Synthesis of Sulfated Cerebroside Analogs Having Mimicks of Ceramide and Their Anti-human Immunodeficiency Virus Type 1 Activities

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Various sulfated cerebroside analogs, which are mimicks of cerebroside, have been prepared from per-*O*-acetylated D-glucose, per-*O*-acetylated D-galactose, and per-*O*-acetylated D-lactose with ethyleneglycol dodecyl ether, 3-docosyloxy-1-propanol, 2-hydroxymethyl-1,3-*O*-dimyristyl-1,3-propanediol, and L-serine diamide derivatives as ceramide moieties. The synthesized sulfated glycolipids showed anti-HIV-1 activities.

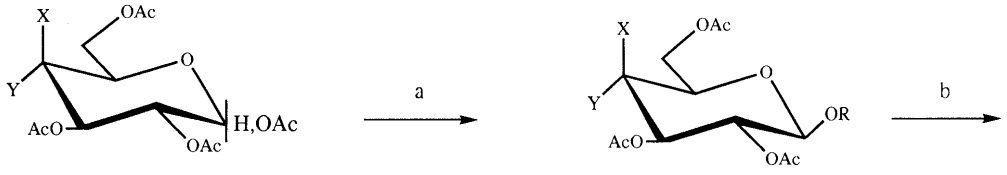
Key words sulfated cerebroside analog; ganglioside analog; anti-HIV-1 activity; L-serine diamide derivative

The glycoconjugates located on cell surface glycoprotein and glycolipids serve as recognition markers for the immune system and also play critical roles in the binding of lectins, hormones, and enzymes, the targeting of viruses and bacteria to the cell, and cell-cell recognition and development.[1] It has been reported that dextran sulfate, heparin, and other sulfated polysaccharides are highly selective inhibitors of human immunodeficiency virus (HIV) replication.[2] Sulfation is assumed to play a critical role in the anti-HIV activity of these polysaccharide.[3]

We have recently reported that sulfated gangliosides have potent anti-HIV activities.[4] However, gangliosides are usually available from natural sources in only limited quantities and are sialic acid-containing glycolipids, the *O*-glycosidic linkage of which is fairly unstable to acids and bases. Therefore, versatile synthesis of cerebroside analogs as mimicks of gangliosides seems to be of importance.

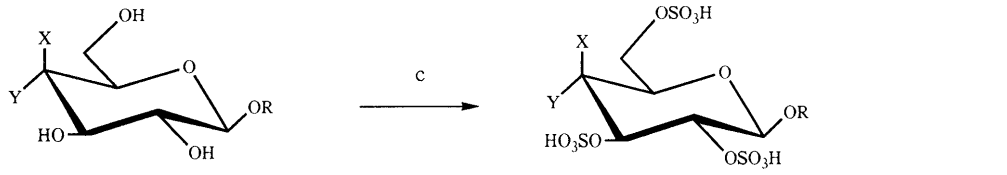
As part of our synthetic studies[5] on biologically active new compounds designed on the basis of the chemical structure of glycoconjugates, including some found in nature, we planned to develop practical syntheses of biologically active cerebroside analogs containing modified ceramides as ganglioside analogs. We describe herein the synthesis of biologically active cerebroside analogs as mimicks of the ceramide moieties of gangliosides and the results of evaluation of their biological activities.

We chose the ethylene glycol dodecyl ether (**11**), 3-



12: D-Glu: X=H,Y=OAc
15: D-Gal: X=OAc,Y=H
18: D-Lacto: X=H, Y=Gal (tetra-O-Ac)

13: X=H,Y=OAc, R= -$C_2H_4OC_{12}H_{25}$
16: X=OAc,Y=H, R= -$C_2H_4OC_{12}H_{25}$
19: X=H, Y=Gal (tetra-O-Ac), R= -$C_2H_4OC_{12}H_{25}$
25: X=H, Y=OAc, R= -$C_3H_6OC_{22}H_{45}$
27: X=OAc, Y=H, R= -$C_3H_6OC_{22}H_{45}$
29: X=H, Y=Gal(tetra-O-Ac), R= -$C_3H_6OC_{22}H_{45}$



14: X=H,Y=OH, R= -$C_2H_4OC_{12}H_{25}$
17: X=OH,Y=H, R= -$C_2H_4OC_{12}H_{25}$
20: X=H, Y=Gal, R= -$C_2H_4OC_{12}H_{25}$
26: X=H, Y=OH, R= -$C_3H_6OC_{22}H_{45}$
28: X=OH, Y=H, R= -$C_3H_6OC_{22}H_{45}$
30: X=H, Y=Gal, R= -$C_3H_6OC_{22}H_{45}$

1: X=H,Y=OSO_3H, R= -$C_2H_4OC_{12}H_{25}$
2: X=OSO_3H,Y=H, R= -$C_2H_4OC_{12}H_{25}$
3: X=H, Y=Gal (tetra-O-SO_3H), R= -$C_2H_4OC_{12}H_{25}$
4: X=H, Y=OSO_3H, R= -$C_3H_6OC_{22}H_{45}$
5: X=OSO_3H, Y=H, R= -$C_3H_6OC_{22}H_{45}$
6: X=H, Y=Gal(tetra-O-SO_3H), R= -$C_3H_6OC_{22}H_{45}$

reagents and conditions : a) TMSOTf, **11** (in the case of **1**, **2**, **3**), **24** (in the case of **4**, **5**, **6**); b) NH_4OH-MeOH (1:20)
c) i) SO_3NMe_3, ii) CF_3CO_2H

Chart 1

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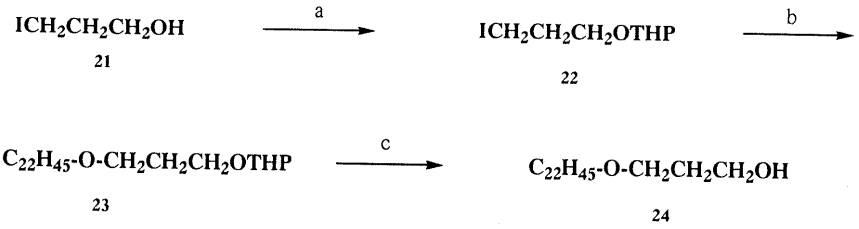


reagents and conditions : a) 3,4-dihydro-2*H*-pyran, PPTS; b) $C_{22}H_{45}OH$, NaH; c) PPTS, EtOH

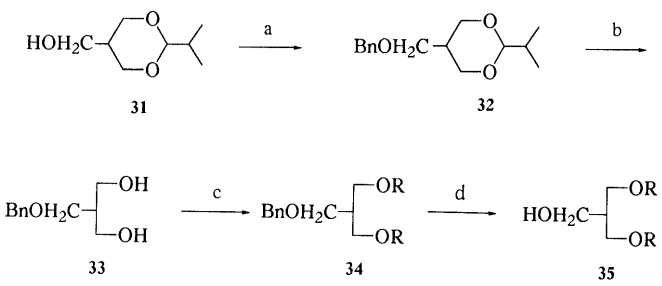
Chart 2

docosyloxy-1-propanol (**24**) and 2-hydroxymethyl-1,3-*O*-dimyristyl-1,3-propanediol (**35**) as ceramide moieties for the derivatives. First, for preparing **1**, **2**, and **3**, the neighboring-group-assisted coupling of per-*O*-acetylated D-glucose (**12**), per-*O*-acetylated D-galactose (**15**), and per-*O*-acetylated D-lactose (**18**) with ethylene glycol dodecyl ether (**11**) in the presence of trimethylsilyl trifluoromethanesulfonate (TMSOTf) and molecular sieves 4 Å in $ClCH_2CH_2Cl$ gave the desired glycosides **13**, **16**, and **19** in yields of 25, 42 and 59%, respectively, as shown in Chart 1.

Compounds **25**, **27**, and **29** were also obtained by the condensation of **12**, **15**, and **18** with 3-docosyloxy-1-propanol (**24**), readily prepared from 3-iodo-propanol (**21**) in 3 steps, according to Chart 2, in yields of 15, 20, and 72%, respectively.

The ^{1}H-NMR signal of the anomeric proton H-1 at δ 4.62 ($J_{1,2}=8.3$ Hz) in **13**, δ 4.58 ($J_{1,2}=7.9$ Hz) in **16**, δ 4.50 ($J_{1,2}=8.3$ Hz) in **19**, δ 4.48 ($J_{1,2}=8.3$ Hz) in **25**, δ 4.46 ($J_{1,2}=8.2$ Hz) in **27**, and δ 4.46 ($J_{1,2}=7.8$ Hz) in **29** indicated the stereochemistry of the newly formed glycosidic bond to be β. Removal of acetyl groups in **13**, **16**, **19**, **25**, **27**, and **29** by treatment with NH_4OH–MeOH (1 : 10) gave the alcohols **14**, **17**, **20**, **26**, **28**, and **30** in yields of 31, 20, 46, 46, 53, and 29%, respectively. *O*-Sulfation of **14**, **17**, **20**, **26**, **28**, and **30** was achieved with sulfur trioxide–trimethylamine complex in *N*,*N*-dimethylformamide[6] (DMF). Removal of trimethylamine was readily accomplished by brief treatment with trifluoromethanesulfonic acid in dichloromethane, and purification by chromatography on Sephadex LH-20 ($CHCl_3$: MeOH : H_2O = 20 : 20 : 1) followed by lyophilization of the aqueous solution afforded the sulfated glycosides **1**, **2**, **3**, **4**, **5**, and **6** in yields of 34, 31, 61, 33, 42, and 28%, respectively. Absorptions at 1215—1268 cm^{-1} (due to S=O stretching) and 756—834 cm^{-1} (due to C–O–S vibration) were observed in the infrared (IR) spectra of **1**, **2**, **3**, **4**, **5**, and **6**, indicating the presence of sulfate esters. Furthermore, these compounds gave a positive test with the specific spray-reagent (azure A reagent) for sulfated glycolipids.[7]

Secondly, for the synthesis of **7** and **8**, we prepared 2-hydroxymethyl-1,3-*O*-dimyristyl-1,3-propanediol (**35**) as the aglycone (Chart 3). Treatment of 2-isopropyl-5-hydroxymethyl-1,3-dioxane (**31**)[8] with benzyl bromide in DMF in the presence of sodium hydride gave, after chromatography, a monobenzyl ether (**32**) in 94% yield. Hydrolysis of **32** with 1 N HCl in MeOH gave the diol **33** in 50% yield. Then treatment of **33** with myristyl



reagents and conditions : a) $C_6H_5CH_2Br$, NaH, *n*-Bu_4NI; b) 1 N HCl; c) NaH, $C_{14}H_{29}Br$, *n*-Bu_4NI; d) Pd-C, H_2

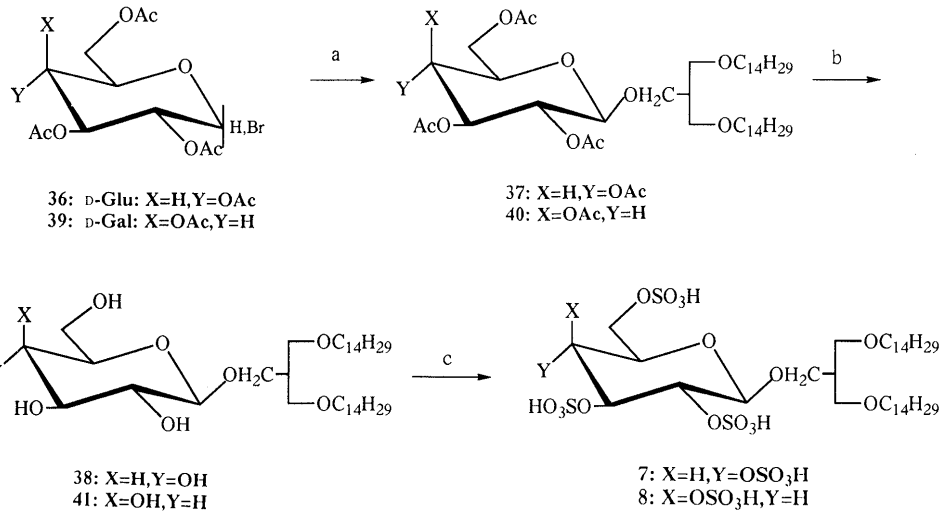
Chart 3

bromide in DMF in the presence of sodium hydride and *n*-tetrabutylammonium iodide, followed by hydrogenolysis over Pd–C with H_2 gave the alcohol **35** in 61% yield in two steps.

Condensation of **36** and **39** with **35** in the presence of $HgBr_2$ in 1,2-dichloroethane gave the expected glycosides **37** and **40**, in yields of 52 and 65%, respectively, as illustrated in Chart 4. ^{1}H-NMR spectra revealed a doublet due to H-1 at δ 4.47 ($J_{1,2}=8.3$ Hz) for **37** and δ 4.44 ($J_{1,2}=7.8$ Hz) for **40**, indicating the stereochemistry of the glycosidic bond formed to be β in both **37** and **40**. Subsequent saponification of **37** and **40** with NH_4OH–MeOH (1 : 10) gave the β-linked glycosides **38** and **41** in quantitative yields. Compounds **38** and **41** were then per-*O*-sulfated in the same manner to afford the sulfated glycosides **7** and **8**, in yields of 43 and 30%, respectively.

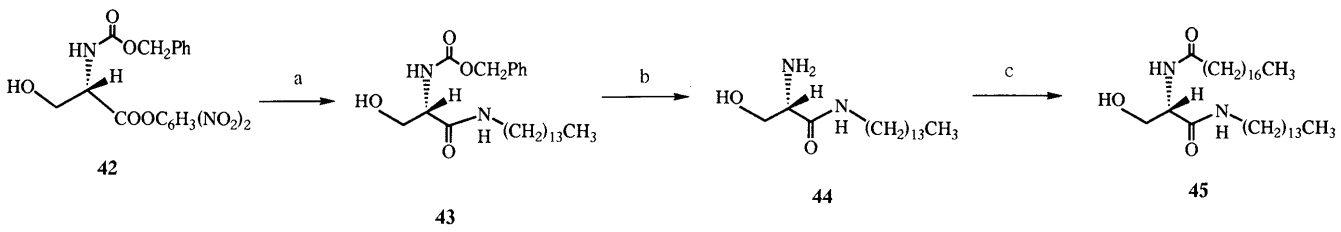
Thirdly, to obtain more effective compounds, we tried further structural modifications of the ceramide unit. We designed the L-serine diamide derivatives (**45**) bearing two amide functions as complicated mimicks of ceramides, as shown in Fig. 1.

That is, the (*S*)-configuration of the *N*-stearoyl group of **45** at the carbon of attachment is the same as that of natural sphingosines. In addition, the native allyl group has been replaced by an isosteric amide group consisting of a saturated fourteen-carbon fatty acid residue. For the preparation of **45**, *N*-carbobenzoxy-L-serine-2,4-dinitrophenol (**42**) was treated with myristylamine in the presence of triethylamine to give the amide **43** in 65% yield. Deprotection of the benzyloxycarbonyl group of **43** was carried out with Pd–C and H_2, followed by acylation with stearoyl chloride and $NaHCO_3$ to give the diamide **45** in almost quantitative yield in 2 steps, as illustrated in



reagents and conditions : a) $HgBr_2$, 35; b) NH_4OH-MeOH (1:10); c) i) SO_3NMe_3, ii) CF_3CO_2H

Chart 4



reagents and conditions : a) $C_{14}H_{29}NH_2$, Et_3N; b) Pd-C, H_2; c) $C_{17}H_{35}COCl$, $NaHCO_3$

Chart 5

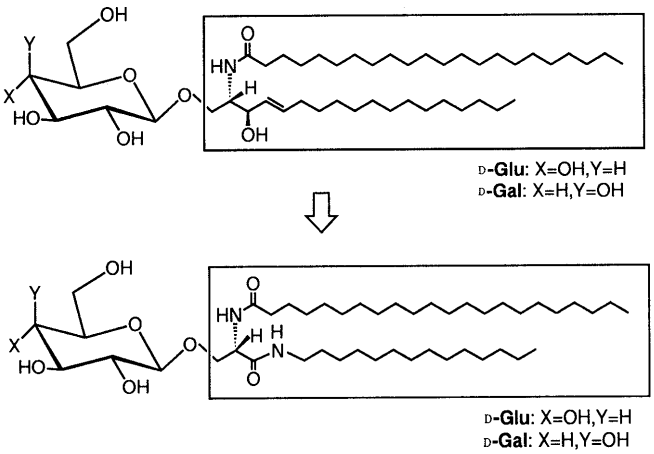
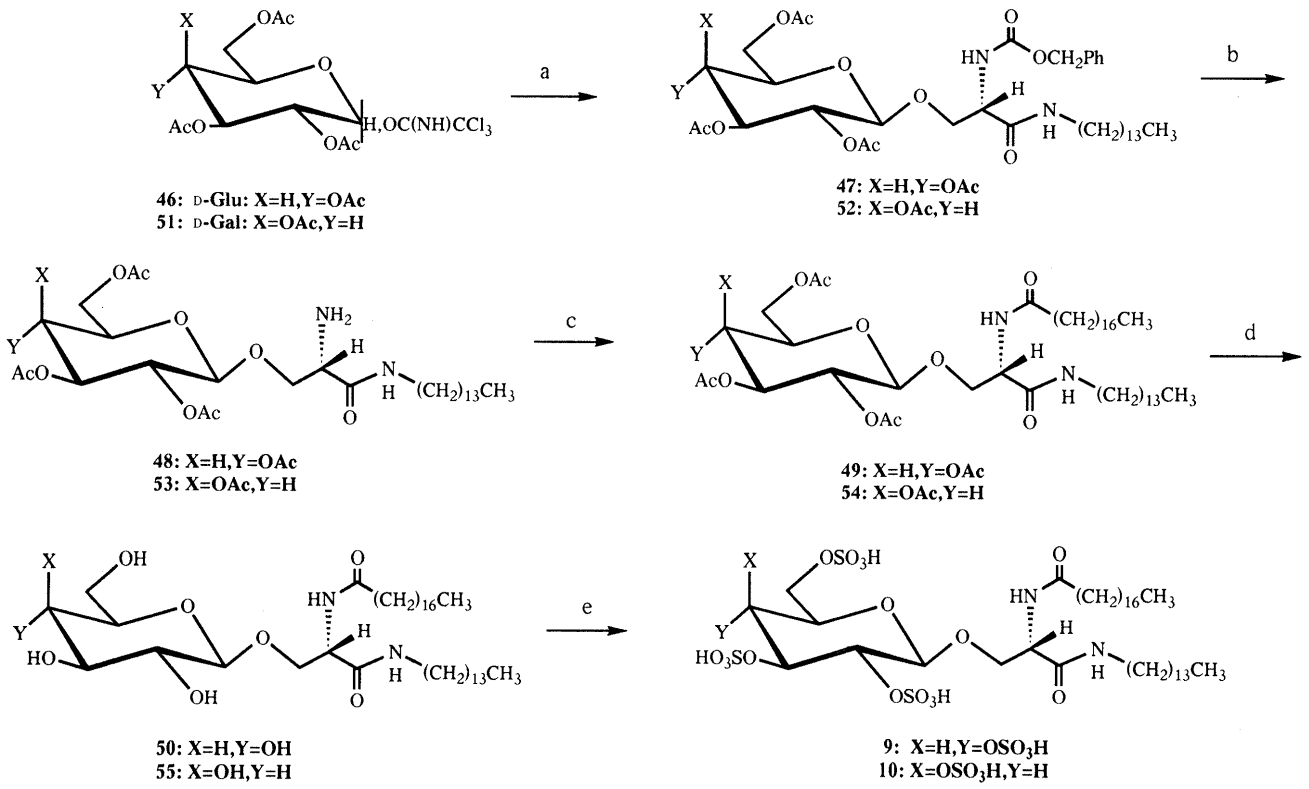


Fig. 1

Chart 5. Our attempts to prepare the glycoside **49** from **45** proceeded as follows. Glycosylation of **45** with glycosyl acetate (**12**), glycosyl bromide (**36**), and glycosyl trichloroacetimidate (**46**)[9] did not proceed using TMSOTf, $HgBr_2$, and BF_3–Et_2O as promoters, probably due to the low reactivity of **45** and its low solubility in both organic solvents and water. We searched for an alternative method for the preparation of **9** and **10**. We examined the amide **43** instead of **45**. However, no reaction of **43** with glycosyl acetate (**12**) or glycosyl bromide (**36**) could be observed.

We turned out attention to the corresponding fluoride in place of **36**. The reaction of glycosyl fluoride and **43** gave the desired compound **47** in the presence of $SnCl_2$–$AgClO_4$[10] in a low yield (6%). The problem was overcome by the use of glycosyl imidate (**46**) as the glycosyl donor. That is, coupling of **43** and **46** using BF_3–Et_2O as the promoter afforded the β-glycoside **47** exclusively, in 77% yield. Using the same methodology, coupling of **51** and **43** proceeded to give **52** in 33% yield using the same method. In the ^{13}C-NMR spectra of **47** and **52**, the ^{13}C–^1H coupling constants observed for the anomeric carbon signals, 161.2 Hz in **47** and 159.5 Hz in **52**, suggested the stereochemistry of the glycosidic bond formed to be β[11] in both **47** and **52**. Subsequent hydrogenation of **47** and **52** with 10% Pd-on-carbon and H_2 in MeOH gave the amino compounds **48** and **53** in quantitative yields. The acylation of **48** and **53** was carried out with stearoyl chloride and $NaHCO_3$ to give the amides **49** and **54** in yields of 67 and 100%, respectively. Next, several attempts to remove the acetyl groups of **49** and **54** using usual mild de-*O*-acetylating reagents such as NH_4OH–MeOH, $H_2NNH_2H_2O$ in EtOH,[12] and $H_2NNH_2H_2O$ in AcOH–pyridine (1 : 4)[13] resulted in β-elimination of the glycosides, because the reaction is complicated by the acid-lability of glycosides in general and the base-sensitivity (retro-Michael reaction) of the *O*-serinyl glycosides in particular.[14] The best result was obtained as follows. Basic



reagents and conditions : a) BF_3-EtO_2, **43**; b) Pd-C, H_2; c) $C_{17}H_{35}COCl$, $NaHCO_3$; d) NEt_3-MeOH; e) i) SO_3NMe_3, ii) CF_3CO_2H

Chart 6

Table 1. Results of Anti-HIV Assay by IFA Using MT-4 Cells

Compd. No.	HIV-1 infection (IC_{50}) (μg/ml)[a]	CT[b]
1	>100	(−)
2	>100	(−)
3	>100	(−)
4	30	(−)
5	30—100	(−)
6	30—100	(−)
7	30—100	(−)
8	>100	(−)
9	>100	(++)
10	>100	(++)

a) Concentrations (μg/ml) of compounds at which 50% of MT-4 cells expressed HIV-1 antigens. *b*) CT: cytotoxic (− to ++).

hydrolysis of **49** and **54** was smoothly accomplished by stirring in 10% NEt_3–MeOH[15] at 45 °C to give the alcohols **50** and **55** in 89 and 70% yields, respectively. During the de-*O*-acetylation, no β-elimination product was detected. Finally, *O*-sulfation of **50** and **55** was achieved with sulfur trioxide–pyridine complex in DMF, followed by treatment with CF_3CO_2H, purification by chromatography on Sephadex LH-20 and lyophilization of the aqueous solution to afford the sulfated glycosides **9** and **10**, in yields of 28 and 43%, respectively.

The structures of all compounds were characterized by ^{1}H- and ^{13}C-NMR spectral methods, as well as IR spectroscopy, elemental analyses and positive FAB-mass spectrometry.

The anti-HIV-1 activities of the ten sulfated glycolipids are shown in Table 1. The anti-HIV-1 activity was tested by the syncytium-formation assay method using MT-4 cells according to our previously reported procedure.[4] Among the synthesized compounds, **4**, **5**, **6**, **7** showed moderate activity with 50%-inhibitory concentration (IC_{50}) value of 30 μM, 30—100 μM, 30—100 μM, and 30—100 μM, respectively. Compound **1**, **2**, **3**, **8**, **9**, **10** were found to be practically inactive (IC_{50} > 100 μM) against HIV-1 and noncytotoxic, except for compounds **9** and **10**.

Experimental

All melting points are uncorrected. Optical rotations were measured with a JASCO DIP-140 digital polarimeter. IR spectra were recorded on a JASCO A-202 infrared spectrophotometer. ^{1}H-NMR spectra were taken on a JEOL JNM-GX270 (270 MHz) spectrometer. ^{13}C-NMR spectra were recorded with a JEOL JNM-GX270 (67.5 MHz) spectrometer. ^{1}H and ^{13}C chemical shifts (δ) are given in ppm relative to that of Me_4Si (δ=0) in $CDCl_3$ or CD_3OD, or sodium 4,4-dimethyl-4-silapentane-1-sulfonate hydrate (DSS, δ=0 in D_2O) as an internal standard. The abbreviations of signal patterns are as follows: s, singlet; br s, broad singlet; d, doublet; t, triplet; q, quartet; m, multiplet. Column chromatography was carried out on silica gel 60 (70—230 mesh, Merck). Gel filtration was performed on Sephadex LH-20 (Pharmacia). Thin-layer chromatography (TLC) on Silica gel $60F_{254}$ (Merck) was used to monitor the reaction and to ascertain the purity of the reaction products. The spots were visualized by spraying the plates with 5% aqueous sulfuric acid and then heating. Sulfated glycolipids were visualized with azure A reagent. The bands of lipids containing sulfate esters were stained blue.

2-(Dodecyloxy)ethyl 2,3,4,6-Tetra-*O*-acetyl-β-D-glucopyranoside (13) A solution of 1,2,3,4,6-penta-*O*-acetyl-β-D-glucopyranose (**12**) (210 mg, 0.54 mmol) and ethyleneglycol dodecyl ether (186 mg, 0.81 mmol) in

anhydrous $ClCH_2CH_2Cl$ (10 ml) was stirred for 1 h at room temperature under argon in the presence of 4 Å powdered molecular sieves. The mixture was cooled to 0 °C, then $Me_3SiOSO_2CF_3$ (TMSOTf) (132 mg, 0.59 mmol) was added. Stirring was continued for 3 h at room temperature, then the solution was poured into ice-water, and extracted with $CHCl_3$. The extract was successively washed with aqueous $NaHCO_3$ and H_2O, dried ($MgSO_4$), and evaporated *in vacuo*. The residual product was chromatographed on SiO_2 with 10:1 $CHCl_3$–CH_3COCH_3 to give **13** (75 mg, 25%) as an amorphous powder. $[\alpha]_D$ −24.9° (c=0.18, $CHCl_3$). IR (neat): 1752, 1375, 1113 cm^{-1}. ^{1}H-NMR ($CDCl_3$) δ: 0.88 (3H, t, J=6.4 Hz, $OC_{11}H_{22}C\underline{H}_3$), 1.26 (18H, s, $OCH_2CH_2(C\underline{H}_2)_9CH_3$), 1.54 (2H, m, $OCH_2C\underline{H}_2C_{10}H_{21}$), 2.01, 2.02, 2.04, 2.09 (each 3H, s, $OCOCH_3$ ×4), 3.43 (2H, t, J=6.4 Hz, $OC\underline{H}_2C_{11}H_{23}$), 3.57 (2H, t, J=4.9 Hz, $C\underline{H}_2OC_{12}H_{25}$), 3.66—3.77 (2H, m, Glu-H5, $OC\underline{H}_aH_bCH_2O$), 3.93 (1H, dt, J=4.4, 10.7 Hz, $OCH_a\underline{H}_bCH_2O$), 4.14 (1H, dd, J=12.3, 2.5 Hz, Glu-H6$_a$), 4.27 (1H, dd, J=12.3, 4.9 Hz, Glu-H6$_b$), 4.62 (1H, d, J=8.3 Hz, Glu-H1), 5.00 (1H, dd, J=8.3, 9.3 Hz, Glu-H2), 5.09 (1H, t, J=9.3 Hz, Glu-H4), 5.21 (1H, t, J=9.3 Hz, Glu-H3). Positive FAB-MS m/z: 561 $(M+H)^+$, 583 $(M+Na)^+$.

2-(Dodecyloxy)ethyl β-D-Glucopyranoside (14) A mixture of **13** (75 mg, 0.13 mmol) and NH_4OH–MeOH (1:20) (10 ml) was stirred at room temperature for 15 h, and evaporated *in vacuo*. The residue was chromatographed on SiO_2 in $CHCl_3$–MeOH (5:1) to give **14** (16 mg, 31%), mp 62—64 °C. $[\alpha]_D$ +25.2° (c=0.22, MeOH). IR (KBr): 3383, 1115 cm^{-1}. ^{1}H-NMR ($CDCl_3$) δ: 0.88 (3H, t, J=7.3 Hz, $OC_{11}H_{22}C\underline{H}_3$), 1.26 (18H, s, $OCH_2CH_2(C\underline{H}_2)_9CH_3$), 1.56 (2H, m, $OCH_2C\underline{H}_2C_{10}H_{21}$), 3.45 (2H, t, J=6.7 Hz, $OC\underline{H}_2C_{11}H_{23}$), 3.55 (2H, m, $OCH_2C\underline{H}_2OC_{12}H_{25}$), 3.73 (2H, m, $OC\underline{H}_2CH_2OC_{12}H_{25}$), 4.34 (1H, d, J=7.6 Hz, H-1). Positive FAB-MS m/z: 393 $(M+H)^+$, 415 $(M+Na)^+$.

2-(Dodecyloxy)ethyl 2,3,4,6-Tetra-*O*-sulfo-β-D-glucopyranoside (1) A solution of **14** (16 mg, 0.041 mmol) in DMF (2 ml) was stirred for 20 h at 45—50 °C in the presence of sulfur trioxide–trimethylamine complex (46 mg, 0.33 mmol). The mixture was cooled and chromatographed on a column of Sephadex LH-20 equilibrated in 20:20:1 (v/v) $CHCl_3$–MeOH–H_2O. Elution with the same solvent gave a residue that was dissolved in CH_2Cl_2 (2 ml). The solution was treated with CF_3SO_3H (37 mg, 0.33 mmol) for 2 h under ice-cooling, then evaporated *in vacuo*. The residue was dissolved in H_2O (1 ml) and chromatographed on a column of Sephadex LH-20. Elution with 20:20:1 (v/v) in $CHCl_3$–MeOH–H_2O afforded **1** (10 mg, 34%) as an amorphous powder, after lyophilization from H_2O. $[\alpha]_D$ +51.4° (c=0.22, MeOH). IR (KBr): 1255, 1109, 803 cm^{-1}. ^{1}H-NMR (D_2O) δ: 0.90 (3H, t, J=6.9 Hz, $OC_{11}H_{23}C\underline{H}_3$), 1.29 (18H, br s, $OCH_2CH_2(C\underline{H}_2)_9CH_3$). *Anal.* Calcd for $C_{20}H_{40}O_{19}S_4 \cdot N(CH_3)_3$: C, 35.79; H, 6.40; N, 1.81. Found: C, 35.14; H, 6.68; N, 1.97.

2-(Dodecyloxy)ethyl 2,3,4,6-Tetra-*O*-acetyl-β-D-galactopyranoside (16) The same procedure as described for the preparation of **13** provided a crude product from 1,2,3,4,6-penta-*O*-acetyl-D-galactopyranose (**15**) (119 mg, 0.31 mmol), ethylene glycol dodecyl ether (105 mg, 0.46 mmol) and TMSOTf (75 mg, 0.34 mmol), and this was purified by column chromatography with 10:1 $CHCl_3$–CH_3COCH_3 to give **16** (72 mg, 42%) as an amorphous powder. $[\alpha]_D$ −24.8° (c=0.22, $CHCl_3$). IR (neat): 1752, 1369, 1120 cm^{-1}. ^{1}H-NMR ($CDCl_3$) δ: 0.88 (3H, t, J=7.0 Hz, $OC_{11}H_{22}C\underline{H}_3$), 1.26 (18H, br s, $OCH_2CH_2(C\underline{H}_2)_9CH_3$), 1.54 (2H, m, $OCH_2C\underline{H}_2C_{10}H_{21}$), 1.96, 2.05, 2.06, 2.15 (each 3H, s, $OCOCH_3$ ×4), 3.43 (2H, t, J=6.7 Hz, $OC\underline{H}_2C_{11}H_{23}$), 3.58 (2H, t, J=4.6 Hz, $C\underline{H}_2OC_{12}H_{25}$), 3.71—3.76 (1H, m, $OC\underline{H}_aH_bCH_2OC_{12}H_{25}$), 3.89—3.93 (2H, m, H-5, $OCH_a\underline{H}_bCH_2OC_{12}H_{25}$), 4.13 (1H, dd, J=6.7, 11.2 Hz, H-6$_a$), 4.18 (1H, dd, J=6.4, 11.2 Hz, H-6$_b$), 4.58 (1H, d, J=7.9 Hz, H-1), 5.02 (1H, dd, J=3.3, 10.7 Hz, H-3), 5.22 (1H, t, J=7.9, 10.7 Hz, H-2), 5.39 (1H, d, J=3.3 Hz, H-4). ^{13}C-NMR ($CDCl_3$) δ: 14.1 (q, $C_{11}H_{22}\underline{C}H_3$), 20.6, 20.7, 20.8 (q, $OCO\underline{C}H_3$ ×4), 22.7, 26.1, 29.4, 29.5, 29.6, 29.8, 31.9 (t, $OCH_2(\underline{C}H_2)_{10}CH_3$), 61.3 (t, C-6), 67.1 (d, C-4), 68.9 (t, $OCH_2\underline{C}H_2O$-$C_{12}H_{25}$), 69.0 (t, $O\underline{C}H_2CH_2OC_{12}H_{25}$), 69.8 (t, $O\underline{C}H_2C_{11}H_{23}$), 70.7 (d, C-5), 71.0 (d, C-3), 71.7 (d, C-2), 101.4 (d, C-1), 169.5, 170.2, 170.3, 170.4 (s, $O\underline{C}OCH_3$ ×4). Positive FAB-MS m/z: 561 $(M+H)^+$, 583 $(M+Na)^+$.

2-(Dodecyloxy)ethyl β-D-Galactopyranoside (17) The same procedure as described for the preparation of **14** provided a crude product from **16** (72 mg, 0.13 mmol), and this was purified by column chromatography with 5:1 $CHCl_3$–MeOH to give **17** (21 mg, 20%) as an amorphous powder. $[\alpha]_D$ −23.1° (c=0.30, MeOH). IR (KBr): 3382, 1118 cm^{-1}. ^{1}H-NMR ($CDCl_3$) δ: 0.88 (3H, t, J=7.0 Hz, $OC_{11}H_{22}C\underline{H}_3$), 1.26 (18H, br s, $CH_2(C\underline{H}_2)_9CH_3$), 1.57 (2H, m, $OCH_2C\underline{H}_2C_{10}H_{21}$), 3.46 (2H, t, J=6.7 Hz, $OC\underline{H}_2C_{11}H_{23}$). Positive FAB-MS m/z: 393 $(M+H)^+$, 415 $(M+Na)^+$, 431 $(M+K)^+$.

2-(Dodecyloxy)ethyl 2,3,4,6-Tetra-*O*-sulfo-β-D-galactopyranoside (2) The same procedure as described for the preparation of **1** provided a crude product from **17** (21 mg, 0.054 mmol) and sulfur trioxide–trimethylamine complex (30 mg, 0.22 mmol), followed by trifluoroacetic acid (TFA, 24 mg, 0.22 mmol), and this was purified on a column of Sephadex LH-20 equilibrated in and eluted with 20:20:1 (v/v) $CHCl_3$–MeOH–H_2O to give **9** (12 mg, 31%) as an amorphous powder. $[\alpha]_D$ −121.4° (c=0.05, MeOH). IR (KBr): 1255, 1109, 834 cm^{-1}. ^{1}H-NMR (D_2O) δ: 0.90 (3H, t, J=7.3 Hz, $OC_{11}H_{22}C\underline{H}_3$), 1.29 (18H, br s, $OCH_2CH_2(C\underline{H}_2)_9CH_3$). *Anal.* Calcd for $C_{20}H_{40}O_{19}S_4 \cdot 2 \times N(CH_3)_3$: C, 37.58; H, 7.04; N, 3.37. Found: C, 37.74; H, 7.68; N, 3.97.

2-(Dodecyloxy)ethyl 2,3,6-Tri-*O*-acetyl-4-*O*-(2,3,4,6-tetra-*O*-acetyl-β-D-galactopyranosyl)-β-D-glucopyranoside (19) The same procedure as described for the preparation of **13** provided a crude product from 1,2,3,6-tetra-*O*-acetyl-4-*O*-(2,3,4,6-tetra-*O*-acetyl-β-D-galactopyranosyl)-β-D-glucopyranose (**18**) (192 mg, 0.28 mmol), ethylene glycol dodecyl ether (98 mg, 0.43 mmol) and TMSOTf (69 mg, 0.31 mmol), and this was purified by column chromatography with 10:1 $CHCl_3$–CH_3COCH_3 to give **7** (141 mg, 59%) as an amorphous powder. $[\alpha]_D$ +7.0° (c=0.27, $CHCl_3$). IR (neat): 1751, 1113 cm^{-1}. ^{1}H-NMR ($CDCl_3$) δ: 0.88 (3H, t, J=6.9 Hz, $OC_{11}H_{22}C\underline{H}_3$), 1.26 (18H, br s, $OCH_2CH_2(C\underline{H}_2)_9CH_3$), 1.54 (2H, m, $OCH_2C\underline{H}_2C_{10}H_{21}$), 1.96, 2.04, 2.05, 2.06, 2.12, 2.15 (21H, s, $OCOC\underline{H}_3$ ×7), 3.41 (2H, t, J=6.3 Hz, $OC\underline{H}_2C_{11}H_{23}$), 4.11 (4H, m, Gal-H6, Glu-H6), 4.50 (1H, d, J=8.3 Hz, H-1), 4.57 (1H, d, J=7.8 Hz, Gal-H1), 4.90 (1H, dd, J=8.3, 9.3 Hz, Glu-H2), 4.96 (1H, dd, J=3.4, 10.7 Hz, Gal-H3), 5.11 (1H, dd, J=7.8, 10.7 Hz, Gal-H2), 5.20 (1H, t, J=9.3 Hz, Glu-H3). *Anal.* Calcd for $C_{40}H_{58}O_{19} \cdot H_2O$: C, 55.81; H, 7.02. Found: C, 55.89; H, 7.68.

2-(Dodecyloxy)ethyl 4-*O*-(β-D-Galactopyranosyl)-β-D-glucopyranoside (20) The same procedure as described for the preparation of **14** provided a crude product from **19** (141 mg, 0.17 mmol), and this was purified by column chromatography with 5:1 $CHCl_3$–MeOH to give **20** (42 mg, 46%), mp 133—137 °C. $[\alpha]_D$ +2.4° (c=0.36, MeOH). IR (KBr): 3395, 1110 cm^{-1}. ^{1}H-NMR ($CDCl_3$) δ: 0.88 (3H, t, J=7.0 Hz, $OC_{11}H_{22}C\underline{H}_3$), 1.26 (18H, br s, $OCH_2CH_2(C\underline{H}_2)_9CH_3$), 1.60 (2H, m, $OCH_2C\underline{H}_2C_{10}H_{21}$), 4.32 (1H, d, J=7.9 Hz, Glu-H1), 4.37 (1H, d, J=8.0 Hz, Gal-H1). Positive FAB-MS m/z: 555 $(M+H)^+$, 577 $(M+Na)^+$ 593 $(M+K)^+$.

2-(Dodecyloxy)ethyl 2,3,6-Tri-*O*-sulfo-4-*O*-(2,3,4,6-tetra-*O*-sulfo-β-D-galactopyranosyl)-β-D-glucopyranoside (3) The same procedure as described for the preparation of **1** provided a crude product from **20** (42 mg, 0.076 mmol) and sulfur trioxide–trimethylamine complex (149 mg, 1.07 mmol), followed by TFA (122 mg, 1.07 mmol), and this was purified on a column of Sephadex LH-20 equilibrated in and eluted with 20:20:1 (v/v) $CHCl_3$–MeOH–H_2O to give **3** (52 mg, 61%) as a colorless amorphous solid after lyophilization from H_2O. $[\alpha]_D$ +16.7° (c=0.24, MeOH). IR (KBr): 1218, 1132, 812 cm^{-1}. ^{1}H-NMR ($CDCl_3$) δ: 0.88 (3H, t, J=6.3 Hz, $OC_{11}H_{22}C\underline{H}_3$), 1.26 (18H, br s, OCH_2CH_2-$(C\underline{H}_2)_9CH_3$). *Anal.* Calcd for $C_{26}H_{50}O_{33}S_7 \cdot 6 \times N(CH_3)_3$: C, 35.96; H, 7.13; N, 5.72. Found: C, 35.55; H, 8.01; N, 5.92.

3-Iodo-1-*O*-tetrahydropyranylpropanol (22) 3,4-Dihydro-2*H*-pyran (THP) (9.76 g, 116 mmol) was added dropwise to a stirred mixture of 3-iodo-1-propanol (**21**) (10.8 g, 58.2 mmol) and pyridinium toluene-*p*-sulfonic acid (PPTS) (0.73 g, 29.1 mmol) in dry CH_2Cl_2 (100 ml) at 0 °C and was kept at 0 °C overnight, after which it was washed with saturated aqueous $NaHCO_3$ and saturated aqueous NaCl, dried ($MgSO_4$), and evaporated to dryness. Chromatography of the residual oil on a column of SiO_2 with 2:1 hexane–EtOAc gave **22** (14.8 g, 94%). IR (neat): 1182, 1131, 1644 cm^{-1}. ^{1}H-NMR ($CDCl_3$) δ: 2.10 (2H, m, $-CH_2-$), 1.50—1.92 (6H, m, THP), 3.30 (2H, t, J=6.8 Hz, $-CH_2I$), 3.43 (2H, t, J=5.9 Hz, THP), 3.79 (2H, t, J=5.9 Hz, $C\underline{H}_2$OTHP), 4.61 (1H, t, J=3.4 Hz, THP).

1-*O*-Tetrahydropyranyl-3-*O*-docosylpropanediol (23) A solution of 1-docosanol (17.9 g, 54.8 mmol) in dry tetrahydrofuran (THF, 30 ml) was added to an ice-cooled solution of NaH (1.97 g, 82.2 mmol, 60% dispersion in oil) in DMF (100 ml) under an argon atmosphere. The mixture was stirred for 1 h at room temperature, then **22** (14.8 g, 54.8 mmol) was added dropwise and stirring was continued for 4 d at 60 °C. After being cooled to room temperature, the mixture was partitioned between CH_2Cl_2 and water. The organic phase was washed with water, dried ($MgSO_4$), and evaporated to dryness. Chromatography of the residual oil on a column of SiO_2 with 10:1 hexane–EtOAc gave **23** (3.08 g, 12%) as an oil. IR (neat): 1647, 1118, 1057 cm^{-1}. ^{1}H-NMR ($CDCl_3$) δ: 0.88 (3H, t, J=5.4 Hz, $O(CH_2)_{21}C\underline{H}_3$), 1.25 (38H, s,

$OCH_2CH_2(C\underline{H}_2)_{19}CH_3$), 1.43—1.82 (8H, m, THP, $OCH_2C\underline{H}_2C_{20}H_{41}$), 1.87 (2H, m, $OCH_2C\underline{H}_2CH_2O$), 3.40 (2H, t, J=6.3 Hz, $OC\underline{H}_2C_{21}H_{43}$), 3.50 (2H, t, J=6.3 Hz, $C\underline{H}_2OC_{22}H_{45}$), 3.51 (2H, t, J=6.6 Hz, THP), 3.84 (2H, t, J=6.4 Hz, $-CH_2O-$), 4.59 (1H, t, J=2.5 Hz, THP).

3-Docosyloxy-1-propanol (24) A mixture of **23** (3.08 g, 6.57 mmol) and PPTS (0.165 g, 0.66 mmol) in ethanol (30 ml) was heated at 55 °C for 3 h. The solution was cooled, then saturated aqueous $NaHCO_3$ was added and the whole was extracted with ether. The extract was washed with water, dried ($MgSO_4$) and evaporated to dryness. Chromatography of the residue on a column of SiO_2 with 10:1 hexane–EtOAc gave **24** (1.07 g, 43%), mp 57—61 °C. IR (KBr): 3382, 1024 cm^{-1}. ^{1}H-NMR ($CDCl_3$) δ: 0.88 (3H, t, J=6.8 Hz, $O(CH_2)_{21}C\underline{H}_3$), 1.25 (38H, br s, $OCH_2CH_2(C\underline{H}_2)_{19}CH_3$), 1.55 (2H, m, $OCH_2C\underline{H}_2C_{19}H_{39}$), 1.83 (2H, m, $OCH_2C\underline{H}_2CH_2O$), 3.43 (2H, t, J=6.4 Hz, $OC\underline{H}_2C_{21}H_{43}$), 3.62 (2H, t, J=5.4 Hz, $C\underline{H}_2OC_{22}H_{45}$), 3.78 (2H, t, J=5.5 Hz, $-C\underline{H}_2OH$). Positive FAB-MS m/z: 385 $(M+H)^+$.

3-(Docosyloxy)propyl 2,3,4,6-Tetra-*O*-acetyl-β-D-glucopyranoside (25) The same procedure as described for the preparation of **13** provided a crude product from 1,2,3,4,6-penta-*O*-acetyl-β-D-glucopyranose (**12**) (201 mg, 0.52 mmol), **24** (298 mg, 0.77 mmol) and TMSOTf (126 mg, 0.57 mmol), and this was purified by column chromatography with 10:1 $CHCl_3$–CH_3COCH_3 to give **17** (55 mg, 15%) as white prisms, mp 63—65 °C. $[\alpha]_D$ +44.1° (c=0.03, $CHCl_3$). IR (KBr): 1744, 1059 cm^{-1}. ^{1}H-NMR ($CDCl_3$) δ: 0.88 (3H, t, J=7.3 Hz, $O(CH_2)_{21}C\underline{H}_3$), 1.25 (38H, br s, $OCH_2CH_2(C\underline{H}_2)_{19}CH_3$), 1.58 (2H, m, $OCH_2C\underline{H}_2C_{20}H_{41}$), 1.83 (2H, m, $OCH_2C\underline{H}_2CH_2O$), 2.00, 2.02, 2.04, 2.09 (each 3H, s, $OCOCH_3\times4$), 3.38 (2H, t, J=7.8 Hz, $OC\underline{H}_2C_{21}H_{43}$), 3.44 (2H, t, J=6.4 Hz, $C\underline{H}_2OC_{22}H_{45}$), 4.13 (1H, dd, J=2.4, 14.4 Hz, H-6a), 4.27 (1H, dd, J=4.8, 14.4 Hz, H-6b), 4.48 (1H, d, J=8.3 Hz, H-1), 4.98 (1H, dd, J=8.3, 9.2 Hz, H-2), 5.08 (1H, t, J=9.2 Hz, H-4), 5.20 (1H, t, J=9.2 Hz, H-3).

3-(Docosyloxy)propyl β-D-Glucopyranoside (26) The same procedure as described for the preparation of **14** provided a crude product from **25** (55 mg, 0.077 mmol) and NH_4OH–MeOH (1:20), and this was purified by column chromatography with 5:1 $CHCl_3$–MeOH to give **26** (19 mg, 46%) as a white powder, mp 67—69 °C. $[\alpha]_D$ +47.5° (c=0.10, MeOH). IR (KBr): 3384, 1038 cm^{-1}. ^{1}H-NMR ($CDCl_3$) δ: 0.88 (3H, t, J=6.8 Hz, $O(CH_2)_{21}C\underline{H}_3$), 1.25 (38H, br s, $OCH_2CH_2(C\underline{H}_2)_{19}CH_3$), 1.55 (2H, m, $OCH_2C\underline{H}_2C_{20}H_{41}$), 1.88 (2H, m, $OCH_2C\underline{H}_2CH_2O$), 3.39 (2H, t, J=6.8 Hz, $OC\underline{H}_2C_{21}H_{43}$), 3.52 (2H, t, J=5.9 Hz, $C\underline{H}_2OC_{22}H_{45}$), 4.32 (1H, d, J=7.3 Hz, Glu-H1). ^{13}C-NMR ($CDCl_3$) δ: 14.1 (q, $OC_{21}H_{42}\underline{C}H_3$), 22.7, 26.2, 29.4, 29.6, 29.7, 31.9 (t, $OCH_2(\underline{C}H_2)_{20}CH_3$), 29.7 (t, $OCH_2\underline{C}H_2CH_2O$), 61.6 (t, C-6), 67.6 (t, $\underline{C}H_2OC_{22}H_{45}$), 69.7 (d, C-4), 71.2 (t, $O\underline{C}H_2CH_2CH_2OC_{22}H_{45}$), 73.5 (d, C-2), 75.6 (d, C-3), 77.2 (d, C-5), 102.9 (d, C-1). Positive FAB-MS m/z: 547 $(M+H)^+$, 569 $(M+Na)^+$, 585 $(M+K)^+$.

3-(Docosyloxy)propyl 2,3,4,6-Tetra-*O*-sulfo-β-D-glucopyranoside (4) The same procedure as described for the preparation of **1** provided a crude product from **26** (19 mg, 0.036 mmol) and sulfur trioxide–trimethylamine complex (40 mg, 0.029 mmol), followed by treatment with CF_3CO_2H (25 mg, 0.22 mmol), and this was purified on a column of Sephadex LH-20 equilibrated in and eluted with 20:20:1 (v/v) $CHCl_3$–MeOH–H_2O to give **4** (13 mg, 33%) as an amorphous solid. $[\alpha]_D$ +0.3° (c=0.37, MeOH). IR (KBr): 1250, 1109, 812 cm^{-1}. ^{1}H-NMR ($CDCl_3$) δ: 0.88 (3H, t, J=6.9 Hz, $OC_{21}H_{42}C\underline{H}_3$), 1.25 (38H, br s, $OCH_2CH_2(C\underline{H}_2)_{19}CH_3$), 1.53 (2H, m, $OCH_2C\underline{H}_2C_{20}H_{41}$), 1.86 (2H, m, $OCH_2C\underline{H}_2CH_2OC_{22}H_{45}$), 2.89 (9H, s, $HN^+\underline{Me}_3$). ^{13}C-NMR ($CDCl_3$) δ: 14.1 (q, $OC_{21}H_{42}\underline{C}H_3$), 19.0, 22.7, 26.2, 29.4, 29.7, 29.8, 32.0 (t, $OCH_2(\underline{C}H_2)_{20}CH_3$).

3-(Docosyloxy)propyl 2,3,4,6-Tetra-*O*-acetyl-β-D-galactopyranoside (27) The same procedure as described for the preparation of **13** provided a crude product from 1,2,3,4,6-penta-*O*-acetyl-β-D-galactopyranose (**15**) (212 mg, 0.55 mmol), **24** (314 mg, 0.82 mmol) and TMSOTf (200 mg, 0.90 mmol), and this was purified by column chromatography with 10:1 $CHCl_3$–CH_3COCH_3 to give **27** (79 mg, 20%) as an amorphous solid. $[\alpha]_D$ +41.5° (c=0.12, $CHCl_3$). IR (neat): 1754, 1055 cm^{-1}. ^{1}H-NMR ($CDCl_3$) δ: 0.88 (3H, t, J=6.8Hz, $O(CH_2)_{21}C\underline{H}_3$), 1.26 (38H, br s, $OCH_2CH_2(C\underline{H}_2)_{19}CH_3$), 1.58 (2H, m, $OCH_2C\underline{H}_2C_{20}H_{41}$), 1.84 (2H, m, $OCH_2C\underline{H}_2CH_2O$), 2.04, 2.05, 2.06, 2.15 (each 3H, s, $OCOCH_3\times4$), 3.38 (2H, t, J=6.0 Hz, $OC\underline{H}_2C_{21}H_{43}$), 3.44 (2H, t, J=7.9 Hz, $C\underline{H}_2OC_{22}H_{45}$), 3.61 (1H, d, J=8.7 Hz, $OC\underline{H}_aH_bCH_2CH_2O$), 3.90 (1H, d, J=7.4 Hz, $OCH_a\underline{H}_bCH_2CH_2O$), 4.46 (1H, d, J=8.2 Hz, H-1), 5.02 (1H, dd, J=5.9, 15.6 Hz, H-3), 5.20 (1H, dd, J=5.9, 8.2 Hz, H-2), 5.39 (1H, d, J=3.6 Hz, H-4).

3-(Docosyloxy)propyl β-D-Galactopyranoside (28) The same procedure as described for the preparation of **14** provided a crude product from **27** (79 mg, 0.11 mol) and NH_4OH–MeOH (1:20), and this was purified by column chromatography with 5:1 $CHCl_3$–MeOH to give **28** (32 mg, 53%). $[\alpha]_D$ +19.3° (c=0.13, MeOH). IR (neat): 3418, 1055 cm^{-1}. ^{1}H-NMR ($CDCl_3$) δ: 0.88 (3H, t, J=7.3 Hz, $O(CH_2)_{21}C\underline{H}_3$), 1.26 (38H, br s, $OCH_2CH_2(C\underline{H}_2)_{19}CH_3$), 1.56 (2H, m, $OCH_2C\underline{H}_2C_{20}H_{41}$), 1.88 (2H, m, $OCH_2C\underline{H}_2CH_2O$). ^{13}C-NMR ($CDCl_3$) δ: 14.2 (q, $OC_{21}H_{42}\underline{C}H_3$), 18.1, 19.8, 22.8, 26.2, 27.2, 29.5, 29.7, 29.8, 30.2, 32.1, 32.9, 37.2 (t, $OCH_2(\underline{C}H_2)_{20}CH_3$), 29.8 (t, $OCH_2\underline{C}H_2CH_2O$), 61.6 (t, C-6), 67.4 (t, $\underline{C}H_2OC_{22}H_{45}$), 67.8 (d, C-2), 69.2 (d, C-4), 71.6 (t, $O\underline{C}H_2CH_2CH_2O$-$C_{22}H_{45}$), 73.8 (d, C-3), 74.9 (d, C-5), 103.6 (d, C-1). Positive FAB-MS m/z: 547 $(M+H)^+$, 569 $(M+Na)^+$, 585 $(M+K)^+$.

3-(Docosyloxy)propyl 2,3,4,6-Tetra-*O*-sulfo-β-D-galactopyranoside (5) The same procedure as described for the preparation of **1** provided a crude product from **28** (32 mg, 0.058 mmol) and sulfur trioxide–trimethylamine complex (65 mg, 0.47 mmol), followed by treatment with CF_3CO_2H (40 mg, 0.35 mmol), and this was purified on a column of Sephadex LH-20 equilibrated in and eluted with 20:20:1 (v/v) $CHCl_3$–MeOH–H_2O to give **5** (27 mg, 42%) as an amorphous solid. $[\alpha]_D$ +14.7° (c=0.24, MeOH). IR (KBr): 1268, 1055, 756 cm^{-1}. ^{1}H-NMR ($CDCl_3$) δ: 0.88 (3H, t, J=6.8 Hz, $OC_{21}H_{42}C\underline{H}_3$), 1.25 (38H, br s, $OCH_2CH_2(C\underline{H}_2)_{19}CH_3$), 1.55 (2H, m, $OCH_2C\underline{H}_2C_{20}H_{41}$), 1.87 (2H, m, $OCH_2C\underline{H}_2CH_2O$–). ^{13}C-NMR ($CDCl_3$) δ: 14.1 (q, $OC_{21}H_{42}\underline{C}H_3$), 22.7, 29.4, 29.7, 29.8, 31.9 (t, $OCH_2(\underline{C}H_2)_{20}CH_3$), 107.3 (d, C-1).

3-(Dodecyloxy)propyl 4-*O*-(2,3,4,6-Tetra-*O*-acetyl-β-D-galactopyranosyl)-2,3,6-tri-*O*-acetyl-β-D-glucopyranoside (29) The same procedure as described for the preparation of **13** provided a crude product from **18** (119 mg, 0.18 mmol), **24** (73 mg, 0.19 mmol) and TMSOTf (43 mg, 0.19 mmol), and this was purified by column chromatography with 10:1 $CHCl_3$–CH_3COCH_3 to give **29** (126 mg, 72%) as an amorphous solid, mp 44—45 °C. $[\alpha]_D$ +16.7° (c=0.19, $CHCl_3$). IR (KBr): 1751, 1370, 1052, 1637 cm^{-1}. ^{1}H-NMR ($CDCl_3$) δ: 0.88 (3H, t, J=6.9 Hz, $O(CH_2)_{21}C\underline{H}_3$), 1.25 (38H, br s, $OCH_2CH_2(C\underline{H}_2)_{19}CH_3$), 1.54 (2H, m, $OCH_2C\underline{H}_2C_{20}H_{41}$), 1.83 (2H, m, $OCH_2C\underline{H}_2CH_2O$), 1.97, 2.04, 2.05, 2.06, 2.12, 2.15 (21H, s, $OCOCH_3\times7$), 3.43 (2H, dd, J=4.5, 6.0 Hz, $OC\underline{H}_2C_{21}H_{43}$), 3.60 (2H, t, J=7.4 Hz, $C\underline{H}_2OC_{22}H_{45}$), 3.79 (1H, t, J=9.6 Hz, Glu-H5), 3.86—3.92 (2H, m, Gal-H5, Glu-H4), 4.46 (1H, d, J=7.8 Hz, Glu-H1), 4.49 (1H, d, J=7.8 Hz, Gal-H1), 4.89 (1H, t, J=7.8 Hz, Glu-H2), 4.96 (1H, dd, J=3.3, 10.1 Hz, Gal-H_3), 5.11 (1H, dd, J=7.8, 10.1 Hz, Gal-H2), 5.19 (1H, t, J=7.8 Hz, Glu-H3), 5.33 (1H, dd, J=3.3, 14.2 Hz, Gal-H4). *Anal.* Calcd for $C_{51}H_{80}O_{19}\cdot5H_2O$: C, 56.34; H, 8.34. Found: C, 55.98; H, 8.11.

3-(Dodecyloxy)propyl 4-*O*-(β-D-Galactopyranosyl)-β-D-glucopyranoside (30) The same procedure as described for the preparation of **14** provided a crude product from **29** (126 mg, 0.13 mmol) and NH_4OH–MeOH (1:20), and this was purified by column chromatography with 5:1 $CHCl_3$–MeOH to give **30** (26 mg, 29%) as a white powder, mp 153—156 °C. $[\alpha]_D$ +6.8° (c=0.96, MeOH). IR (KBr): 1114, 1639 cm^{-1}. ^{13}C-NMR ($CDCl_3$) δ: 14.2 (q, $OC_{21}H_{42}C\underline{H}_3$), 19.9, 23.0, 25.8, 26.5, 29.7, 29.8, 29.9, 30.0, 30.1, 30.3, 32.3, 34.8, 39.2 (t, $OCH_2(\underline{C}H_2)_{20}CH_3$), 32.3 (t, $OCH_2\underline{C}H_2CH_2O$), 61.6 (t, Gal-C6), 62.0 (t, Glu-C6), 68.0 (d, Gal-C4), 69.5 (d, Gal-C2), 71.5 (t, $O\underline{C}H_2CH_2\underline{C}H_2O$), 73.7 (d, Glu-C2), 73.9 (d, Gal-C3), 75.3 (d, Glu-C5), 75.9 (d, Glu-C3), 78.0 (d, Gal-C5), 80.4 (d, Glu-C4), 103.3 (d, Glu-C1), 104.2 (d, Gal-C1). Positive FAB-MS m/z: 732 $(M+Na)^+$.

3-(Dodecyloxy)propyl 4-*O*-(2,3,4,6-Tetra-*O*-sulfo-β-D-galactopyranosyl)-2,3,6-tri-*O*-sulfo-β-D-glucopyranoside (6) The same procedure as described for the preparation of **1** provided a crude product from **30** (26 mg, 0.037 mmol) and sulfur trioxide–trimethylamine complex (71 mg, 0.051 mmol), followed by treatment with CF_3CO_2H (44 mg, 0.38 mmol), and this was purified on a column of Sephadex LH-20 equilibrated in and eluted with 20:20:1 (v/v) $CHCl_3$–MeOH–H_2O to give **6** (17 mg, 28%) as an amorphous solid. $[\alpha]_D$ −23.7° (c=0.13, MeOH). IR (KBr): 1215, 1051, 757 cm^{-1}. ^{1}H-NMR ($CDCl_3$) δ: 0.88 (3H, t, J=6.9 Hz, $OC_{21}H_{42}C\underline{H}_3$), 1.25 (38H, br s, $OCH_2CH_2(C\underline{H}_2)_{19}CH_3$), 1.54 (2H, m, $OCH_2C\underline{H}_2C_{20}H_{41}$), 1.85 (2H, m, $OCH_2C\underline{H}_2CH_2O$).

2-Isopropyl-5-benzyloxymethyl-1,3-dioxane (32) A solution of 2-isopropyl-5-hydroxymethyl-1,3-dioxane (*cis*, *trans* mixture) (**31**) (8.20 g, 0.052 mol) in dry THF (50 ml) was added portionwise to an ice-cooled solution of sodium hydride (2.00 g, 0.082 mol, 60% dispersion in oil) and *n*-tetrabutylammonium iodide (6.10 g, 0.016 mol) in dry THF (100 ml) under argon. The mixture was stirred at room temperature for 1 h, then benzyl bromide (18.8 g, 0.11 mol) was added dropwise to it at 0 °C and

the whole was left overnight at room temperature. The reaction was quenched with MeOH and the mixture was concentrated under reduced pressure. The residue was extracted with ether, and the ethereal layer was washed with brine. The organic layer was dried over $MgSO_4$, and concentrated to an oil, which was applied to a column of silica gel and eluted with 5:1 *n*-hexane–EtOAc to give **32** (12.6 g, 94%) as an oil. IR (neat): 2958, 2918, 2852, 1039, 1112, 736, 698 cm^{-1}. ^{1}H-NMR ($CDCl_3$) δ: 0.91 (6H, d, J=6.9 Hz, $CHCH(C\underline{H}_3)_2$), 1.62 (1H, m, $C\underline{H}CH_2OCH_2Ph$), 1.76 (1H, m, $CHC\underline{H}(CH_3)_2$), 3.77 (2H, d, J=7.8 Hz, $CHC\underline{H}_2OCH_2Ph$), 3.82 (2H, m, $CHC\underline{H}_aH_bOCH$), 4.07 (2H, dd, J=1.5, 11.7 Hz, $CHCH_a\underline{H}_bOCH$), 4.24 (1H, d, J=4.4 Hz, $C\underline{H}CH(CH_3)_2$), 4.54 (2H, s, $OC\underline{H}_2Ph$), 7.28 (5H, m, Ph). *Anal.* Calcd for $C_{14}H_{20}O_3$: C, 71.58; H, 8.53. Found: C, 71.77; H, 9.06.

2-Benzyloxymethyl-1,3-propanediol (33) Compound **32** (12.6 g, 0.05 mol) was dissolved in 1 N HCl (90 ml) and MeOH (180 ml). The mixture was refluxed for 3 h, neutralized with 1 N NaOH, diluted with CH_2Cl_2, and washed with brine. The organic phase was dried over $MgSO_4$, and concentrated under reduced pressure. The residual oily product was applied to a column of silica gel and eluted with 5:1 *n*-hexane–AcOEt to give **32** (4.50 g, 50%) as an oil. IR (neat): 3384, 1029, 1074, 738, 697 cm^{-1}. ^{1}H-NMR ($CDCl_3$) δ: 2.00 (1H, m, $CH_2C\underline{H}(CH_2OH)$), 3.40 (2H, br s, $CH(CH_2O\underline{H})_2$), 3.55 (2H, d, J=6.0 Hz, $CHC\underline{H}_2OCH_2Ph$), 3.72 (4H, d, J=6.0 Hz, $CH(CH_2O\underline{H})_2$), 4.47 (2H, s, $OC\underline{H}_2Ph$), 7.29 (5H, m, Ph). *Anal.* Calcd for $C_{11}H_{16}O_3 \cdot 1/3H_2O$: C, 65.33; H, 8.31. Found: C, 65.65; H, 8.41.

2-Benzyloxymethyl-1,3-dimyristylpropanediol (34) A solution of **33** (1.20 g, 6.59 mol) in dry THF (10 ml) was added to an ice-cooled solution of sodium hydride (0.63 g, 26.4 mol) and *n*-tetrabutylammonium iodide (1.46 g, 3.95 mmol) in dry THF (50 ml) under argon. The mixture was stirred at room temperature for 1 h, then myristyl bromide (5.48 g, 19.8 mmol) was added dropwise at 0 °C and the reaction mixture was left overnight at room temperature. The reaction was quenched with MeOH and the mixture was concentrated under reduced pressure. The residue was extracted with ether, and the ethereal layer was washed with brine. The organic layer was dried over $MgSO_4$, and concentrated to an oil, which was applied to a column of silica gel and eluted with 5:1 *n*-hexane–EtOAc to give **34** (2.70 g, 69%) as an oil. IR (neat): 1027, 1109, 733, 697 cm^{-1}. ^{1}H-NMR ($CDCl_3$) δ: 0.88 (6H, t, J=6.6 Hz, $OC_{13}H_{26}C\underline{H}_3 \times 2$), 1.25 (44H, br s, $OCH_2CH_2(C\underline{H}_2)_{11}CH_3 \times 2$), 1.53 (4H, m, $OCH_2C\underline{H}_2C_{12}H_{25} \times 2$), 2.20 (1H, m, $OCH_2C\underline{H}(CH_2OC_{14}H_{29})_2$), 3.38 (4H, t, J=6.6 Hz, $OC\underline{H}_2C_{13}H_{27} \times 2$), 3.47 (4H, d, J=5.9 Hz, $OCH_2CH(C\underline{H}_2OC_{14}H_{29})_2 \times 2$), 3.53 (2H, d, J=5.9 Hz, $OC\underline{H}_2CH(CH_2OC_{14}H_{29})_2$), 4.49 (2H, s, $OC\underline{H}_2C_6H_5$), 7.31 (5H, m, $OCH_2C_6\underline{H}_5$). *Anal.* Calcd for $C_{39}H_{72}O_3$: C, 79.53; H, 12.32. Found: C, 79.61; H, 12.19.

2-Hydroxymethyl-1,3-*O*-dimyristyl-1,3-propanediol (35) A mixture of **34** (2.70 g, 4.70 mmol) and 10% Pd-on-charcol (0.27 g) suspended in EtOH (30 ml) was hydrogenated for 3 h at room temperature under atmospheric pressure, then filtered, and the filtrate was concentrated to dryness. The residue was column-chromatographed with *n*-hexane–EtOAc (5:1) to give **35** (2.00 g, 88%) as a white powder, mp 52—54 °C. IR (KBr): 3342, 1036 cm^{-1}. ^{1}H-NMR ($CDCl_3$) δ: 0.88 (6H, t, J=6.6 Hz, $OC_{13}H_{26}C\underline{H}_3 \times 2$), 1.26 (44H, br s, $OCH_2CH_2(C\underline{H}_2)_{11}CH_3 \times 2$), 1.56 (4H, m, $OCH_2C\underline{H}_2C_{12}H_{25} \times 2$), 2.10 (1H, m, $HOCH_2C\underline{H}(CH_2OC_{14}H_{29})_2$), 2.94 (1H, br, $CH_2O\underline{H}$), 3.41 (4H, t, J=6.6 Hz, $OC\underline{H}_2C_{13}H_{27} \times 2$), 3.76 (2H, t, J=5.2 Hz, $C\underline{H}_2OH$). *Anal.* Calcd for $C_{32}H_{66}O_3$: C, 77.04; H, 13.33. Found: C, 77.40; H, 13.51. Positive FAB-MS *m/z*: 500 $(M+H)^+$.

2-*O*-(2,3,4,6-Tetra-*O*-acetyl-β-D-glucopyranosyl)methyl-1,3-*O*-dimyristylpropanediol (37) A solution of 2,3,4,6-tetra-*O*-acetyl-D-glucopyranosyl bromide (**36**) (111 mg, 0.29 mmol) in $ClCH_2CH_2Cl$ (1 ml) was added to a suspension of **35** (71 mg, 0.15 mmol), $HgBr_2$ (106 mg, 0.29 mmol) and MS4 Å in $ClCH_2CH_2Cl$ (5 ml). The mixture was stirred overnight at room temperature, then filtered, and the filtrate was diluted with $ClCH_2CH_2Cl$. The mixture was successively washed with 10% aqueous KI and brine, then dried ($MgSO_4$) and concentrated to a syrup. This was column-chromatographed with *n*-hexane–EtOAc (5:1) to give **37** (63 mg, 52%) as an oil. $[\alpha]_D$ −9.1° (c=0.21, $CHCl_3$). IR (neat): 1742, 1107 cm^{-1}. ^{1}H-NMR ($CDCl_3$) δ: 0.88 (6H, t, J=6.8 Hz, $OC_{13}H_{26}C\underline{H}_3 \times 2$), 1.26 (44H, br s, $OCH_2CH_2(C\underline{H}_2)_{11}CH_3 \times 2$), 1.53 (4H, m, $OCH_2C\underline{H}_2C_{12}H_{25} \times 2$), 2.00, 2.02, 2.04, 2.09 (each 3H, s, $OCOC\underline{H}_3 \times 4$), 2.10 (1H, m, $OCH_2C\underline{H}(CH_2OC_{14}H_{29})_2$), 3.68 (1H, m, H-5), 4.12 (1H, dd, J=2.5, 12.2 Hz, H-6$_a$), 4.28 (1H, dd, J=4.9, 12.2 Hz, H-6$_b$), 4.47 (1H, d, J=8.3 Hz, H-1), 4.99 (1H, dd, J=8.3, 9.7 Hz, H-2), 5.08 (1H, t, J=9.3 Hz, H-4), 5.19 (1H, dd, J=9.3, 9.7 Hz, H-3). Positive FAB-MS *m/z*: 830 $(M+H)^+$, 852 $(M+Na)^+$.

2-*O*-(β-D-Glucopyranosyl)methyl-1,3-dimyristylpropanediol (38) A solution of **37** (63 mg, 0.076 mmol) in NH_4OH–MeOH (1:10) (10 ml) was stirred at room temperature overnight. It was concentrated to dryness under reduced pressure and the residual product was purified by column chromatography with *n*-hexane–EtOAc 2:1 to give **38** (50 mg, quant.) as a white powder, mp 60—63 °C. $[\alpha]_D$ −18.8° (c=0.40, MeOH). IR (KBr): 3392, 1102 cm^{-1}. ^{1}H-NMR ($CDCl_3$) δ: 0.88 (6H, J=6.8 Hz, $OC_{13}H_{26}C\underline{H}_3 \times 2$), 1.26 (44H, br s, $OCH_2CH_2(C\underline{H}_2)_{11}CH_3 \times 2$), 1.55 (4H, m, $OCH_2C\underline{H}_2C_{12}H_{25} \times 2$), 2.20 (1H, m, $OCH_2C\underline{H}(CH_2OC_{14}H_{29})_2$), 4.28 (1H, d, J=7.8 Hz, Glu-H1). ^{13}C-NMR ($CDCl_3$) δ: 14.1 (q, $OC_{13}H_{26}\underline{C}H_3 \times 2$), 22.7, 26.2, 29.4, 29.6, 29.7, 29.8, 32.0 (t, $OCH_2(\underline{C}H_2)_{12}CH_3 \times 2$), 40.2 (d, $OCH_2\underline{C}H(CH_2OC_{14}H_{29})_2$), 62.0 (t, C-6), 69.2 (t, $OCH_2CH(\underline{C}H_2OC_{14}H_{29})_2$), 69.4 (t, $O\underline{C}H_2CH(CH_2OC_{14}H_{29})_2$), 70.2 (d, C-4), 71.6 (t, $O\underline{C}H_2C_{13}H_{27} \times 2$), 73.7 (d, C-2), 75.9 (d, C-5), 76.4 (d, C-3), 103.3 (d, C-1). Positive FAB-MS *m/z*: 662 $(M+H)^+$, 684 $(M+Na)^+$.

2-*O*-(2,3,4,6-Tetra-*O*-sulfo-β-D-glucopyranosyl)methyl-1,3-dimyristylpropanediol (7) The same procedure described for the preparation of **1** provided a crude product from **38** (50 mg, 0.076 mmol) and sulfur trioxide–trimethylamine complex (96 mg, 0.61 mmol), followed by TFA (69 mg, 0.61 mmol), and this was purified on a column of Sephadex LH-20 equilibrated in and eluted with 20:20:1 (v/v) $CHCl_3$–MeOH–H_2O to give **7** (32 mg, 43%) as an amorphous solid. $[\alpha]_D$ +1.6° (c=0.81, MeOH). IR (neat): 1205, 1107, 799 cm^{-1}. ^{1}H-NMR ($CDCl_3$) δ: 0.88 (6H, br s, $OC_{13}H_{26}C\underline{H}_3 \times 2$), 1.25 (44H, br s, $OCH_2CH_2(C\underline{H}_2)_{11}CH_3 \times 2$), 1.50 (4H, br, $OCH_2C\underline{H}_2C_{12}H_{25} \times 2$). ^{13}C-NMR ($CDCl_3$) δ: 14.1 (q, $OC_{13}H_{26}\underline{C}H_3 \times 2$), 22.7, 26.2, 29.4, 29.5, 29.6, 29.7, 31.9 (t, $OCH_2(\underline{C}H_2)_{12}CH_3 \times 2$), 68.7 (t, $OCH_2CH(\underline{C}H_2OC_{14}H_{29})_2$), 71.0 (t, $O\underline{C}H_2CH(CH_2OC_{14}H_{29})_2$), 71.4, 71.6 (t, $O\underline{C}H_2C_{13}H_{27} \times 2$). Positive FAB-MS *m/z*: 923 $(M+Na-SO_3)^+$. *Anal.* Calcd for $C_{38}H_{76}O_{20}S_4 \cdot 1/3H_2O$: C, 46.23; H, 8.36. Found: C, 46.51; H, 7.81.

2-*O*-(2,3,4,6-Tetra-*O*-acetyl-β-D-galactopyranosyl)-1,3-dimyristylpropanediol (40) The same procedure described for the preparation of **37** provided a crude product from **40** (59 mg, 0.12 mmol), and 2,3,4,6-tetra-*O*-acetyl-D-galactopyranosyl bromide (**39**) (89 mg, 0.24 mmol) and $HgBr_2$ (85 mg, 0.24 mmol), and this was purified by column chromatography with *n*-hexane–EtOAc 5:1 to give **40** (62 mg, 65%) as a syrup. $[\alpha]_D$ +7.4° (c=0.39, $CHCl_3$). IR (neat): 1752, 1076 cm^{-1}. ^{1}H-NMR ($CDCl_3$) δ: 0.88 (6H, t, J=6.9 Hz, $OC_{13}H_{26}C\underline{H}_3 \times 2$), 1.26 (44H, br s, $OCH_2CH_2(C\underline{H}_2)_{11}CH_3 \times 2$), 1.56 (4H, m, $OCH_2C\underline{H}_2C_{12}H_{25} \times 2$), 1.98, 2.04, 2.05, 2.15 (each 3H, s, $OCOC\underline{H}_3 \times 4$), 3.57 (1H, dd, J=6.4, 10.0 Hz, H-5), 3.90 (1H, m, H-6$_a$), 4.14 (1H, m, H-6$_b$), 4.44 (1H, d, J=7.8 Hz, H-1), 4.50 (1H, dd, J=3.7, 10.6 Hz, H-3), 5.19 (1H, dd, J=7.8, 10.6 Hz, H-2), 5.38 (1H, d, J=2.3 Hz, H-4). Positive FAB-MS *m/z*: 830 $(M+H)^+$.

2-*O*-(β-D-Galactopyranosyl)methyl-1,3-*O*-dimyristylpropanediol (41) The same procedure as described for the preparation of **38** provided a crude product from **40** (63 mg, 0.076 mmol), and this was purified by column chromatography with *n*-hexane–EtOAc 2:1 to give **41** (50 mg, quant.) as a white powder, mp 69—71 °C. $[\alpha]_D$ −7.3° (c=0.37, MeOH). IR (KBr): 3392, 1074 cm^{-1}. ^{1}H-NMR ($CDCl_3$) δ: 0.88 (6H, J=6.8 Hz, $OC_{13}H_{26}C\underline{H}_3 \times 2$), 1.26 (44H, br s, $OCH_2CH_2(C\underline{H}_2)_{11}CH_3 \times 2$), 1.55 (4H, m, $OCH_2C\underline{H}_2C_{12}H_{25} \times 2$), 2.20 (1H, m, $OCH_2C\underline{H}(CH_2OC_{14}H_{29})_2$), 4.21 (1H, d, J=7.4 Hz, H-1). ^{13}C-NMR ($CDCl_3$) δ: 14.1 (q, $OC_{13}H_{26}\underline{C}H_3 \times 2$), 22.8, 26.2, 29.4, 29.6, 29.8, 32.0 (t, $OCH_2(\underline{C}H_2)_{12}CH_3 \times 2$), 40.3 (d, $OCH_2\underline{C}H(CH_2OC_{14}H_{29})_2$), 61.8 (t, C-6), 69.1 (d, C-4), 69.2 (t, $OCH_2CH(\underline{C}H_2OC_{14}H_{29})_2$), 69.4 (t, $O\underline{C}H_2CH(CH_2OC_{14}H_{29})_2$), 71.6 (d, C-2), 73.6 (d, C-3), 74.8 (d, C-5), 103.9 (d, C-1). Positive FAB-MS *m/z*: 661 $(M)^+$, 662 $(M+H)^+$.

2-*O*-(2,3,4,6-Tetra-*O*-sulfo-β-D-galactopyranosyl)-1,3-dimyristylpropanediol (8) The same procedure described for the preparation of **1** provided a crude product from **41** (50 mg, 0.076 mmol) and sulfur trioxide–trimethylamine complex (96 mg, 0.61 mmol), followed by TFA (69 mg, 0.61 mmol), and this was purified on a column of Sephadex LH-20 equilibrated in and eluted with 20:20:1 (v/v) $CHCl_3$–MeOH–H_2O to give **8** (22 mg, 30%) as an amorphous solid. $[\alpha]_D$ +6.8° (c=0.68, MeOH). IR (neat): 1251, 1101, 818 cm^{-1}. ^{1}H-NMR ($CDCl_3$) δ: 0.88 (6H, t, J=6.4 Hz, $OC_{13}H_{26}-C\underline{H}_3 \times 2$), 1.26 (44H, br s, $OCH_2CH_2(C\underline{H}_2)_{11}CH_3 \times 2$), 1.54 (4H, m, $OCH_2C\underline{H}_2C_{13}H_{27} \times 2$). ^{13}C-NMR ($CDCl_3$) δ: 13.9 (q, $OC_{13}H_{26}\underline{C}H_3 \times 2$), 22.5, 23.6, 25.5, 28.9, 29.2, 29.5, 31.8 (t, $OCH_2(\underline{C}H_2)_{12}CH_3$). Positive FAB-MS *m/z*: 981 $(M)^+$, 923 $(M+Na-SO_3)^+$. *Anal.* Calcd for $C_{38}H_{76}O_{20}S_4 \cdot 1/2H_2O$: C, 46.09; H, 7.94. Found: C, 46.51; H, 7.81.

***N*-Benzyloxycarbonyl-L-serine Myristylamide (43)** *N*-Carbobenzoxy-L-serine-2,4-dinitrophenol (**42**) (997 mg, 2.40 mmol) was added to a solution of myristylamine (614 mg, 2.88 mmol) and triethylamine (262 mg, 2.88 mmol) in CH_2Cl_2 (10 ml) at room temperature under argon. The mixture was stirred for 5 h, washed with aqueous $NaHCO_3$ and brine, dried ($MgSO_4$), filtered and evaporated to dryness. The residue was crystallized from *n*-hexane to afford **43** (675 mg, 65%) as a white powder, mp 108—112 °C. $[\alpha]_D$ −7.3° (*c*=0.34, $CHCl_3$). IR (KBr): 3274, 1647, 1071, 720, 691 cm^{-1}. ^{1}H-NMR ($CDCl_3$) δ: 0.88 (3H, t, *J*=6.4 Hz, $C_{13}H_{26}C\underline{H}_3$), 1.25 (22H, s, $(C\underline{H}_2)_{11}CH_3$), 1.47 (2H, m, $C\underline{H}_2C_{12}H_{25}$), 3.23 (2H, m, $C\underline{H}_2C_{13}H_{27}$), 3.65 (1H, m, $C\underline{H}CH_2OH$), 4.15 (2H, m, $CHC\underline{H}_2OH$), 5.14 (2H, s, $C\underline{H}_2C_6H_5$), 7.36 (5H, m, $CH_2C_6\underline{H}_5$). *Anal.* Calcd for $C_{25}H_{42}N_2O_4$: C, 69.09; H, 9.74; N, 6.45. Found: C, 69.32; H, 9.76; N, 6.34.

L-Serine Myristylamide (44) A mixture of **43** (323 mg, 0.74 mmol) and 10% Pd–C (0.10 g) in MeOH (10 ml) was stirred under H_2 overnight at room temperature. The catalyst was removed by filtration and the filtrate was concentrated to dryness to give **44** (400 mg, quant.). Compound **44** was used for the subsequent acylation without further purification. ^{1}H-NMR ($CDCl_3$) δ: 0.88 (3H, t, *J*=6.4 Hz, $C_{13}H_{26}C\underline{H}_3$), 1.26 (22H, br s, $(C\underline{H}_2)_{11}CH_3$), 1.51 (2H, m, $C\underline{H}_2C_{12}H_{25}$), 3.25 (2H, m, $C\underline{H}_2C_{13}H_{27}$), 3.42 (1H, t, *J*=5.5 Hz, $C\underline{H}CH_2OH$), 3.69 (1H, dd, *J*=6.0, 10.6 Hz, $CHC\underline{H}_aOH$), 3.86 (1H, dd, *J*=5.1, 10.6 Hz, $CHC\underline{H}_bOH$).

***N*-Stearoyl-L-serine Myristylamide (45)** A solution of stearoyl chloride (304 mg, 1.00 mmol) in ether (2 ml) was added to a stirred solution of **44** (232 mg, 0.77 mmol) and $NaHCO_3$ (260 mg, 3.09 mmol) in H_2O (10 ml) at room temperature. Stirring was continued overnight, and the solid that separated was collected by filtration, washed with ether and water, and dried *in vacuo*. Crystallization from acetone gave **45** (546 mg, quant.) as an amorphous powder. ^{1}H-NMR ($CDCl_3$) δ: 0.88 (6H, t, *J*=6.4 Hz, $C_{13}H_{26}C\underline{H}_3$, $C_{16}H_{32}C\underline{H}_3$), 1.26 (50H, br s, $(C\underline{H}_2)_{11}CH_3$, $(CH_2)_{14}C\underline{H}_3$), 1.49 (2H, br s, $C\underline{H}_2C_{12}H_{25}$), 1.62 (2H, br s, $C\underline{H}_2(CH_2)_{14}CH_3$), 2.23 (2H, br s, $C\underline{H}_2C_{16}H_{33}$), 3.22 (2H, br s, $C\underline{H}_2C_{13}H_{27}$), 3.41 (1H, br s, $HOCH_2C\underline{H}$–), 3.56 (1H, m, $HOC\underline{H}_aCH$–), 3.94 (1H, d, *J*=8.9 Hz, $HOCHC\underline{H}_b$–). Positive FAB-MS *m/z*: 568 $(M+H)^+$.

***N*-Benzyloxycarbonyl-*O*-(2,3,4,6-tetra-*O*-acetyl-β-D-glucopyranosyl)-L-serine Myristylamide (47)** A stirred mixture of **46** (489 mg, 1.13 mmol), prepared from 2,3,4,6-tetra-*O*-acetyl-β-D-glucopyranose and trichloroacetonitrile and 1,8-diazabicyclo[5.4.0]-7-undecene, was treated with $BF_3 \cdot OEt_2$ (159 mg, 1.13 mmol) and powdered 4 Å molecular sieves in CH_2Cl_2 (5 ml) at 0 °C under Ar. The mixture was stirred overnight at room temperature, diluted with CH_2Cl_2, and filtered through Celite. The filtrate was washed with saturated aqueous $NaHCO_3$ and dried ($MgSO_4$) and the solvent was evaporated *in vacuo*. The residue was chromatographed over SiO_2 with 10:1 $CHCl_3$–MeOH to give **47** (801 mg, 77%) as an amorphous powder. $[\alpha]_D$ +8.4° (*c*=1.15, $CHCl_3$). IR (neat): 1752, 1524, 1222, 1113 cm^{-1}. ^{1}H-NMR ($CDCl_3$) δ: 0.88 (3H, t, *J*=6.9 Hz, $C_{13}H_{26}C\underline{H}_3$), 1.26 (22H, br s, $-(C\underline{H}_2)_{11}CH_3$), 1.48 (2H, br s, $C\underline{H}_2C_{12}H_{25}$), 2.00, 2.02, 2.03, 2.05 (each 3H, s, $OCOC\underline{H}_3 \times 4$), 3.23 (2H, dd, *J*=6.3, 13.2 Hz, $-C\underline{H}_2C_{13}H_{27}$), 3.77 (1H, dd, *J*=8.3, 10.5 Hz, $-OCH_2C\underline{H}$–), 5.11 (2H, s, $OC\underline{H}_2C_6H_5$), 7.35 (5H, s, $OCH_2C_6\underline{H}_5$). ^{13}C-NMR ($CDCl_3$) δ: 14.1 (q, $CONHC_{13}H_{26}\underline{C}H_3$), 20.6, 20.7 (q, $OCO\underline{C}H_3$), 22.7, 23.0, 26.9, 28.9, 29.3, 29.4, 29.6, 29.7, 30.4, 31.9, 38.7, 39.8 (t, $OCONHC_{13}H_{26}CH_3$), 53.8 (t, $O\underline{C}H_2CH$–), 61.7 (t, C-6), 67.2 (t, $COO\underline{C}H_2Ph$), 68.2 (d, C-2), 70.5 (d, $OCH_2\underline{C}H$), 71.1 (d, C-5), 72.1 (d, C-3), 72.6 (d, C-4), 101.8 (d, C-1), 128.2, 128.6, 128.8, 130.9,132.5, 136.1 (d, Ph), 156.0 (s, NHCO), 167.8, 168.9, 169.4, 170.1 (s, $O\underline{C}OCH_3$), 170.6 (s, CONH). *Anal.* Calcd for $C_{39}H_{60}N_2O_{13}$: C, 61.20; H, 7.91; N, 3.66. Found: C, 60.71; H, 7.79; N, 3.15. Positive FAB-MS *m/z*: 765 $(M)^+$.

***O*-(2,3,4,6-Tetra-*O*-acetyl-β-D-glucopyranosyl)-L-serine Myristylamide (48)** A mixture of **47** (133 mg, 0.17 mmol) and 10% Pd–C (50 mg) in MeOH (10 ml) was stirred under H_2 overnight at room temperature. The catalyst was removed by filtration and the filtrate was concentrated to dryness to give **48** (67 mg, 61%). Compound **48** was used for the subsequent acylation without further purification. [a]$_D$ −22.7° (*c*=0.47, $CHCl_3$). IR (neat): 1729, 1694, 1107 cm^{-1}. ^{1}H-NMR ($CDCl_3$) δ: 0.88 (3H, t, *J*=6.4 Hz, $C_{13}H_{26}C\underline{H}_3$), 1.26 (22H, br s, $CH_2(C\underline{H}_2)_{11}CH_3$), 1.54 (2H, br s, $CH_2C\underline{H}_2C_{12}H_{25}$). Positive FAB-MS *m/z*: 631 $(M)^+$.

***N*-Stearoyl-*O*-(2,3,4,6-tetra-*O*-acetyl-β-D-glucopyranosyl)-L-serine Myristylamide (49)** A solution of stearoyl chloride (131 mg, 0.43 mmol) in ether (2 ml) was added to a solution of **48** (210 mg, 0.33 mmol) and $NaHCO_3$ (111 mg 5.3 mmol) in H_2O (10 ml) at 0 °C. The mixture was stirred for 5 h at room temperature, diluted with CH_2Cl_2, washed with aqueous $NaHCO_3$ and brine, dried ($MgSO_4$), and filtered. The filtrate was evaporated to dryness. The residue was chromatographed on a column of silica gel with 10:1 CH_2Cl_2–MeOH to give **49** (201 mg,67%) as an amorphous powder. $[\alpha]_D$ −1.8° (*c*=0.68, $CHCl_3$). IR (neat): 1749, 1639, 1552, 1228, 1062 cm^{-1}. ^{1}H-NMR ($CDCl_3$) δ: 0.86 (3H, t, *J*=7.0 Hz, $-C\underline{H}_3$), 1.26 (52H, br s, $-CH_2-$), 1.50, 1.59 (4H, br s, $NCH_2C\underline{H}_2$ and $C(O)CH_2C\underline{H}_2$), 2.01, 2.05, 2.10 (12H, s, $OCOCH_3$), 2.19 (2H, t, *J*=7.6 Hz, $C(O)C\underline{H}_2CH_2$). 3.20 (2H, t, *J*=6.5 Hz, $NC\underline{H}_2CH_2$). *Anal.* Calcd for $C_{49}H_{88}N_2O_{12}$: C, 65.59; H, 9.89; N, 3.12. Found: C, 65.22; H, 9.75; N, 3.50. Positive FAB-MS *m/z*: 898 $(M+1)^+$.

***N*-Stearoyl-*O*-(β-D-glucopyranosyl)-L-serine Myristylamide (50)** A solution of **49** (62 mg, 0.069 mmol) in NEt_3–MeOH (1:9) (2 ml) was stirred at 45 °C overnight. The mixture was concentrated to dryness under reduced pressure and the residual product was purified by column chromatography with 5:1 CH_2Cl_2–MeOH to give **42** (50 mg, 81%). $[\alpha]_D$ −1.0° (*c*=0.88, $CHCl_3$). IR (neat): 1749, 1639, 1522 cm^{-1}. ^{1}H-NMR ($CDCl_3$) δ: 0.88 (3H, t, *J*=7.0 Hz, $-CH_3$), 1.26 (52H, br s, $-CH_2-$), 1.50 (2H, br s, $C(O)CH_2C\underline{H}_2$), 2.20 (2H, t, *J*=8.1 Hz, $C(O)C\underline{H}_2CH_2$). *Anal.* Calcd for $C_{41}H_{80}N_2O_8$: C, 67.54; H, 11.06; N, 3.84. Found: C, 67.35; H, 11.25; N, 3.54. Positive FAB-MS *m/z*: 729 $(M)^+$ and 752 $(M+Na)^+$.

***N*-Stearoyl-*O*-(2,3,4,6-penta-*O*-sulfo-β-D-glucopyranosyl)-L-serine Myristylamide (9)** The same procedure described for the preparation of **1** provided a crude product from **50** (50 mg, 0.069 mmol) and sulfur trioxide–pyridine complex (66 mg, 0.41 mmol), followed by TFA (66 mg, 0.58 mmol), and this was purified on a column of Sephadex LH-20 equilibrated in and eluted with 20:20:1 (v/v) $CHCl_3$–MeOH–H_2O to give **9** (20 mg, 28%) as an amorphous powder, followed by lyophilization from H_2O. $[\alpha]_D$ −2.9° (*c*=0.20, MeOH). IR (Nujol): 1654, 1546, 1227, 1047 cm^{-1}. *Anal.* Calcd for $C_{41}H_{80}N_2O_{20}S_4 \cdot 1/2C_5H_5N$: C, 47.98; H, 7.46; N, 3.22. Found: C, 48.57; H, 8.15; N, 3.84.

***N*-Benzyloxycarbonyl-*O*-(2,3,4,6-tetra-*O*-acetyl-β-D-galactopyranosyl)-L-serine Myristylamide (52)** The same procedure described for the preparation of **47** provided a crude product from **51** (1.23 g, 2.48 mmol), itself prepared from 2,3,4,6-tetra-*O*-acetyl-β-D-galactopyranose, trichloroacetonitrile, 1,8-diazabicyclo[5.4.0]-7-undecene, **43** (1.08 g, 2.48 mmol) and $BF_3 \cdot OEt_2$ (0.35 g, 2.48 mmol), and this was purified on a column of silica gel with 10:1 $CHCl_3$–MeOH to give **52** (0.62 g, 33%) as prisms, mp 98—100 °C. $[\alpha]_D$ +9.6° (*c*=0.80, $CHCl_3$). IR (neat): 1747, 1665, 1536, 737, 699 cm^{-1}. ^{1}H-NMR ($CDCl_3$) δ: 0.91 (3H, t, *J*=6.8 Hz, $C_{13}H_{26}C\underline{H}_3$), 1.28 (22H, br s, $CH_2(C\underline{H}_2)_{11}CH_3$), 1.50 (2H, br s, $NCH_2C\underline{H}_2$), 2.02, 2.07, 2.12, 2.17 (each 3H, s, $OCOC\underline{H}_3 \times 4$), 3.24 (2H, m, $NHC\underline{H}_2CH_2$), 3.69 (1H, dd, *J*=5.4, 11.3 Hz, $OCH_2C\underline{H}N$), 5.15 (2H, s, $OC\underline{H}_2C_6H_5$), 5.99 (1H, br d, *J*=7.3 Hz, NHCO), 6.72 (1H, br s, $N\underline{H}CH_2$), 7.37 (5H, s, $OCH_2C_6\underline{H}_5$). ^{13}C-NMR ($CDCl_3$) δ: 14.1 (q, $C_{13}H_{26}\underline{C}H_3$), 20.6, 20.7 (q, $OCO\underline{C}H_3$), 22.7, 26.8, 26.9, 29.3, 29.4, 29.5, 29.6, 29.7, 31.9, 39.7, 39.9 (t, $\underline{C}_{13}H_{26}CH_3$), 55.4 (t, $O\underline{C}H_2CH$), 62.8 (t, C-6), 67.2 (t, $COO\underline{C}H_2Ph$), 68.2 (d, C-2), 70.5 (d, $OCH_2\underline{C}H$), 71.0 (d, C-5), 101.9 (d, C-1), 128.1, 128.3, 128.6, 136.0 (s, Ph), 156.0 (s, NHCO), 170.1, 170.3, 170.4, 170.5, 170.6 (s, C=O). *Anal.* Calcd for $C_{39}H_{60}N_2O_{13}$: C, 61.20; H, 7.91; N, 3.66. Found: C, 61.57; H, 7.83; N, 3.15.

***O*-(2,3,4,6-Tetra-*O*-acetyl-β-D-galactopyranosyl)-L-serine Myristylamide (53)** The same procedure described for the preparation of **48** provided a crude product from **52** (622 mg, 0.81 mmol) and this was concentrated to dryness to give **53** (48 mg, 94%). Compound **53** was used for the subsequent acylation without further purification. $[\alpha]_D$ +11.4° (*c*=0.95, $CHCl_3$). IR (neat): 1748, 1674, 1538, 1226, 1071 cm^{-1}. ^{1}H-NMR ($CDCl_3$) δ: 0.87 (3H, t, *J*=6.4 Hz, $-C_{13}H_{26}C\underline{H}_3$), 1.25 (22H, br s, $CH_2(C\underline{H}_2)_{11}CH_3$), 1.50 (2H, br s, $CH_2C\underline{H}_2C_{12}H_{25}$), 1.98, 2.03, 2.14 (12H, s, $COCH_3$). Positive FAB-MS *m/z*: 731 $(M)^+$.

***N*-Stearoyl-*O*-(2,3,4,6-tetra-*O*-acetyl-β-D-galactopyranosyl)-L-serine Myristylamide (54)** The same procedure described for the preparation of **54** provided a crude product from **53** (483 mg, 0.77 mmol) and this was purified on a column of silica gel with 10:1 $CHCl_3$–MeOH to give **46** (702 mg, quant.). $[\alpha]_D$ +4.3° (*c*=0.51, 1:1 $CHCl_3$–MeOH). IR (KBr): 1747, 1641, 1555, 1223, 1059 cm^{-1}. ^{1}H-NMR ($CDCl_3$) δ: 0.86 (3H, t, *J*=7.3 Hz, $-CH_3$), 1.26 (52H, br s, $-CH_2-$), 1.51—1.60 (4H, m, $NCH_2C\underline{H}_2$ and $C(O)CH_2C\underline{H}_2$), 1.99, 2.06, 2.16 (12H, s, $OCOCH_3$), 2.26 (2H, t, *J*=7.6 Hz, $C(O)C\underline{H}_2CH_2$), 3.21 (2H, t, *J*=6.5 Hz, $NC\underline{H}_2CH_2-$). *Anal.* Calcd for $C_{49}H_{88}N_2O_{12}$: C, 65.59; H, 9.89; N, 3.12 . Found: C, 65.19; H, 9.77; N, 3.75. Positive FAB-MS *m/z*: 920 $(M+Na)^+$

***N*-Stearoyl-*O*-(β-D-galactopyranosyl)-L-serine Myristylamide (55)** The same procedure described for the preparation of **50** provided a crude product from **54** (60 mg, 0.067 mmol), and this was purified on a column

of silica gel with 5:1 $CHCl_3$–MeOH to give **55** (34 mg, 70%) as an amorphous powder. $[\alpha]_D$ +1.2° (c=0.29, $CHCl_3$). IR (neat): 3324, 2918, 1666, 1553 cm^{-1}. ^{1}H-NMR ($CDCl_3$) δ: 0.88 (3H, t, J=7.0 Hz, $-CH_3$), 1.26 (52H, br s, $-CH_2-$), 1.54—1.68 (4H, m, $C(O)CH_2C\underline{H}_2$ and $NCH_2C\underline{H}_2$), 2.27 (2H, t, J=7.0 Hz, $C(O)C\underline{H}_2CH_2$). Positive FAB-MS m/z: 752 $(M+Na)^+$.

***N*-Stearoyl-*O*-(2,3,4,6-penta-*O*-sulfo-β-D-galactopyranosyl)-L-serine Myristylamide (10)** The same procedure described for the preparation of **1** provided a crude product from **55** (44 mg, 0.06 mmol) and sulfur trioxide–pyridine complex (57 mg, 0.36 mmol), followed by TFA (41 mg, 0.36 mmol), and this was purified by column of Sephadex LH-20 equilibrated in and eluted with 20:20:1 (v/v) $CHCl_3$–MeOH–H_2O to give **10** (27 mg, 43%) as an amorphous powder, after lyophilization from H_2O. $[\alpha]_D$ −10.4° (c=0.36, MeOH). IR (Nujol): 1649, 1539, 1230 cm^{-1}. *Anal.* Calcd for $C_{41}H_{80}N_2O_{20}S_4 \cdot 2C_5H_5N$: C, 49.12; H, 7.27; N, 3.37. Found: C, 49.06; H, 7.74; N, 3.62.

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