Glycoconjugate Journal (1996) **13:** 241–254

Synthesis of deoxygalactose-containing sialyl Le^X ganglioside analogues to elucidate the structure necessary for selectin recognition*

SHIRO KOMBA, HIDEHARU ISHIDA, MAKOTO KISO and AKIRA HASEGAWA‡

Department of Applied Bioorganic Chemistry, Gifu University, Gifu 501-11, Japan

Received 5 July 1995, revised 17 August 1995

Sialyl Lewis X ganglioside analogues containing 4-deoxy-, 6-deoxy-, and 4,6-dideoxy-D-galactopyranose in place of D-galactopyranose have been synthesized. Glycosylations of 2-(trimethylsilyl)ethyl 2,6-di-*O*-benzyl-β-D-galactopyranoside and 2-(trimethylsilyl)ethyl β-D-fucopyranoside with the phenyl 2-thioglycoside derivative of sialic acid, using *N*-iodosuccinimide (NIS)-trifluoromethanesulfonic acid (TfOH) as the promoter in acetonitrile, gave the desired 2-(trimethylsilyl)ethyl sialyl-α-(2→3)-β-D-galactopyranoside and -β-D-fucopyranoside, respectively. The sialylgalactose derivative obtained was then modified to 4-deoxy and 4,6-dideoxy derivatives. These were converted, by *O*-benzoylation, transformation of the 2-(trimethylsilyl)ethyl group to trichloroacetimidates, and introduction of the methylthio group with methylthiomethylsilane, into the corresponding glycosyl donors, which were then coupled with 2-(trimethylsilyl)ethyl *O*-(2,3,4-tri-*O*-benzyl-α-L-fucopyranosyl)-(1→3)-*O*-(2-acetamido-6-*O*-benzyl-2-deoxy-β-D-glucopyranosyl)-(1→3)-2,4,6-tri-*O*-benzyl-β-D-galactopyranoside in the presence of dimethyl(methylthio)sulfonium triflate (DMTST). The resulting pentasaccharides were each converted to the corresponding α-trichloroacetimidates, which, on coupling with (2*S*, 3*R*, 4*E*)-2-azido-3-*O*-benzoyl-4-octadecene-1,3-diol, gave the desired sphingosine derivatives. Selective reduction of the azide group, *N*-acylation with octadecanoic acid, *O*-deacylation, and saponification of the methyl ester afforded the target compounds.

Keywords: 6-deoxy-Gal, 4-deoxy-Gal, 4,6-dideoxy-Gal, sialyl Le^X, sialoglycoconjugate, selectin family

Introduction

Sialyl Le^X ganglioside was first isolated from kidney and found to be widespread as the tumour-associated ganglioside antigen. Since the demonstration [1–4] that the selectin family of cell adhesion proteins recognize the sialyl Le^X determinant, α-Neu5Ac-(2→3)-β-D-Gal-(1→4)-[α-L-Fuc-(1→3)]-β-D-GlcNAc, which is found as the terminal carbohydrate structure in both glycolipids and glycoproteins of cell membranes, much attention has been focused on the biological importance of this structure not only in leukocyte-endothelium adhesion but also in tumour metastasis. We have reported the synthesis of a series of sialyl Le^X gangliosides including hexasaccharidic [5] and pentasaccharidic [6] glycolipids, and sialyl α(2→6)-Le^X ganglioside [7], and demonstrated an energy minimized conformation [8] for the selectin recognition. Based on this three-dimensional structure, various types of sialyl Le^X analogues [9, 10] containing chemically modified sialic acid or fucose residues have been synthesized in order to clarify the structural features of the sialic acid or fucose moieties required for selectin recognition. As a part of our continuing studies on structure-activity correlations in the sialyl Le^X epitope, we describe here the synthesis of sialyl Le^X ganglioside (pentasaccharide) analogues containing three kinds of galactose derivatives, in which the C-4, C-6 and C-4,6 positions are deoxygenated.

Results and discussion

For the systematic synthesis of the galactose-modified sialyl Le^X pentasaccharides, 2-(trimethylsilyl)ethyl *O*-(2,3,4-tri-*O*-benzyl-α-L-fucopyranosyl)-(1→3)-*O*-(2-acetamido-6-*O*-benzyl-2-deoxy-β-D-glucopyranosyl)-(1→3)-2,-

*Synthetic Studies on Sialoglycoconjugates, Part 79.
‡To whom correspondence should be addressed.

4,6-tri-*O*-benzyl-β-D-galactopyranoside [6] (**28**) was used as the common glycosyl acceptor, which was coupled with methyl *O*-(methyl 5-acetamido-4,7,8,9-tetra-*O*-acetyl-3,5-dideoxy-D-*glycero*-α-D-*galacto*-2-nonulopyranosylonate)-(2→3)-2,6-di-*O*-benzoyl-4-deoxy-1-thio-β-D-*xylo*-hexopyranoside (**16**), -(2→3)-2,4-di-*O*-benzoyl-1-thio-β-D-fucopyranoside (**21**), and -(2→3)-2-*O*-benzoyl-4,6-dideoxy-1-thio-β-D-*xylo*-hexopyranoside (**27**), respectively.

Treatment of 2-(trimethylsilyl)ethyl 3,4-*O*-isopropylidene-β-D-galactopyranoside [11] (**1**) with sodium hydride and benzyl bromide in DMF, and subsequent de-isopropylidenation afforded the corresponding 2,6-di-*O*-benzyl derivative **3** in good yield. The glycosylation [12, 13] of **3** with Neu5Ac donor **6** (1.5 equiv with respect to the acceptor), in acetonitrile for 1.5 h at −35 °C in the presence of NIS-TfOH [14–16] and 3 Å molecular sieves, gave exclusively the α-glycoside **7** in 70% yield. The significant ^{1}H-NMR signals of the Neu5Ac residue [17, 18] were H-3*eq* (δ 2.53, dd, J_{gem} 13.0, $J_{3eq,4}$ 4.6 Hz), H-7 (δ 5.30, dd, $J_{6,7}$ 1.8, $J_{7,8}$ 7.7 Hz), and H-8 (δ 5.39, ddd, $J_{8,9}$ 2.2, $J_{8,9'}$ 5.9 Hz), indicating the anomeric configuration to be α. In the ^{1}H-NMR spectrum of the acetate **8**, the observed chemical shift and coupling constants of H-4 of the Gal residue (δ 5.40, d, $J_{3,4}$ 3.1 Hz) indicated the glycosylated position to be C-3.

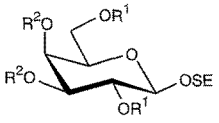
2-(Trimethylsilyl)ethyl β-D-fucopyranoside (**5**) was employed for preparing the 6-deoxy-D-galactose derivative. The regio- and α-stereoselective glycosylation of **5** with **6** was achieved by the same procedure described for **7** to give sialyl-α-(2→3)-D-fucopyranoside **17** in 70% yield, which showed the characteristic ^{1}H-NMR signals at δ 2.71 (dd, J_{gem} 13.0, $J_{3eq,4}$ 4.4 Hz, H-3*eq*) and δ 5.31 (dd, $J_{6,7}$ 1.8, $J_{7,8}$ 8.8 Hz, H-7) showing the α-glycosidic linkage. The glycosylation site was confirmed by the chemical shifts and coupling constants of the D-Fuc residue in **18**; H-2 (δ 5.46, dd, $J_{1,2}$ 8.1, $J_{2,3}$ 10.1 Hz) and H-4 (δ 5.16, d, $J_{3,4}$ 3.1 Hz).

Treatment of **8** with phenyl chlorothionoformate [19] in pyridine and dichloromethane, gave the corresponding sialyl-α-(2→3)-2,6-di-*O*-benzyl-4-*O*-(phenoxy)thiocarbonyl-β-D-galactopyranoside **9** and subsequent radical reduction with tributyltin hydride and α,α′-azobis-isobutyronitrile (AIBN) in toluene afforded the corresponding sialyl-4-deoxygalactose derivative **10** in good yield. In the ^{1}H-NMR spectrum of **11**, the characteristic H-4*ax* (δ 1.41, $J_{gem} = J_{4ax,5} = J_{4ax,3}$ 11.6 Hz) and H-4*eq* (δ 1.87) of the galactose residue were clearly observed indicating the structure assigned.

The 6-bromination [20] of sialyl-α-(2→3)-4-deoxy-β-D-*xylo*-hexopyranoside **12** with carbon tetrabromide and triphenylphosphine gave **22**, and subsequent *O*-benzoylation afforded the corresponding 2-*O*-benzoyl derivative **23**, which was hydrogenolyzed [21] in the presence of 10% Pd-C and diethylamine, to afford sialyl-α-(2→3)-2-*O*-benzoyl-4,6-dideoxy-β-D-*xylo*-hexopyranoside **24** in 77% yield. Significant signals in the ^{1}H-NMR spectra of **24** were at δ 1.27 (d, $J_{5,6}$ 5.5 Hz, H-6) and δ 4.91 (dd, $J_{1,2}$ 8.8, $J_{2,3}$ 9.0 Hz, H-2).

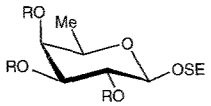
Treatment of **13**, **18** and **24** with trifluoroacetic acid gave the corresponding 1-hydroxy compounds **14**, **19** and **25** in good yields, which, on treatment [11, 22, 23] with trichloroacetonitrile in the presence of 1,8-diazabicyclo[5.4.0]undec-7-ene (DBU) in dichloromethane at 0 °C, gave the corresponding anomeric mixture of trichloroacetimidates **15**, **20** and **26** in high yields. Significant signals in the ^{1}H-NMR spectra of **15**, **20** and **26** were at δ 6.00–6.17 ($J_{1,2}$ 7.7 ~ 8.4 Hz, H-1$_\beta$), δ 6.57–6.76 ($J_{1,2}$ 3.4 ~ 3.6 Hz, H-1$_\alpha$), δ 8.60–8.65 (C = NH$_\beta$), and δ 8.46–8.56 (C = NH$_\alpha$) indicating the structures assigned. These trichloroacetimidates **15**, **20** and **26** were each exclusively converted to the methyl β-thioglycosides **16**, **21** and **27** in high yields by treatment with methylthiotrimethylsilane and boron trifluoride etherate in dichloromethane at room temperature. The β-configuration was determined by the significant signals at δ 4.54–4.73 ($J_{1,2}$ 9.8 ~ 9.9 Hz, H-1) and δ 5.10–5.52 ($J_{2,3}$ 9.4 ~ 9.7 Hz, H-2) in the ^{1}H-NMR spectra of **16**, **21** and **27**.

Glycosylations of **28** with **16**, **21** and **27** (1.8 equivalent with respect to the acceptor), in dichloromethane for 72 h at 7 °C in the presence of DMTST and

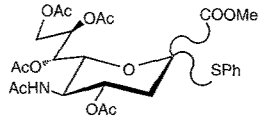


	R^1	R^2
1	H	isopropylidene
2	Bn	isopropylidene
3	Bn	H

SE = 2-(trimethylsilyl)ethyl

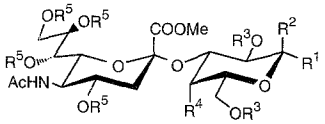


4 R = Ac
5 R = H

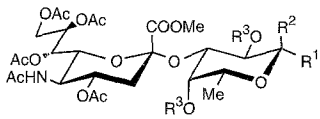


6

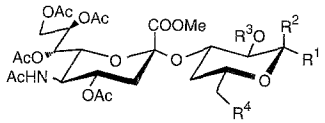
Figure 1.



	R^1	R^2	R^3	R^4	R^5
7	OSE	H	Bn	OH	Ac
8	OSE	H	Bn	OAc	Ac
9	OSE	H	Bn	OC(S)OPh	Ac
10	OSE	H	Bn	H	Ac
11	OSE	H	Bn	H	H
12	OSE	H	H	H	Ac
13	OSE	H	Bz	H	Ac
14	OH, H		Bz	H	Ac
15	$OC(=NH)CCl_3$, H		Bz	H	Ac
16	SMe	H	Bz	H	Ac



	R^1	R^2	R^3
17	OSE	H	H
18	OSE	H	Bz
19	OH, H		Bz
20	$OC(=NH)CCl_3$, H		Bz
21	SMe	H	Bz



	R^1	R^2	R^3	R^4
22	OSE	H	H	Br
23	OSE	H	Bz	Br
24	OSE	H	Bz	H
25	OH, H		Bz	H
26	$OC(=NH)CCl_3$, H		Bz	H
27	SMe	H	Bz	H

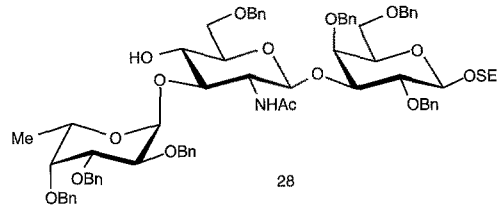
Figure 2.

4 Å molecular sieves, gave the expected β-glycosides **29**, **33** and **37** in 45, 35 and 43% yields, respectively. The characteristic signals of H-2c in the ^{1}H-NMR spectra of **29**, **33** and **37** appeared at δ 5.40–5.45 (near t, $J_{1,2} = J_{2,3} = 8.2 \sim 9.3$ Hz), indicating the newly formed glycosidic linkage to be β.

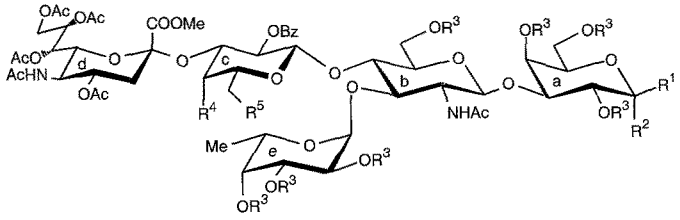
Hydrogenolytic removal of the benzyl groups in **29**, **33** or **37**, and subsequent *O*-acetylation gave the per-*O*-acetyl derivatives **30**, **34** and **38** in 92, 84, and 86% yields after purification by silica gel column chromatography. These compounds were converted to the corresponding 1-hydroxy compounds **31**, **35** and **39** in quantitative yields, which, on treatment with trichloroacetonitrile as described for **15**, **20** and **26**, afforded the corresponding α-trichloroacetimidates **32**, **36** and **40** in high yields.

The final glycosylation [11, 24] of (2*S*, 3*R*, 4*E*)-2-azido-3-*O*-benzoyl-4-octadecene-1,3-diol) [25, 26] (**41**) with **32**, **36** or **40** thus obtained, in dichloromethane in the presence of boron trifluoride etherate for 2 h at 0 °C, gave the desired β-glycosides **42**, **45** and **48** in 60, 72, and 40% yields, respectively. Selective reduction [27, 28] of the azide group in **42**, **45** or **48** with hydrogen sulfide in aqueous pyridine gave the amine which, on condensation with octadecanoic acid, using 1-ethyl-3-(3-dimethylaminopropyl)carbodiimide hydrochloride (WSC) in dichloromethane, gave the corresponding acylated sialyl Le^X gangliosides **43**, **46** and **49** in 70, 88, and 90% yields, after column chromatography. Finally, *O*-deacylation with sodium methoxide in methanol and subsequent saponification of the methyl ester group yielded the end products **44**, **47** and **50** in quantitative yields after chromatography on a column of Sephadex LH-20.

The sialyl Le^X ganglioside (**44**) containing 4-deoxy-Gal was not recognized by E- and L-selectin, while it was recognized by P-selectin in almost the same order as sialyl Le^X ganglioside (Brandley BK, Kiso M, Hasegawa A, *et al.*, unpublished results). On the other hand, the sialyl Le^X ganglioside (**47**) containing the 6-deoxy-Gal was not recognized by any of the selectin family. The results indicate that the hydroxyl groups of the C-4 and C-6 positions of the galactose moiety in sialyl Le^X ganglioside are critically important for the selectin recognition. Very recently, similar results have also been reported for the sialyl Le^X tetrasaccharide epitope analogues [29]. By removal of the galactose residue [30] the E-selectin recognition was, of course, completely lost. In a series of structure-function studies [31] on selectin carbohydrate ligands using a variety of sialyl Le^X ganglioside analogues [32], we have already demonstrated

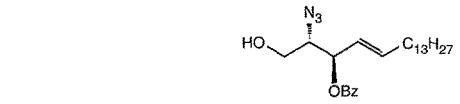


28

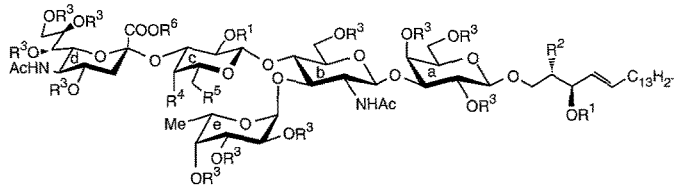


	R^1	R^2	R^3	R^4	R^5
29	OSE	H	Bn	H	OBz
30	OSE	H	Ac	H	OBz
31		OH, H	Ac	H	OBz
32	H	$OC(=NH)CCl_3$	Ac	H	OBz
33	OSE	H	Bn	OBz	H
34	OSE	H	Ac	OBz	H
35		OH, H	Ac	OBz	H
36	H	$OC(=NH)CCl_3$	Ac	OBz	H
37	OSE	H	Bn	H	H
38	OSE	H	Ac	H	H
39		OH, H	Ac	H	H
40	H	$OC(=NH)CCl_3$	Ac	H	H

Figure 3.



41



	R^1	R^2	R^3	R^4	R^5	R^6
42	Bz	N_3	Ac	H	OBz	Me
43	Bz	$NHCOC_{17}H_{35}$	Ac	H	OBz	Me
44	H	$NHCOC_{17}H_{35}$	H	H	OH	H
45	Bz	N_3	Ac	OBz	H	Me
46	Bz	$NHCOC_{17}H_{35}$	Ac	OBz	H	Me
47	H	$NHCOC_{17}H_{35}$	H	OH	H	H
48	Bz	N_3	Ac	H	H	Me
49	Bz	$NHCOC_{17}H_{35}$	Ac	H	H	Me
50	H	$NHCOC_{17}H_{35}$	H	H	H	H

Figure 4.

that E- and L-selectin require the hydroxyl groups at the C-2, C-3 and C-4 positions of the fucose residue. P-Selectin, however, requires only the C-3 hydroxyl group. Therefore, the present results must contribute to the systematic understanding of the selectin-carbohydrate interaction at the molecular level.

Materials and methods

General methods

Specific rotations were determined with a Union PM-201 polarimetar at 25 °C, and IR spectra were recorded with a JASCO A-100 spectrophotometer. ^{1}H-NMR spectra were recorded with a JEOL JNM-GX 270 spectrometer. Preparative chromatography was performed on silica gel (Wako Co., 200 mesh, or Fuji Silysia Co., 300 mesh) with the solvent systems specified. Concentrations were conducted *in vacuo*.

*2-(Trimethylsilyl)ethyl 2,6-di-*O*-benzyl-3,4-*O*-isopropylidene-β-D-galactopyranoside* (**2**)

To a solution of 2-(trimethylsilyl)ethyl 3,4-*O*-isopropylidene-β-D-galactopyranoside (**1**; 7.15 g, 22.3 mmol) in *N*,*N*-dimethylformamide (DMF, 32 ml) was added a suspension of sodium hydride in oil (2.68 g, 60% of sodium hydride by weight, 67.0 mmol). The mixture was stirred for 30 min at 0 °C, benzyl bromide (7.96 ml, 66.9 mmol) was added dropwise, and stirring was continued for 2 h at room temperature. The reaction was monitored by TLC and, when complete, methanol (5 ml) was added, and the mixture was concentrated and extracted with dichloromethane. The extract was washed with water, dried (Na_2SO_4) and concentrated. Column chromatography (1:3 ethyl acetate:hexane) of the residue on silica gel (600 g) gave **2** (9.86 g, 88%) as an amorphous mass; $[\alpha]_D$ +25.4° (*c* 1.0, chloroform); IR (film) 860 and 840 (TMS), 850 (isopropylidene), and 710 cm^{-1} (Ph); ^{1}H-NMR data ($CDCl_3$) δ 1.05 (m, 2H, $Me_3SiCH_2CH_2$), 1.32 and 1.34 (2s, 6H, Me_2C), 3.58 and 4.02 (2m, 2H, $Me_3SiCH_2CH_2$), 4.32 (d, 1H, $J_{1,2}$ 8.1 Hz, H-1), 4.55, 4.64, 4.82 and 4.86 (4d, 4H, $2C_6H_5CH_2O$), and 7.24–7.41 (m, 10H, 2Ph).

Analytical data. Calculated for $C_{28}H_{40}O_6Si$: C, 67.17; H, 8.05. Found: C, 67.07; H, 8.05.

*2-(Trimethylsilyl)ethyl 2,6-di-*O*-benzyl-β-D-galactopyranoside* (**3**)

A solution of **2** (9.86 g, 19.7 mmol) in aqueous 80% acetic acid (100 ml) was heated for 3 h at 60 °C and concentrated. Column chromatography (1:3 ethyl acetate:hexane) of the residue on silica gel (400 g) gave **3** (8.89 g, 98%) as an

amorphous mass; $[\alpha]_D$ +7.5° (*c* 1.0, chloroform); IR (film) 3450 (OH), 860 and 840 (TMS), and 710 cm^{-1} (Ph); ^{1}H-NMR data ($CDCl_3$) δ 1.01 (m, 2H, $Me_3SiCH_2CH_2$), 3.58 and 4.02 (2m, 2H, $Me_3SiCH_2CH_2$), 4.34 (d, 1H, $J_{1,2}$ 8.1 Hz, H-1), 4.55 (s, 2H, $C_6H_5CH_2O$), 4.65 and 4.94 (2d, 2H, $C_6H_5CH_2O$), and 7.22–7.33 (m, 10H, 2Ph).

Analytical data. Calculated for $C_{25}H_{36}O_6Si$: C, 65.19; H, 7.88. Found: C, 65.17; H, 7.61.

*2-(Trimethylsilyl)ethyl 2,3,4-tri-*O*-acetyl-β-*D*-fucopyranoside* (**4**)

1,2,3,4-Tetra-*O*-acetyl-D-fucopyranose prepared by acetylation of D-fucose (5 g, 30.5 mmol) was dissolved in dichloromethane (25 ml), and cooled to 0 °C. Hydrogen bromide (25% acetic acid solution) (20 ml) was added, and the mixture was stirred for 2 h at room temperature. The solution was successively washed with ice water and 1 M sodium carbonate, dried (Na_2SO_4) and concentrated. The residue was dissolved in dichloromethane (21 ml) and stirred with powdered molecular sieves 4 Å (6 g) for 5 h at room temperature (mixture A). A mixture of silver carbonate (8.28 g, 30.0 mmol), silver perchlorate hydrate (6.22 g, 30.0 mmol) and (trimethylsilyl)ethanol (10.75 ml, 75.0 mmol) in dichloromethane (21 ml) was stirred with powdered molecular sieves 4 Å (10 g) for 5 h at room temperature (mixture B). The mixture A was added to the mixture B at 0 °C, and the suspension was stirred for 12 h at room temperature. The precipitate was filtered off and washed with dichloromethane. The filtrate and washings were combined and concentrated. Column chromatography (1:5 ethyl acetate:hexane) of the residue on silica gel (60 g) gave **4** (8.21 g, 70%) as an amorphous mass; $[\alpha]_D$ −8.2° (*c* 1.8, dichloromethane); IR (film) 3000–2820 (CH), 1750 and 1240 (ester), and 860 and 840 cm^{-1} (TMS); ^{1}H-NMR data ($CDCl_3$) δ 0.93 (m, 2H, $Me_3SiCH_2CH_2$), 1.21 (d, 3H, $J_{5,6}$ 6.4 Hz, H-6), 1.96, 2.03 and 2.16 (3s, 9H, 3AcO), 3.52 and 4.00 (2m, 2H, $Me_3SiCH_2CH_2$), 3.80 (q, 1H, $J_{5,6}$ 6.4 Hz, H-5), 4.45 (d, 1H, $J_{1,2}$ 7.6 Hz, H-1), 5.00 (dd, 1H, $J_{2,3}$ 10.4, $J_{3,4}$ 3.4 Hz, H-3), 5.16 (dd, 1H, $J_{1,2}$ 7.6, $J_{2,3}$ 10.4 Hz, H-2), and 5.22 (d, 1H, $J_{3,4}$ 3.4 Hz, H-4).

Analytical data. Calculated for $C_{17}H_{30}O_7Si$: C, 54.52; H, 8.07. Found: C, 54.26; H, 7.80.

*2-(Trimethylsilyl)ethyl β-*D*-fucopyranoside* (**5**)

To a solution of **4** (8.21 g, 21 mmol) in methanol (20 ml) was added 28% sodium methoxide (1 ml), and the mixture was stirred for 12 h at room temperature, neutralized with Amberlite IR-120 (H^+) resin and filtered. The resin was washed with methanol, and the combined filtrate and washings were concentrated. Column chromatography (4:1 ethyl acetate:hexane) of the residue on silica gel (150 g) gave **5** (5.56 g, quantitative) as an amorphous mass; $[\alpha]_D$ −23.9° (*c* 3.3, dichloromethane); IR (film) 3650–3050 (OH) 3000–2850 (CH), and 860 and 840 cm^{-1} (TMS); ^{1}H-NMR data ($CDCl_3$) δ 1.01 (m, 2H, $Me_3SiCH_2CH_2$), 1.28 (d, 3H, $J_{5,6}$ 6.4 Hz, H-6), 3.94 (m, 1H, $Me_3SiCH_2CH_2$), 4.58 (d, 1H, $J_{3,4}$ 3.3 Hz, H-4), and 5.02 (d, 1H, $J_{1,2}$ 5.5 Hz, H-1).

Analytical data. Calculated for $C_{11}H_{24}O_5Si$: C, 49.97; H, 9.15. Found: C, 49.79; H, 9.10.

2-(Trimethylsilyl)ethyl O*-(methyl 5-acetamido-4,7,8,9-tetra-*O*-acetyl-3,5-dideoxy-*D*-*glycero*-α-*D*-galacto-2-nonulopyranosylonate)-(2→3)-2,6-di-*O*-benzyl-β-*D*-galactopyranoside* (**7**)

To a solution of **3** (96 mg, 0.21 mmol) and methyl (phenyl 5-acetamido-4,7,8,9-tetra-*O*-acetyl-3,5-dideoxy-2-thio-D-*glycero*-D-*galacto*-2-nonulopyranosid)onate (**6**; 0.18 g, 0.31 mmol) in acetonitrile (1.5 ml) were added molecular sieves 3 Å (0.35 g). The mixture was stirred for 5 h at room temperature and then cooled to −35 °C. To the cooled mixture were added *N*-iodosuccinimide (159 mg, 0.71 mmol) and trifluoromethanesulfonic acid (5.5 μl, 0.06 mmol), and the mixture was stirred for 1.5 h at −35 °C. The precipitate was filtered off and washed with dichloromethane. The filtrate and washings were combined and successively washed with 1 M sodium carbonate and sodium thiosulfate, dried (Na_2SO_4) and concentrated. Column chromatography (50:1 toluene:methanol) of the residue on silica gel (40 g) gave **7** (136 mg, 70%) as an amorphous mass; $[\alpha]_D$ +41.2° (*c* 0.1, chloroform); IR (film) 3600–3200 (OH, NH), 1760 and 1230 (ester), 1670 and 1545 (amide), 860 and 840 (TMS), and 725 cm^{-1} (Ph); ^{1}H-NMR data ($CDCl_3$) Gal unit δ 0.98 (m, 2H, $Me_3SiCH_2CH_2$), 4.43 (d, 1H, $J_{1,2}$ 7.7 Hz, H-1), 4.57 (s, 2H, $C_6H_5CH_2O$), 4.70 and 4.84 (2d, 2H, $C_6H_5CH_2O$), 7.24–7.41 (m, 10H, 2Ph); Neu5Ac unit δ 1.86 (s, 3H, AcN), 1.95, 1.98, 2.01 and 2.09 (4s, 12H, 4AcO), 2.53 (dd, 1H, J_{gem} 13.0, $J_{3eq,4}$ 4.6 Hz, H-3*eq*), 3.76 (s, 3H, MeO), 4.33 (dd, 1H, $J_{8,9}$ 2.4, J_{gem} 12.5 Hz, H-9), 5.30 (dd, 1H, $J_{6,7}$ 1.8, $J_{7,8}$ 7.7 Hz, H-7), 5.39 (ddd, 1H, $J_{8,9}$ 2.2, $J_{8,9}$ 5.9 Hz, H-8), and 5.47 (d, 1H, $J_{NH,5}$ 9.5 Hz, NH).

Analytical data. Calculated for $C_{45}H_{63}O_{18}NSi$: C, 57.86; H, 6.80; N, 1.50. Found: C, 57.81; H, 6.58; N, 1.23.

A sample of **7** (50 mg, 54 μmol) was acetylated with acetic anhydride (1 ml) and pyridine (1 ml) for 2 h at room temperature to give **8** (52 mg, quantitative) as an amorphous mass; ^{1}H-NMR data ($CDCl_3$) Gal unit δ 1.02 (m, 2H, $Me_3SiCH_2CH_2$), 1.87 (s, 3H, AcO), 4.53 (d, 1H, $J_{1,2}$ 8.9 Hz, H-1), 4.46 and 4.54 (2d, 2H, $C_6H_5CH_2O$), 4.84 (s, 2H, $C_6H_5CH_2O$), 5.04 (d, 1H, $J_{3,4}$ 3.1 Hz, H-4), 7.24–7.47 (m, 10H, 2Ph); Neu5Ac unit δ 1.85 (s, 3H, AcN), 2.02, 2.03, 2.04 and 2.13 (4s, 12H, 4AcO), 2.58 (dd, 1H, J_{gem} 12.8, $J_{3eq,4}$ 4.9 Hz, H-3*eq*), 3.84 (s, 3H, MeO), 4.35 (dd, 1H, $J_{8,9}$ 2.4, J_{gem} 12.5 Hz, H-9), 4.91 (m, 1H, H-4), 5.20 (d, 1H, $J_{NH,5}$ 10.1 Hz, NH), 5.33 (dd, 1H, $J_{6,7}$ 2.4, $J_{7,8}$ 8.2 Hz, H-7), and 5.53 (m, 1H, H-8).

Analytical data. Calculated for $C_{47}H_{65}O_{19}NSi$: C, 57.83; H, 6.71; N, 1.43. Found: C, 57.61; H, 6.62; N, 1.19.

2-(Trimethylsilyl)ethyl O-*(methyl 5-acetamido-4,7,8,9-tetra*-O-*acetyl-3,5-dideoxy-D*-glycero-α-*D*-galacto-*2-nonulopyranosylonate)-(2→3)-2,6-di-O-benzyl-4-O-(phenoxy)-thiocarbonyl-β-D-galactopyranoside* (**9**)

To a solution of **7** (1.0 g, 1.07 mmol) in 1:1 dichloromethane:pyridine (20 ml) was added phenyl chlorothionoformate (0.22 ml, 1.59 mmol), and the mixture was heated for 5 h at 45 °C. After completion of the reaction, methanol (1 ml) was added, and the solution was concentrated to a residue which was then extracted with dichloromethane. The extract was successively washed with 2 M hydrochloric acid and water, dried (Na_2SO_4) and concentrated. Column chromatography (3:1 ethyl acetate:-hexane) of the residue on silica gel (60 g) gave **9** (1.13 g, 98%) as an amorphous mass; $[\alpha]_D$ −27.4° (*c* 1.1, chloroform); IR (film) 3450–3200 (NH), 1760 (ester), 1670 and 1545 (amide), 860 and 840 (TMS) and 720 cm^{-1} (Ph); ^{1}H-NMR data ($CDCl_3$) Gal unit δ 0.99 (m, 2H, $Me_3SiCH_2CH_2$), 4.55 (s, 2H, $C_6H_5CH_2O$), 4.59 (d, 1H, $J_{1,2}$ 7.7 Hz, H-1), 4.64 (dd, 1H, $J_{2,3}$ 9.7, $J_{3,4}$ 2.9 Hz, H-3), 4.85 (s, 2H, $C_6H_5CH_2O$), 5.62 (d, 1H, $J_{3,4}$ 2.9 Hz, H-4), 7.02–7.48 (m, 15H, 3Ph); Neu5Ac unit δ 1.82 (s, 3H, AcN), 1.86, 2.02, 2.03 and 2.12 (4s, 12H, 4AcO), 2.61 (dd, 1H, J_{gem} 12.6, $J_{3eq,4}$ 4.6 Hz, H-3eq), 3.78 (s, 3H, MeO), 5.28 (d, 1H, $J_{NH,5}$ 10.3 Hz, NH), 5.35 (dd, 1H, $J_{6,7}$ 2.6, $J_{7,8}$ 8.3 Hz, H-7), and 5.55 (m, 1H, H-8).

Analytical data. Calculated for $C_{52}H_{67}O_{19}HSiS$: C, 58.36; H, 6.31; N, 1.31. Found: C, 58.08; H, 6.29; N, 1.24.

2-(Trimethylsilyl)ethyl O-*(methyl 5-acetamido-4,7,8,9-tetra*-O-*acetyl-3,5-dideoxy-D*-glycero-α-*D*-galacto-*2-nonulopyranosylonate)-(2→3)-2,6-di*-O-*benzyl-4-deoxy-β-D*-xylo-*hexopyranoside* (**10**)

To a solution of **9** (161 mg, 0.15 mmol) in toluene (6 ml) were added tributyltin hydride (81 μl, 0.30 mmol) and α,α′-azobis-isobutyronitrile (AIBN, 1.2 mg, 7.3 μmol), and the mixture was stirred for 10 h at 100 °C, then concentrated. Column chromatography (50:1 toluene: methanol) of the residue on silica gel (100 g) gave **10** (114 mg, 83%) as an amorphous mass; $[\alpha]_D$ −25.0° (*c* 0.3, dichloromethane); IR (film) 3400–3200 (NH), 1740 (ester), 1670 and 1545 (amide), 860 and 840 (TMS), and 700 cm^{-1} (Ph); ^{1}H-NMR data ($CDCl_3$) Gal unit δ 1.02 (m, 2H, $Me_3SiCH_2CH_2$), 4.53 (d, 1H, $J_{1,2}$ 7.7 Hz, H-1), 4.57 (s, 2H, $C_6H_5CH_2O$), 4.77 (s, 2H, $C_6H_5CH_2O$), 7.22–7.41 (m, 10H, 2Ph); Neu5Ac unit δ 1.86 (s, 3H, AcN), 1.95, 1.99, 2.01 and 2.09 (4s, 12H, 4AcO), 2.53 (dd, 1H, J_{gem} 13.0, $J_{3eq,4}$ 4.8 Hz, H-3*eq*), 3.76 (s, 3H, MeO), 4.35 (dd, 1H, $J_{8,9}$ 2.4, J_{gem} 12.5 Hz, H-9), 5.30 (d, 1H, $J_{NH,5}$ 10.1 Hz, NH), 5.30 (dd, 1H, H-7), and 5.40 (m, 1H, H-8).

Analytical data. Calculated for $C_{45}H_{63}O_{17}NSi$: C, 58.87; H, 6.92; N, 1.53. Found: C, 58.76; H, 6.85; N, 1.28.

A sample of **10** (30 mg, 33 μmol) was deacetylated with 28% sodium methoxide (30 μl) in methanol (1 ml) overnight at room temperature to give **11** (24 mg, quantitative) as an amorphous mass; ^{1}H-NMR data ($CDCl_3$) Gal unit δ 0.99 (m, 2H, $Me_3SiCH_2CH_2$), 1.41 (q, 1H, $J_{gem} = J_{4ax,5} = J_{4ax,3}$ 11.6 Hz, H-4*ax*), 1.87 (m, 1H, H-4*eq*), 3.11 (t, 1H, $J_{1,2} = J_{2,3}$ 8.3 Hz, H-2), 4.06 (m, 1H, H-3), 4.32 (d, 1H, $J_{1,2}$ 7.7 Hz, H-1), 4.53 (s, 2H, $C_6H_5CH_2O$), 4.68 and 4.86 (2d, 2H, $C_6H_5CH_2O$), 7.23–7.40 (m, 10H, 2Ph); Neu5Ac unit δ 1.95 (s, 3H, AcN), 2.61 (dd, 1H, H-3*eq*), 3.73 (s, 3H, MeO), and 6.90 (d, 1H, $J_{NH,5}$ 7.0 Hz, NH).

Analytical data. Calculated for $C_{37}H_{55}O_{13}NSi$: C, 59.26; H, 7.39; N, 1.87. Found: C, 59.03; H, 7.20, N, 1.81.

2-(Trimethylsilyl)ethyl O-*(methyl 5-acetamido-4,7,8,9-tetra*-O-*acetyl-3,5-dideoxy-D*-glycero-α-*D*-galacto-*2-nonulopyranosylonate)-(2→3)-4-deoxy-β-D*-xylo-*hexopyranoside* (**12**)

A solution of **10** (1.30 g, 1.42 mmol) in ethanol (12 ml) and acetic acid (2 ml) was stirred with 10% Pd-C (100 mg) for 48 h at 45 °C under hydrogen. The catalyst was collected and washed with ethanol, and the combined filtrate and washings were concentrated. Column chromatography (50:1 toluene:methanol) of the residue on silica gel (50 g) gave **12** (822 mg, 79%) as an amorphous mass; $[\alpha]_D$ −18.7° (*c* 1.1, dichloromethane); IR (film) 3650–3200 (OH, NH), 1740 (ester), 1660 and 1545 (amide), and 860 and 840 cm^{-1} (TMS); ^{1}H-NMR data ($CDCl_3$) Gal unit δ 1.04 (m, 2H, $Me_3SiCH_2CH_2$), 3.21 (t, 1H, $J_{1,2} = J_{2,3}$ 7.9 Hz, H-2), 4.39 (d, 1H, $J_{1,2}$ 7.7 Hz, H-1); Neu5Ac unit δ 1.87 (s, 3H, AcN), 2.01, 2.02, 2.10 and 2.13 (4s, 12H, 4AcO), 2.65 (dd, 1H, J_{gem} 13.0, $J_{3eq,4}$ 4.6 Hz, H-3*eq*), 3.79 (s, 3H, MeO), 4.30 (dd, 1H, $J_{8,9}$ 2.6, J_{gem} 12.5 Hz, H-9), 4.90 (m, 1H, H-4), 5.30 (dd, 1H, $J_{6,7}$ 1.5, $J_{7,8}$ 8.6 Hz, H-7), 5.42 (m, 1H, H-8), and 5.48 (d, 1H, $J_{NH,5}$ 9.5 Hz, NH).

Analytical data. Calculated for $C_{31}H_{51}O_{17}NSi$: C, 50.46; H, 6.97; N, 1.90. Found: C, 50.44; H, 6.92; N, 1.60.

2-(Trimethylsilyl)ethyl O-*(methyl 5-acetamido-4,7,8,9-tetra*-O-*acetyl-3,5-dideoxy-D*-glycero-α-*D*-galacto-*2-nonulopyranosylonate)-(2→3)-2,6-di*-O-*benzoyl-4-deoxy-β-D*-xylo- *hexopyranoside* (**13**)

To a solution of **12** (1.0 g, 1.36 mmol) in pyridine (30 ml) were added benzoic anhydride (1.23 g, 5.44 mmol) and 4-dimethylaminopyridine (0.05 g, 0.41 mmol), and the mixture was stirred for 24 h at room temperature; the course of the reaction was monitored by TLC. After completion of the reaction, methanol was added, and the mixture was stirred for 30 min, then concentrated. The residue was extracted with dichloromethane, and successively washed with 2 M hydrochloric acid and water, dried (Na_2SO_4) and concentrated. Column chromatography (50:1

toluene: methanol) of the residue on silica gel (40 g) gave **13** (0.91 g, 71%) as an amorphous mass; $[\alpha]_D$ +3.7° (*c* 1.0, dichloromethane); IR (film) 3425–3200 (NH), 1740 (ester), 1660 and 1545 (amide), 860 and 840 (TMS), and 710 cm^{-1} (Ph); ^{1}H-NMR data ($CDCl_3$) Gal unit δ 0.97 (m, 2H, $Me_3SiCH_2CH_2$), 4.79 (d, 1H, $J_{1,2}$ 7.9 Hz, H-1), 5.10 (dd, 1H, $J_{1,2}$ 7.9, $J_{2,3}$ 9.2 Hz, H-2), 7.55–8.28 (m, 10H, 2Ph); Neu5Ac unit δ 1.65 (s, 3H, AcN), 1.92, 2.09, 2.19 and 2.29 (4s, 12H, 4AcO), 2.66 (dd, 1H, J_{gem} 12.8, $J_{3eq,4}$ 4.6 Hz, H-3*eq*), 3.84 (s, 3H, MeO), 4.41 (dd, 1H, $J_{8,9}$ 2.4, J_{gem} 12.5 Hz, H-9), 4.90 (m, 1H, H-4), 5.32 (d, 1H, $J_{NH,5}$ 10.8 Hz, NH), and 5.65 (m, 1H, H-8).

Analytical data. Calculated for $C_{45}H_{59}O_{19}NSi$: C, 57.13; H, 6.29; N, 1.48. Found: C, 56.94; H, 6.20; N, 1.23.

O-*(Methyl 5-acetamido-4,7,8,9-tetra*-O-*acetyl-3,5-dideoxy-D*-glycero-α-*D*-galacto-*2-nonulopyranosylonate)-(2→3)-2,6-di*-O-*benzoyl-4-deoxy-D*-xylo-*hexopyranose* (**14**)

To a solution of **13** (120 mg, 0.13 mmol) in dichloromethane (0.6 ml) was added trifluoroacetic acid (1.2 ml), and the mixture was stirred for 30 min at room temperature and concentrated. Column chromatography (4:1 ethyl acetate:hexane) of the residue on silica gel (20 g) gave **14** (92.6 mg, 87%) as an amorphous mass; IR (film) 3700–3200 (OH, NH), 1740 (ester), 1660 and 1550 (amide), and 710 cm^{-1} (Ph).

Analytical data. Calculated for $C_{40}H_{47}O_{19}N$: C, 56.80; H, 5.60; N, 1.66. Found: C, 56.74; H, 5.49; N, 1.50.

O-*(Methyl 5-acetamido-4,7,8,9-tetra*-O-*acetyl-3,5-dideoxy-D*-glycero-α-*D*-galacto-*2-nonulopyranosylonate)-(2→3)-2,6-di*-O-*benzoyl-4-deoxy-D*-xylo-*hexopyranosyl trichloroacetimidate* (**15**)

To a solution of **14** (90 mg, 0.11 mmol) in dichloromethane (2 ml) and trichloroacetonitrile (320 μl, 3.19 mmol) was added DBU (16 μl, 0.11 mmol) at 0 °C, and the mixture was stirred for 2 h at 0 °C, then concentrated. Column chromatography (4:1 ethyl acetate: hexane) of the residue on silica gel (20 g) gave **15** (102.6 mg, 97%) as an amorphous mass; IR (film) 3450–3200 (NH), 1740 (ester), 1660 and 1550 (amide), and 710 cm^{-1} (Ph). The anomeric ratio (α:β) was estimated as ~ 1:2 from the ratio of the intensities of the anomeric proton signals of Gal unit in the ^{1}H-NMR spectrum.

Analytical data. Calculated for $C_{42}H_{47}O_{19}N_2Cl_3$: C, 50.95; H, 4.78; N, 2.83. Found: C, 50.80; H, 4.66; N, 2.60.

Methyl O-*(methyl 5-acetamido-4,7,8,9-tetra*-O-*acetyl-3,5-dideoxy-D*-glycero-α-*D*-galacto-*2-nonulopyranosylonate)-(2→3)-2,6-di*-O-*benzoyl-4-deoxy-1-thio-β-D*-xylo-*hexopyranoside* (**16**)

To a stirred solution of **15** (104 mg, 100 μmol) in dichloromethane (1.3 ml) were added methylthiotrimethylsilane (30 μl, 210 μmol) and boron trifluoride etherate (56 μl, 210 μmol), and the mixture was stirred for 3 h at room temperature. Dichloromethane (50 ml) was added and the mixture was washed with 1 M sodium carbonate, dried (Na_2SO_4) and concentrated. Column chromatography (50:1 toluene:methanol) of the residue on silica gel (50 g) gave **16** (83.1 mg, 91%) as an amorphous mass; $[\alpha]_D$ +9.4° (*c* 1.7, dichloromethane); IR (film) 3425–3200 (NH), 1740 (ester), 1660 and 1540 (amide), and 710 cm^{-1} (Ph); ^{1}H-NMR data ($CDCl_3$) Gal unit δ 2.16 (s, 3H, SMe), 4.65 (d, 1H, $J_{1,2}$ 9.9 Hz, H-1), 5.10 (t, 1H, $J_{1,2} = J_{2,3}$ 9.5 Hz, H-2), 7.29–8.16 (m, 10H, 2Ph); Neu5Ac unit δ 1.56 (s, 3H, AcN), 1.81, 1.97, 2.07 and 2.16 (4s, 12H, 4AcO), 2.54 (dd, 1H, J_{gem} 12.6, $J_{3eq,4}$ 4.4 Hz, H-3*eq*), 3.70 (s, 3H, MeO), 4.30 (dd, 1H, $J_{8,9}$ 2.4, J_{gem} 12.5 Hz, H-9), 4.77 (m, 1H, H-4), 5.22 (dd, 1H, H-7), 5.32 (d, 1H, $J_{NH,5}$ 11.2 Hz, NH), and 5.53 (m, 1H, H-8).

Analytical data. Calculated for $C_{41}H_{49}O_{18}NS$: C, 56.22; H, 5.64; N, 1.60. Found: C, 56.06; H, 5.50; N, 1.49.

2-(Trimethylsilyl)ethyl O-*(methyl 5-acetamido-4,7,8,9-tetra*-O-*acetyl-3,5-dideoxy-D*-glycero-α-*D*-galacto-*2-nonulopyranosylonate)-(2→3)-β-D-fucopyranoside* (**17**)

Glycosylation of **5** (3.1 g, 11.7 mmol) with **6** (10.24 g, 17.6 mmol), as described for the synthesis of **7** gave **17** (6.0 g, 70%) as an amorphous mass; $[\alpha]_D$ −12.4° (*c* 1.1, dichloromethane); IR (film) 3600–3200 (OH, NH), 1750 and 1230 (ester), 1670 and 1545 (amide), 860 and 840 (TMS), and 725 cm^{-1} (Ph); ^{1}H-NMR data ($CDCl_3$) Gal unit δ 1.02 (m, 2H, $Me_3SiCH_2CH_2$), 1.29 (d, 3H, $J_{5,6}$ 6.6 Hz, H-6), 4.36 (d, 1H, $J_{1,2}$ 7.7 Hz, H-1); Neu5Ac unit δ 1.88 (s, 3H, AcN), 2.02, 2.03, 2.10, 2.13 (4s, 12H, 4AcO) 2.71 (dd, 1H, J_{gem} 13.0, $J_{3eq,4}$ 4.4 Hz, H-3*eq*), 3.81 (s, 3H, MeO), 4.28 (dd, 1H, $J_{8,9}$ 2.8, J_{gem} 12.6 Hz, H-9), 4.93 (m, 1H, H-4), 5.31 (dd, 1H, $J_{6,7}$ 1.8, $J_{7,8}$ 8.8 Hz, H-7), 5.33 (d, 1H, $J_{NH,5}$ 9.3 Hz, NH), and 5.43 (m, 1H, H-8).

Analytical data. Calculated for $C_{31}H_{51}O_{17}NSi$: C, 50.46; H, 6.97; N, 1.90. Found: C, 50.20; H, 6.70; N, 1.68.

2-(Trimethylsilyl)ethyl O-*(methyl 5-acetamido-4,7,8,9-tetra*-O-*acetyl-3,5-dideoxy-D*-glycero-α-*D*-galacto-*2-nonulopyranosylonate)-(2→3)-2,4-di*-O-*benzoyl-β-D-fucopyranoside* (**18**)

Benzoylation of **17** (4.0 g, 5.5 mmol), as described for the synthesis of **13**, gave **18** (4.03 g, 78%) as an amorphous mass; $[\alpha]_D$ +41.4° (*c* 1.1, dichloromethane); IR (film) 3425–3200 (NH), 1750 (ester), 1660 and 1545 (amide), 860 and 840 (TMS), and 710 cm^{-1} (Ph); ^{1}H-NMR data ($CDCl_3$) Gal unit δ 0.96 (m, 2H, $Me_3SiCH_2CH_2$), 1.32 (d, 3H, $J_{5,6}$ 6.4 Hz, H-6), 4.87 (d, 1H, $J_{1,2}$ 7.9 Hz, H-1), 5.16 (d, 1H, $J_{3,4}$ 3.1 Hz, H-4), 5.46 (dd, 1H, $J_{1,2}$ 8.1, $J_{2,3}$ 10.1 Hz, H-2), 7.54–8.28 (m, 10H, 2Ph); Neu5Ac unit δ 1.54 (s, 3H, AcN), 1.88, 2.02, 2.18 and 2.34 (4s, 12H, 4AcO), 2.56 (dd, 1H, J_{gem} 12.5, $J_{3eq,4}$ 4.4 Hz, H-3*eq*), 3.99 (s, 3H, MeO), 4.45 (dd, 1H, $J_{8,9}$ 2.4, J_{gem} 12.5 Hz, H-9), 5.23 (d, 1H, $J_{NH,5}$ 9.9 Hz, NH), 5.29 (dd, 1H, $J_{6,7}$ 2.6, $J_{7,8}$

9.5 Hz, H-7), and 5.73 (ddd, 1H, $J_{7,8}$ 9.2, $J_{8,9}$ 2.6, $J_{8,9'}$ 5.9 Hz, H-8).

Analytical data. Calculated for $C_{45}H_{59}O_{19}NSi$: C, 57.13; H, 6.29; N, 1.48. Found: C, 57.12; H, 6.23; N, 1.40.

O-*(Methyl 5-acetamido-4,7,8,9-tetra*-O-*acetyl-3,5-dideoxy-D*-glycero-*α-D*-galacto-*2-nonulopyranosylonate)-(2→3)-2,4-di*-O-*benzoyl-D-fucopyranose* (**19**)

Selective removal of the 2-(trimethylsilyl)ethyl group in **18** (0.1 g, 0.11 mmol) as described for the synthesis of **14**, gave **19** (87.8 mg, 98%) as an amorphous mass; IR (film) 3700–3200 (OH, NH), 1740 (ester), 1660 and 1550 (amide), and 710 cm^{-1} (Ph).

Analytical data. Calculated for $C_{40}H_{47}O_{19}N$: C, 56.80; H, 5.60; N, 1.66. Found: C, 56.73; H, 5.30; N, 1.53.

O-*(Methyl 5-acetamido-4,7,8,9-tetra*-O-*acetyl-3,5-dideoxy-D*-glycero-*α-D*-galacto-*2-nonulopyranosylonate)-(2→3)-2,4-di*-O-*benzoyl-D-fucopyranosyl trichloroacetimidate* (**20**)

A solution of **19** (76 mg, 90 μmol) in dichloromethane (1 ml) was treated with trichloroacetonitrile (272 μl, 2.71 mmol) in a fashion similar to that described for **15**, to get amorphous **20** (81.4 mg, 91%); IR (film) 3450–3200 (NH), 1740 (ester), 1660 and 1550 (amide), and 710 cm^{-1} (Ph). The anomeric ratio (α:β) was estimated as ~ 1:1 from the ratio of the intensities of the anomeric proton signals of Gal unit in the ^{1}H-NMR spectrum.

Analytical data. Calculated for $C_{42}H_{47}O_{19}N_2Cl_3$: C, 50.95; H, 4.78; N, 2.83. Found: C, 50.79; H, 4.65; N, 2.56.

Methyl O-*(methyl 5-acetamido-4,7,8,9-tetra*-O-*acetyl-3,5-dideoxy-D*-glycero-*α-D*-galacto-*2-nonulopyranosylonate)-(2→3)-2,4-di*-O-*benzoyl-1-thio-β-D-fucopyranoside* (**21**)

A solution of **20** (45.5 mg, 46 μmol) in dichloromethane (1.3 ml) was treated with methylthiotrimethylsilane (13 μl, 92 μmol) and boron trifluoride etherate (12 μl, 46 μmol), as described for **16**, to yield amorphous **21** (39.4 mg, 98%); $[\alpha]_D$ +57.3° (*c* 0.2, dichloromethane); IR (film) 3425–3200 (NH), 1740 (ester), 1660 and 1540 (amide), and 710 cm^{-1} (Ph); ^{1}H-NMR data ($CDCl_3$) Gal unit δ 1.22 (d, 3H, $J_{5,6}$ 6.4 Hz, H-6), 2.24 (s, 3H, SMe), 4.73 (d, 1H, $J_{1,2}$ 9.9 Hz, H-1), 4.84 (dd, 1H, $J_{2,3}$ 9.7, $J_{3,4}$ 3.3 Hz, H-3), 5.52 (dd, 1H, $J_{1,2}$ 9.9, $J_{2,3}$ 9.7 Hz, H-2), 7.46–8.18 (m, 10H, 2Ph); Neu5Ac unit δ 1.46 (s, 3H, AcN), 1.78, 1.92, 2.08 and 2.23 (4s, 12H, 4AcO), 2.47 (dd, 1H, J_{gem} 12.6, $J_{3eq,4}$ 4.4 Hz, H-3*eq*), 3.90 (s, 3H, MeO), 4.33 (dd, 1H, $J_{8,9}$ 2.4, J_{gem} 12.6 Hz, H-9), 5.08 (d, 1H, $J_{NH,5}$ 10.3 Hz, NH), 5.21 (dd, 1H, $J_{6,7}$ 2.6, $J_{7,8}$ 9.4 Hz, H-7), and 5.61 (m, 1H, $J_{7,8}$ 9.2, $J_{8,9}$ 2.4, $J_{8,9'}$ 5.5 Hz, H-8).

Analytical data. Calculated for $C_{41}H_{49}O_{18}NS$: C, 56.22; H, 5.64; N, 1.60. Found: C, 56.20; H, 5.54; N, 1.31.

2-(Trimethylsilyl)ethyl O-*(methyl 5-acetamido-4,7,8,9-tetra*-O-*acetyl-3,5-dideoxy-D*-glycero-*α-D*-galacto-*2-nonulopyra-nosylonate)-(2→3)-6-bromo-4,6-dideoxy-β-D*-xylo-*hexopyranoside* (**22**)

To a solution of **12** (0.89 g, 1.21 mmol) in pyridine (10 ml) were added carbon tetrabromide (0.80 g, 2.41 mmol) at room temperature, and then triphenylphosphine (0.63 g, 2.40 mmol) at 0 °C. The mixture was stirred for 5 h at room temperature; the course of the reaction was monitored by TLC. After completion of the reaction, methanol (5 ml) was added, the mixture was stirred for 30 min, and concentrated. Column chromatography (30:1 dichloromethane:methanol) of the residue on silica gel (80 g) gave **22** (0.73 g, 76%) as an amorphous mass; $[\alpha]_D$ −14.7° (*c* 1.9, dichloromethane); IR (film) 3650–3200 (OH, NH), 1740 (ester), 1660 and 1545 (amide), and 860 and 840 cm^{-1} (TMS); ^{1}H-NMR data ($CDCl_3$) Gal unit δ 1.04 (m, 2H, $Me_3SiCH_2CH_2$), 4.39 (d, 1H, $J_{1,2}$ 7.7 Hz, H-1); Neu5Ac δ 1.87 (s, 3H, AcN), 2.01, 2.03, 2.10 and 2.14 (4s, 12H, 4AcO), 2.65 (dd, 1H, J_{gem} 13.0, $J_{3eq,4}$ 4.6 Hz, H-3*eq*), 3.80 (s, 3H, MeO), 4.28 (dd, 1H, $J_{8,9}$ 2.6, J_{gem} 12.5 Hz, H-9), 4.92 (m, 1H, H-4), 5.31 (d, 1H, $J_{NH,5}$ 9.2 Hz, NH), 5.43 (m, 1H, H-8).

Analytical data. Calculated for $C_{31}H_{50}O_{16}BrNSi$: C, 46.50; H, 6.29; N, 1.75. Found: C, 46.35; H, 6.28; N, 1.65.

2-(Trimethylsilyl)ethyl O-*(methyl 5-acetamido-4,7,8,9-tetra*-O-*acetyl-3,5-dideoxy-D*-glycero-*α-D*-galacto-*2-nonulo-pyranosylonate)-(2→3)-2*-O-*benzoyl-6-bromo-4,6-dideoxy-β-D*-xylo-*hexopyranoside* (**23**)

To a solution of **22** (0.32 g, 0.40 mmol) in pyridine (9 ml) were added benzoic anhydride (0.18 g, 0.80 mmol) and 4-dimethylaminopyridine (15 mg, 0.12 mmol), and the mixture was stirred for 24 h at room temperature; the course of the reaction was monitored by TLC. Work-up as described for **13**, gave **23** (0.31 g, 87%) as an amorphous mass; $[\alpha]_D$ +3.2° (*c* 1.1, dichloromethane); IR (film) 3425–3200 (NH), 1740 (ester), 1660 and 1545 (amide), 860 and 840 (TMS), 710 cm^{-1} (Ph); ^{1}H-NMR data ($CDCl_3$) Gal unit δ 0.85 (m, 2H, $Me_3SiCH_2CH_2$), 4.42 (m, 1H, H-3), 4.65 (d, 1H, $J_{1,2}$ 7.9 Hz, H-1), 4.95 (dd, 1H, $J_{1,2}$ 7.9, $J_{2,3}$ 9.4 Hz, H-2), 7.43–8.16 (m, 5H, Ph); Neu5Ac unit δ 1.55 (s, 3H, AcN), 1.78, 1.97, 2.06, 2.18 (4s, 12H, 4AcO), 2.54 (dd, 1H, J_{gem} 12.6, $J_{3eq,4}$ 4.5 Hz, H-3*eq*), 3.77 (s, 3H, MeO), 4.30 (dd, 1H, $J_{8,9}$ 2.6, J_{gem} 12.6 Hz, H-9), 4.75 (m, 1H, H-4), 5.22 (dd, 1H, H-7), 5.42 (d, 1H, NH), 5.55 (m, 1H, H-8).

Analytical data. Calculated for $C_{38}H_{54}O_{17}BrNSi$: C, 50.44; H, 6.02; N, 1.55. Found: C, 50.19; H, 5.80; N, 1.34.

2-(Trimethylsilyl)ethyl O-*(methyl 5-acetamido-4,7,8,9-tetra*-O-*acetyl-3,5-dideoxy-D*-glycero-*α-D*-galacto-*2-nonulopyranosylonate)-(2→3)-2*-O-*benzoyl-4,6-dideoxy-β-D*-xylo-*hexopyranoside* (**24**)

To a solution of **23** (85 mg, 94 μmol) in cyclohexane (1.5 ml) and dichloromethane (0.5 ml) were added diethylamine (20 μl) and 10% Pd-C (10 mg), and the suspension was stirred for 48 h at room temperature under hydrogen. The catalyst was collected and washed with dichloromethane, and the combined filtrate and washings were concentrated. Column chromatography (30:1 dichloromethane:methanol) of the residue on silica gel (80 g) gave **24** (60 mg, 77%) as an amorphous mass; $[\alpha]_D$ +3.3° (*c* 1.2, dichloromethane); IR (film) 3425–3200 (NH), 1740 (ester), 1660 and 1545 (amide), 860 and 840 (TMS) and 710 cm^{-1} (Ph); ^{1}H-NMR data ($CDCl_3$) Gal unit δ 0.84 (m, 2H, $Me_3SiCH_2CH_2$), 1.27 (d, 3H, $J_{5,6}$ 5.5 Hz, H-6), 4.37 (m, 1H, H-3), 4.57 (d, 1H, $J_{1,2}$ 7.9 Hz, H-1), 4.91 (dd, 1H, $J_{1,2}$ 8.8, $J_{2,3}$ 9.0 Hz, H-2), 7.42–8.16 (m, 5H, Ph); Neu5Ac unit δ 1.52 (s, 3H, AcN), 1.80, 1.97, 2.07 and 2.19 (4s, 12H, 4AcO), 2.53 (dd, 1H, J_{gem} 12.8, $J_{3eq,4}$ 4.4 Hz, H-3*eq*), 3.77 (s, 3H, MeO), 4.31 (dd, 1H, $J_{8,9}$ 2.4, J_{gem} 12.5 Hz, H-9), 4.76 (m, 1H, H-4), 5.20 (d, 1H, $J_{NH,5}$ 9.0 Hz, NH), 5.52 (m, 1H, H-8).

Analytical data. Calculated for $C_{38}H_{55}O_{17}NSi$: C, 55.26; H, 6.71; N, 1.70. Found: C, 55.11; H, 6.70; N, 1.59.

O-*(Methyl 5-acetamido-4,7,8,9-tetra*-O-*acetyl-3,5-dideoxy-D*-glycero-*α-D*-galacto-*2-nonulopyranosylonate)-(2→3)-2*-O-*benzoyl-4,6-dideoxy-D*-xylo-*hexopyranose* (**25**)

Selective removal of the 2-(trimethylsilyl)ethyl group in **24** (59.4 mg, 72 μmol) as described for the synthesis of **14**, gave **25** (52.0 mg, quantitative) as an amorphous mass; IR (film) 3700–3200 (OH, NH), 1740 (ester), 1660 and 1550 (amide), and 710 cm^{-1} (Ph).

Analytical data. Calculated for $C_{33}H_{43}O_{17}N$: C, 54.62; H, 5.97; N, 1.93. Found: C, 54.54; H, 5.95; N, 1.66.

O-(Methyl 5-acetamido-4,7,8,9-tetra-O-*acetyl-3,5-dideoxy-D*-glycero-*α-D*-galacto-*2-nonulopyranosylonate)-(2→3)-2*-O-*benzoyl-4,6-dideoxy-D*-xylo-*hexopyranosyl trichloroacetimidate* (**26**)

A solution of **25** (49.0 mg, 68 μmol) in dichloromethane (1 ml) was treated with trichloroacetonitrile (200 μl, 2.0 mmol) in a fashion similar to that described for **15**, to get amorphous **26** (52,3 mg, 89%); IR (film) 3450–3200 (NH), 1740 (ester), 1660 and 1550 (amide), and 710 cm^{-1} (Ph). The anomeric ratio (α:β) was estimated as ~ 2:3 from the ratio of the intensities of the anomeric proton signals of Gal unit in the ^{1}H-NMR spectrum.

Analytical data. Calculated for $C_{35}H_{43}O_{17}N_2Cl_3$: C, 48.32; H, 4.98; N, 3.22. Found: C, 48.03; H, 4.74; N, 3.05.

Methyl-O-*(methyl 5-acetamido-4,7,8,9-tetra*-O-*acetyl-3,5-dideoxy-D*-glycero-*α-D*-galacto-*2-nonulopyranosylonate)-(2→3)-2*-O-*benzoyl-4,6-dideoxy-1-thio-β-D*-xylo-*hexopyranoside* (**27**)

A solution of **26** (52.3 mg, 60 μmol) in dichloromethane (1.3 ml) was treated with methylthiotrimethylsilane (17 μl, 120 μmol) and boron trifluoride etherate (32 μl, 120 μmol), as described for **16**, to yield amorphous **27** (38.3 mg, 84%); $[\alpha]_D$ +6.3° (*c* 0.8, dichloromethane); IR (film) 3425–3200 (NH), 1740 (ester), 1660 and 1540 (amide), and 710 cm^{-1} (Ph); ^{1}H-NMR data ($CDCl_3$) Gal unit δ 1.27 (d, 3H, $J_{5,6}$ 6.0 Hz, H-6), 2.18 (s, 3H, SMe), 4.44 (m, 1H, H-3), 4.54 (d, 1H, $J_{1,2}$ 9.8 Hz, H-1), 5.10 (t, 1H, $J_{1,2} = J_{2,3}$ 9.4 Hz, H-2), 7.43–8.16 (m, 5H, Ph); Neu5Ac unit δ 1.54 (s, 3H, AcN), 1.80, 1.97, 2.07 and 2.14 (4s, 12H, 4AcO), 2.53 (dd, 1H, J_{gem} 12.8, $J_{3eq,4}$ 4.7 Hz, H-3*eq*), 3.78 (s, 3H, MeO), 4.29 (dd, 1H, $J_{8,9}$ 2.6, J_{gem} 12.6 Hz, H-9), 4.78 (m, 1H, H-4), 5.12 (d, 1H, $J_{NH,5}$ 8.6 Hz, NH), 5.19 (dd, 1H, $J_{6,7}$ 1.7, $J_{7,8}$ 9.0 Hz, H-7), 5.50 (m, 1H, H-8).

Analytical data. Calculated for $C_{34}H_{45}O_{16}NS$: C, 54.03; H, 6.00; N, 1.85. Found: C, 53.74; H, 5.87; N, 1.70.

2-(Trimethylsilyl)ethyl O-*(methyl 5-acetamido-4,7,8,9-tetra*-O-*acetyl-3,5-dideoxy-D*-glycero-*α-D*-galacto-*2-nonulopyranosylonate)-(2→3)*-O-*(2,6-di*-O-*benzoyl-4-deoxy-β-D*-xylo-*hexopyranosyl)-(1→4)*-O-*[(2,3,4-tri*-O-*benzyl-α-L-fucopyranosyl)-(1→3)]*-O-*(2-acetamido-6-*O-*benzyl-2-deoxy-β-D-glucopyranosyl)-(1→3)-2,4,6-tri*-O-*benzyl-β-D-galactopyranoside* (**29**)

To a solution of **28** (79.9 mg, 60 μmol) with **16** (83.1 mg, 0.10 mmol) in dichloromethane (0.25 ml) were added molecular sieves 4 Å (111 mg), and the mixture was stirred for 5 h at room temperature, then cooled to 0 °C. A mixture of dimethyl(methylthio)sulfonium triflate (DMTST) and molecular sieves 4 Å (467 mg; 60% DMTST by weight) was added to the mixture, and the resultant mixture was stirred for further 72 h at 7 °C. The precipitate was filtered off, and washed with dichloromethane. The filtrate and washings were combined, and successively washed with 1 M sodium carbonate and water, dried (Na_2SO_4) and concentrated. Column chromatography (30:1 dichloromethane:methanol) of the residue on silica gel (80 g) gave **29** (60 mg, 45%) as an amorphous mass; $[\alpha]_D$ −28.7° (*c* 0.7, dichloromethane); IR (film) 3425–3200 (NH), 1740 (ester), 1660 and 1530 (amide), 860 and 840 (TMS), and 710 cm^{-1} (Ph); ^{1}H-NMR data ($CDCl_3$) δ 0.98 (m, 2H, $Me_3SiCH_2CH_2$), 1.11 (d, 3H, $J_{5,6}$ 6.4 Hz, H-6e), 1.64 and 1.70 (2s, 6H, 2AcN), 1.84, 1.99, 2.00 and 2.15 (4s, 12H, 4AcO), 2.52 (dd, 1H, J_{gem} 12.6, $J_{3eq,4}$ 4.6 Hz, H-3d-*eq*), 3.72 (s, 3H, MeO), 5.45 (t, 1H, $J_{1,2} = J_{2,3}$ 9.3 Hz, H-2c), 5.55 (m, 1H, H-8d), 5.78 (d, 1H, $J_{NH,5}$ 7.7 Hz, NHd), 7.14–8.16 (m, 45H, 9Ph).

Analytical data. Calculated for $C_{114}H_{134}O_{33}N_2Si$: C,

65.56; H, 6.47; N, 1.34. Found: C, 65.52; H, 6.26; N, 1.12.

2-(Trimethylsilyl)ethyl O-*(methyl 5-acetamido-4,7,8,9-tetra*-O-*acetyl-3,5-dideoxy-D*-glycero-α-*D*-galacto-*2-nonulopyranosylonate)-(2→3)*-O-*(2,6-di*-O-*benzoyl-4-deoxy-β-D*-xylo-*hexopyranosyl)-(1→4)*-O-*[(2,3,4-tri*-O-*acetyl-α-L-fucopyranosyl)-(1→3)]*-O-*(2-acetamido-6*-O-*acetyl-2-deoxy-β-D- glucopyranosyl)-(1→3)-2,4,6-tri*-O-*acetyl-β-D-galactopyranoside* (**30**)

A solution of **29** (182 mg, 90 μmol) in ethanol (24 ml) and acetic acid (5 ml) was stirred with 10% Pd-C (180 mg) for 72 h at 45 °C under hydrogen. The catalyst was collected and washed with ethanol. The combined filtrate and washings were concentrated, and the residue was heated with acetic anhydride (1 ml) and pyridine (5 ml) for 24 h at 40 °C. The mixture was concentrated, and the residue was extracted with dichloromethane and successively washed with 2 M hydrochloric acid and water, dried (Na_2SO_4) and concentrated. Column chromatography (30:1 dichloromethane:methanol) of the residue on silica gel (60 g) gave **30** (141 mg, 92%) as an amorphous mass; $[\alpha]_D$ −26.1° (*c* 0.4, dichloromethane); IR (film) 3425–3200 (NH), 1750 (ester), 1540 (amide), 860 and 840 (TMS), and 710 cm^{-1} (Ph); ^{1}H-NMR data ($CDCl_3$) δ 0.90 (m, 2H, Me_3Si CH_2CH_2), 1.21 (d, 3H, $J_{5,6}$ 6.4 Hz, H-6e), 1.79–2.16 (13s, 39H, 2AcN and 11AcO), 2.54 (dd, 1H, J_{gem} 13.2, $J_{3eq,4}$ 4.8 Hz, H-3d-*eq*), 3.71 (s, 3H, MeO), 5.58 (m, 1H, H-8d), 7.48–8.16 (m, 10H, 2Ph).

Analytical data. Calculated for $C_{79}H_{106}O_{40}N_2Si$: C, 54.17, H, 6.10; N, 1.60. Found: C, 53.99; H, 5.92; N, 1.53.

O-*(Methyl 5-acetamido-4,7,8,9-tetra*-O-*acetyl-3,5-dideoxy-D*-glycero-α-*D*-galacto-*2-nonulopyranosylonate)-(2→3)*-O-*(2,6-di*-O-*benzoyl-4-deoxy-β-D*-xylo-*hexopyranosyl)-(1→4)*-O-*[(2,3,4-tri*-O-*acetyl-α-L-fucopyranosyl)-(1→3)]*-O-*(2- acetamido-6*-O-*acetyl-2-deoxy-β-D-glucopyranosyl)-(1→3)-2,4,6-tri*-O-*acetyl-D-galactopyranose* (**31**)

To a solution of **30** (138 mg, 80 μmol) in dichloromethane (9 ml) was added trifluoroacetic acid (1.4 ml), and the mixture was stirred for 1 h at room temperature and concentrated. Column chromatography (4:1 ethyl acetate: hexane) of the residue on silica gel (80 g) gave **31** (123 mg, 95%) as an amorphous mass; IR (film) 3700–3200 (OH, NH), 1750 (ester), 1670 and 1540 (amide), and 710 cm^{-1} (Ph).

Analytical data. Calculated for $C_{74}H_{94}O_{40}N_2$: C, 53.82; H, 5.74; N, 1.70. Found: C, 53.74; H, 5.47; N, 1.57.

O-*(Methyl 5-acetamido-4,7,8,9-tetra*-O-*acetyl-3,5-dideoxy-D*-glycero-α-*D*-galacto-*2-nonulopyranosylonate)-(2→3)*-O-*(2,6-di*-O-*benzoyl-4-deoxy-β-D*-xylo-*hexopyranosyl)-(1→4)*-O-*[(2,3,4-tri*-O-*acetyl-α-L-fucopyranosyl)-(1→3)]*-O-*(2-acetamido-6*-O-*acetyl-2-deoxy-β-D-glucopyranosyl)-(1→3)-2,4,6-tri*-O-*acetyl-α-D-galactopyranosyl trichloroacetimidate* (**32**)

To a solution of **31** (123 mg, 70 μmol) in dichloromethane (1.4 ml) and trichloroacetonitrile (220 μl, 2.19 mmol) was added DBU (13 μl, 87 μmol) at 0 °C, and the mixture was stirred for 2 h at 0 °C, then concentrated. Column chromatography (15:1 dichloromethane:methanol) of the residue on silica gel (30 g) gave **32** (116 mg, 87%) as an amorphous mass; $[\alpha]_D$ +5.4° (*c* 1.4, dichloromethane); IR (film) 3430–3200 (NH), 1750 (ester), 1680 and 1540 (amide), and 710 cm^{-1} (Ph); ^{1}H-NMR data ($CDCl_3$) δ 1.22 (d, 3H, $J_{5,6}$ 6.4 Hz, H-6e), 1.79–2.15 (13s, 39H, 2AcN and 11AcO), 2.55 (dd, 1H, J_{gem} 12.8, $J_{3eq,4}$ 4.6 Hz, H-3d-*eq*), 3.72 (s, 3H, MeO), 5.56 (m, 1H, H-8d), 6.48 (d, 1H, $J_{1,2}$ 3.7 Hz, H-1a), 7.16–8.15 (m, 10H, 2Ph), and 8.63 (s, 1H, C = NH).

Analytical data. Calculated for $C_{76}H_{94}O_{40}N_3Cl_3$: C, 50.83; H, 5.28; N, 2.34. Found: C, 50.63; H, 5.14; N, 2.12.

2-(Trimethylsilyl)ethyl O-*(methyl 5-acetamido-4,7,8,9-tetra*-O-*acetyl-3,5-dideoxy-D*-glycero-α-*D*-galacto-*2-nonulopyranosylonate)-(2→3)*-O-*(2,4-di*-O-*benzoyl-β-D-fucopyranosyl)-(1→4)*-O-*[(2,3,4-tri-O-benzyl-α-L-fucopyranosyl)-(1→3)]*-O-*(2-acetamido-6*-O-*benzyl-2-deoxy-β-D-glucopyranosyl)-(1→3)-2,4,6-tri*-O-*benzyl-β-D-galactopyranoside* (**33**)

Glycosylation of **28** (357 mg, 0.28 mmol) with **21** (446 mg, 0.51 mmol), as described for the synthesis of **29**, gave **33** (212 mg, 36%) as an amorphous mass; $[\alpha]_D$ −21.3° (*c* 1.9, dichloromethane); IR (film) 3425–3200 (NH), 1740 (ester), 1660 and 1530 (amide), 860 and 840 (TMS), and 710 cm^{-1} (Ph); ^{1}H-NMR data ($CDCl_3$) δ 0.99 (m, 2H, $Me_3SiCH_2CH_2$), 1.16 (d, 3H, $J_{5,6}$ 6.2 Hz, H-6e), 1.26 (d, 3H, $J_{5,6}$ 6.6 Hz, H-6c), 1.54 and 1.56 (2s, 6H, 2AcN), 1.80, 1.92, 2.02, 2.18 (4s, 12H, 4AcO), 2.42 (dd, 1H, J_{gem} 12.6, $J_{3eq,4}$ 4.6 Hz, H-3d-*eq*), 3.80 (s, 3H, MeO), 5.00 (d, 1H, $J_{1,2}$ 3.9 Hz, H-1e), 5.09 (d, 1H, $J_{NH,5}$ 10.1 Hz, NHd), 5.19 (d, 1H, $J_{3,4}$ 3.5 Hz, H-4c), 5.23 (dd, 1H, $J_{6,7}$ 2.6, $J_{7,8}$ 9.5 Hz, H-7d), 5.40 (t, 1H, $J_{1,2} = J_{2,3}$ 8.2 Hz, H-2c), 5.67 (ddd, 1H, $J_{7,8}$ 8.4, $J_{8,9}$ 2.6, $J_{8,9'}$ 5.9 Hz, H-8d), 7.10–8.23 (m, 45H, 9Ph).

Analytical data. Calculated for $C_{114}H_{134}O_{33}N_2Si$: C, 65.56; H, 6.47; N, 1.34. Found: C, 65.39; H, 6.19; N, 1.25.

2-(Trimethylsilyl)ethyl O-*(methyl 5-acetamido-4,7,8,9-tetra*-O-*acetyl-3,5-dideoxy-D*-glycero-α-*D*-galacto-*2-nonulopyranosylonate)-(2→3)*-O-*(2,4-di*-O-*benzoyl-β-D-fucopyranosyl)-(1→4)*-O-*[(2,3,4-tri-O-acetyl-α-L-fucopyranosyl)-(1→3)]*-O-*(2-acetamido-6*-O-*acetyl-2-deoxy-β-D-glucopyranosyl)-(1→3)-2,4,6-tri*-O-*acetyl-β-D-galactopyranoside* (**34**)

A solution of **33** (212 mg, 0.10 mmol) in ethanol (24 ml) and acetic acid (5 ml) was stirred with 10% Pd-C

(210 mg) for 72 h at 45 °C under hydrogen. Work-up as described for **30**, gave **34** (149 mg, 84%) as an amorphous mass; $[\alpha]_D$ −14.7° (*c* 1.2, dichloromethane); IR (film) 3425–3200 (NH), 1750 (ester), 1660 and 1540 (amide), 860 and 840 (TMS), and 710 cm^{-1} (Ph); ^{1}H-NMR data ($CDCl_3$) δ 0.92 (m, 2H, $Me_3SiCH_2CH_2$), 1.18 (d, 3H, $J_{5,6}$ 6.4 Hz, H-6e), 1.39 (d, 3H, $J_{5,6}$ 6.4 Hz, H-6c), 1.78–2.22 (13s, 39H, 2AcN and 11AcO), 2.38 (dd, 1H, J_{gem} 12.6, $J_{3eq,4}$ 4.6 Hz, H-3d-*eq*), 3.70 (s, 3H, MeO), 7.44–8.18 (m, 10H, 2Ph).

Analytical data. Calculated for $C_{79}H_{106}O_{40}N_2Si$: C, 54.17; H, 6.10; N, 1.60. Found: C, 54.01; H, 6.04; N, 1.47.

O-*(Methyl 5-acetamido-4,7,8,9-tetra*-O-*acetyl-3,5-dideoxy-D*-glycero-α-*D*-galacto-*2-nonulopyranosylonate)-(2→3)*-O-*(2,4-di*-O-*benzoyl-β-D-fucopyranosyl)-(1→4)*-O-*[(2,3,4-tri*-O-*acetyl-α-L-fucopyranosyl)-(1→3)]*-O-*(2-acetamido-6*-O-*acetyl-2-deoxy-β-D-glucopyranosyl)-(1→3)-2,4,6-tri*-O-*acetyl-D-galactopyranose* (**35**)

Selective removal of the 2-(trimethylsilyl)ethyl group in **34** (147 mg, 84 μmol) as described for the synthesis of **31**, gave **35** (139 mg, 92%) as an amorphous mass; IR (film) 3700–3200 (OH, NH), 1750 (ester), 1670 and 1540 (amide), and 710 cm^{-1} (Ph).

Analytical data. Calculated for $C_{74}H_{94}O_{40}N_2$: C, 53.82; H, 5.74; N, 1.70. Found: C, 53.59; H, 5.61; N, 1.56.

O-*(Methyl 5-acetamido-4,7,8,9-tetra*-O-*acetyl-3,5-dideoxy-D*-glycero-α-*D*-galacto-*2-nonulopyranosylonate)-(2→3)*-O-*(2,4-di*-O-*benzoyl-β-D-fucopyranosyl)-(1→4)-O-[(2,3,4-tri*-O-*acetyl-α-L-fucopyranosyl)-(1→3)]*-O-*(2-acetamido-6*-O-*acetyl-2-deoxy-β-D-glucopyranosyl)-(1→3)-2,4,6-tri*-O-*acetyl-α-D-galactopyranosyl trichloroacetimidate* (**36**)

A solution of **35** (121 mg, 73 μmol) in dichloromethane (1.4 ml) was treated with trichloroacetonitrile (220 μl, 2.19 mmol) in a fashion similar to that described for **32**, to get amorphous **36** (128 mg, 97%); $[\alpha]_D$ +11.3° (*c* 1.3, dichloromethane); IR (film) 3430–3200 (NH), 1750 (ester), 1680 and 1540 (amide), and 710 cm^{-1} (Ph); ^{1}H-NMR data ($CDCl_3$) δ 1.17 (d, 3H, $J_{5,6}$ 6.4 Hz, H-6e), 1.39 (d, 3H, $J_{5,6}$ 6.4 Hz, H-6c), 1.76–2.22 (13s, 39H, 2AcN and 11AcO), 2.38 (dd, 1H, J_{gem} 11.9, $J_{3eq,4}$ 4.4 Hz, H-3d-*eq*), 3.84 (s, 3H, MeO), 5.64 (m, 1H, H-8d), 6.48 (d, 1H, $J_{1,2}$ 3.9 Hz, H-1a), 7.16–8.18 (m, 10H, 2Ph), 8.63 (s, 1H, C = NH).

Analytical data. Calculated for $C_{76}H_{94}O_{40}N_3Cl_3$: C, 50.83; H, 5.28; N, 2.34. Found: C, 50.68; N, 5.25; N, 2.13.

2-(Trimethylsilyl)ethyl O-*(methyl 5-acetamido-4,7,8,9-tetra*-O-*acetyl-3,5-dideoxy-D*-glycero-α-*D*-galacto-*2-nonulopyranosylonate)-(2→3)*-O-*(2*-O-*benzoyl-4,6-dideoxy-β-D*-xylo-*hexopyranosyl)-(1→4)*-O-*[(2,3,4-tri*-O-*benzyl-α-L-fucopyranosyl)-(1→3)]*-O-*(2-acetamido-6*-O-*benzyl-2-deoxy-β-D-glucopyranosyl)-(1→3)-2,4,6-tri*-O-*benzyl-β-D-galactopyranoside* (**37**)

Glycosylation of **28** (179.9 mg, 140 μmol) with **27** (161.5 mg, 0.21 mmol), as described for the synthesis of **29**, gave **37** (122 mg, 43%) as an amorphous mass; $[\alpha]_D$ −4.0° (*c* 2.4, dichloromethane); IR (film) 3425–3200 (NH), 1740 (ester), 1660 and 1530 (amide), 860 and 840 (TMS), and 710 cm^{-1} (Ph); ^{1}H-NMR data ($CDCl_3$) δ 0.96 (m, 2H, $Me_3SiCH_2CH_2$), 1.16 (d, 3H, $J_{5,6}$ 7.0 Hz, H-6e), 1.18 (d, 3H, $J_{5,6}$ 6.8 Hz, H-6c), 1.59 and 1.64 (2s, 6H, 2AcN), 1.81, 1.95, 1.99 and 2.14 (4s, 12H, 4AcO), 2.47 (dd, 1H, H-3d-*eq*), 3.75 (s, 3H, MeO), 5.42 (t, 1H, $J_{1,2} = {}_{2,3}$ 9.0 Hz, H-2c), 5.52 (m, 1H, H-8d), 5.75 (d, 1H, $J_{NH,5}$ 8.1 Hz, NHd), 7.15–8.12 (m, 40H, 8Ph).

Analytical data. Calculated for $C_{107}H_{130}O_{31}N_2Si$: C, 65.29; H, 6.66; N, 1.42. Found: C, 65.07; H, 6.56; N, 1.17.

2-(Trimethylsilyl)ethyl O-*(methyl 5-acetamido-4,7,8,9-tetra*-O-*acetyl-3,5-dideoxy-D*-glycero-α-*D*-galacto-*2-nonulopyranosylonate)-(2→3)*-O-*(2*-O-*benzoyl-4,6-dideoxy-β-D*-xylo-*hexopyranosyl)-(1→4)*-O-*[(2,3,4-tri*-O-*acetyl-α-L-fucopyranosyl)-(1→3)]*-O-*(2-acetamido-6*-O-*acetyl-2-deoxy-β-D- glucopyranosyl)-(1→3)-2,4,6-tri*-O-*acetyl-β-D-galactopyranoside* (**38**)

A solution of **37** (122 mg, 62 μmol) in ethanol (20 ml) and acetic acid (4 ml) was stirred with 10% Pd-C (130 mg) for 72 h at 45 °C under hydrogen. A workup similar to that described for **30**, gave **38** (101 mg, 86%) as an amorphous mass; $[\alpha]_D$ −30.3° (*c* 1.4, dichloromethane); IR (film) 3425–3200 (NH), 1750 (ester), 1660 and 1540 (amide), 860 and 840 (TMS), and 710 cm^{-1} (Ph); ^{1}H-NMR data ($CDCl_3$) δ 0.93 (m, 2H, $Me_3SiCH_2CH_2$), 1.21 (d, 3H, $J_{5,6}$ 6.4 Hz, H-6e), 1.40 (d, 3H, $J_{5,6}$ 6.0 Hz, H-6c), 1.51 and 1.79 (2s, 6H, 2AcN), 1.89–2.17 (11s, 33H, 11AcO), 2.51 (dd, 1H, J_{gem} 12.5, $J_{3eq,4}$ 4.4 Hz, H-3d-*eq*), 3.76 (s, 3H, MeO), 4.29 (d, 1H, $J_{1,2}$ 8.1 Hz, H-1c), 5.49 (d, 1H, $J_{NH,5}$ 8.1 Hz, NHd), 5.55 (m, 1H, H-8d), and 7.48–8.15 (m, 5H, Ph).

Analytical data. Calculated for $C_{72}H_{102}O_{38}N_2Si$: C, 53.00; H, 6.30; N, 1.72. Found: C, 52.80; H, 6.24; N, 1.70.

O-*(Methyl 5-acetamido-4,7,8,9-tetra*-O-*acetyl-3,5-dideoxy-D*-glycero-α-*D*-galacto-*2-nonulopyranosylonate)-(2→3)*-O-*(2*-O-*benzoyl-4,6-dideoxy-β-D*-xylo-*hexopyranosyl)-(1→4)*-O-*[(2,3,4-tri*-O-*acetyl-α-L-fucopyranosyl)-(1→3)]*-O-*(2-acetamido-6*-O-*acetyl-2-deoxy-β-D-glucopyranosyl)-(1→3)-2,4,6-tri*-O-*acetyl-D-galactopyranose* (**39**)

Selective removal of the 2-(trimethylsilyl)ethyl group in **38** (76.3 mg, 47 μmol) as described for the synthesis of **31**, gave **39** (67.9 mg, 95%) as an amorphous mass; IR

(film) 3700–3200 (OH, NH), 1750 (ester), 1670 and 1540 (amide), and 710 cm^{-1} (Ph).

Analytical data. Calculated for $C_{67}H_{90}O_{38}N_2$: C, 52.55; H, 5.92; N, 1.83. Found: C, 52.54; H, 5.67; N, 1.80.

O-*(Methyl 5-acetamido-4,7,8,9-tetra*-O-*acetyl-3,5-dideoxy-D*-glycero-α-*D*-galacto-*2-nonulopyranosylonate)-(2→3)*-O-*(2*-O-*benzoyl-4,6-dideoxy-β-D*-xylo-*hexopyranosyl)-(1→4)*-O-*[(2,3,4-tri*-O-*acetyl-α-L-fucopyranosyl)-(1→3)]*-O-*(2-acetamido-6*-O-*acetyl-2-deoxy-β-D-glucopyranosyl)-(1→3)-2,4,6-tri*-O-*acetyl-α-D-galactopyranosyl trichloroacetimidate* (**40**)

A solution of **39** (67.9 mg, 44 μmol) in dichloromethane (0.8 ml) was treated with trichloroacetonitrile (130 μl, 1.30 mmol) as described for **32**, to give amorphous **40** (67.1 mg, 90%); $[\alpha]_D$ −0.4° (*c* 1.3, dichloromethane); IR (film) 3430–3200 (NH), 1750 (ester), 1680 and 1540 (amide), and 710 cm^{-1} (Ph); ^{1}H-NMR data ($CDCl_3$) δ 1.21 (d, 3H, $J_{5,6}$ 6.4 Hz, H-6e), 1.40 (d, 3H, $J_{5,6}$ 6.1 Hz, H-6c), 1.51 and 1.79 (2s, 6H, 2AcN), 1.86–2.17 (11s, 33H, 11AcO), 2.52 (dd, 1H, H-3d-*eq*), 3.77 (s, 3H, MeO), 5.41 (d, 1H, $J_{NH,5}$ 8.6 Hz, NHd), 5.55 (m, 1H, H-8d), 6.47 (d, 1H, $J_{1,2}$ 3.7 Hz, H-1a), 7.28–8.15 (m, 5H, Ph), 8.61 (s, 1H, C = NH).

Analytical data. Calculated for $C_{69}H_{90}O_{38}N_3Cl_3$: C, 49.45; H, 5.41; N, 2.51. Found: C, 49.26; H, 5.20; N, 2.37.

O-*(Methyl 5-acetamido-4,7,8,9-tetra*-O-*acetyl-3,5-dideoxy-D*-glycero-α-*D*-galacto-*2-nonulopyranosylonate)-(2→3)*-O-*(2,6-di*-O-*benzoyl-4-deoxy-β-D*-xylo-*hexopyranosyl)-(1→4)*-O-*[(2,3,4-tri*-O-*acetyl-α-L-fucopyranosyl)-(1→3)]*-O-*(2- acetamido-6*-O-*acetyl-2-deoxy-β-D-glucopyranosyl)-(1→3)*-O-*(2,4,6-tri*-O-*acetyl-β-D-galactopyranosyl)-(1→1)-(2S, 3R,4E)-2-azido-3*-O-*benzoyl-4-octadecene-1,3-diol* (**42**)

To a solution of **41** (55 mg, 0.13 mmol) and **32** (116 mg, 60 μmol) in dichloromethane (1 ml) were added molecular sieves 4 Å (type AW 300; 1.2 g) and the mixture was stirred for 5 h at room temperature, and then cooled to 0 °C. Boron trifluoride etherate (34 μl, 127 μmol) was added to the mixture, and this was stirred for 3 h at 0 °C. The precipitate was filtered off and washed with dichloromethane. The filtrate and washings were combined, and successively washed with 1 M sodium carbonate and water, dried (Na_2SO_4) and concentrated. Column chromatography (30:1 dichloromethane:methanol) of the residue on silica gel (30 g) gave **42** (98 mg, 60%) as an amorphous mass; $[\alpha]_D$ −20.9° (*c* 1.1, dichloromethane); IR (film) 3450–3200 (NH), 2100 (N_3), 1750 (ester), 1690 and 1530 (amide) and 710 cm^{-1} (Ph); ^{1}H-NMR data ($CDCl_3$) aglycon part δ 0.88 (t, 3H, $J_{Me,CH2}$ 7.0 Hz, CH_3CH_2), 1.24 (s, 22H, $11CH_2$), 5.88 (m, 1H, H-5); oligosaccharide part δ 1.92–2.16 (13s, 39H, 2AcN and 11AcO), 2.54 (dd, 1H, J_{gem} 12.6, $J_{3eq,4}$ 4.6 Hz, H-3d-*eq*), 3.71 (s, 3H, MeO), 4.32 (d, 1H, $J_{1,2}$ 8.1 Hz, H-1a), and 7.41–8.16 (m, 15H, 3Ph).

Analytical data. Calculated for $C_{99}H_{131}O_{42}N_5$: C, 57.64; H, 6.40; N, 3.39. Found: C, 57.55; H, 6.16; N, 3.22.

O-*(Methyl 5-acetamido-4,7,8,9-tetra*-O-*acetyl-3,5-dideoxy-D*-glycero-α-*D*-galacto-*2-nonulopyranosylonate)-(2→3)*-O-*(2,6-di-O-benzoyl-4-deoxy-β-D*-xylo-*hexopyranosyl)-(1→4)*-O-*[(2,3,4-tri*-O-*acetyl-α-L-fucopyranosyl)-(1→3)]*-O-*(2- acetamido-6*-O-*acetyl-2-deoxy-β-D-glucopyranosyl)-(1→3)*-O-*(2,4,6-tri*-O-*acetyl-β-D-galactopyranosyl)-(1→1)-(2S, 3R,4E)-3*-O-*benzoyl-2-octadecanamido-4-octadecene- 1,3-diol* (**43**)

Hydrogen sulfide was bubbled through a stirred solution of **42** (98 mg, 48 μmol) in pyridine (8.3 ml) and water (1.7 ml) for 48 h at 0 °C. The mixture was concentrated to give the syrupy amine, which was used for the next reaction without further purification. To a solution of the amine in dichloromethane (2.3 ml) were added octadecanoic acid (27 mg, 95 μmol) and 1-ethyl-3-(3-dimethylaminopropyl)carbodiimide hydrochloride (WSC; 27 mg, 141 μmol), and the mixture was stirred overnight at room temperature. After completion of the reaction, the solution was washed with water, dried (Na_2SO_4) and concentrated. Column chromatography (30:1 dichloromethane-methanol) of the residue on silica gel (20 g) gave **43** (77 mg, 70%) as an amorphous mass; $[\alpha]_D$ −11.7° (*c* 1.5, dichloromethane); IR (film) 3450–3200 (NH), 1750 (ester), 1690 and 1530 (amide), and 710 cm^{-1} (Ph); ^{1}H-NMR data ($CDCl_3$) aglycon part δ 0.88 (t, 6H, $2CH_3CH_2$), 1.26 (s, 50H, $25CH_2$), 5.80 (m, 1H, H-5); oligosaccharide part δ 1.79–2.16 (13s, 39H, 2AcN and 11AcO), 2.55 (dd, 1H, J_{gem} 13.1, $J_{3eq,4}$ 4.6 Hz, H-3d-*eq*), 3.71 (s, 3H, MeO), 4.27 (d, 1H, $J_{1,2}$ 7.7 Hz, H-1a), 5.56 (m, 1H, H-8d), and 7.40–8.16 (m, 15H, 3Ph).

Analytical data. Calculated for $C_{117}H_{167}O_{43}N_3$: C, 61.00; H, 7.31; N, 1.82. Found: C, 60.87; H, 7.24; N, 1.76.

O-*(5-Acetamido-3,5-dideoxy-D*-glycero-α-*D*-galacto-*2-nonulopyranosylonic acid)-(2→3)*-O-*(4-deoxy-β-D*-xylo-*hexopyranosyl)-(1→4)*-O-*[(α-L-fucopyranosyl)-(1→3)]*-O-*(2-acetamido-2-deoxy-β-D-glucopyranosyl)-(1→3)*-O-*(β-D-galactopyranosyl)-(1→1)-(2S,3R,4E)-2-octadecanamido-4-octadecene-1,3-diol* (**44**)

To a solution of **43** (69.3 mg, 30 μmol) in methanol (4 ml) was added 28% sodium methoxide (1 ml) and the mixture was stirred for 1 week at 40 °C; the course of the reaction was monitored by TLC. Water (1 ml) was added to the mixture, and this was stirred for 12 h at 40 °C, neutralized with Amberlite IR-120 (H^+) resin and filtered. The resin was washed with methanol, and the combined filtrate and washings were concentrated. Column chromatography (5:4:0.7 chloroform:methanol:water) of the residue on Sephadex LH-20 (40 g) gave **44** (41 mg, 98%) as an

amorphous mass; $[\alpha]_D$ −21.9° (*c* 0.7, 5:4:0.7 chloroform: methanol:water); IR (KBr) 3600–3400 (OH, NH), 2920 and 2850 (Me, methylene), 1710 (COOH), 1660 and 1550 cm^{-1} (amide); ^{1}H-NMR data (DMSO-d6) ceramide part δ 0.85 (t, 6H, 2CH_3CH$_2$), 1.24 (s, 50H, 25CH$_2$), 2.03 (t, 2H, COCH_2CH$_2$), 5.36 (dd, 1H, $J_{3,4}$ 6.8, $J_{4,5}$ 15.4 Hz, H-4), 5.54 (m, 1H, $J_{5,6} = J_{5,6'}$ 6.4 Hz, H-5); oligosaccharide part δ 1.01 (d, 3H, $J_{5,6}$ 6.4 Hz, H-6e), 1.81 and 1.89 (2s, 6H, 2AcN), and 4.90 (d, 1H, $J_{1,2}$ 4.1 Hz, H-1e).

Analytical data. Calculated for $C_{73}H_{131}O_{29}N_3$: C, 57.88; H, 8.72; N, 2.77. Found: C, 57.79; H, 8.50; N, 2.73.

O-*(Methyl 5-acetamido-4,7,8,9-tetra*-O-*acetyl-3,5-dideoxy-D*-glycero-α-*D*-galacto-*2-nonulopyranosylonate)-(2→3)*-O-*(2,4-di*-O-*benzoyl-β-D-fucopyranosyl)-(1→4)*-O-*[(2,3,4-tri*-O-*acetyl-α-L-fucopyranosyl)-(1→3)]*-O-*(2-acetamido-6*-O-*acetyl-2-deoxy-β-D-glucopyranosyl)-(1→3)*-O-*(2,4,6-tri*-O-*acetyl-β-D-galactopyranosyl)-(1→1)-(2*S,*3*R,*4*E*)-2-azido-3*-O-*benzoyl-4-octadecene-1,3-diol* (**45**)

Glycosylation of **41** (61 mg, 0.14 mmol) with **36** (128 mg, 71 μmol), as described for the synthesis of **42**, gave **45** (105 mg, 72%) as an amorphous mass; $[\alpha]_D$ −16.4° (*c* 1.4, dichloromethane); IR (film) 3450–3200 (NH), 2100 (N_3), 1750 (ester), 1690 and 1530 (amide), and 710 cm^{-1} (Ph); ^{1}H-NMR data ($CDCl_3$) aglycon part δ 0.88 (t, 3H, $J_{Me,CH2}$ 7.0 Hz, CH_3CH$_2$), 1.24 (s, 22H, 11CH$_2$), 5.90 (m, 1H, H-5); oligosaccharide part δ 1.19 (d, 3H, $J_{5,6}$ 6.4 Hz, H-6e), 1.39 (d, 3H, $J_{5,6}$ 6.2 Hz, H-6c), 1.78–2.22 (13s, 39H, 2AcN and 11AcO), 2.38 (dd, 1H, J_{gem} 12.6, $J_{3eq,4}$ 4.4 Hz, H-3d-*eq*), 3.84 (s, 3H, MeO), 5.67 (m, 1H, H-8d), 7.41–8.18 (m, 15H, 3Ph).

Analytical data. Calculated for $C_{99}H_{131}O_{42}N_5$: C, 57.64; H, 6.40; N, 3.39. Found: C, 57.46; H, 6.24; N, 3.11.

O-*(Methyl 5-acetamido-4,7,8,9-tetra*-O-*acetyl-3,5-dideoxy-D*-glycero-α-*D*-galacto-*2-nonulopyranosylonate)-(2→3)*-O-*(2,4-di*-O-*benzoyl-β-D-fucopyranosyl)-(1→4)*-O-*[(2,3,4-tri*-O-*acetyl-α-L-fucopyranosyl)-(1→3)]*-O-*(2-acetamido-6*-O-*acetyl-2-deoxy-β-D-glucopyranosyl)-(1→3)*-O-*(2,4,6-tri*-O-*acetyl-β-D-galactopyranosyl)-(1→1)-(2*S,*3*R,*4*E*)-3*-O-*benzoyl-2-octadecanamido-4-octadecene-1,3-diol* (**46**)

Reduction of **45** (105 mg, 51 μmol) and subsequent introduction of octadecanoic acid (29 mg, 102 μmol), as described for the synthesis of **43**, gave **46** (103 mg, 88%) as an amorphous mass; $[\alpha]_D$ −5.7° (*c* 2.1, dichloromethane); IR (film) 3450–3200 (NH), 1750 (ester), 1690 and 1530 (amide), and 710 cm^{-1} (Ph); ^{1}H-NMR data ($CDCl_3$) aglycon part δ 0.88 (t, 6H, 2CH_3CH$_2$), 1.25 (s, 50H, 25CH$_2$), 5.84 (m, 1H, H-5); oligosaccharide part δ 1.39 (d, 3H, $J_{5,6}$ 6.2 Hz, H-6c), 1.78–2.22 (13s, 39H, 2AcN and 11AcO), 2.38 (dd, 1H, H-3d-*eq*), 3.84 (s, 3H, MeO), 5.71 (m, 1H, H-8d), and 7.40–8.18 (m, 15H, 3Ph).

Analytical data. Calculated for $C_{117}H_{167}O_{43}N_3$: C, 61.00; H, 7.31; N, 1.82. Found: C, 60.81; H, 7.12; N, 1.74.

O-*(5-Acetamido-3,5-dideoxy-D*-glycero-α-*D*-galacto-*2-nonulopyranosylonic acid)-(2→3)*-O-*(β-D-fucopyranosyl)-(1→4)*-O-*[(α-L-fucopyranosyl)-(1→3)]*-O-*(2-acetamido-2-deoxy-β-D-glucopyranosyl)-(1→3)*-O-*(β-D-galactopyranosyl)-(1→1)-(2*S,*3*R,*4*E*)-2-octadecanamido-4-octadecene-1,3-diol* (**47**)

Deprotection of **46** (88.0 mg, 38 μmol), as described for the synthesis of **44**, gave **47** (45 mg, 85%) as an amorphous mass; $[\alpha]_D$ −21.4° (*c* 0.7, 5:4:0.7 chloroform: methanol:water); IR (KBr) 3600–3400 (OH, NH), 2920 and 2850 (Me, methylene), 1710 (COOH), 1660 and 1550 cm^{-1} (amide); ^{1}H-NMR data (DMSO-d6) ceramide part δ 0.85 (t, 6H, 2CH_3CH$_2$), 1.24 (s, 50H, 25CH$_2$), 2.03 (5, 2H, COCH_2CH$_2$), 5.37 (dd, 1H, $J_{3,4}$ 6.8, $J_{4,5}$ 15.6 Hz, H-4), 5.55 (m, 1H, H-5); oligosaccharide part δ 1.01 (d, 3H, $J_{5,6}$ 6.4 Hz, H-6e), 1.08 (d, 3H, $J_{5,6}$ 6.0 Hz, H-6c), 1.81 and 1.89 (2s, 6H, 2AcN), 4.88 (d, 1H, $J_{1,2}$ 3.4 Hz, H-1e).

Analytical data. Calculated for $C_{73}H_{131}O_{29}N_3$: C, 57.88; H, 8.72; N, 2.77. Found: C, 57.71; H, 8.71; N, 2.62.

O-*(Methyl 5-acetamido-4,7,8,9-tetra*-O-*acetyl-3,5-dideoxy-D*-glycero-α-*D*-galacto-*2-nonulopyranosylonate)-(2→3)-(2-*O-*benzoyl-4,6-dideoxy-β-D*-xylo-*hexopyranosyl)-(1→4)*-O-*[(2,3,4-tri*-O-*acetyl-α-L-fucopyranosyl)-(1→3)]*-O-*(2-acetamido-6*-O-*acetyl-2-deoxy-β-D-glucopyranosyl)-(1→3)*-O-*(2,4,6-tri*-O-*acetyl-β-D-galactopyranosyl)-(1→1)-(2*S,*3*R,*4*E*)-2-azido-3*-O-*benzoyl-4-octadecene-1,3-diol* (**48**)

Glycosylation of **41** (51 mg, 120 μmol) with **40** (100 mg, 60 μmol), as described for the synthesis of **42**, gave **48** (46.9 mg, 40%) as an amorphous mass; $[\alpha]_D$ −29.1° (*c* 0.9, dichloromethane); IR (film) 3450–3200 (NH), 2100 (N_3), 1750 (ester), 1690 and 1530 (amide) and 710 cm^{-1} (Ph); ^{1}H-NMR data ($CDCl_3$) aglycon part δ 0.88 (t, 3H, $J_{Me,CH2}$ 6.7 Hz, CH_3CH$_2$), 1.23 (s, 22H, 11CH$_2$), 5.90 (m, 1H, H-5); oligosaccharide part δ 1.40 (d, 3H, $J_{5,6}$ 6.0 Hz, H-6c), 1.51–2.17 (13s, 39H, 2AcN and 11AcO), 2.52 (dd, 1H, J_{gem} 12.3, $J_{3eq,4}$ 4.6 Hz, H-3d-*eq*), 3.77 (s, 3H, MeO), 4.33 (d, 1H, $J_{1,2}$ 7.9 Hz, H-1a), and 7.41–8.15 (m, 10H, 2Ph).

Analytical data. Calculated for $C_{92}H_{127}O_{40}N_5$: C, 56.87; H, 6.59; N, 3.60. Found: C, 56.78; H, 6.30; N, 3.32.

O-*(Methyl 5-acetamido-4,7,8,9-tetra*-O-*acetyl-3,5-dideoxy-D*-glycero-α-*D*-galacto-*2-nonulopyranosylonate)-(2→3)-(2-*O-*benzoyl-4,6-dideoxy-β-D*-xylo-*hexopyranosyl)-(1→4)*-O-*[(2,3,4-tri*-O-*acetyl-α-L-fucopyranosyl)-(1→3)]*-O-*(2-acetamido-6*-O-*acetyl-2-deoxy-β-D-glucopyranosyl)-(1→3)*-O-*(2,4,6-tri*-O-*acetyl-β-D-galactopyranosyl)-(1→1)-(2*S,*3*R,*4*E*)-3*-O-*benzoyl-2-octadecanamido-4-octadecene-1,3-diol* (**49**)

Reduction of **48** (47 mg, 24 μmol) and subsequent introduction of octadecanoic acid (14 mg), as described for the synthesis of **43**, gave **49** (48 mg, 90%) as an amorphous mass; $[\alpha]_D$ −14.9° (*c* 1.0, dichloromethane); IR (film)

3450–3200 (NH), 1750 (ester), 1690 and 1530 (amide), and 710 cm^{-1} (Ph); ^{1}H-NMR data ($CDCl_3$) aglycon part δ 0.88 (t, 6H, $2CH_3CH_2$), 1.26 (S, 50H, $25CH_2$), 5.85 (m, 1H, H-5); oligosaccharide part δ 1.39 (d, 3H, $J_{5,6}$ 5.9 Hz, H-6c), 1.51–2.17 (13s, 39H, 2AcN and 11AcO), 2.52 (dd, 1H, J_{gem} 12.5, $J_{3eq,4}$ 4.0 Hz, H-3d-*eq*), 3.77 (s, 3H, MeO), 4.27 (d, 1H, $J_{1,2}$ 7.9 Hz, H-1a), and 7.27–8.15 (m, 10H, 2Ph).

Analytical data. Calculated for $C_{110}H_{163}O_{41}N_3$: C, 60.51; H, 7.52; N, 1.92. Found: C, 60.25; H, 7.33; N, 1.81.

O-*(5-Acetamido-3,5-dideoxy-D*-glycero-α-*D*-galacto-*2-nonulopyranosylonic acid)-(2→3)*-O-*(4,6-dideoxy-β-D*-xylo-*hexopyranosyl)-(1→4)*-O-*[(α-L-fucopyranosyl)-(1→3)]*-O-*(2-acetamido-2-deoxy-β-D-glucopyranosyl)- (1→3)*-O-*(β-D-galactopyranosyl)-(1→1)-(2*S,*3*R,*4*E*)-2-octadecanamido-4-octadecene-1,3-diol* (**50**)

Deprotection of **49** (47.5 mg, 22 μmol), as described for the synthesis of **44**, gave **50** (29.8 mg, 99%) as an amorphous mass; $[\alpha]_D$ −25.9° (*c* 0.5, 5:4:0.7 chloroform: methanol:water); IR (KBr) 3600–3400 (OH, NH), 2920 and 2850 (Me, methylene), 1710 (COOH), 1660 and 1550 cm^{-1} (amide); ^{1}H-NMR data (DMSO-d6) ceramide part δ 0.85 (t, 6H, $2CH_3CH_2$), 1.24 (s, 50H, $25CH_2$), 2.02 (t, 2H, $COCH_2CH_2$), 5.34 (dd, 1H, $J_{3,4}$ 6.8, $J_{4,5}$ 15.2 Hz, H-4), 5.51 (m, 1H, H-5); oligosaccharide part δ 1.01 (d, 3H, $J_{5,6}$ 6.2 Hz, H-6e), 1.81 and 1.91 (2s, 6H, 2AcN).

Analytical data. Calculated for $C_{73}H_{131}O_{20}N_3$: C, 63.96; H, 9.63; N, 3.07. Found: C, 63.91; H, 9.57; N, 3.05.

References

1. Lowe JB, Stoolman LM, Nair RP, Larsen RD, Berhend TL, Marks RM (1990) *Cell* **63**: 475–84.
2. Walz G, Aruffo A, Kolanus W, Bevilacqua M, Seed B (1990) *Science* **250**: 1132–35.
3. Tiemeyer M, Swiedler SJ, Ishihara M, Moreland M, Schweingruber H, Hirtzer P, Brandley BK (1991) *Proc Natl Acad Sci USA* **88**: 1138–42.
4. Phillips ML, Nudelman E, Gaeta FCA, Perez M, Singhal AK, Hakomori S, Paulson JC (1990) *Science* **250**: 1130–32.
5. Kameyama A, Ishida H, Kiso M, Hasegawa A (1991) *Carbohydr Res* **209**: c1–c4; *J Carbohydr Chem* **10**: 549–60.
6. Hasegawa A, Ando T, Kameyama A, Kiso M (1992) *Carbohydr Res* **230**: c1–c5; *J Carbohydr Chem* **11**: 645–58.
7. Kameyama A, Ishida H, Kiso M, Hasegawa A (1991) *J Carbohydr Chem* **10**: 729–38.
8. Tyrrell D, James P, Rao N, Foxall C, Abbas S, Dasgupta F, Nashed M, Hasegawa A, Kiso M, Asa D, Kidd J, Brandley BK (1991) *Proc Natl Acad Sci USA* **88**: 10372–76.
9. Yoshida M, Uchimura A, Kiso M, Hasegawa A (1993) *Glycoconjugate J* **10**: 3–15.
10. Hasegawa A, Ando T, Kato M, Ishida H, Kiso M (1994) *Carbohydr Res* **257**: 67–80.
11. Murase T, Kameyama A, Kartha KPR, Ishida H, Kiso M, Hasegawa A (1989) *J Carbohydr Chem* **8**: 265–83.
12. Murase T, Ishida H, Kiso M, Hasegawa A (1988) *Carbohydr Res* **184**: c1–c4.
13. Hasegawa A, Ohki H, Nagahama T, Ishida H, Kiso M (1991) *Carbohydr Res* **212**: 277–81.
14. Hasegawa A, Nagahama T, Ohki H, Hotta K, Ishida H, Kiso M (1991) *J Carbohydr Chem* **10**: 493–98.
15. Konradsson P, Mootoo DR, McDevitt RE, Fraser-Reid B (1990) *J Chem Soc, Chem Communs* : 270–72.
16. Veeneman GH, van Leeuwen SH, van Boom JH (1990) *Tetrahedron Lett* **31**: 1331–34.
17. Kanie O, Kiso M, Hasegawa A (1988) *J Carbohydr Chem* **7**: 501–6.
18. Okamoto K, Goto T (1990) *Tetrahedron* **46**: 5835–57.
19. Robins MJ, Wilson JS (1981) *J Am Chem Soc* **103**: 932–33.
20. Kashem A, Anisuzzaman M, Whistler RL (1978) *Carbohydro Res* **61**: 511–18.
21. Schuep W, Hardegger E (1970) *Helv Chem Acta* **53**: 154–55.
22. Numata M, Sugimoto M, Koike K, Ogawa T (1987) *Carbohydr Res* **163**: 209–25.
23. Schmidt RR, Michel J (1980) *Angew Chem Int Ed Engl* **19**: 731–32.
24. Schmidt RR, Grundler G (1981) *Synthesis* 885–87.
25. Ito Y, Kiso M, Hasegawa A (1989) *J Carbohydr Chem* **8**: 285–94.
26. Schmidt RR, Zimmermann P (1986) *Angew Chem Int Ed Engl* **25**: 725–26.
27. Adachi T, Yamada Y, Inoue I, Saneyoshi M (1977) *Synthesis* 45–46.
28. Murase T, Ishida H, Kiso M, Hasegawa A (1989) *Carbohydr Res* **188**: 71–80.
29. Stahl W, Sprengard U, Kretzschmar G, Kunz H (1994) *Angew Chem Ind Ed Engl* **33**: 2096–98.
30. Hanessian S, Prabhanjann H (1994) *Synlett* 868–70.
31. Brandley BK, Kiso M, Abbas S, Nikrad P, Srivasatava O, Foxall C, Oda Y, Hasegawa A (1993) *Glycobiology* **3**: 633–39.
32. Hasegawa A, Kiso M (1994) *Methods Enzymol* **242**: 158–73.