to give pH 3.5. Reversed-phase column chromatography (RP 18, water followed by 7:1 MeOH–water) and lyophilization from water yielded **14a,b** or **31a,b** (86%) as a colourless powder; TLC (RP 18, 7:1 MeOH–water): 0.58 (**14a**), 0.63 (**14b**), 0.44 (**31a**), 0.46 (**31b**); $[\alpha]_D$ −39.0° (**14a**), −37.9° (**14b**), −17.7° (**31a**), −16.2° (**31b**) (*c* 1, MeOH); ^{1}H NMR (250 MHz, CD_3OD): **14a,b**: δ 0.89 (t, *J* 6.5 Hz, 6 H, CH_3), 1.29 (mc, 20/28 H, 10/14 CH_2), 1.56 (mc, 4 H, OCH_2CH_2), 2.02–2.18 (m, 2 H, H-3a,3b), 3.42–3.51 (m, 4 H, OCH_2CH_2, H-6a,6b), 3.55–3.71 (m, 5 H, OCH_2CH_2, H-5, H-6′a, H-6′b), 3.77 (mc, 1 H, H-2), 3.81 (mc, 1 H, H-4′), 3.86 (mc, 1 H, H-4), 3.99 (mc, 1 H, H-5′), 4.08 (mc, 1 H, H-2′), 4.15 (mc, 1 H, H-3′), 4.90 (d, $J_{1',2'}$ 4.8 Hz, 1 H, H-1′); **31a,b**: δ 0.89 (t, *J* 6.6 Hz, 6 H, CH_3), 1.30 (mc, 20/28 H, 10/14 CH_2), 1.47–1.69 (m, 4 H, OCH_2CH_2), 2.12 (mc, 2 H, H-3a,3b), 3.34–3.61 (m, 8 H, H-2, OCH_2CH_2, H-6a,6b, H-4), 3.67 (dd, $J_{5',6'a}$ 5.4, $J_{6'a,6'b}$ 11.5 Hz, 1 H, H-6′a), 3.79 (dd, $J_{5',6'a}$ 3.1, $J_{6'a,6'b}$ 11.5 Hz, 1 H, H-6′b), 3.89 (m, 3 H, H-5, H-4′, H-5′), 4.04 (dd, $J_{1',2'}$ 4.5, $J_{2',3'}$ 4.7 Hz, 1 H, H-2′), 4.14 (dd, $J_{2',3'}$ 4.7, $J_{3',4'}$ 4.5 Hz, 1 H, H-3′), 5.17 (d, $J_{1',2'}$ 4.5 Hz, 1 H, H-1′). **14a**: Anal. Calcd for $C_{29}H_{54}O_{12} \cdot 0.5H_2O$ (607.7): C, 57.31; H, 9.12. Found: C, 56.90; H, 8.63. **14b**: Anal. Calcd for $C_{33}H_{62}O_{12} \cdot H_2O$ (655.8): C, 58.60; H, 9.68. Found: C, 58.66; H, 9.51. **31a**: Anal. Calcd for $C_{29}H_{54}O_{12} \cdot H_2O$ (616.7): C, 56.47; H, 9.15. Found: C, 56.53; H, 9.20. **31b**: Anal. Calcd for $C_{33}H_{62}O_{12}$ (637.8): C, 58.60; H, 9.68. Found: C, 58.46; H, 9.52.

General procedure for the preparation of 2-O-(2,3:5,6-di-O-isopropylidene-β-D-mannofuranosyl)-3,4-di-O-octyl-L-erythritol 1-(sodium sulfate) (**15a**), *the homologous decyl compound* **15b**, *and the isomeric 2,4-dialkyl compounds* **32a,b**.—To a solution of **11a,b**β or **28a,b** (0.30 mmol) in dry pyridine (8 mL) was added SO_3–Me_3N complex (80 mg, 0.58 mmol). After stirring for 15 h the mixture was concentrated in vacuo. After addition of 4 M NaOH (10 mL) the mixture was stirred for 2 h. The aqueous solution was extracted with EtOAc (4 × 20 mL). The combined organic extracts were dried ($MgSO_4$) and concentrated in vacuo. Column chromatography (9:1 CH_2Cl_2–MeOH) of the residue yielded **15a,b** or **32a,b** (86%) as a colourless oil; TLC (6:1 CH_2Cl_2–MeOH): R_f 0.44 (**15a**), 0.46 (**15b**); TLC (9:1 CH_2Cl_2–MeOH), 0.23 (**32a**), 0.24 (**32b**); $[\alpha]_D$ −10.7° (**15a**), −10.0° (**15b**), −18.5° (**32a**), −15.8° (**32b**) (*c* 1, $CHCl_3$); ^{1}H NMR (250 MHz, $CDCl_3$): **15a,b**: δ 0.85 (t, *J* 6.6 Hz, 6 H, CH_3), 1.23 (mc, 20/28 H, 10/14 CH_2), 1.34, 1.35, 1.39, 1.49 [4 s, 12 H, $C(CH_3)_2$], 1.42–1.57 (m, 4 H, OCH_2CH_2), 3.37 (t, *J* 6.6 Hz, 2 H, OCH_2CH_2), 3.39–3.45 (m, 1 H, OCH_2CH_2), 3.51–3.69 (m, 5 H, 1/2 OCH_2CH_2, H-4a,4b, H-3, H-4′), 3.92–4.06 (m, 3 H, H-2, H-6′a,6′b), 4.24 (m, 2 H, H-1a,1b), 4.35 (ddd, $J_{4',5'}$ 7.2, $J_{5',6'a}$ 5.1, $J_{5',6'b}$ 5.8 Hz, 1 H, H-5′), 4.65 (dd, $J_{1',2'}$ 3.6, $J_{2',3'}$ 5.9 Hz, 1 H, H-2′), 4.80 (dd, $J_{2',3'}$ 5.8, $J_{3',4'}$ 3.9 Hz, 1 H, H-3′), 4.94 (d, $J_{1',2'}$ 3.7 Hz, 1 H, H-1′); **32a,b**: δ 0.85 (t, *J* 6.5 Hz, 6 H, CH_3), 1.24 (mc, 20/28 H, 10/14 CH_2), 1.34, 1.35, 1.40, 1.49 [4 s, 12 H, $C(CH_3)_2$], 1.49 (m, 4 H, OCH_2CH_2), 3.32–3.45 (m, 4 H, OCH_2CH_2), 3.59–3.64 (m, 3 H, H-4a,4b, H-4′), 3.69–3.73 (m, 1 H, H-2), 3.85–3.89 (m, 1 H, H-3), 4.02 (mc, 2 H, H-6′a,6′b), 4.21 (mc, 2 H, H-1a,1b), 4.39 (ddd, $J_{4',5'}$ 6.9, $J_{5',6'a} = J_{5',6'b} = 5.5$ Hz, 1 H, H-5′), 4.66 (dd, $J_{2',3'}$ 6.0, $J_{3',4'}$ 3.8 Hz, 1 H, H-3′), 4.74 (dd, $J_{1',2'}$ 3.6, $J_{2',3'}$ 6.0 Hz, 1 H, H-2′), 4.97 (d, $J_{1',2'}$ 3.5 Hz, 1 H, H-1′). **15a**: Anal. Calcd for $C_{32}H_{59}O_{12}SNa \cdot 0.5H_2O$ (700.9): C, 54.84; H, 8.63. Found: C, 54.78; H, 8.27. **15b**: Anal. Calcd for $C_{36}H_{67}O_{12}SNa \cdot H_2O$ (765.0): C, 56.52; H, 9.09. Found: C, 56.33; H, 9.38. **32a**: Anal. Calcd for $C_{32}H_{59}O_{12}SNa \cdot H_2O$ (709.9): C, 54.14; H, 8.66. Found: C, 53.96; H, 8.56. **32b**: Anal. Calcd for $C_{36}H_{67}O_{12}SNa \cdot 0.5H_2O$ (756.0): C, 57.19; H, 8.66. Found: C, 57.14; H, 8.56.

General procedure for the preparation of ethyl (4R,5S)-4-(2,3:5,6-di-O-isopropylidene-2-ethoxycarbonyl-β-D-mannofuranosyloxy)-5,6-dioctyloxyhexanoate (**16a**), *the homologous decyl compound* **16b**, *and the isomeric 4,6-dialkyl compounds* **33a,b**.—Diethyl malonate (0.30 g, 1.87 mmol) was dissolved in 1.5 M ethanolic NaOEt (1.2 mL, 1.8 mmol). After 30 min **17a,b** or **34a,b** (0.56 mmol) was added and the mixture was heated to 60 °C for 20 h. Then water (20 mL) and EtOAc (20 mL) were added and the aq layer was extracted with EtOAc (5 × 20 mL). The combined organic extracts were dried ($MgSO_4$) and concentrated in vacuo. Column chromatography (3:1 light

petroleum–EtOAc) of the residue yielded **16a,b** or **33a,b** (84%) as a colourless oil; TLC (3:1 light petroleum–EtOAc): R_f 0.40 (**16a**), 0.43 (**16b**), 0.38 (**33a**), 0.41 (**33b**); $[\alpha]_D$ −6.6° (**16a**), −3.7° (**16b**), −7.5° (**33a**), −7.0° (**33b**) (*c* 1, $CHCl_3$); ^{1}H NMR (250 MHz, $CDCl_3$): **16a,b**: δ 0.85 (t, *J* 6.5 Hz, 6 H, CH_3), 1.24 (mc, 20/28 H, 10/14 CH_2), 1.15–1.29 (m, 6 H, OCH_2CH_3), 1.32, 1.35, 1.41, 1.48 [4 s, 12 H, $C(CH_3)_2$], 1.40–1.58 (m, 4 H, OCH_2CH_2), 2.09–2.19 (m, 2 H, H-3a,3b), 3.24–3.34 (m, 1 H, OCH_2CH_2), 3.39 (t, *J* 6.6 Hz, 2 H, OCH_2CH_2), 3.44–3.67 (m, 6 H, H-2, H-6a,6b, H-5, 1/2 OCH_2CH_2, H-4′), 3.91–3.98 (m, 1 H, H-4), 4.04 (mc, 2 H, H-6′a,6′b), 4.08–4.24 (m, 4 H, OCH_2CH_3), 4.42 (ddd, $J_{4',5'}$ 7.8, $J_{5',6'a}$ 5.1, $J_{5',6'b}$ 5.8 Hz, 1 H, H-5′), 4.58 (dd, $J_{1',2'}$ 3.7, $J_{2',3'}$ 6.1 Hz, 1 H, H-2′), 4.65 (dd, $J_{2',3'}$ 6.1, $J_{3',4'}$ 3.8 Hz, 1 H, H-3′), 4.95 (d, $J_{1',2'}$ 3.7 Hz, 1 H, H-1′); **33a,b**: δ 0.85 (t, *J* 6.6 Hz, 6 H, CH_3), 1.24 (mc, 20/28 H, 10/14 CH_2), 1.15–1.29 (m, 6 H, OCH_2CH_3), 1.32, 1.35, 1.41, 1.47 [4 s, 12 H, $C(CH_3)_2$], 1.47 (mc, 4 H, OCH_2CH_2), 2.10–2.19 (m, 2 H, H-3a,3b), 3.29 (dt, J_{vic} 6.5, J_{gem} 9.0 Hz, 1 H, OCH_2CH_2), 3.39 (mc, 2 H, OCH_2CH_2), 3.44–3.62 (m, 6 H, H-2, H-6a,6b, H-4, 1/2 OCH_2CH_2, H-4′), 3.91–3.98 (m, 1 H, H-5), 3.99–4.08 (m, 2 H, H-6′a,6′b), 4.08–4.24 (m, 4 H, OCH_2CH_3), 4.42 (ddd, $J_{4',5'}$ 7.7, $J_{5',6'a}$ 5.1, $J_{5',6'b}$ 5.8 Hz, 1 H, H-5′), 4.58 (dd, $J_{1',2'}$ 3.7, $J_{2',3'}$ 6.1 Hz, 1 H, H-2′), 4.66 (dd, $J_{2',3'}$ 6.1, $J_{3',4'}$ 3.9 Hz, 1 H, H-3′), 4.96 (d, $J_{1',2'}$ 3.7 Hz, 1 H, H-1′). **16a**: Anal. Calcd for $C_{39}H_{70}O_{12}$ (731.0): C, 64.08, H, 9.65. Found: C, 64.30; H, 9.76. **16b**: Anal. Calcd for $C_{43}H_{78}O_{12}$ (787.1): C, 65.62; H, 9.99. Found: C, 64.78; H, 10.07. **33a**: Anal. Calcd for $C_{39}H_{70}O_{12} \cdot H_2O$ (740.0): C, 63.30; H, 9.67. Found: C, 63.21; H, 9.62. **33b**: Anal. Calcd for $C_{43}H_{78}O_{12}$ (787.1): C, 65.62; H, 9.99. Found: C, 64.78; H, 10.07.

General procedure for the preparation of 2-O-(2,3:5,6-di-O-isopropylidene-β-D-mannofuranosyl)-3,4-di-O-octyl-1-O-toluenesulfonyl-L-erythritol (**17a**), *the homologous decyl compound* **17b**, *and the isomeric 2,4-dialkyl compounds* **34a,b**.—A solution of **11a,b**β or **28a,b** (1.21 mmol) and *p*-toluenesulfonyl chloride (0.30 g, 1.57 mmol) in dry pyridine (15 mL) was stirred until the reaction was completed. After evaporation of the pyridine in vacuo water (20 mL) was added and the mixture was extracted with EtOAc (5 × 20 mL). The combined organic extracts were dried ($MgSO_4$) and concentrated in vacuo. Column chromatography (7:3 light petroleum–EtOAc) of the residue yielded **17a,b** or **34a,b** (94%) as a colourless oil. TLC (7:3 light petroleum-EtOAc): R_f 0.31 (**17a**), 0.35 (**17b**), 0.37 (**34a**), 0.40 (**34b**); $[\alpha]_D$ −8.6° (**17a**), −7.4° (**17b**), −9.8° (**34a**), −8.2° (**34b**) (*c* 1, $CHCl_3$); ^{1}H NMR (250 MHz, $CDCl_3$): **17a,b**: δ 0.85 (t, *J* 6.5 Hz, 6 H, CH_3), 1.23 (mc, 20/28 H, 10/14 CH_2), 1.32, 1.35, 1.41, 1.45 [4 s, 12 H, $C(CH_3)_2$], 1.45–1.54 (m, 4 H, OCH_2CH_2), 2.42 (s, 3 H, $ArCH_3$), 3.35 (t, *J* 6.7 Hz, 4 H, OCH_2CH_2), 3.39–3.62 (m, 5 H, H-4a,4b, H-3, H-2, H-4′), 3.97–4.16 (m, 4 H, H-1a,1b, H-6′a,6′b), 4.37 (ddd, $J_{4',5'}$ 7.4, $J_{5',6'a}$ 5.1, $J_{5',6'b}$ 5.9 Hz, 1 H, H-5′), 4.54 (dd, $J_{1',2'}$ 3.4, $J_{2',3'}$ 6.1 Hz, 1 H, H-2′), 4.64 (dd, $J_{2',3'}$ 6.1, $J_{3',4'}$ 3.7 Hz, 1 H, H-3′), 4.87 (d, $J_{1',2'}$ 3.4 Hz, 1 H, H-1′), 7.31 (mc, 2 H, Ar), 7.77 (mc, 2 H, Ar); **34a,b**: δ 0.86 (t, *J* 6.6 Hz, 6 H, CH_3), 1.23 (mc, 20/28 H, 10/14 CH_2), 1.31, 1.35, 1.41, 1.43 [4 s, 12 H, $C(CH_3)_2$], 1.43–1.50 (m, 4 H, OCH_2CH_2), 2.43 (s, 3 H, $ArCH_3$), 3.30–3.48 (m, 4 H, OCH_2CH_2), 3.55 (dd, $J_{3',4'}$ 3.9, $J_{4',5'}$ 7.6 Hz, 1 H, H-4′), 3.56–3.65 (m, 2 H, H-4a,4b), 3.67–3.73 (m, 1 H, H-2), 3.75–3.80 (m, 1 H, H-3), 4.04 (mc, 2 H, H-6′a,6′b), 4.24 (m, 2 H, H-1a,1b), 4.40 (ddd, $J_{4',5'}$ 7.8, $J_{5',6'a}$ 5.7, $J_{5',6'b}$ 5.2 Hz, 1 H, H-5′), 4.52 (dd, $J_{1',2'}$ 3.7, $J_{2',3'}$ 6.1 Hz, 1 H, H-2′), 4.64 (dd, $J_{2',3'}$ 6.1, $J_{3',4'}$ 3.9 Hz, 1 H, H-3′), 4.38 (d, $J_{1',2'}$ 3.7 Hz, 1 H, H-1′), 7.31 (mc, 2 H, Ar), 7.78 (mc, 2 H, Ar). **17a**: Anal. Calcd for $C_{39}H_{66}O_{12}S$ (743.0): C, 63.04; H, 8.95. Found: C, 63.21; H, 9.13. **17b**: Anal. Calcd for $C_{43}H_{74}O_{12}S$ (799.1): C, 64.63; H, 9.33. Found: C, 64.78; H, 9.33. **34a**: Anal. Calcd for $C_{39}H_{66}O_{12}S$ (743.0): C, 63.04; H, 8.95. Found: C, 63.06; H, 9.37. **34b**: Anal. Calcd for $C_{43}H_{74}O_{12}S$ (799.1): C, 64.63; H, 9.33. Found: C, 64.41; H, 9.25.

General procedure for the preparation of 1-deoxy-2-O-(2,3:5,6-di-O-isopropylidene-β-D-mannofuranosyl)-1-iodo-3,4-di-O-octyl-L-erythritol (**18a**), *the homologous decyl compound* **18b**, *and the isomeric 2,4-dialkyl compounds* **35a,b**.—A mixture of **11a,b**β or **28a,b** (0.6 mmol), Ph_3P (0.33 g, 1.26 mmol), and triiodoimidazole (0.28 g, 0.63 mmol) in dry toluene (10 mL) was stirred at 100 °C for 15 h. Then satd aq $NaHCO_3$ was added at room temperature and stirring was continued for 15 min. Then I_2 was added until the solution remained brown. Then a little aq 10% $NaHSO_3$ was added until the mixture became colourless. Toluene was evaporated in vacuo and the remaining aq solution was extracted with light petroleum (5 × 40 mL). The combined organic solutions were dried ($MgSO_4$) and concentrated in vacuo. Column chromatography (4:1 light petroleum–EtOAc) of the residue yielded **18a,b** or **35a,b** (77%) as a colourless oil; TLC (3:1 light petroleum–EtOAc): R_f 0.59 (**18a**), 0.60 (**18b**), 0.59 (**35a**), 0.55 (**35b**); $[\alpha]_D$ −21.5° (**18a**), −19.5° (**18b**), −17.9° (**35a**),

−16.3° (**35b**) (*c* 1, $CHCl_3$); ^{1}H NMR (250 MHz, $CDCl_3$): **18a,b**: δ 0.84 (t, J = 6.5 Hz, 6 H, CH_3), 1.24 (mc, 20/28 H, 10/14 CH_2), 1.32, 1.34, 1.39, 1.48 [4 s, 12 H, $C(CH_3)_2$], 1.46–1.55 (m, 4 H, OCH_2CH_2), 3.38 (mc, 2 H, OCH_2CH_2), 3.43–3.54 (m, 6 H, 1/2 OCH_2CH_2, H-4a,4b, H-3, H-1a, H-4′), 3.56–3.74 (m, 3 H, 1/2 OCH_2CH_2, H-2, H-1b), 3.96–4.05 (m, 2 H, H-6′a, H-6′b), 4.37 (ddd, $J_{4',5'}$ 6.8, $J_{5',6'a}$ 5.1, $J_{5',6'b}$ 5.9 Hz, 1 H, H-5′), 4.66 (mc, 2 H, H-3′, H-4′), 4.88 (d, $J_{1',2'}$ 1.0 Hz, 1 H, H-1′); **35a,b**: δ 0.84 (t, J 6.6 Hz, 6 H, CH_3), 1.22 (mc, 20/28 H, 10/14 CH_2), 1.31, 1.34, 1.40, 1.46 [4 s, 12 H, $C(CH_3)_2$], 1.46–1.55 (m, 4 H, OCH_2CH_2), 3.26–3.47 (m, 5 H, OCH_2CH_2, H-2), 3.48–3.55 (m, 2 H, H-4a,4b), 3.57 (dd, $J_{3',4'}$ 3.7, $J_{4',5'}$ 7.5 Hz, 1 H, H-4′), 3.61–3.66 (m, 2 H, H-1a,1b), 3.65–4.69 (m, 1 H, H-3), 4.04 (mc, 2 H, H-6′a,6′b), 4.40 (ddd, $J_{4',5'}$ 7.4, $J_{5',6'a}$ 5.5, $J_{5',6'b}$ 5.5 Hz, 1 H, H-5′), 4.59 (dd, $J_{1',2'}$ 3.6, $J_{2',3'}$ 6.0 Hz, 1 H, H-2′), 4.65 (dd, $J_{2',3'}$ 6.0, $J_{3',4'}$ 3.8 Hz, 1 H, H-3′), 4.94 (d, $J_{1',2'}$ 3.6 Hz, 1 H, H-1′). **18a**: Anal. Calcd for $C_{32}H_{59}IO_8$ (698.7): C, 55.00; H, 8.51. Found: C, 55.21; H, 8.69. **18b**: Anal. Calcd for $C_{36}H_{67}IO_8$ (754.8): C, 57.28; H, 8.95. Found: C, 57.39; H, 9.10. **35a**: Anal. Calcd for $C_{32}H_{59}IO_8$ (698.7): C, 55.00; H, 8.51. Found: C, 55.20; H, 8.54. **35b**: Anal. Calcd for $C_{36}H_{67}IO_8$ (754.8): C, 57.28; H, 8.95. Found: C, 57.09; H, 9.01.

2-O-(2,3:5,6-Di-O-isopropylidene-β-D-mannofuranosyl)-1-O-(11-hydroxy-3,6,9-trioxaundecyl)-3,4-di-O-octyl-L-erythritol (**19a**), *the homologous decyl compound* **19b**, *and the isomeric 2,4-dialkyl compounds* **36a,b**.—To a solution of tetraethylene glycol (0.20 g, 1.03 mmol) in dry DMF (3 mL) at 0 °C was added NaH (24 mg, 1.0 mmol). Then **17a,b** or **34a,b** (0.24 mmol) and tetrabutylammonium iodide (25 mg, 0.06 mmol) were added and the mixture was stirred at 50 °C for 15 h. Then brine (10 mL) was added at room temperature and the mixture was extracted with light petroleum (6 × 20 mL). The combined organic extracts were dried ($MgSO_4$) and concentrated in vacuo. Column chromatography (14:1 CH_2Cl_2–MeOH) of the residue yielded **19a,b** or **36a,b** (78%) as a colourless oil; TLC (9:1 CH_2Cl_2–MeOH): R_f 0.57 (**19a**), 0.54 (**19b**), 0.51 (**36a**), 0.54 (**36b**); $[\alpha]_D$ −12.0° (**19a**), −10.2° (**19b**), −10.5° (**36a**), −9.2° (**36b**) (*c* 1, $CHCl_3$); ^{1}H NMR (250 MHz, $CDCl_3$): **19a**: 0.84 (t, J 6.6 Hz, 6 H, CH_3), 1.22 (mc, 20/28 H, 10/14 CH_2), 1.31, 1.34, 1.40, 1.47 [4 s, 12 H, $C(CH_3)_2$], 1.51 (mc, 4 H, OCH_2CH_2), 2.43 (br s, 1 H, OH), 3.37 (mc, 2 H, OCH_2CH_2), 3.42–3.47 (m, 1 H, OCH_2CH_2), 3.46 (dd, $J_{3',4'}$ 3.5, $J_{4',5'}$ 7.5 Hz, 1 H, H-4′), 3.50–3.72 [m, 21 H, H-1a, $(OCH_2CH_2)_4O$, H-3, H-4a,4b, 1/2 OCH_2CH_2], 3.75 (dd, $J_{1b,2}$ 2.5, $J_{1a,1b}$ 10.6 Hz, 1 H, H-1b), 3.87–3.94 (m, 1 H, H-2), 4.00 (dd, $J_{5',6'a}$ 5.0, $J_{6'a,6'b}$ 8.7 Hz, 1 H, H-6′a), 4.06 (dd, $J_{5',6'b}$ 5.8, $J_{6'a,6'b}$ 8.7 Hz, 1 H, H-6′b), 4.37 (ddd, $J_{4',5'}$ 7.5, $J_{5',6'a}$ 5.0, $J_{5',6'b}$ 5.8 Hz, 1 H, H-5′), 4.58 (dd, $J_{1',2'}$ 3.3, $J_{2',3'}$ 6.1 Hz, 1 H, H-2′), 4.64 (dd, $J_{2',3'}$ 6.1, $J_{3',4'}$ 3.5 Hz, 1 H, H-3′), 4.96 (d, $J_{1',2'}$ 3.3 Hz, 1 H, H-1′); **36a,b**: δ 0.85 (t, J 6.6 Hz, 6 H, CH_3), 1.22 (mc, 20/28 H, 10/14 CH_2), 1.31, 1.34, 1.40, 1.47 [4 s, 12 H, $C(CH_3)_2$], 1.50 (mc, 4 H, OCH_2CH_2), 3.33–3.49 (m, 4 H, OCH_2CH_2), 3.52–3.71 [m, 21 H, H-1a,1b, $(OCH_2CH_2)_4O$, H-2, H-4a,4b], 3.84–3.88 (m, 1 H, H-3), 4.05 (mc, H-6′a,6′b), 4.41 (ddd, $J_{4',5'}$ 7.6, $J_{5',6'a}$ 5.3, $J_{5',6'b}$ 5.7 Hz, 1 H, H-5′), 4.57 (dd, $J_{1',2'}$ 3.6, $J_{2',3'}$ 6.0 Hz, 1 H, H-2′), 4.65 (dd, $J_{2',3'}$ 6.0, $J_{3',4'}$ 3.9 Hz, 1 H, H-3′), 4.92 (d, $J_{1',2'}$ 3.6 Hz, 1 H, H-1′). **19a**: Anal. Calcd for $C_{40}H_{76}O_{13}$ (765.0): C, 62.80; H, 10.01. Found: C, 62.68; H, 10.32. **19b**: Anal. Calcd for $C_{44}H_{84}O_{13} \cdot 0.5H_2O$ (830.1): C, 63.66; H, 10.32. Found: C, 63.39; H, 10.43. **36a**: Anal. Calcd for $C_{40}H_{76}O_{13} \cdot 0.5H_2O$ (774.0): C, 62.07; H, 10.03. Found: C, 62.13; H, 10.13. **36b**: Anal. Calcd for $C_{44}H_{84}O_{13}$ (821.1): C, 64.30; H, 10.31. Found: C, 64.03, H, 10.53.

General procedure for the preparation of diethyl N-[1-deoxy-2-O-(2,3:5,6-di-O-isopropylidene-β-D-mannofuranosyl)-3,4-di-O-octyl-L-erythritol-1-yl]iminodiacetate (**20a**), *the homologous decyl compound* **20b**, *and the isomeric 2,4-dialkyl compounds* **37a,b**.—To a solution of diethyl iminodiacetate (0.25 g, 1.3 mmol) in dry *N*-methyl-2-pyrrolidone (0.25 mL) was added NaH (25 mg, 1.04 mol). After 30 min **18a,b** or **35a,b** (0.34 mmol) was added and stirring was continued at 65 °C for 7 days. Then water (10 mL) was added and the mixture was extracted with EtOAc (6 × 10 mL). The combined organic extracts were dried ($MgSO_4$) and concentrated in vacuo. Column chromatography (3:1 light petroleum–EtOAc) of the residue yielded **20a,b** or **37a,b** (77%) as a colourless oil; TLC (3:1 light petroleum–EtOAc): R_f 0.24 (**20a**), 0.31 (**20b**), 0.24 (**37a**), 0.30 (**37b**); $[\alpha]_D$ −3.0° (**20a**), −1.8° (**20b**), −7.0° (**37a**), −6.5° (**37b**) (*c* 1, $CHCl_3$); ^{1}H NMR (250 MHz, $CDCl_3$): **20a,b**: δ 0.85 (t, J 6.6 Hz, 6 H, CH_3), 1.23 (mc, 20/28 H, 10/14 CH_2), 1.20–1.26 (m, 6 H, OCH_2CH_3), 1.31, 1.35, 1.40, 1.46 [4 s, 12 H, $C(CH_3)_2$], 1.45 (mc, 4 H, OCH_2CH_2), 2.82 (dd, $J_{1a,2}$ 8.6, $J_{1a,1b}$ 14.6 Hz, 1 H, H-1a), 3.12 (dd, $J_{1b,2}$ 2.2, $J_{1a,1b}$ 14.6 Hz, 1 H, H-1b), 3.37 (mc, 2 H, OCH_2CH_2), 3.45 (dd, $J_{3',4'}$ 3.7, $J_{4',5'}$ 7.3 Hz, 1 H, H-4′), 3.41–3.53 (m, 3 H, OCH_2CH_2, H-4a, H-3), 3.58 (s, 4 H, $NCH_2COOC_2H_5$), 3.58–3.66 (m, 2 H, OCH_2CH_2, H-4b), 3.75–3.80 (m, 1 H,

H-2), 4.03 (mc, 2 H, H-6′a,6′b), 4.11 (q, J 7.1 Hz, 4 H, OCH_2CH_3), 4.37 (ddd, $J_{4',5'}$ 7.3, $J_{5',6'a}$ 5.1, $J_{5',6'b}$ 5.9 Hz, 1 H, H-5′), 4.59 (dd, $J_{1',2'}$ 3.7, $J_{2',3'}$ 5.9 Hz, 1 H, H-2′), 4.64 (dd, $J_{2',3'}$ 5.9, $J_{3',4'}$ 3.7 Hz, 1 H, H-3′), 5.09 (d, $J_{1',2'}$ 3.7 Hz, 1 H, H-1′); **37a,b**: δ 0.82 (t, J 6.6 Hz, 6 H, CH_3), 1.20 (m, 20/28 H, 10/14 CH_2), 1.17–1.21 (m, 6 H, OCH_2CH_3), 1.28, 1.32, 1.38, 1.44 [4 s, 12 H, $C(CH_3)_2$], 1.39–1.53 (m, 4 H, OCH_2CH_2), 2.93 (dd, $J_{1a,2}$ 5.9, $J_{1a,1b}$ 13.7 Hz, 1 H, H-1a), 3.05 (dd, $J_{1b,2}$ 2.9, $J_{1a,1b}$ 13.7 Hz, 1 H, H-1b), 3.31–3.47 (m, 4 H, OCH_2CH_2), 3.50 (dd, $J_{3',4'}$ 3.7, $J_{4',5'}$ 8.1 Hz, 1 H, H-4′), 3.56 (s, 4 H, $NCH_2COOC_2H_5$), 3.53–3.63 (m, 3 H, H-4a,4b, H-2), 3.88–3.99 (m, 1 H, H-3), 4.00–4.03 (m, 2 H, H-6′a,6′b), 4.06 (q, J 7.2 Hz, 4 H, OCH_2CH_3), 4.37 (dd, $J_{4',5'}$ 8.1, $J_{5',6'a}$ 5.1, $J_{5',6'b}$ 5.8 Hz, 1 H, H-5′), 4.52 (dd, $J_{1',2'}$ 3.7, $J_{2',3'}$ 5.9 Hz, 1 H, H-2′), 4.61 (dd, $J_{2',3'}$ 5.9, $J_{3',4'}$ 3.7 Hz, 1 H, H-3′), 4.96 (d, $J_{1',2'}$ 3.7 Hz, 1 H, H-1′). **20a**: Anal. Calcd for $C_{40}H_{73}NO_{12}$ (760.0): C, 63.21; H, 9.68; N, 1.84. Found: C, 63.54; H, 9.84; N, 1.80. **20b**: Anal. Calcd for $C_{44}H_{81}NO_{12}$ (816.1): C, 64.75; H, 10.00; N, 1.72. Found: C, 64.82; H, 10.32; N, 1.30. **37a**: Anal. Calcd for $C_{40}H_{73}NO_{12}$ (760.0): C, 63.21; H, 9.68; N, 1.84. Found: C, 62.89; H, 9.62; N, 1.30. **37b**: Anal. Calcd for $C_{44}H_{81}NO_{12}$ (816.1): C, 64.75; H, 10.00; N, 1.72. Found: C, 64.44; H, 10.03; N, 1.30.

General procedure for the preparation of 1-O-(11-hydroxy-3,6,9-trioxaundecyl)-2-O-(β-D-mannofuranosyl)-3,4-di-O-octyl-L-erythritol (**21a**), *the homologous decyl compound* (**21b**), *and the isomeric 2,4-dialkyl compounds* **38a,b**.—A mixture of **19a,b** or **36a,b** (0.18 mmol) and *p*-toluenesulfonic acid (60 mg, 0.31 mmol) in MeOH (5 mL) and water (1 mL) was stirred until the reaction was completed. After neutralization with solid $NaHCO_3$ the solution was concentrated in vacuo. Column chromatography (9:1 CH_2Cl_2–MeOH) yielded **21a,b** or **38a,b** (96%) as a colourless oil; TLC (9:1 CH_2Cl_2–MeOH): R_f 0.24 (**21a**), 0.25 (**21b**), 0.22 (**38a**), 0.24 (**38b**); $[\alpha]_D$ −27.0° (**21a**), −25.3° (**21b**), −42.5° (**38a**), −38.3° (**38b**) (*c* 1, MeOH); ^{1}H NMR (250 MHz, $CDCl_3$): **21a,b**: δ 0.84 (t, J 6.6 Hz, 6 H, CH_3), 1.22 (mc, 20/28 H, 10/14 CH_2), 1.48–1.53 (m, 4 H, OCH_2CH_2), 3.27–3.42 (m, 2 H, OCH_2CH_2), 3.43–3.51 (m, 3 H, H-4a,4b, H-3), 3.52–3.69 [m, 20 H, H-1a,1b, $O(CH_2CH_2)_4O$, H-4a,4b], 3.72–3.81 (m, 2 H, H-6′a, H-6′b), 3.91–3.96 (m, 2 H, H-2, H-4′), 3.98–4.03 (m, 2 H, H-2′, H-5′), 4.19 (dd, $J_{2',3'} = J_{3',4'}$ = 4.8 Hz, 1 H, H-3′), 5.09 (d, $J_{1',2'}$ 4.6 Hz, 1 H, H-1′); **38a,b**: δ 0.82 (t, J 6.5 Hz, 6 H, CH_3), 1.22 (mc, 20/28 H, 10/14 CH_2), 1.47–1.54 (m, 4 H, OCH_2CH_2), 2.92 (br s, 5 H, OH), 3.31–3.49 (m, 4 H, OCH_2CH_2), 3.52–3.68 [m, 21 H, H-1a,1b, $O(CH_2CH_2)_4O$, H-4a,4b, H-2], 3.76–3.81 (m, 3 H, H-3, H-6′a,6′b), 3.98–4.05 (m, 3 H, H-2′, H-4′, H-5′), 4.17 (dd, $J_{2',3'} = J_{3',4'} = 4.7$ Hz, 1 H, H-3′), 5.06 (d, $J_{1',2'}$ 4.2 Hz, 1 H, H-1′); **21a**: Anal. Calcd for $C_{34}H_{68}O_{13} \cdot 0.5H_2O$ (693.8): C, 58.58; H, 10.02. Found: C, 58.79; H, 10.22. **21b**: Anal. Calcd for $C_{38}H_{76}O_{13}$ (741.0): C, 60.13; H, 10.36. Found: C, 60.35; H, 10.34. **38a**: Anal. Calcd for $C_{34}H_{68}O_{13}$ (684.9): C, 59.62; H, 10.01. Found: C, 59.12; H, 10.04. **38b**: Anal. Calcd for $C_{38}H_{76}O_{13}$ (741.0): C, 60.13; H, 10.36. Found: C, 60.30; H, 10.42.

General procedure for the preparation of diethyl N-[1-deoxy-2-O-(β-D-mannofuranosyl)-3,4-di-O-octyl-L-erythritol-1-yl]iminodiacetate (**22a**), *the homologous decyl compound* **22b**, *and the isomeric 2,4-dialkyl compounds* **39a,b**.—A solution of **20a,b** or **37a,b** (0.1 mmol) in MeOH (5 mL) and 1 M aq HCl (1 mL) was stirred until the reaction was completed. Then the solution was neutralized with satd aq $NaHCO_3$ and concentrated in vacuo. Column chromatography (9:1 CH_2Cl_2–MeOH) of the residue yielded **22a,b** or **39a,b** (82%) as colourless oils. TLC (9:1 CH_2Cl_2–MeOH): R_f 0.49 (**22a**), 0.52 (**22b**), 0.50 (**39a**), 0.52 (**39b**); $[\alpha]_D$ −24.5° (**22a**), −23.2° (**22b**), −44.2° (**39a**), −42.5° (**39b**) (*c* 1, $CHCl_3$); ^{1}H NMR (250 MHz, $CDCl_3$): **22a,b**: δ 0.84 (t, J 6.6 Hz, 6 H, CH_3), 1.22 (mc, 20/28 H, 10/14 CH_2), 1.21–1.25 (m, 6 H, OCH_2CH_3), 1.50 (mc, 4 H, OCH_2CH_2), 2.72 (dd, $J_{1a,2}$ 9.5, $J_{1a,1b}$ 13.9 Hz, 1 H, H-1a), 3.00 (dd, $J_{1b,2}$ 2.9, $J_{1a,1b}$ 13.9 Hz, 1 H, H-1b), 3.33–3.40 (m, 3 H, OCH_2CH_2, H-4a), 3.42–3.48 (m, 1 H, H-4b), 3.52, 3.55 (2 s, 4 H, $NCH_2COOC_2H_5$), 3.49–3.63 (m, 5 H, OCH_2CH_2, H-3), 3.75 (mc, 2 H, H-6′a,6′b), 3.80–3.85 (m, 1 H, H-2), 3.94 (dd, $J_{3',4'}$ 5.1, $J_{4',5'}$ 5.9 Hz, 1 H, H-4′), 4.01 (dd, $J_{1',2'}$ 4.4, $J_{2',3'}$ 5.1 Hz, 1 H, H-2′), 4.06 (ddd, $J_{4',5'}$ 5.9, $J_{5',6'a}$ 6.6, $J_{5',6'b}$ 6.6 Hz, 1 H, H-5′), 4.13 (q, J 7.3 Hz, 4 H, OCH_2CH_3), 4.19 (dd, $J_{2',3'} = J_{3',4'} = 5.1$ Hz, 1 H, H-3′), 5.12 (d, $J_{1',2'}$ 4.4 Hz, 1 H, H-1′); **39a,b**: δ 0.84 (t, J 6.5 Hz, 6 H, CH_3), 1.22 (mc, 20/28 H, 10/14 CH_2), 1.19–1.29 (m, 6 H, OCH_2CH_3), 1.44–1.56 (m, 4 H, OCH_2CH_2), 2.81 (dd, $J_{1a,2}$ 4.7, $J_{1a,1b}$ 14.3 Hz, 1 H, H-1a), 3.12 (dd, $J_{1b,2}$ 2.9, $J_{1a,1b}$ 14.3 Hz, 1 H, H-1b), 3.22–3.58 (m, 5 H, OCH_2CH_2, H-2), 3.57, 3.58 (2 s, 4 H, $NCH_2COOC_2H_5$), 3.54–3.73 (m, 2 H, H-4a,4b), 3.76–3.86 (m, 2 H, H-6′a,6′b), 3.91–3.95 (m, 2 H, H-3, H-2′), 3.98–4.05 (m, 1 H, H-4′), 4.06–4.12 (m, 1 H, H-5′), 4.11 (q, J 7.2 Hz, 4 H, OCH_2CH_3), 4.16 (dd, $J_{2',3'}$ 5.1, $J_{3',4'}$ 5.3 Hz, 1 H, H-3′), 5.16 (d, $J_{1',2'}$

4.5 Hz, 1 H, H-1′). **22a**: Anal. Calcd for $C_{34}H_{65}NO_{12}$ (679.9): C, 60.06; H, 9.64; N, 2.06. Found C, 60.47; H, 9.24; N, 2.13. **22b**: Anal. Calcd for $C_{38}H_{73}NO_{12}$ (736.0): C, 62.01; H, 10.00; N, 1.90. Found: C, 61.68; H, 10.19; N, 2.00. **39a**: Anal. Calcd for $C_{34}H_{65}NO_{12}$ (679.9): C, 60.06; H, 9.64; N, 2.06. Found: C, 60.10; H, 9.54; N, 2.30. **39b**: Anal. Calcd for $C_{38}H_{73}NO_{12}$ (736.0): C, 62.01; H, 10.00; N, 1.90. Found: C, 62.02; H, 10.06; N, 1.79.

General procedure for the preparation of N-*[1-deoxy-2-*O*-(β-*D*-mannofuranosyl)-3,4-di-*O*-octyl-*L*-erythritol-1-yl]iminodiacetic acid hydrochloride* (**23a**), *the homologous decyl compound* **23b**, *and the isomeric dialkyl compounds* **40a,b**.—To a solution of **22a,b** or **39a,b** (0.2 mmol) in MeOH (3 mL) and water (1.5 mL) was added NaOH (0.32 g, 8.0 mmol). The mixture was stirred until the reaction was completed. After concentration in vacuo 4 M HCl was added to give pH 3.5. Reversed-phase column chromatography (RP 18, 7:1 MeOH–water) and lyophilization from water yielded **23a,b** or **40a,b** (86%) as a colourless powder; TLC (RP 18, 7:1 MeOH–water): R_f 0.56 (**23a**), 0.54 (**23b**), 0.37 (**40a**), 0.34 (**40b**); $[\alpha]_D$ −19.0° (**23a**), −18.0° (**23b**), −31.8° (**40a**), −28.3° (**40b**) (*c* 1, MeOH); ^{1}H NMR (250 MHz, $CDCl_3$): **23a,b**: δ 0.89 (t, *J* 6.5 Hz, 6 H, CH_3), 1.29 (m, 20/28 H, 10/14 CH_2), 1.55 (m, 4 H, OCH_2CH_2), 3.34–3.48 (m, 3 H, OCH_2CH_2), 3.53–3.77 (m, 10 H, H-1a,1b, NCH_2COOH, 1/2 OCH_2CH_2, H-3, H-4a,4b), 3.81–3.91 (m, 3 H, H-4′, H-6′a,6′b), 3.98 (mc, 1 H, H-5′), 4.07 (mc, 1 H, H-2), 4.21 (mc, 2 H, H-2′, H-3′), 5.08 (d, $J_{1',2'}$ 4.6 Hz, 1 H, H-1′); **40a,b**: δ 0.89 (t, *J* 6.6 Hz, 6 H, CH_3), 1.28 (mc, 20/28 H, 10/14 CH_2), 1.60 (mc, 4 H, OCH_2CH_2), 3.34–3.69 (m, 9 H, H-1a,1b, OCH_2CH_2, H-4a,4b, H-6′a), 3.75–3.82 (m, 1 H, H-6′b), 3.82 (m, 4 H, NCH_2COOH), 3.87–4.03 (m, 4 H, H-3, H-2, H-4′, H-5′), 4.17 (dd, $J_{1',2'} = J_{2',3'} =$ 4.8 Hz, 1 H, H-2′), 4.22 (dd, $J_{2',3'}$ 4.8, $J_{3',4'}$ 3.8 Hz, 1 H, H-3′), 5.16 (d, $J_{1',2'}$ 4.7 Hz, 1 H, H-1′). **23a**: Anal. Calcd for $C_{30}H_{58}ClNO_{12}$ (664.3): C, 54.24; H, 8.92; N, 2.00. Found: C, 54.44; H, 8.77; N, 2.08. **23b**: Anal. Calcd for $C_{34}H_{66}ClNO_{12} \cdot 0.5H_2O$ (725.4): C, 56.30; H, 9.21; N, 1.93. Found: C, 56.27; H, 9.29; N, 2.01. **40a**: Anal. Calcd for $C_{30}H_{57}NO_{12}$ (623.8): C, 57.76; H, 9.21; N, 2.24. Found: C, 57.39; H, 9.42; N, 2.45. **40b**: Anal. Calcd for $C_{34}H_{66}ClNO_{12} \cdot 1.5H_2O$ (743.4): C, 54.93; H, 9.36; N, 1.85. Found C, 54.88; H, 9.09; N, 1.88.

*1-*O*-Benzyl-2,4-di-*O*-octyl-*D*-threitol* (**25a**) *and the homologous decyl compound* **25b**.—To a solution of 1,3-*O*-benzylidene-2,4-di-*O*-octyl-D-threitol [6] (**24a**) or the homologous decyl compound [6] **24b** in dry *n*-hexane–diethyl ether (70 mL, 6:1) was added $LiAlH_4$ (1.20 g, 31.6 mmol). After cooling to −20 °C a solution of $AlCl_3$ (3.70 g, 27.7 mmol) in dry diethyl ether (20 mL) was added dropwise during several hours to keep the solution cold. When the reaction was finished a little EtOAc was added. Then M H_2SO_4 was added dropwise until two layers formed. The aq layer was extracted with diethyl ether (2 × 60 mL), and the combined organic layers were washed with satd aq $NaHCO_3$, dried ($MgSO_4$), and concentrated in vacuo to yield **25a** or **25b** (97%) as a colourless oil. For analytical purpose a small amount of the crude product was purified by flash chromatography (6:1 light petroleum–EtOAc); TLC (6:1 light petroleum–EtOAc): R_f 0.29 (**25a**), 0.29 (**25b**); $[\alpha]_D$ −9.0° (**25a**), −7.5° (**25b**) (*c* 1, $CHCl_3$); ^{1}H NMR (250 MHz, $CDCl_3$): δ 0.86 (t, *J* 6.6 Hz, 6 H, CH_3), 1.26 (mc, 20/28 H, 10/14 CH_2), 1.50–1.55 (m, 2 H, OCH_2CH_2), 2.72 (s, 1 H, OH), 3.41 (mc, 2 H, OCH_2CH_2), 3.43–3.58 (m, 5 H, H-4a,4b, H-2, H-1a,1b), 3.61–3.70 (m, 2 H, OCH_2CH_2), 3.82–3.88 (m, 1 H, CHOH), 4.50, 4.55 (2 d, J_{gem} 12.0 Hz, 2 H, CH_2Ph), 7.25–7.31 (m, 5 H, Ph). **25a**: Anal. Calcd for $C_{27}H_{48}O_4 \cdot 0.25H_2O$ (441.2): C, 73.50; H, 11.08. Found: C, 73.50; H, 11.40. **25b**: Anal. Calcd for $C_{31}H_{56}O_4$ (492.8): C, 75.50; H, 11.46. Found: C, 73.49; H, 11.45.

The experimental details for **26a,b**: see **7a,b**.

The experimental details for **27a,b**: see **10a,b** α and β.

The experimental details for **28a,b**: see **11a,b** β.

The experimental details for **29a,b**: see **12a,b**.

The experimental details for **30a,b**: see **13a,b**.

The experimental details for **31a,b**: see **14a,b**.

The experimental details for **32a,b**: see **15a,b**.

The experimental details for **33a,b**: see **16a,b**.

The experimental details for **34a,b**: see **17a,b**.

The experimental details for **35a,b**: see **18a,b**.

The experimental details for **36a,b**: see **19a,b**.

The experimental details for **37a,b**: see **20a,b**.

The experimental details for **38a,b**: see **21a,b**.

The experimental details for **39a,b**: see **22a,b**.

The experimental details for **40a,b**: see **23a,b**.

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