Carbohydrate Research, 167 (1987) 197–210
Elsevier Science Publishers B.V., Amsterdam – Printed in The Netherlands

TOTAL SYNTHESIS OF X HAPTEN, III^3 Fucα-nLc$_4$ Cer*

SUSUMU SATO, YUKISHIGE ITO, TOMOO NUKADA, YOSHIAKI NAKAHARA, AND TOMOYA OGAWA†
RIKEN (The Institute of Physical and Chemical Research), Wako-shi, Saitama, 351-01 (Japan)
(Received July 25th 1986; accepted for publication in revised form, January 15th, 1987)

ABSTRACT

Total synthesis of *O*-β-D-galactopyranosyl-(1→4)-*O*-[α-L-fucopyranosyl-(1→3)]-*O*-(2-acetamido-2-deoxy-β-D-glucopyranosyl)-(1→3)-*O*-β-D-galactopyranosyl-(1→4)-*O*-β-D-glucopyranosyl-(1→1)-2-*N*-tetracosanoyl-(2*S*,3*R*,4*E*)-sphingenine was achieved by use of the key glycosyl donors *O*-(2,3,4,6-tetra-*O*-acetyl-β-D-galactopyranosyl)-(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→4)-2,3,6-tri-*O*-acetyl-α-D-glucopyranosyl trichloroacetimidate and fluoride, as well as key glycosyl acceptor 3-*O*-benzoyl-2-*N*-tetracosanoyl-(2*S*,3*R*,4*E*)-sphingenine, in an unambiguous manner.

INTRODUCTION

X-Antigen (Le^X), III^3 Fucα-nLc$_4$ Cer, a glycosphingolipid containing the carbohydrate sequence occurring in lacto-*N*-fucopentaose III (ref. 2) was first isolated from human adenocarcinoma[3] and the structure was proposed to be **1** from methylation and mass-spectrometric studies[4]. Glycolipid **1** has also been shown to occur in hog stomach[5], dog small-intestine[6], human brain[7], human erythrocytes[8], human granulocytes[9], and human plasma[10]. The proposed structure **1** was further supported by ^{1}H-n.m.r. data both for permethylated[6] and peracetylated[10] derivatives.

Owing to the biological significance of X-antigen, two approaches to the synthesis of antigenic trisaccharide have been reported[11]. Synthetic approaches to the type 2 hexotetraose back-bone structure, β-Gal-(1→4)-β-GlcNAc-(1→3)-β-Gal-(1→4)-Glc, have also been reported by using either the *N*,*N*-phthaloyl[12] or oxazoline derivative[13] of lactosamine as the key glycosyl donor. However, an approach to the total synthesis of X-antigen **1** has remained to be developed. As

*Part 49 in the series "Synthetic Studies on Cell-Surface Glycans". For Part 48, see ref. 1. Part of this work was presented orally at the annual meeting of the Agricultural and Biological Chemical Society of Japan (August, 1985, Sapporo), and also at the XIIIth International Carbohydrate Symposium (August, 1986, Ithaca).

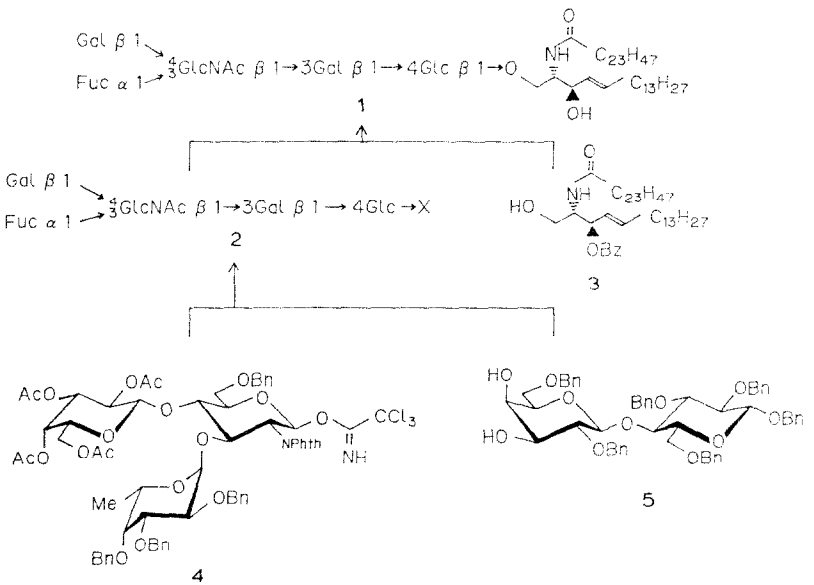
†To whom enquiries should be addressed.

0008-6215/87/$ 03.50

part of our project on the synthesis of glycosphingolipids, we describe here the first total synthesis of X-antigen **1** in a stereocontrolled manner.

RESULTS AND DISCUSSION

Retrosynthetic analysis of Le^X antigen **1** led to the glycopentaosyl donor equivalent **2** and protected ceramide **3**. Synthetic precursors for compound **2** may be designed as the glycotriosyl imidate **4** and the glycosyl acceptor **5**. Among these key intermediates, ceramide derivatives **3** (ref. 14) and hexa-*O*-benzyllactose derivative **5** (ref. 15) have already been reported. Therefore, we first describe a synthesis of hexotriosyl imidate **4**, and then the use of compound **4** as a key intermediate for the synthesis of the target glycolipid **1** *via* glycopentaosyl donor **2**.



Scheme 1

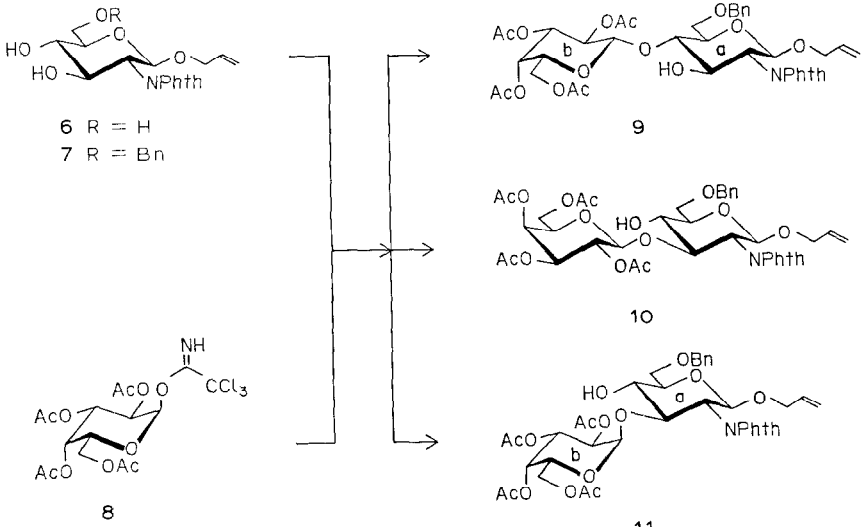
Regioselective benzylation of allyl glycoside **6** (ref. 16) at the primary hydroxyl group was achieved in one flask, in 71% yield, by the stannyl method[17], to give monobenzyl ether **7**. An alternative approach via the benzylidene derivative of **6** and subsequent reductive ring opening by use of the borane–trimethylamine complex in the presence of aluminium chloride[18] also afforded **7** (in 61% overall yield). Glycosylation of the diol system **7** with the imidate **8** (ref. 19) afforded a mixture of disaccharides **9**, **10**, and **11** in 33, 2.0, and 29% yield, respectively. The regiochemistry of **9** and **10** was assigned by ^{1}H-n.m.r. data, which contained the signals CH_2Ph-6a as two doublets at δ 4.762 and 4.539 with $^2J_{HH}$ 12.2 Hz for compound **9**, and at δ 4.664 and 4.620, with $^2J_{HH}$ 12.5 Hz, for compound **10**, indicating the presence of more steric congestion around CH_2Ph-6a in compound **9** compared

with compound **10**. The ^{1}H-n.m.r. spectrum of the acetylation product of **9** showed a deshielded signal for H-3a at δ 5.684, which was also in agreement with the assigned regiochemistry of **9**. The structure of **11** was assigned as (1→3) by observing a similar signal pattern for CH_2Ph-6a in the spectrum of **10**. The anomeric stereochemistry was evident from the ^{1}H- and ^{13}C-n.m.r. data. A reasonable explanation for the formation of **11** as the major product from the glycosylation at OH-3 of **7** with the imidate **8** is not yet available.

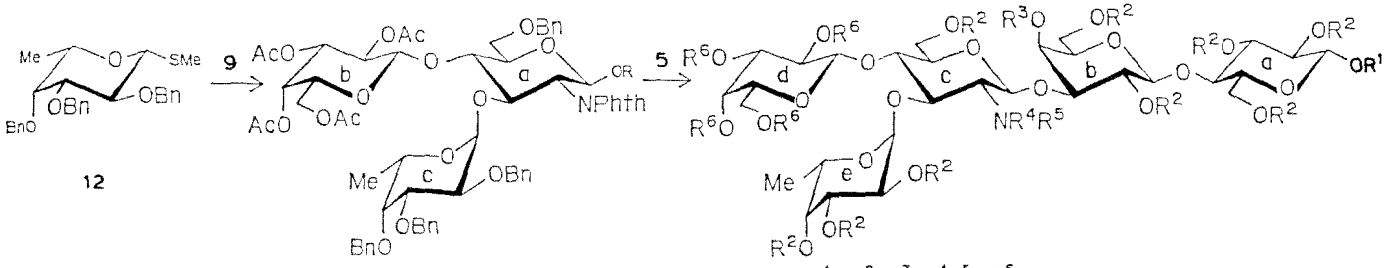
The introduction of an L-fucosyl group at O-3a of **9** was performed according to Lönn[20] by using the methyl 1-thioglycoside **12**, which was readily available from L-fucose (see the Experimental section). Thus, treatment of **9** with **12** in the presence of methyl triflate in ether afforded stereoselectively a 77% yield of the desired trisaccharide **13**. Deallylation of **13** with palladium(II) chloride and sodium acetate in aq. acetic acid[21] gave hemiacetal **14** in 66% yield. Treatment of **14** with trichloroacetonitrile[22] in the presence of 1,8-diazabicyclo[5.4.0]undec-7-ene (DBU) afforded the desired imidate **4** in 67% yield.

Having both the hexotriosyl donor **4** and the glycosyl acceptor **5** in hand, crucial glycosylation was examined in the presence of boron trifluoride etherate in dichloroethane. To our surprise, complete regioselectivity was observed in this case[23], and the (1→3)-linked pentasaccharide **15** was isolated in 67% yield. The regiochemistry of **15** was readily assigned from the ^{1}H-n.m.r. data for pentaacetate **16**, obtained from **15** by acetylation, which revealed a deshielded signal for H-4b at δ 5.445.

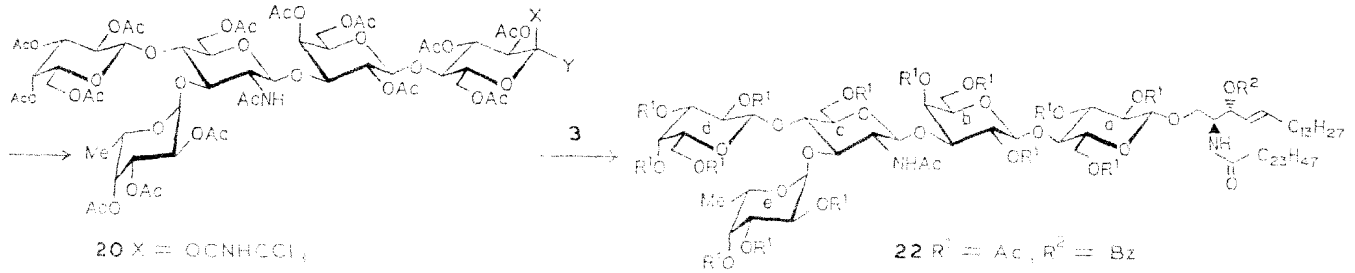
Conventional protective-group modulation of **15** was performed to give the designed pentasaccharide donors, either **20** (38%) or **21** (19%), in 7 steps: (*i*) sodium methoxide in methanol, (*ii*) hydrazine hydrate and ethanol[24], (*iii*) acetic anhydride–pyridine–4-(dimethylamino)pyridine (DMAP), (*iv*) 10% palladium-on-



Scheme 2



	R^1	R^2	R^3	R^4R^5	R^6
15	Bn	Bn	H	Phth	Ac
16	Bn	Bn	Ac	Phth	Ac
17	Bn	Bn	Ac	Ac H	Ac
18	Ac	Ac	Ac	Ac H	Ac
19	H	Ac	Ac	Ac H	Ac



Scheme 3

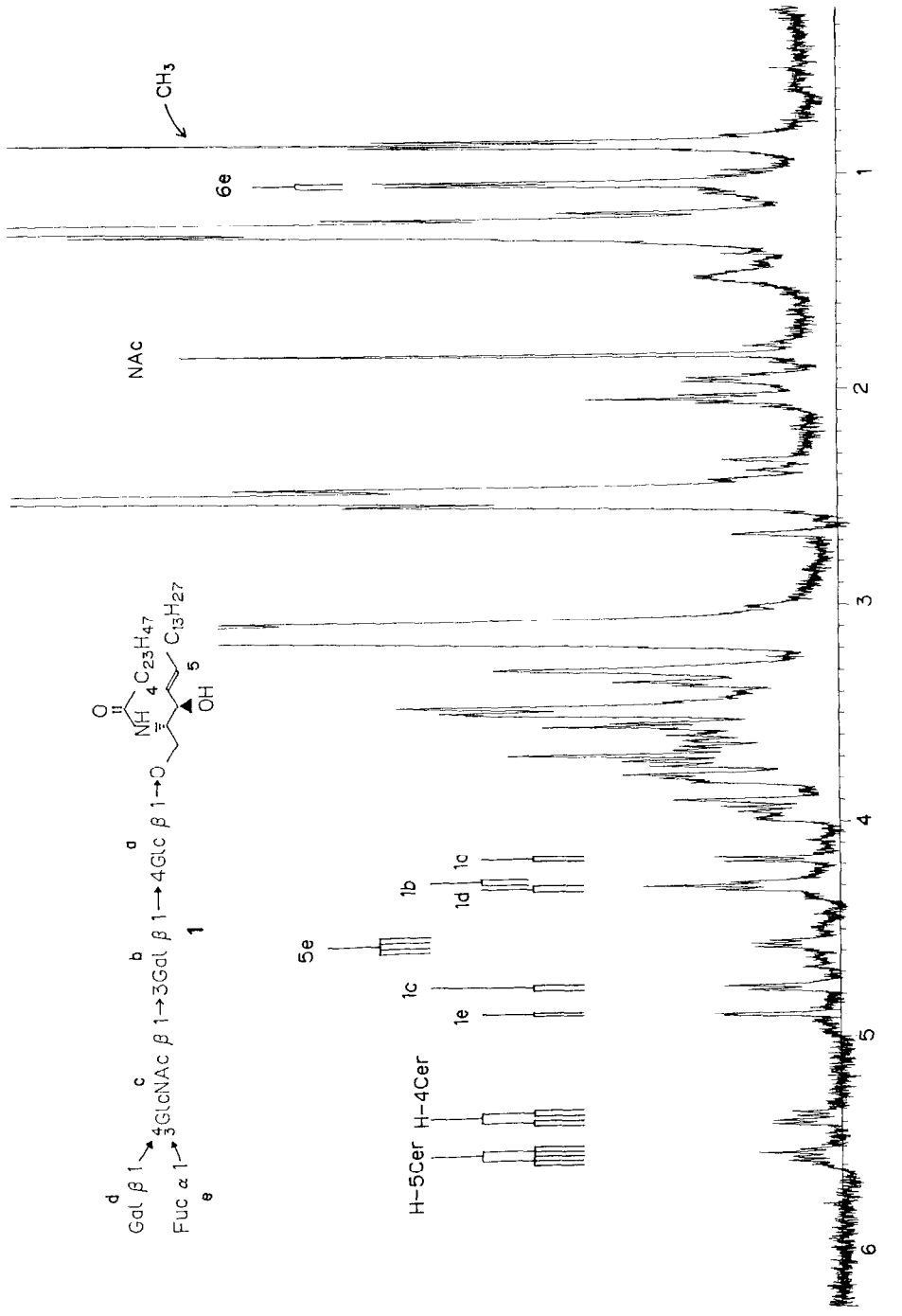


Fig. 1. 400-MHz, ^{1}H-n.m.r. spectrum of synthetic Le^x antigen (**1**). The spectrum was recorded for the sample in 49:1 Me_2SO-d_6–D_2O after exchanging several times with Me_2SO–D_2O at 60°.

carbon and hydrogen, (*v*) Ac_2O–pyridine–DMAP, (*vi*) hydrazinium acetate in *N*,*N*-dimethylformamide[25], and (*vii*) trichloroacetonitrile–DBU (for **20**), or diethylaminosulfur trifluoride[26] (for **21**).

Finally, glycosylation of benzoyl ceramide **3**, prepared from D-glucose[15], with either the glycosyl donor **20** in the presence of boron trifluoride etherate or the glycosyl donor **21** in the presence of silver triflate and stannous chloride[27] afforded protected Le^X glycolipid **22** in 7.3 or 21% yield, respectively; this was deacylated with sodium methoxide in 1:1 methanol–THF, to afford Le^X antigen **1** quantitatively. The ^{1}H-n.m.r. data recently reported[28] for natural Le^X glycopentaosylsphingolipid **1** were in good agreement with those of synthetic **1** in Me_2SO-*d*$_6$–D_2O (see Fig. 1).

In conclusion, a total synthesis of Le^X hexopentaosylceramide **1** was achieved with stereo- and regio-control by use of hexotriaosyltrichloroacetimidate **4**, hexopentaosyl donors **20** and **21** as the key glycosyl donors, and optically active benzoyl ceramide **3** as the key glycosyl acceptor.

EXPERIMENTAL

General. — Melting points were determined with a Yanagimoto micro melting-point apparatus and are uncorrected. Optical rotations were measured with a Perkin–Elmer Model 241 MC polarimeter, for solutions in $CHCl_3$ at 25°, unless noted otherwise. Column chromatography was performed on columns of Silica Gel (Merck, 70–230 mesh). Flash chromatography was performed on columns of Wako gel C-300 (200–300 mesh). T.l.c. and high-performance t.l.c. were performed on Silica Gel 60 F_{254} (Merck, Darmstadt). Molecular sieves were purchased from Nakarai Chemicals, Ltd. I.r. spectra were recorded with an EPI-G2 Hitachi spectrophotometer, using KBr pellets for the crystalline samples, and films for the liquid samples. ^{1}H-N.m.r. spectra were recorded with either a JNM-GX400 or a JNM-FX90Q n.m.r. spectrometer. ^{13}C-N.m.r. spectra were recorded with a JNM-FX 100FT n.m.r. spectrometer operated at 25.05 MHz. The values of δ_C and δ_H are expressed in p.p.m. downward from the signal for internal Me_4Si, for solutions in $CDCl_3$, unless noted otherwise. Values of δ_H (D_2O) and δ_C (D_2O) are expressed in p.p.m. downward from the signal for Me_4Si, by reference to internal standards of Me_2CO (δ 2.225) or Me_3COH (δ 1.230), and 1,4-dioxane (δ 67.4) or MeOH (δ 49.8), respectively.

*Allyl 6-O-benzyl-2-deoxy-2-phthalimido-β-*D*-glucopyranoside* (**7**). — (*A*) A mixture of compound **6** (25.0 g, 71.6 mmol) and $(Bu_3Sn)_2O$ (29.0 g, 50 mmol) in toluene (300 mL) was stirred for 4 h under reflux, with continuous azeotropic removal of water, cooled, and concentrated to ~150 mL. α-Bromotoluene (36.0 g, 210 mmol) and Bu_4NBr (11.3 g, 35 mmol) were added, and the mixture was stirred for 16 h at 90–100°, cooled, and evaporated. A solution of the residue in EtOAc (500 mL) was washed with aq. KF, and filtered through Celite. The filtrate was successively washed with aq. $NaHCO_3$ and satd. NaCl, dried ($MgSO_4$), and evapo-

rated *in vacuo*. Chromatography of the residue over SiO_2 in 1:1 toluene–EtOAc afforded crystalline **7** (22.3 g, 71%); m.p. 116–117°, $[\alpha]_D$ −27° (*c* 0.8); R_F 0.36 in 3:2 EtOAc–toluene; n.m.r. data: δ_H 5.222 (d, 1 H, *J* 8.5 Hz, H-1), 4.638 (d, 1 H, *J* 12.2 Hz, CH_2Ph), and 4.581 (d, 1 H, *J* 12.2 Hz, CH_2Ph); δ_C 97.5 (C-1) and 56.5 (C-2).

Anal. Calc. for $C_{24}H_{25}NO_7$: C, 65.59; H, 5.73; N, 3.19. Found: C, 65.97; H, 5.84; N, 3.09.

(*B*) A mixture of compound **6** (20.3 g, 58 mmol), α,α-dimethoxytoluene (13.2 g, 87 mmol), and $TsOH \cdot H_2O$ (1 g) in DMF (100 mL) was stirred for 6 h at 60° at a pressure of 2.7–5.3 kPa. Et_3N (1 mL) was added, the mixture was evaporated *in vacuo*, and a solution of the residue in EtOAc was washed successively with aq. $NaHCO_3$ and aq. NaCl, dried ($MgSO_4$), and evaporated *in vacuo* to give crystalline *allyl 4,6-O-benzylidene-2-deoxy-2-phthalimido-β-*D*-glucopyranoside* (22.6 g, 88.5%); $[\alpha]_D$ −36° (*c* 0.7), m.p. 184–186° (*i*Pr_2O); R_F 0.58 in 2:3 EtOAc–hexane; n.m.r. data: δ_H 5.57 (s, 1 H, CHPh) and 5.16 (d, 1 H, *J* 9.2 Hz, H-1). To a stirred mixture of the benzylidene derivative (19.7 g, 45 mmol) and $BH_3 \cdot NMe_3$ (19.7 g, 270 mmol) in THF (400 mL) was added, portionwise, powdered $AlCl_3$ (35.9 g, 270 mmol) at 20°. The mixture was stirred for 3 h at 20°, poured into ice–water, and extracted with EtOAc. The extract was successively washed with aq. $NaHCO_3$ and aq. NaCl, dried ($MgSO_4$), and evaporated *in vacuo*. Chromatography of the residue over SiO_2 in 2:3 EtOAc–toluene afforded **7** (13.7 g, 69.3%).

Allyl O-*(2,3,4,6-tetra-*O*-acetyl-β-*D*-galactopyranosyl)-(1→4)-6-*O*-benzyl-2-deoxy-2-phthalimido-β-*D*-glucopyranoside* (**9**), *allyl* O-*(2,3,4,6-tetra-*O*-acetyl-β-*D*-galactopyranosyl-(1→3)-6-*O*-benzyl-2-deoxy-2-phthalimido-β-*D*-glucopyranoside* (**10**), *and allyl* O-*(2,3,4,6-tetra-*O*-acetyl-α-*D*-galactopyranosyl)-(1→3)-6-*O*-benzyl-2-deoxy-2-phthalimido-β-*D*-glucopyranoside* (**11**). — To a stirred mixture of compound **7** (1.310 g, 3 mmol), imidate **8** (1.770 g, 3.6 mmol), and powdered molecular sieves 4A (3 g) in $Cl(CH_2)_2Cl$ (30 mL) was added dropwise $BF_3 \cdot$ etherate (0.36 mL) under Ar, with cooling by a CCl_4–Dry Ice bath (−23°). The mixture was stirred for 4 h at −23°, and filtered. The filtrate was successively washed with aq. $NaHCO_3$ and satd. saline, dried ($MgSO_4$), and evaporated *in vacuo*. Chromatography of the residue over SiO_2 in 1:1 EtOAc–hexane afforded **9** (760 mg, 33%), **10** (50 mg, 2.2%), and **11** (680 mg, 29%).

Compound **9** had $[\alpha]_D$ +15.1° (*c* 1.1); R_F 0.60 in 3:2 EtOAc–hexane; n.m.r. data: δ_H 5.80–5.68 (m, 1 H, $-CH{=}CH_2$), 5.331 (d, 1 H, *J* 2.4 Hz, H-4b), 5.249 (d, 1 H, *J* 8.5 Hz, H-1a), 5.190 (dd, 1 H, *J* 7.9 and 10.4 Hz, H-2b), 5.141 (tdd, 1 H, *J* 1.5, 2.2, and 17.4 Hz, $=CH_2$), 5.064 (tdd, 1 H, *J* 1.5, 2.2, and 10.4 Hz, $=CH_2$), 4.932 (dd, 1 H, *J* 3.7 and 10.5 Hz, H-3b), 4.762 (d, 1 H, *J* 12.2 Hz, CH_2Ph), 4.539 (d, 1 H, *J* 12.2 Hz, CH_2Ph), 4.484 (d, 1 H, *J* 7.9 Hz, H-1b), 4.411 (ddd, 1 H, *J* 1.5, 8.2, and 10.7 Hz, H-3a), 4.286 (tdd, 1 H, *J* 1.5, 4.9 and 13.3 Hz, $OCH_2CH=$), 4.207 (dd, 1 H, *J* 8.6 and 10.7 Hz, H-2a), 3.972 (d, 1 H, *J* 1.5 Hz, H-3a), 3.907 (t, 1 H, *J* 7.0 Hz, H-5b), 2.124 (s, 3 H, Ac), 2.008 (s, 3 H, Ac), 1.981 (s, 3 H, Ac), and 1.923 (s, 3 H, Ac); δ_C 101.6 (C-1b), 97.5 (C-1a), 82.2 (C-4a), 61.5 (C-6b), and 56.1 (C-2a).

Anal. Calc. for $C_{38}H_{43}NO_{16}\cdot 0.5\ H_2O$: C, 58.60; H, 5.69; N, 1.80. Found: C, 58.40; H, 5.56; N, 1.80.

Acetylation of **9** with Ac_2O-C_5H_5N–DMAP afforded the penta-*O*-acetyl derivative of **9**; δ_H 5.8–5.67 (m, 1 H, C*H*=CH_2), 5.684 (dd, 1 H, *J* 8.8 and 10.7 Hz, H-3a), 5.372 (d, 1 H, *J* 8.3 Hz, H-1a), 5.269 (d, 1 H, *J* 2.7 Hz, H-4b), 5.131 (tdd, 1 H, *J* 1.5, 2.2, and 17.3 Hz, =CH_2), 5.059 (dd, 1 H, *J* 1.2 and 10.3 Hz, =CH_2), 5.019 (dd, 1 H, *J* 8.1 and 10.5 Hz, H-2b), 4.820 (d, 1 H, *J* 12.2 Hz, CH_2Ph), 4.814 (dd, 1 H, *J* 3.2 and 10.5 Hz, H-3b), 4.515 (d, 1 H, *J* 12.2 Hz, CH_2Ph), 4.475 (d, 1 H, *J* 8.1 Hz, H-1b), 4.270 (dd, 1 H, *J* 8.3 and 10.5 Hz, H-2a), 2.114, 2.068, 1.974, 1.962, and 1.878 (5 s, 15 H, 5 Ac).

Compound **10** had $[\alpha]_D$ +4.5° (*c* 1.1); R_F 0.52 in 3:2 EtOAc–hexane; n.m.r. data: δ_H 5.70–5.60 (m, 1 H, –C*H*=CH_2), 5.294 (d, 1 H, *J* 2.8 Hz, H-4b), 5.141 (dd, 1 H, *J* 7.9 and 10.4 Hz, H-2b), 5.074 (tdd, 1 H, *J* 1.5, 2.2, and 18.0 Hz, =CH_2), 5.047 (d, 1 H, *J* 8.2 Hz, H-1a), 5.001 (tdd, 1 H, *J* 1.5, 2.2, and 10.4 Hz, =CH_2), 4.820 (dd, 1 H, *J* 3.4 and 10.7 Hz, H-3b), 4.664 (d, 1 H, *J* 12.5 Hz, CH_2Ph), 4.620 (d, 1 H, *J* 12.5 Hz, CH_2Ph), 4.503 (dd, 1 H, *J* 7.6 and 10.7 Hz, H-3a), 4.407 (d, 1 H, *J* 7.9 Hz, H-1b), 2.131 (s, 3 H, Ac), 2.036 (s, 3 H, Ac), 1.879 (s, 3 H, Ac), and 1.455 (s, 3 H, Ac); δ_C 101.2 (C-1b), 97.3 (C-1a), 82.2 (C-3a), 61.5 (C-6b), and 54.9 (C-2a).

Anal. Calc. for $C_{38}H_{43}NO_{16}$: C, 59.29; H, 5.63; N, 1.82. Found: C, 59.83; H, 5.68; N, 1.73.

Compound **11** had $[\alpha]_D$ +98.1° (*c* 0.7); R_F 0.40 in 3:2 EtOAc–hexane; n.m.r. data: δ_H 5.7–5.6 (m, 1 H, C*H*=CH_2), 5.181 (d, 1 H, *J* 8.3 Hz, H-1a), 5.175 (d, 1 H, *J* 3.4 Hz, H-4b), 5.134 (t, 1 H, *J* 9.5 Hz, H-4a), 5.074 (tdd, 1 H, *J* 1.5, 2.2, and 17.1 Hz, =CH_2), 5.023 (d, 1 H, *J* 4.6 Hz, H-1b), 5.018 (tdd, 1 H, *J* 1.5, 2.2, and 10.4 Hz, =CH_2), 4.943 (dd, 1 H, *J* 3.3 and 10.7 Hz, H-3b), 4.755 (dd, 1 H, *J* 9.2 and 10.7 Hz, H-3a), 4.560 (d, 1 H, *J* 11.9 Hz, CH_2Ph), 4.526 (d, 1 H, *J* 11.9 Hz, CH_2Ph), 4.345 (dd, 1 H, *J* 8.5 and 10.7 Hz, H-2a), 4.267 (tdd, 1 H, *J* 1.5, 5.2, and 13.1 Hz, OCH_2CH=), 4.014 (dd, 1 H, *J* 6.1 and 12.8 Hz, OCH_2CH=), 1.996 (s, 3 H, Ac), 1.985 (s, 3 H, Ac), 1.967 (s, 3 H, Ac), and 1.827 (s, 3 H, Ac); δ_C 101.4 (C-1b, $^1J_{CH}$ 173.4 Hz), 97.2 (C-1a, $^1J_{CH}$ 163.5 Hz), 78.0 (C-3a), 59.9 (C-6b), and 55.7 (C-2a).

Anal. Calc. for $C_{38}H_{43}NO_{16}\cdot 0.5\ H_2O$: C, 58.60; H, 5.69; N, 1.80. Found: C, 58.50; H, 5.59; N, 1.76.

Methyl 2,3,4-tri-O-acetyl-1-thio-β-L-fucopyranoside. — To a stirred solution of 2,3,4-tri-*O*-acetyl-L-fucopyranosyl acetate (3.3 g, 10 mmol) and Bu_3SnSMe (3.8 g, 10.5 mmol) in $Cl(CH_2)_2Cl$ (40 mL) was added $SnCl_4$ (1.4 mL) at −5°. The mixture was stirred for 4 h at 20°, evaporated *in vacuo*, and the residue diluted with EtOAc. The solution was successively washed with aq. KF and aq. NaCl, dried ($MgSO_4$), and filtered. The filtrate was evaporated *in vacuo*, and chromatography of the residue over SiO_2 in 2:1 hexane–EtOAc afforded the α (1.1 g, 34%) and β anomer (1.8 g, 56%).

The α anomer had m.p. 80–81°, $[\alpha]_D$ −222° (*c* 1.2); R_F 0.5 in 1:2 EtOAc–hexane; n.m.r. data: δ_H 5.27 (d, 1 H, *J* 3.3 Hz, H-1), 2.16, 2.07, 2.05, 1.99 (4 s, 12 H, 4 Ac), and 1.17 (d, 3 H, *J* 6.6 Hz, CHCH_3).

Anal. Calc. for $C_{13}H_{20}O_7S$: C, 48.74; H, 6.29; S, 10.01. Found: C, 48.82; H, 6.28; S, 10.07.

The β anomer had $[\alpha]_D$ −0.7° (*c* 1.0), m.p. 139–141°; R_F 0.43 in 1:2 EtOAc–hexane; n.m.r. data: δ_H 4.35 (d, 1 H, *J* 9.4 Hz, H-1), 2.19, 2.17, 2.07, 1.99 (4 s, 12 H, 4 Ac), and 1.22 (d, 3 H, *J* 6.6 Hz, $CHCH_3$).

Anal. Calc. for $C_{13}H_{20}O_7S$: C, 48.74; H, 6.29; S, 10.01. Found: C, 48.75; H, 6.27; S, 9.87.

*Methyl 2,3,4-tri-*O*-benzyl-1-thio-β-*L*-fucopyranoside* (**12**). — A solution of methyl 2,3,4-tri-*O*-acetyl-1-thio-β-L-fucopyranoside (27.2 g, 85 mmol) in 0.01M NaOMe–MeOH (350 mL) was stirred for 4 h at 20°, made neutral with Amberlyst 15, and evaporated to a solid residue (17.4 g). To a suspension of NaH (60%, 16 g, 320 mmol) in DMF (200 mL) was added portionwise this solid (15.5 g, 80 mmol), the mixture was stirred for 30 min at 20°. To this mixture was added dropwise $PhCH_2Br$ (38 mL, 320 mmol) at 0–5°, and the mixture was stirred for 16 h at 20°. The usual processing, and chromatography over SiO_2 in 10:1 hexane–EtOAc, afforded **12** (33.5 g, 90%); $[\alpha]_D$ −0.2° (*c* 1.5); R_F 0.50 in 4:1 hexane–EtOAc; n.m.r. data: δ_H 7.5–7.2 (m, 15 H, aromatic) and 1.20 (d, 3 H, *J* 6.4 Hz, $CHCH_3$).

Anal. Calc. for $C_{28}H_{32}O_4S$: C, 72.38; H, 6.94; S, 6.90. Found: C, 72.44; H, 6.91; S, 6.65.

Allyl O-*(2,3,4,6-tetra-*O*-acetyl-β-*D*-galactopyranosyl)-(1→4)-*O*-[(2,3,4-tri-*O*-benzyl-α-*L*-fucopyranosyl)-(1→3)]-6-*O*-benzyl-2-deoxy-2-phthalimido-β-*D*-glucopyranoside* (**13**). — To a stirred mixture of compound **9** (154 mg, 0.2 mmol), compound **12** (139 mg, 0.3 mmol), and molecular sieves 4A (500 mg) in Et_2O (6 mL) was added $MeOSO_2CF_3$ (70 μL). The mixture was stirred for 16 h and filtered. The filtrate was washed with aq. NaCl, dried ($MgSO_4$), and evaporated *in vacuo*. Chromatography of the residue over SiO_2 in 6:1 toluene–EtOAc afforded **13** (182 mg, 76.8%); m.p. 164–165° (from MeOH), $[\alpha]_D$ +3.3° (*c* 0.9), R_F 0.56 in 1:1 hexane–EtOAc; n.m.r. data: δ_H 5.7–5.58 (m, 1 H, $-CH{=}CH_2$), 5.218 (d, 1 H, *J* 2.7 Hz, H-4b), 5.097 (d, 1 H, *J* 8.5 Hz, H-1a), 2.017, 2.008, 1.947, 1.816 (4 s, 12 H, 4 Ac), and 1.193 (d, 3 H, *J* 6.6 Hz, $CHCH_3$); δ_C 99.7 (C-1b, $^1J_{CH}$ 164 Hz), 97.6 (C-1a, $^1J_{CH}$ 161 Hz), 97.6 (C-1c, $^1J_{CH}$ 169 Hz), 60.5 (C-6b), 56.5 (C-2a), 20.7 ($COCH_3$), and 16.8 ($CHCH_3$).

Anal. Calc. for $C_{65}H_{71}NO_{20}$: C, 65.81; H, 6.03; N, 1.18. Found: C, 66.20; H, 6.16; N, 1.24.

*O-(2,3,4,6-Tetra-*O*-acetyl-β-*D*-galactopyranosyl)-(1→4)-*O*-[(2,3,6-tri-*O*-benzyl-α-*L*-fucopyranosyl)-(1→3)]-6-*O*-benzyl-2-deoxy-2-phthalimido-*D*-glucopyranose* (**14**). — A mixture of compound **13** (443 mg, 373 μmol), $PdCl_2$ (318 mg, 1.8 mmol), and NaOAc (147 mg, 1.8 mmol) in 95% aq. AcOH (6 mL) was sonicated by an ultrasonic cleaner (Tocho) for 16 h, and filtered. The filtrate was diluted with $CHCl_3$, successively washed with water, aq. $NaHCO_3$, and aq. NaCl, dried ($MgSO_4$), and filtered. The filtrate was evaporated *in vacuo*, and chromatography of the residue over SiO_2 in 3:2 toluene–EtOAc afforded **14** (280 mg, 65.7%); R_F 0.43 in 1:1 toluene–EtOAc; n.m.r. data: δ_H 5.222 (d, 1 H, *J* 3.4 Hz, H-4b), 1.233

(d, 0.9 H, *J* 6.7 Hz, $CHCH_3\beta$), and 1.200 (d, 2.1 H, *J* 6.7 Hz, $CHCH_3\alpha$): δ_C 99.6 (C-1b), 98.4 (C-1aβ), 97.4 (C-1c), 93.0 (C-1aα), and 16.7 ($CHCH_3$).

Anal. Calc. for $C_{62}H_{67}NO_{20}$: C, 64.97; H, 5.89; N, 1.22. Found: C, 64.64; H, 5.89; N, 1.20.

Benzyl O-*(2,3,4,6-tetra-O-acetyl-β-*D*-galactopyranosyl)-(1→4)-O-[(2,3,4-tri-O-benzyl-α-*L*-fucopyranosyl)-(1→3)]-O-(6-O-benzyl-2-deoxy-2-phthalimido-β-*D*-glucopyranosyl)-(1→3)-O-(2,6-di-O-benzyl-β-*D*-galactopyranosyl)-(1→4)-2,3,6-tri-O-benzyl-β-*D*-glucopyranoside* (**15**). — Into a solution of compound **14** (458 mg, 0.4 mmol) and Cl_3CCN (720 mg, 5 mmol) in $Cl(CH_2)_2Cl$ (5 mL) was injected a solution of DBU (61 mg, 0.4 mmol) in $Cl(CH_2)_2Cl$ (2 mL) at −5° under Ar. The mixture was stirred for 1 h at 20° and evaporated *in vacuo*. Chromatography of the residue over SiO_2 in 2:3:1 EtOAc–hexane–$CHCl_3$ afforded O-*(2,3,4,6-tetra-O-acetyl-β-*D*-galactopyranosyl)-(1→4)-O-[(2,3,4-tri-O-benzyl-α-*L*-fucopyranosyl)-(1→3)]-6-O-benzyl-2-deoxy-2-phthalimido-β-*D*-glucopyranosyl trichloroacetimidate* (**4**) (346 mg, 67.1%); $[\alpha]_D$ +16.7° (*c* 1.5); R_f 0.55 in 1:1 EtOAc–hexane; n.m.r. data: δ_H 6.366 (d, 1 H, *J* 8.6 Hz, H-1a), 5.226 (d, 1 H, *J* 3.1 Hz, H-4b), 5.015 (dd, 1 H, *J* 8.2 and 10.4 Hz, H-2b), 2.024 (s, 6 H, 2 Ac), 1.951 (s, 3 H, Ac), 1.826 (s, 3 H, Ac), and 1.206 (d, 3 H, *J* 6.4 Hz, $CHCH_3$): δ_C 160.9 (O–C=N), 99.5 (C-1b), 97.7 (C-1c), 94.3 (C-1a), 90.5 (CCl_3), 60.5 (C-6b), 55.2 (C-2a), and 16.7 ($CHCH_3$).

To a solution of compound **4** (291 mg, 225 μmol) and compound **5** (199 mg, 225 μmol) in $Cl(CH_2)_2Cl$ (5 mL) was added dropwise a 0.5M solution of BF_3·Et_2O in $Cl(CH_2)_2Cl$ (0.5 mL) at 0°. The mixture was stirred for 30 min at 20°, and diluted with $CHCl_3$ (50 mL), successively washed with aq. $NaHCO_3$ and aq. NaCl, dried ($MgSO_4$), and evaporated *in vacuo*. Chromatography of the residue over SiO_2 in 4:2:1 hexane–EtOAc–$CHCl_3$ gave **15** (303 mg, 67.0%); $[\alpha]_D$ +4.1° (*c* 0.5); R_f 0.36 in 3:2 hexane–EtOAc; n.m.r. data: δ_H 5.311 (d, 1 H, *J* 8.5 Hz, H-1c), 5.246 (d, 1 H, *J* 3.3 Hz, H-4d), 5.016 (dd, 1 H, *J* 8.5 and 10.2 Hz, H-2d), 1.992 (s, 6 H, 2 Ac), 1.954 (s, 3 H, Ac), 1.827 (s, 3 H, Ac), and 1.182 (d, 3 H, *J* 6.6 Hz, $CHCH_3$): δ_C 102.5 (C-1a), 102.0 (C-1b), 99.6 (C-1d), 99.0 (C-1c), 97.6 (C-1e), 83.5, 82.9, 81.9, 79.7 (C-4a, C-3b, C-3c, C-4c), 60.5 (C-6d), 56.3 (C-2c), and 16.7 (C-6e).

Anal. Calc. for $C_{116}H_{123}NO_{30}$: C, 69.27; H, 6.16; N, 0.70. Found: C, 69.20; H, 6.14; N, 0.82.

The usual acetylation of **15** with Ac_2O–pyridine afforded *benzyl* O-*(2,3,4,6-tetra-O-acetyl-β-*D*-galactopyranosyl)-(1→4)-O-[(2,3,4-tri-O-benzyl-α-*L*-fucopyranosyl)-(1→3)]-O-(6-O-benzyl-2-deoxy-2-phthalimido-β-*D*-glucopyranosyl)-(1→3)-O-(4-O-acetyl-2,6-di-O-benzyl-β-*D*-galactopyranosyl)-(1→4)-2,3,6-tri-O-benzyl-β-*D*-glucopyranoside* (**16**); n.m.r. data: δ_H 5.445 (d, 1 H, *J* 3.7 Hz, H-4b), 5.256 (d, 1 H, *J* 3.3 Hz, H-4d), 5.234 (d, 1 H, *J* 8.3 Hz, H-1c), 5.031 (dd, 1 H, *J* 8.1 and 10.5 Hz, H-2d), 2.074, 2.032, 2.000, 1.951, 1.812 (5 s, 15 H, 5 Ac), and 1.190 (d, 3 H, *J* 6.3 Hz, $CHCH_3$).

Benzyl O-*(2,3,4,6-tetra-O-acetyl-β-*D*-galactopyranosyl)-(1→4)-O-[2,3,6-tri-O-benzyl-α-*L*-fucopyranosyl)-(1→3)]-O-(2-acetamido-6-O-benzyl-2-deoxy-β-*D*-glucopyranosyl)-(1→3)-O-(4-O-acetyl-2,6-di-O-benzyl-β-*D*-galactopyranosyl)-(1→4)-*

*2,3,6-tri-*O*-benzyl-β-*D*-glucopyranoside* (**17**). — A solution of compound **15** (68.5 mg, 34 μmol) in 5mM NaOMe–MeOH (5.2 mL) was stirred for 16 h at 20°, made neutral with Amberlyst 15, the suspension filtered, and the filtrate evaporated *in vacuo*. A solution of the residual oil in 50:1 EtOH–$H_2NNH_2 \cdot H_2O$ (5 mL) was stirred under reflux for 24 h and then evaporated *in vacuo*. The residue was dissolved in 1:1 Ac_2O–pyridine (2 mL) containing a trace of DMAP, and the solution was stirred for 16 h at 20°, diluted with EtOAc (100 mL), successively washed with M HCl, aq. $NaHCO_3$, and aq. NaCl, dried ($MgSO_4$), and evaporated *in vacuo*. The residue was purified by l.c., using a P-G220 column (Hitachi Kasei) in $CHCl_3$, to give **17** (47.4 mg, 71%); $[\alpha]_D$ −25.5° (*c* 0.15); R_F 0.40 in 1:1 toluene–EtOAc; n.m.r. data: 5.282 (d, 1 H, *J* 2.9 Hz, H-4b), 5.187 (d, 1 H, *J* 3.7 Hz, H-4d), 5.142 (d, 1 H, *J* 5.6 Hz, H-1e), 2.031, 1.952, 1.945, 1.932, 1.851, 1.520 (6 s, 18 H, 6 Ac), and 1.154 (d, 3 H, *J* 6.6 Hz, $CHCH_3$); δ_C 102.5 (C-1a), 102.1 (C-1b), 99.7 (C-1c and C-1d), 96.3 (C-1e), 82.8, 81.8, 80.4, 79.8 (C-4a, C-3b, C-3c, C-4c), 60.2 (C-6d), 56.6 (C-2c), 22.9 ($NHCOCH_3$), 20.1, 20.5 (OAc), and 16.7 (C-6e).

Anal. Calc. for $C_{112}H_{125}NO_{30}$: C, 68.45; H, 6.41; N, 0.71. Found: C, 68.55; H, 6.34; N, 1.11.

*O-(2,3,4,6-Tetra-*O*-acetyl-β-*D*-galactopyranosyl)-(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→4)-2,3,6-tri-*O*-acetyl-*D*-glucopyranosyl acetate* (**18**). — A mixture of compound **17** (44.8 mg, 22.8 μmol) and 10% Pd–C (40 mg) in EtOH (5 mL) was stirred for 16 h at 20° under H_2, filtered, and evaporated *in vacuo*; the residue was dissolved in 1:1 Ac_2O–pyridine (2 mL) containing a trace of DMAP, and the mixture was stirred for 6 h at 20°. The usual work-up, and chromatography over SiO_2 in 3:1 toluene–acetone, afforded **18** (26.8 mg, 79.3%); R_F 0.54 in 1:1 toluene–acetone; n.m.r. data: δ_H 6.255 (d, 0.6 H, *J* 3.7 Hz, H-1aα), 5.661 (d, 0.4 H, *J* 8.3 Hz, H-1aβ), and 1.203 (d, 3 H, *J* 6.6 Hz, $CHCH_3$).

Anal. Calc. for $C_{62}H_{85}NO_{40}$: C, 50.17; H, 5.77; N, 0.94. Found: C, 50.39; H, 5.82; N, 0.91.

Conversion of compound **18** *into glycosyl donors* **20** *and* **21**. — A mixture of compound **18** (23.1 mg, 15.5 mmol) and $H_2NNH_2 \cdot AcOH$ (1.8 mg, 20 μmol) in DMF (1 mL) was stirred for 1 h at 20°, when conversion of **18** (R_F 0.51) into compound **19** (R_F 0.38 in 1:1 acetone–toluene) was complete. The mixture was diluted with EtOAc (50 mL), successively washed with M HCl and aq. NaCl, dried ($MgSO_4$), and evaporated *in vacuo*. To a mixture of the residue and Cl_3CCN (14.4 mg, 100 μmol) in $Cl(CH_2)_2Cl$ (0.5 mL) was added a 0.06M solution of DBU in $Cl(CH_2)_2Cl$ (0.5 mL). The mixture was stirred for 1.5 h at 20°, and then directly submitted to chromatography over SiO_2 in 3:1 toluene–EtOAc, to give *O-(2,3,4,6-tetra-*O*-acetyl-β-*D*-galactopyranosyl)-(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→4)-2,3,6-tri-*O*-acetyl-α-*D*-glucopyranosyl trichloroacetimidate* (**20**; 16.5 mg, 67.1%); $[\alpha]_D$ −10.4° (*c* 0.66); R_F 0.47 in

1:1 toluene–acetone; n.m.r. data: δ_H 6.485 (d, 1 H, *J* 3.7 Hz, H-1a), 5.528 (t, 1 H, *J* 9.7 Hz, H-3a), 4.614 (d, 1 H, *J* 8.0 Hz, H-1b or d), 2.193, 2.174, 2.149, 2.129 (4 s, 12 H, 4 Ac), 2.120 (s, 9 H, 3 Ac), 2.084 (s, 6 H, 2 Ac), 2.073, 2.046, 2.041, 2.009 (4 s, 12 H, 4 Ac), 1.982 (s, 6 H, 2 Ac), 1.951 (s, 3 H, Ac), and 1.203 (d, 3 H, *J* 6.6 Hz, $CHCH_3$).

μmol) in 91% yield as already described] in THF (3 mL) was added diethylaminosulfur trifluoride (DAST, 17 μL, 136 μmol) under Ar at 0°. The mixture was stirred for 1 h at 0°, poured into ice–aq. $NaHCO_3$, and extracted with EtOAc. The extract was washed successively with aq. $NaHCO_3$ and aq. NaCl, dried ($MgSO_4$), and evaporated *in vacuo*. Chromatography of the residue over SiO_2 in 1:3 acetone–toluene afforded *O-(2,3,4,6-tetra-O-acetyl-β-D-galactopyranosyl)-(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→4)-2,3,6-tri-O-acetyl-α- and -β-D-glucopyranosyl fluoride* (**21**; 18.5 mg, 38%), and **19** (25.0 mg, 51%) which was converted into **18** by Ac_2O and pyridine. Compound **21** was a mixture of the α and β anomers in the ratio of 1:10; R_F 0.43 in 1:1 acetone–toluene; n.m.r. data: δ_H 5.675 (dd, 0.09 H, *J* 2.6 and 53 Hz, H-1aα), 5.362 (dd, 0.91 H, partly overlapped signals, H-1aβ), 5.414 (d, 1 H, *J* 4.0 Hz, H-4*), 5.360 (d, 1 H, *J* 2.8 Hz, H-4b*), 4.613 (d, 1 H, *J* 7.9 Hz, H-1b*), 4.398 (d, 1 H, *J* 7.9 Hz, H-1d*), 2.192, 2.172, 2.149, 2.140, 2.124, 2.121, 2.113, 2.094, 2.082, 2.079, 2.069, 2.047, 1.982, 1.980, 1.939 (15 s, 45 H, 15 Ac), and 1.202 (d, 3 H, *J* 6.7 Hz, $CHCH_3$).

Glycosylation of ceramide **3**. — (*A*) To a mixture of compound **20** (15.9 mg, 10 μmol), benzoyl ceramide **3** (8.0 mg, 10 μmol), and powdered molecular sieves AW-300 (0.1 g) in ethanol-free $CHCl_3$ (1 mL) was added a 0.1M solution of $BF_3 \cdot Et_2O$ in $Cl(CH_2)_2Cl$ (100 μL) at −5° under Ar. The mixture was stirred for 1 h at 20°, diluted with $CHCl_3$ (50 mL), successively washed with aq. $NaHCO_3$ and aq. NaCl, dried ($MgSO_4$), and evaporated *in vacuo*. Chromatography of the residue over SiO_2 in 99:1 $CHCl_3$–MeOH afforded *O-(2,3,4,6-tetra-O-acetyl-β-D-galactopyranosyl)-(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→4)-O-(2,3,6-tri-O-acetyl-β-D-glucopyranosyl)-(1→1)-3-O-benzoyl-2-N-tetracosanoyl-(2S,3R,4E)-sphingenine* (**22**; 1.6 mg, 7.3%): $[\alpha]_D$ −39° (*c* 0.04); R_F 0.73 in 1:1 toluene–EtOAc; n.m.r. data: δ_H 5.867 (dt, 1 H, *J* 6.0 and 15.0 Hz, H-5cer), 5.742 (d, 1 H, *J* 8.0 Hz, NH), 5.532 (t, 1 H, *J* 7.4 Hz, H-3cer), 5.456 (dd, 1 H, *J* 7.4 and 15.0 Hz, H-4cer), 4.612 (d, 1 H, *J* 8.2 Hz, H-1b*), 2.19–1.93 (m, 49 H, 15 Ac, $COCH_2$ and $=CHCH_2$–) and 0.879 (t, 6 H, *J* 6.4 Hz, 2 CH_2CH_3).

(*B*) Into a mixture of powdered molecular sieves 4A (100 mg), $AgOSO_2CF_3$ (4 mg, 15 μmol), and $SnCl_2$ (3 mg, 16 μmol) was injected a solution of compound **21** (14.9 mg, 10 μmol) and compound **3** (8 mg, 10 μmol) in 2:1 $CHCl_3$–toluene (3 mL). The mixture was stirred for 3 h at 20°, and filtered through Celite. The filtrate was washed successively with aq. $NaHCO_3$ and aq. NaCl, dried ($MgSO_4$), and

*Assignments with the asterisk may have to be interchanged.

evaporated *in vacuo*. Chromatography of the residue over SiO_2 in 1:2 acetone–toluene afforded **22** (4.5 mg, 21%) and **19** (7.2 mg, 48%).

Deprotection of compound **22**. — A solution of compound **22** (3.1 mg, 1.42 μmol) in 1:1 MeOH–THF (1 mL) containing 0.1M NaOMe–MeOH (140 μL) was stirred for 16 h at 20°, made neutral with Amberlyst 15, the suspension filtered, and the filtrate evaporated *in vacuo*. Chromatography of the residue over Sephadex LH-20 in 60:40:4.6 $CHCl_3$–MeOH–H_2O afforded O-β-D-*galactopyranosyl-(1→4)*-O-[α-L-*fucopyranosyl-(1→3)*]-O-*(2-acetamido-2-deoxy-β-D-glucopyranosyl)-(1→3)*-O-β-D-*galactopyranosyl-(1→4)*-O-β-D-*glucopyranosyl-(1→1)-2*-N-*tetracosanoyl-(2S,3R,4E)-sphingenine* (**1**; 2.1 mg, quantitative); $[\alpha]_D$ −23° (*c* 0.1, MeOH); R_F 0.58 in 2:1:1 BuOH–EtOH–H_2C; n.m.r. data: δ_H (49:1 Me_2SO-d_6–D_2O, 60°) 5.545 (td, 1 H, *J* 6.9 and 15.0 Hz, H-5cer), 5.409 (dd, 1 H, *J* 7.6 and 15.0 Hz, H-4cer), 4.897 (d, 1 H, *J* 2.4 Hz, H-1e), 4.774 (d, 1 H, *J* 7.6 Hz, H-1c), 4.562 (m, 1 H, H-5e), 4.312 (d, 1 H, *J* 7.0 Hz, H-1b*), 4.294 (d, 1 H, *J* 7.0 Hz, H-1d*), 4.177 (d, 1 H, *J* 7.9 Hz, H-1a), 2.044 (t, 2 H, *J* 7.3 Hz, $COCH_2CH_2$), 1.951 (m, 2 H, H-6cer), 1.834 (s, 3 H, NAc), 1.044 (d, 3 H, *J* 6.4 Hz, H-6e), and 0.860 (t, 6 H, *J* 7.0 Hz, 2 CH_2CH_3); lit.[28]: δ_H (49:1 Me_2SO-d_6–D_2O, 55°) 4.876 (d, 1 H, *J* 4.3 Hz, H-1e), 4.778 (d, 1 H, *J* 7.9 Hz, H-1c), 4.590 (q, 1 H, *J* 6.7 Hz and 1.5 Hz, H-5e), 4.295 and 4.280 (d, 1 H, *J* 7.3 Hz, H-1b and H-1d), and 4.206 (H-1a).

ACKNOWLEDGMENTS

We thank Dr. J. Uzawa and Mrs. T. Chijimatsu for recording and measuring the n.m.r. spectra, and Dr. H. Honma and his staff for the elemental analyses. We also thank A. Takahashi and K. Moriwaki for their technical assistance.

REFERENCES

1 S. Sato, Y. Ito, and T. Ogawa, *Carbohydr. Res.*, 155 (1986) c1–c5.
2 A. Kobata and V. Ginsburg, *J. Biol. Chem.*, 244 (1969) 5496–5502.
3 S. Hakomori and R. W. Jeanloz, *J. Biol. Chem.*, 239 (1964) 3606–3607.
4 H.-Y. Yang and S. Hakomori, *J. Biol. Chem.*, 246 (1971) 1192–1200.
5 B. L. Slomiany, A. Slomiany, and M. I. Horowitz, *Eur. J. Biochem.*, 56 (1975) 353–358.
6 J. M. McKibbin, W. A. Spencer, E. L. Smith, J.-E. Masson, K.-A. Karlsson, B. E. Samuelsson, Y.-T. Li, and S.-C. Li, *J. Biol. Chem.*, 257 (1982) 755–760.
7 M. T. Vanier, T.-E. Mansson, and L. Svennerholm, *FEBS Lett.*, 112 (1980) 70–72.
8 R. Kanagi, E. Nudelman, S. B. Leroy, and S. Hakomori, *J. Biol. Chem.*, 257 (1982) 14,865–14,874.
9 L. C. Huang, M. Brockhaus, J. L. Magnani, F. Cuttitta, S. Rosen, J. D. Minna, and V. Ginsburg, *Arch. Biochem. Biophys.*, 220 (1983) 318–320.
10 G. Pfannschmidt, J. P. Katalinic, M. Kordowicz, H. Egge, J. Dabrowski, U. Dabrowski, and P. Hanfland, *FEBS Lett.*, 174 (1984) 55–60.
11 J.-C. Jacquinet and P. Sinaÿ, *J. Chem. Soc., Perkin Trans. 1*, (1979) 314–322; O. Hindsgaul, T. Norberg, J. LePendu, and R. U. Lemieux, *Carbohydr. Res.*, 109 (1982) 109–142.
12 M. M. Ponpipom, R. L. Bugianesi, and T. Y. Shen, *Tetrahedron Lett.*, (1978) 1717–1720; R. U. Lemieux, S. Z. Abbas, and B. Y. Chung, *Can. J. Chem.*, 60 (1982) 68–75.
13 J. Dahmen, G. Gnosspelius, A.-C. Larsson, T. Lave, G. Noori, K. Palsson, T. Frejd, and G. Magnusson, *Carbohydr. Res.*, 138 (1985) 17–28.
14 K. Koike, Y. Nakahara, and T. Ogawa, *Glycoconjugate J.*, 1 (1984) 107–109.

15 T. OGAWA AND M. SUGIMOTO, *Carbohydr. Res.*, 128 (1985) c1–c4; H. PAULSEN, D. HADAMCZYK, W. KUTSCHER, AND A. BUNSCH, *Justus Liebigs Ann. Chem.*, (1985) 129–141.
16 M. KISO AND L. ANDERSON, *Carbohydr. Res.*, 72 (1979) c12–c14; T. OGAWA, K. BEPPU, AND S. NAKABAYASHI, *ibid.*, 93 (1981) c6–c9.
17 T. OGAWA AND M. MATSUI, *Carbohydr. Res.*, 62 (1978) c1–c4; *Tetrahedron*, 37 (1981) 2363–2369; T. OGAWA, T. NUKADA, AND M. MATSUI, *Carbohydr. Res.*, 101 (1982) 263–270; T. OGAWA, Y. TAKAHASHI, AND M. MATSUI, *ibid.*, 102 (1982) 207–215; A. VEYRIÈRES, *J. Chem. Soc., Perkin Trans. 1*, (1981) 1626–1629.
18 M. EK, P. J. GAREGG, H. HULTBERG, AND S. OSCARSON, *J. Carbohydr. Chem.*, 2 (1983) 305–311.
19 R. R. SCHMIDT AND M. STUMPP, *Justus Liebigs Ann. Chem.*, (1983) 1249–1256.
20 H. LÖNN, *Carbohydr. Res.*, 139 (1985) 105–113, 115–121.
21 R. BOSE AND R. SCHEFFOLD, *Angew. Chem.*, 88 (1976) 578–579; T. OGAWA AND S. NAKABAYASHI, *Carbohydr. Res.*, 93 (1981) c1–c5.
22 R. R. SCHMIDT AND J. MICHEL, *Angew. Chem., Int. Ed. Engl.*, 19 (1980) 731–732; R. R. SCHMIDT AND G. GRUNDLER, *Synthesis*, (1981) 885–887; R. R. SCHMIDT AND J. MICHEL, *Angew. Chem., Int. Ed. Engl.*, 21 (1982) 72–73; R. R. SCHMIDT AND G. GRUNDLER, *ibid.*, 21 (1982) 781–782; 22 (1983) 776–777; R. R. SCHMIDT AND R. KLAGER, *ibid.*, 24 (1985) 65–66.
23 H. PAULSEN AND M. PAAL, *Carbohydr. Res.*, 137 (1985) 39–62.
24 R. U. LEMIEUX, T. TAKEDA, AND B. Y. CHUNG, *ACS Symp. Ser.*, 39 (1976) 90–115.
25 G. EXCOFFIER, D. GAGNAIRE, AND J.-P. UTILLE, *Carbohydr. Res.*, 39 (1975) 368–373.
26 W. ROSENBROOK, JR., D. A. RILEY, AND P. A. LARTEY, *Tetrahedron Lett.*, (1985) 3–5; G. H. POSNER AND S. R. HAINES, *ibid.*, 26 (1985) 5–8.
27 T. MUKAIYAMA, Y. MURAI, AND S. SHODA, *Chem. Lett.*, (1981) 431–432.
28 S. B. LEVERY, E. D. NUDELMAN, N. H. ANDERSEN, AND S. HAKOMORI, *Carbohydr. Res.*, 151 (1986) 311–328.