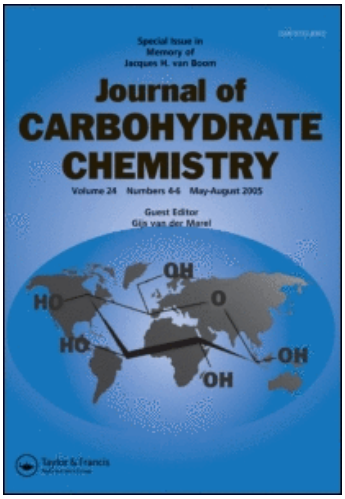

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Synthetic Studies on Tumor-Associated Antigens: Efficient Syntheses of Le^a and Sialyl-Le^a Oligosaccharides, and Their Deaminated Analogs[1]

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SYNTHETIC STUDIES ON TUMOR-ASSOCIATED ANTIGENS: EFFICIENT SYNTHESES OF Le^a AND SIALYL-Le^a OLIGOSACCHARIDES, AND THEIR DEAMINATED ANALOGS[1]

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ABSTRACT

Efficient syntheses of tumor-associated Le^a, sialyl Le^a and their deaminated analogs are described. The suitably protected D-glucosamine (**4**) or D-glucose (**5**) derivative was successively coupled with the methyl-1-thioglycosides (glycosyl donors) of D-galactose (**6**) and L-fucose (**11**) in high yields by using *N*-iodosuccinimide/trifluoromethanesulfonic acid (NIS/TfOH) as the glycosyl promoter. The resulting trisaccharides (**12** and **13**) were each converted, by deprotections, to the Le^a determinant (**17**) and its deaminated analog (**18**), and by further glycosylation with the phenyl-2-thioglycoside of *N*-acetylneuraminic acid (**25**), to the sialyl-Le^a determinant (**30**) and its deaminated analog (**31**), respectively.

INTRODUCTION

The prominent tumor-associated carbohydrate antigens sialyl Lewis x (sLe^x) and sialyl Lewis a (sLe^a) have been identified[2] as the minimal carbohydrate ligands for selectins, a family of lectin-type cell adhesion molecules (LEC-CAMs) involved in

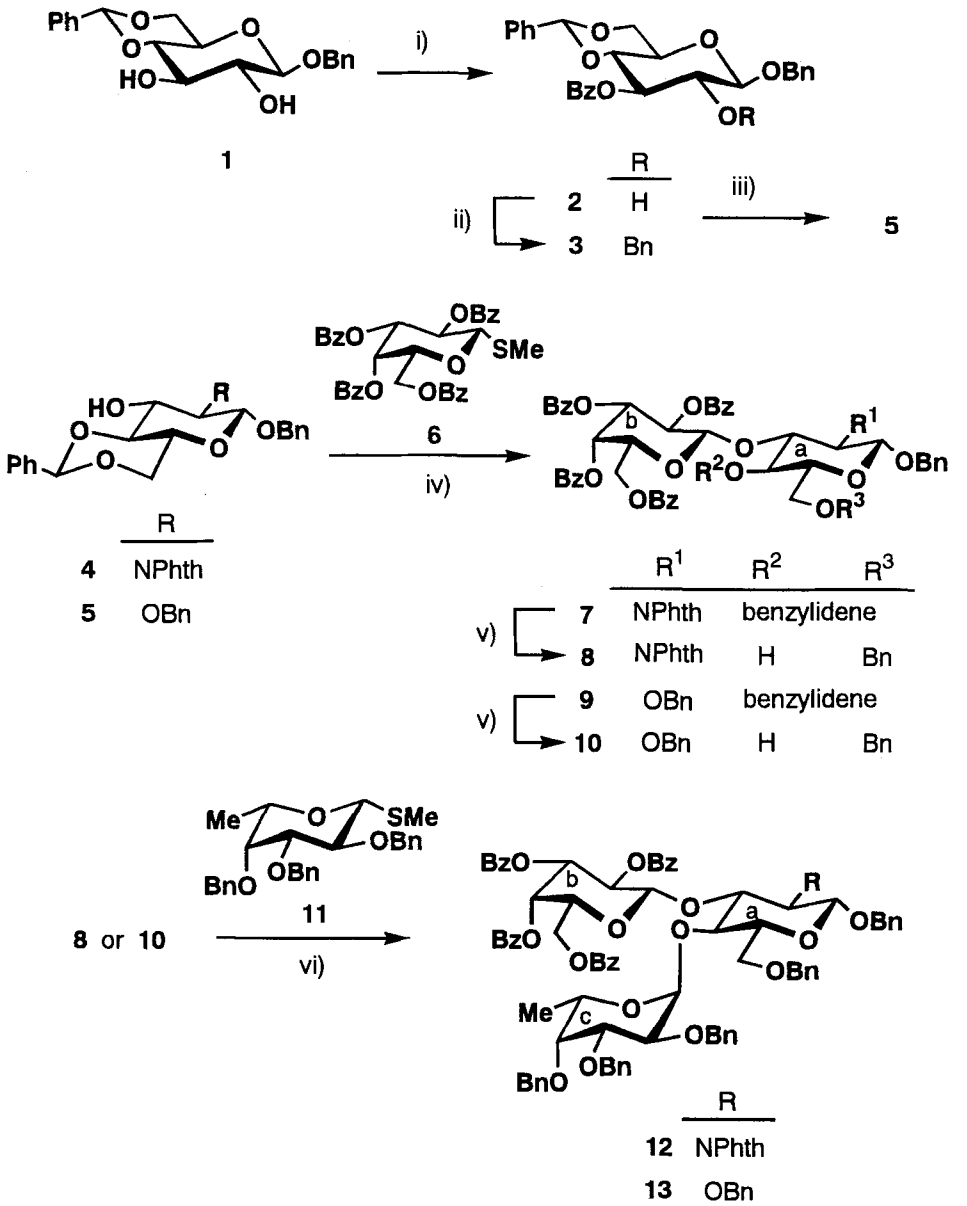
leukocyte trafficking, thrombosis, inflammation, tumor metastasis, and so on. The Lewis a (Le^a) determinant was also detected on human adenocarcinoma cells,[3] and the 3'-*O*-sulfated Le^a structure has recently been suggested[4] to be a superior oligosaccharide ligand for human E-selectin.

We have succeeded[5] in a systematic synthesis of sLe^x gangliosides and their analogs by use of a highly efficient, regio- and α-stereoselective sialylation procedure[6] using 2-thioglycosides of sialic acids in acetonitrile. A number of studies for selectin ligands/inhibitors have been achieved[2,7] by employing those synthetic sLe^x compounds. Along this line, we have previously reported a total synthesis of sLe^a ganglioside[8] and some novel epitope analogs containing *N*-methyl-1-deoxynojirimycin.[9] As a part of our continuing efforts, on the synthesis and elucidation of the biological functions of sialoglycoconjugates, we describe here the efficient syntheses of Le^a (**17**) and sLe^a (**30**) oligosaccharides, and their deaminated analogs (**18** and **31**) by use of thioglycosides as glycosyl donors.

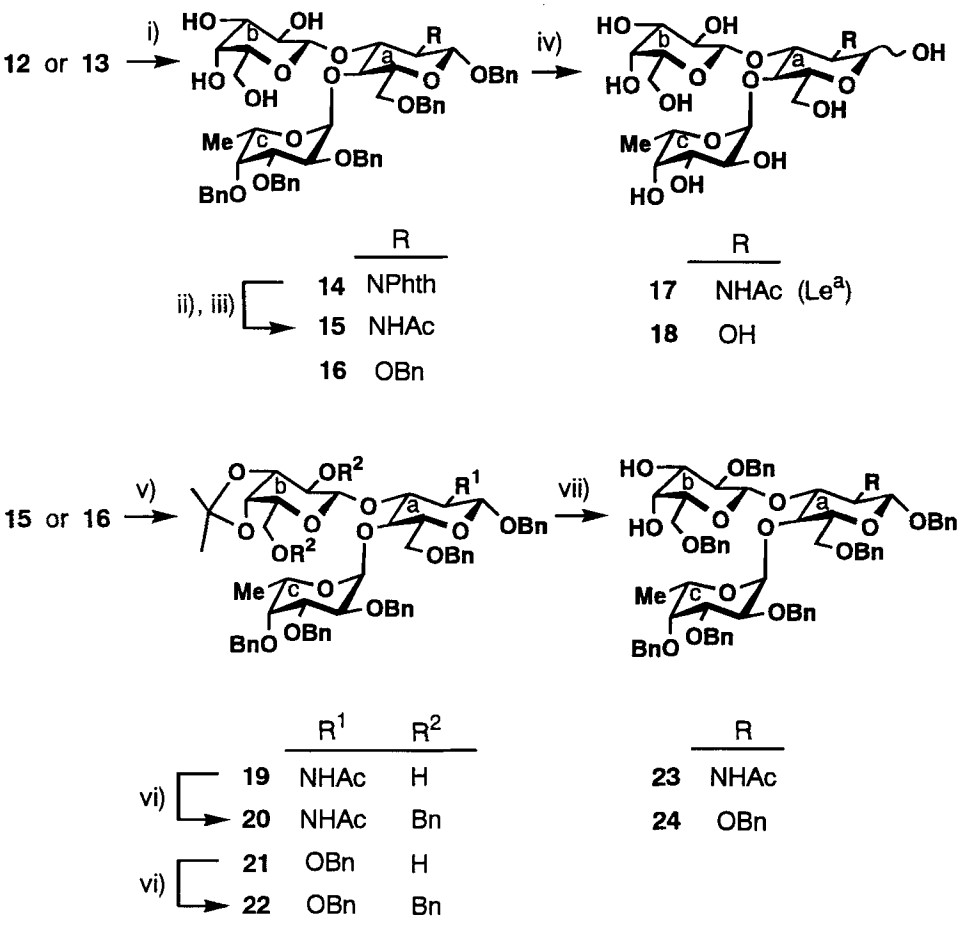
RESULTS AND DISCUSSION

Thioglycosides are highly stable in many organic operations, and capable of specific activations by appropriate thiophilic promoters in very mild conditions, being widely used in oligosaccharide synthesis.[10] In this study, three thioglycosides for D-galactose (**6**), L-fucose (**11**) and *N*-acetylneuraminic acid (**25**) were successfully employed as efficient glycosyl donors.

Benzyl 4,6-*O*-benzylidene-2-deoxy-2-phthalimido-β-D-glucopyranoside[11] (**4**) and the corresponding D-glucopyranose derivative[12] (**5**), which was prepared by the regioselective 3-*O*-benzoylation of **1** and subsequent 2-*O*-benzylation, were each coupled with methyl 2,3,4,6-tetra-*O*-benzoyl-1-thio-β-D-galactopyranoside (**6**), promoted by *N*-iodosuccinimide/trifluoromethanesulfonic acid[13] (NIS/TfOH) in dichloromethane, to give disaccharides **7** (88%) and **9** (94%), respectively (Scheme 1). Reductive ring opening of the benzylidene group in **7** and **9**, and subsequent α-stereoselective L-fucosylation of **8** and **10** with methyl 2,3,4-tri-*O*-benzyl-1-thio-β-L-



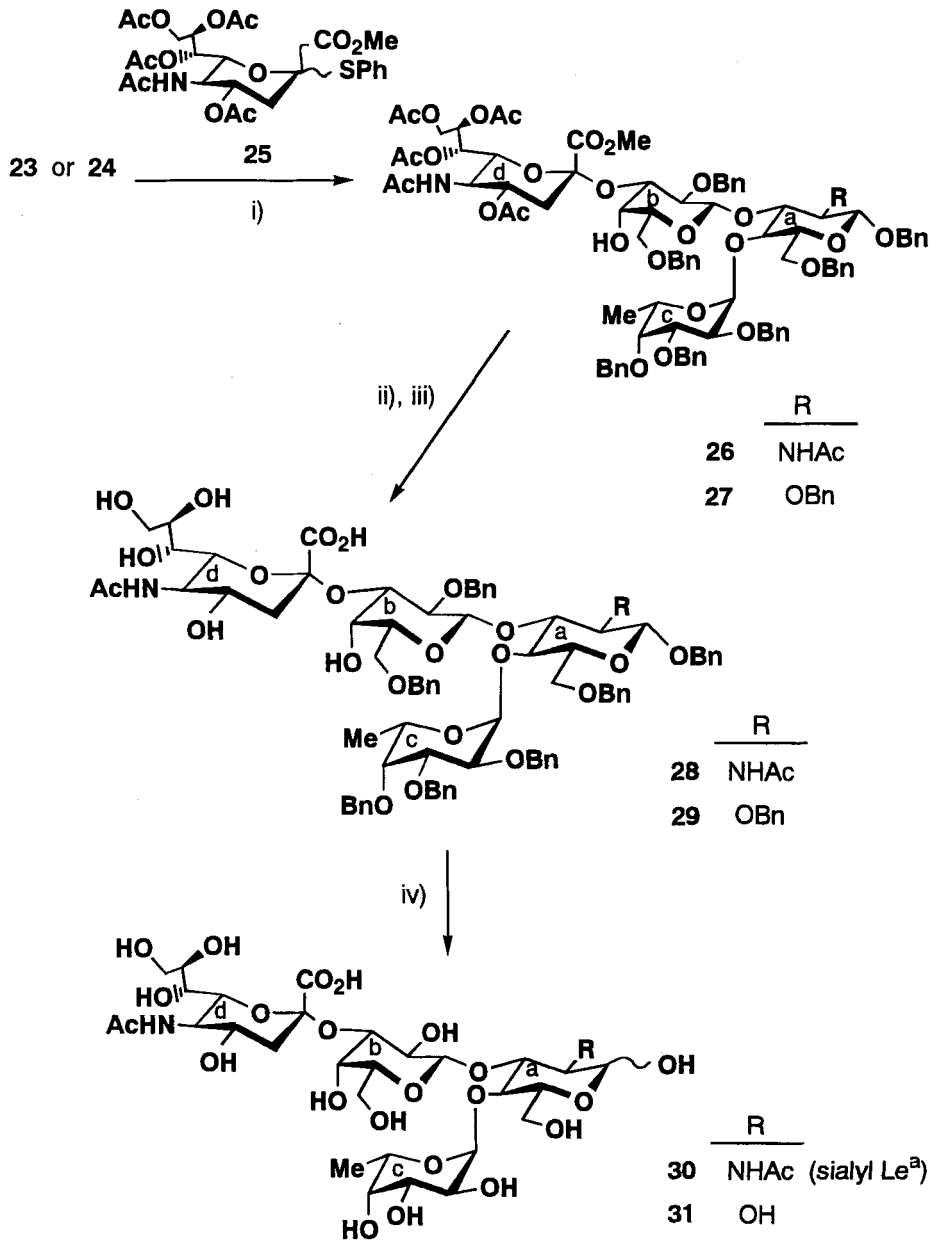
Scheme 1. i) BzCl, pyr.-CH_2Cl_2, -50 °C; ii) BnBr, Ag_2O, CH_2Cl_2, rt (100%); iii) NaOMe, MeOH-THF, rt; iv) NIS, TfOH, CH_2Cl_2, -35 °C, **4**→**7** (88%); **5**→**9** (94%); v) $NaBH_3CN$, HCl/Et_2O, THF; vi) NIS, TfOH, CH_2Cl_2, -35 °C, **8**→**12** (92%), or NIS, TfOH, toluene, -10 °C, **10**→**13** (90%)



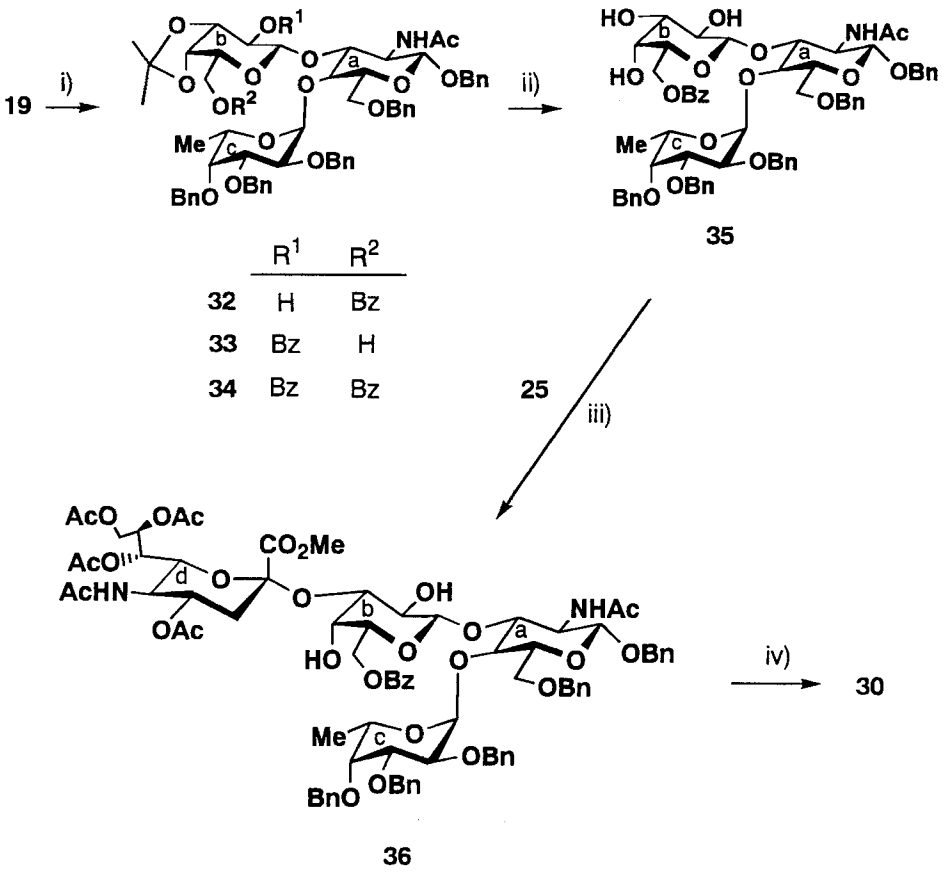
Scheme 2. i) NaOMe, MeOH-CH_2Cl_2 or MeOH-THF; ii) $NH_2NH_2 \cdot H_2O$, 80% EtOH, reflux; iii) Ac_2O, MeOH; iv) H_2, Pd-C, EtOH-AcOH; v) $Me_2C(OMe)_2$, *p*-TsOH or CSA, CH_3CN, rt; vi) NaH, BnBr, DMF; vii) 80% AcOH, 45 °C, or *p*-TsOH, MeOH

fucopyranoside (**11**) afforded the protected Le^a trisaccharide **12** (92%) and its analog **13** (90%) in high yields, respectively. These were converted, by de-*O*-benzoylation and hydrogenolytic removal of the benzyl groups, to the desired Le^a determinant **17**[14] and its deaminated analog **18**, almost quantitatively (Scheme 2).

Treatment of **15** and **16** with 2,2-dimethoxypropane and a catalytic amount of *p*-toluenesulfonic acid or camphorsulfonic acid in acetonitrile gave **19** (67%) and



Scheme 3. i) NIS, TfOH, CH_3CN, -35 °C, **23**→**26** (52%), **24**→**27** (59%); ii) NaOMe, MeOH; iii) 0.2M KOH; iv) H_2, $Pd(OH)_2$-C, 50% aq THF



Scheme 4. i) BzCl, pyr.-CH_2Cl_2, -45 °C; ii) 80% AcOH; iii) NIS, TfOH, CH_3CN, -35 °C (69%); iv) (a) NaOMe, MeOH; (b) 0.2M KOH; (c) H_2, $Pd(OH)_2$-C, 50% aq THF

21(63%) together with the corresponding 4,6-*O*-isopropylidene derivatives (~30%). Benzylation of the remaining hydroxyls and subsequent removal of the isopropylidene group afforded **23** and **24**, which were then coupled with methyl (phenyl 5-acetamido-4,7,8,9-tetra-*O*-acetyl-3,5-dideoxy-2-thio-D-*glycero*-α-D-*galacto*-2-nonulopyranosid) onate[15] (**25**) in the presence of NIS/TfOH in acetonitrile to give **26** (52%) and **27** (59%), respectively. These were converted stepwise, by de-*O*-acetylation, saponification of the methyl ester and hydrogenolysis over palladium hydroxide on

carbon in 50% aq THF, into the desired sLe^a tetrasaccharide **30**[16] and its deaminated analog **31** in almost quantitative yields, respectively (Scheme 3).

We have developed[6] a facile, and highly regio- and α-stereoselective sialyl glycoside syntheses by using the 2-thioglycosides of sialic acids as glycosyl donors in acetonitrile. In this procedure, the use of lightly protected sugar acceptors, in which several OH groups are unprotected, was another prominent feature.[6,15b] Treatment of **19** with a restricted amount of benzoyl chloride in pyridine-dichloromethane mixture at -50 °C gave **32**, which was then converted to the desired trisaccharide acceptor **35** (Scheme 4). Iodonium promoted, regio- and α-stereoselective sialylation of **35** with **25** was performed under reaction conditions similar to these employed for **23** to provide the desired tetrasaccharide **3** in about 70% yield. Compound **36** thus obtained was readily converted into **30** as described for **26**.

Until recently, a variety of synthetic studies on carbohydrate probes which contain the Le^a or sLe^a epitope derivatives have been reported.[15c,17] We here achieved an efficient synthesis of both Le^a and sLe^a oligosaccharides, and their deaminated analogs by employing three thioglycosides **6**, **11**, and **25** as glycosyl donors. These synthetic oligosaccharides might be useful for further investigation of biological functions.

EXPERIMENTAL

General methods. Optical rotations were determined with a Union PM-201 polarimeter at 25 °C. ^{1}H NMR spectra were recorded on JEOL JNM-GX 270 (270 MHz) or JNM-GX 400 (400 MHz) spectrometer using deuterated solvents ($CDCl_3$, CD_3OD) with TMS as the internal standard. Fast atom bombardment-mass (FAB-MS) spectra were recorded on JEOL JMS-SX 102A mass spectrometer/JMA-DA 7000 data system. Each sample was mixed with triethanolamine (TEA) matrix on a target. The ion accelerating voltage was 8.0 kV, and the primary beam for the bombardment was 6.0 keV of xenon.

All reactions were monitored by TLC (Merck silica gel aluminum plates 60F-254) and preparative column chromatography was performed on silica gel (Wako Chemical Co., 200 mesh) with the solvent systems specified. Concentrations were conducted *in vacuo*.

Benzyl 2-*O*-Benzyl-4,6-*O*-benzylidene-β-D-glucopyranoside (5). To a stirred solution of **1** (500 mg, 1.39 mmol) in CH_2Cl_2 (5 mL) and pyridine (0.6 mL) was added benzoyl chloride (1.64 mmol) in CH_2Cl_2 (2 mL) dropwise at -50 °C, and the stirring was continued for 30 min at -50 °C. Methanol was added and the mixture was concentrated. The residue was taken up in CH_2Cl_2, washed with ice-cold M HCl, M Na_2CO_3 and water, dried (Na_2SO_4), and the solvent was evaporated. Column chromatography (1:6 AcOEt-hexane) of the residue on silica gel gave the 3-*O*-benzoyl derivative **2** (390 mg, 60%); ^1H NMR ($CDCl_3$) δ 4.64 (d, 1H, $J_{1,2}$ = 7.7 Hz, H-1), 5.48 (t, 1H, $J_{2,3} = J_{3,4}$ = 9.5 Hz, H-3). The 2-*O*-acetate of **2** showed δ 4.73 (d, 1H, $J_{1,2}$ = 7.9 Hz, H-1), 5.27 (dd, 1H, $J_{1,2}$ = 7.9, $J_{2,3}$ = 9.3 Hz, H-2), 5.56 (t, 1H, $J_{2,3} = J_{3,4}$ = 9.5 Hz, H-3).

To a solution of **2** (4.9 g, 10.6 mmol) in CH_2Cl_2 (50 mL) were added benzyl bromide (3.8 mL, 32 mmol) and silver (I) oxide (14.45 g, 62.4 mmol), and the mixture was stirred in the dark for 10 h at room temperature. Methanol was added and the solids were filtered off through Celite. The filtrate was washed with water, dried, and concentrated to a residue which was chromatographed (1:6 AcOEt-hexane) on a column of silica gel to give **3** (5.85 g, quantitative); ^1H NMR ($CDCl_3$) δ 3.65 (dd, 1H, $J_{1,2}$ = 7.7, $J_{2,3}$ = 9.2 Hz, H-2), 4.78 (d, 1H, $J_{1,2}$ = 7.7 Hz, H-1), 5.59 (~t, 1H, $J_{2,3}$ = 9.2 Hz, $J_{3,4}$ = 9.5 Hz, H-3). Treatment of **3** (5.85 g) with a catalytic amount of NaOMe in MeOH-THF and column chromatography (CH_2Cl_2) on silica gel afforded the title compound **5** (4.74 g, quantitative): $[\alpha]_D$ -42° (*c* 0.8, $CHCl_3$); ^1H NMR ($CDCl_3$) δ 3.41 (dd, 1H, $J_{1,2}$ = 7.9, $J_{2,3}$ = 9.2 Hz, H-2), 3.56 (t, 1H, $J_{2,3} = J_{3,4}$ = 9.2 Hz, H-3), 4.63 (d, 1H, $J_{1,2}$ = 7.9 Hz, H-1).

Anal. Calcd for $C_{27}H_{28}O_6$ (448.5) C, 72.30; H, 6.29. Found: C, 72.52; H, 6.26.

Benzyl *O*-(2,3,4,6-Tetra-*O*-benzoyl-β-D-galactopyranosyl)-(1→3)-4,6-*O*-benzylidene-2-deoxy-2-phthalimido-β-D-glucopyranoside (7). To a solution of **4** (500 mg, 1.0 mmol) and **6** (1 g, 1.6 mmol) in dry CH_2Cl_2 (5 mL) was added powdered molecular sieves 4Å (MS-4Å, 0.5 g), and the mixture was stirred for 5 h at room temperature, then it was cooled to -35 °C. *N*-Iodosuccinimide (NIS; 0.67 g, 3 mmol) and trifluoromethanesulfonic acid (TfOH; 53 μL, 0.6 mmol) were added to the cooled mixture, and it was stirred for 3 h at -35 °C and then neutralized with Et_3N. The precipitate was filtered off and washed with CH_2Cl_2. The filtrate and washings were combined, and the solution was successively washed with M $Na_2S_2O_3$ and water, dried (Na_2SO_4), and concentrated to a syrup which was chromatographed on a column of silica gel (75 g) with 1:3 AcOEt-hexane to give **7** (960 mg, 88%) as an amorphous mass: $[\alpha]_D$ +49° (*c* 0.3, $CHCl_3$); ^1H NMR ($CDCl_3$) δ 4.92 (d, 1H, $J_{1,2}$ = 8.1 Hz, H-1b), 5.15 (d, 1H, $J_{1,2}$ = 8.4 Hz, H-1a), 5.35 (dd, 1H, $J_{2,3}$ = 10.3, $J_{3,4}$ = 3.3 Hz, H-3b), 5.54 (dd, 1H, $J_{1,2}$ = 8.1, $J_{2,3}$ = 10.3 Hz, H-2b), 5.63 (s, 1H, PhC*H*), 5.80 (near d, 1H, $J_{3,4}$ = 3.3 Hz, H-4b), and 6.89-8.05 (m, 34H, aromatic).

Anal. Calcd for $C_{62}H_{51}NO_{16}$ (1066.1): C, 69.85; H, 4.82; N, 1.31. Found: C, 69.83; H, 4.61; N, 1.15.

Benzyl *O*-(2,3,4,6-Tetra-*O*-benzoyl-β-D-galactopyranosyl)-(1→3)-6-*O*-benzyl-2-deoxy-2-phthalimido-β-D-glucopyranoside (8). To a solution of **7** (1 g, 0.9 mmol) in dry THF (10 mL) was added MS-4Å (1 g), and the mixture was stirred for 3 h at room temperature, and sodium cyanoborohydride (1 g, 15 mmol) was gradually added. After the reagent had dissolved, hydrogen chloride in ether was added dropwise at 0 °C until the evolution of gas ceased. TLC indicated that the reaction was complete after 15 min and then neutralized with Et_3N. The precipitate was filtered off and washed with CH_2Cl_2 and water. The filtrate and washings were combined, and the solution was washed with water, dried (Na_2SO_4), and concentrated to a syrup which was chromatographed on a column of silica gel (75 g) with 1:2 AcOEt-hexane to give **8** (900 mg, 90%) as an amorphous mass: $[\alpha]_D$ +54° (*c* 0.16, $CHCl_3$); ^1H NMR ($CDCl_3$) δ 3.47 (bd, 1H, OH-4a), 4.82 (d, 1H, $J_{1,2}$ = 8.1 Hz, H-

1b), 4.95 (d, 1H, $J_{1,2}$ = 8.4 Hz, H-1a), 5.47 (dd, 1H, $J_{2,3}$ = 10.3, $J_{3,4}$ = 3.3 Hz, H-3b), 5.74 (dd, 1H, H-2b), 5.88 (d, 1H, H-4b), and 6.85-8.15 (m, 34H, aromatic).

Anal. Calcd for $C_{62}H_{53}NO_{16}$ (1068.1): C, 69.72; H, 5.00; N, 1.31. Found: C, 69.59; H, 4.98; N, 1.06.

Benzyl *O*-(2,3,4,6-Tetra-*O*-benzoyl-β-D-galactopyranosyl)-(1→3)-2-*O*-benzyl-4,6-*O*-benzylidene-β-D-glucopyranoside (9). To a solution of **5** (1 g, 2.2 mmol) and **6** (2.1 g, 3.3 mmol) in dry CH_2Cl_2 (20 mL) was added MS-4Å (2 g), and the mixture was stirred for 8 h at room temperature, then it was cooled to -35 °C. NIS (1 g, 4.4 mmol) and TfOH (79 μL, 0.89 mmol) were added to the cooled mixture, and it was stirred for 30 min at -35 °C and then neutralized with Et_3N. A workup similar to that described for **7** gave **9** (2.16 g, 94%) as an amorphous mass: $[\alpha]_D$ +9° (*c* 1.2, $CHCl_3$); ^1H NMR ($CDCl_3$) δ 4.57 (d, 1H, $J_{1,2}$ = 7.9 Hz, H-1a), 5.24 (d, 1H, $J_{1,2}$ = 7.9 Hz, H-1b), 5.56 (dd, 1H, $J_{2,3}$ = 10.3 Hz, $J_{3,4}$ = 3.3 Hz, H-3b), 5.61 (s, 1H, PhC*H*), 5.85 (dd, 1H, H-2b), 5.94 (d, 1H, H-4b) and 7.1-8.1 (m, 35H, 7Ph).

Anal. Calcd for $C_{61}H_{54}O_{15}$ (1027.0): C, 71.33; H, 5.30. Found: C, 71.17; H, 5.07.

Benzyl *O*-(2,3,4,6-Tetra-*O*-benzoyl-β-D-galactopyranosyl)-(1→3)-2,6-di-*O*-benzyl-β-D-glucopyranoside (10). To a solution of **9** (190 mg, 0.18 mmol) in dry THF (1.9 mL) was added MS-4Å (0.19 g), and the mixture was stirred for 1 h at room temperature, and sodium cyanoborohydride (170 mg, 2.7 mmol) was gradually added. After the reagent had dissolved, hydrogen chloride in ether was added dropwise at 0 °C until the evolution of gas ceased. TLC indicated that the reaction was complete after 5 min and then neutralized with Et_3N. A workup similar to that described for **8** gave **10** (160 mg, 84%) as an amorphous mass: $[\alpha]_D$ +56° (*c* 1.0, $CHCl_3$); ^1H NMR ($CDCl_3$) δ 4.43 (d, 1H, $J_{1,2}$ = 7.7 Hz, H-1a), 5.15 (d, 1H, $J_{1,2}$ = 7.9 Hz, H-1b), 5.63 (dd, 1H, $J_{2,3}$ = 10.4, $J_{3,4}$ = 3.5 Hz, H-3b), 5.89 (dd, 1H, H-2b), 5.98 (d, 1H, H-4b), and 7.0-8.1 (m, 35H, 7Ph).

Anal. Calcd for $C_{61}H_{56}O_{15}$ (1029.1): C, 71.20; H, 5.49. Found: C, 71.17; H, 5.48.

Benzyl *O*-(2,3,4,6-Tetra-*O*-benzoyl-β-D-galactopyranosyl)-(1→3)-*O*-[2,3,4-tri-*O*-benzyl-α-L-fucopyranosyl-(1 → 4)]-6-*O*-benzyl-2-deoxy-2-phthalimido-β-D-glucopyranoside (12). To a solution of **8** (650 mg, 0.63 mmol) and **11** (583 mg, 1.25 mmol) in dry CH_2Cl_2 (6 mL) was added MS-4Å (0.6 g), and the mixture was stirred for 5 h at room temperature. It was cooled to -40 °C. NIS (790 mg, 3.75 mmol) and TfOH (44 μL, 0.31 mmol) were added to the cooled mixture, and it was stirred for 3 h at -40 °C and then neutralized with Et_3N. A workup similar to that described for **7** gave **12** (860 mg, 92%) as an amorphous mass: $[\alpha]_D$ +4° (*c* 0.7, $CHCl_3$); ^1H NMR ($CDCl_3$) δ 1.52 (d, 3H, $J_{5,6}$ = 6.6 Hz, H-6c), 4.82 (d, 1H, $J_{1,2}$ = 8.2 Hz, H-1b), 5.18 (dd, 1H, $J_{2,3}$ = 10.4, $J_{3,4}$ = 3.7 Hz, H-3b), 5.25 (bd, 1H, $J_{1,2}$ = ~3 Hz H-1c), 5.69 (dd, 1H, H-2b), 5.78 (d, 1H, H-4b), and 6.85-8.12 (m, 49H, aromatic).

Anal. Calcd for $C_{89}H_{81}NO_{20}$ (1484.6): C, 72.00; H, 5.50; N, 0.94. Found: C, 71.93; H, 5.40; N, 0.74.

Benzyl *O*-(2,3,4,6-Tetra-*O*-benzoyl-β-D-galactopyranosyl)-(1→3)-*O*-[2,3,4-tri-*O*-benzyl-α-L-fucopyranosyl-(1 → 4)]-2,6-di-*O*-benzyl-β-D-glucopyranoside (13). To a solution of **10** (500 mg, 0.48 mmol) and **11** (340 mg, 0.72 mmol) in dry toluene (9 mL) was added MS-4Å (0.9 g), and the mixture was stirred overnight at room temperature, then it was cooled to -15 °C. NIS (170 mg, 0.72 mmol) and TfOH (6 μL, 60 mmol) were added to the cooled mixture, and it was stirred overnight at -10 °C and then neutralized with Et_3N. A workup similar to that described for **12** gave **13** (630 mg, 90%) as an amorphous mass: $[\alpha]_D$ -25° (*c* 0.4, $CHCl_3$); ^1H NMR ($CDCl_3$) δ 1.59 (d, 3H, $J_{5,6}$ = 6.4 Hz, H-6c), 4.34 (d, 1H, $J_{1,2}$ = 7.7 Hz, H-1a), 5.16 (d, 1H, $J_{1,2}$ = ~3 Hz, H-1c), 5.57 (dd, 1H, $J_{2,3}$ = 10.3, $J_{3,4}$ = 3.3 Hz, H-3b), 5.57 (d, 1H, $J_{1,2}$ = 8.2 Hz, H-1b overlapping with H-3b), 5.85 (dd, 1H, H-2b), 5.89 (d, 1H, H-4b), and 7.1-8.1 (m, 50H, 10Ph).

Anal. Calcd for $C_{88}H_{84}O_{19}$ (1445.6): C, 73.12; H, 5.86. Found: C, 73.08; H, 5.65.

Benzyl *O*-(β-D-Galactopyranosyl)-(1→3)-*O*-[2,3,4-tri-*O*-benzyl-α-L-fucopyranosyl-(1 → 4)]-6-*O*-benzyl-2-deoxy-2-phthalimido-β-D-gluco-

pyranoside (14). To a solution of **12** (230 mg, 0.16 mmol) in MeOH (4 mL) and CH_2Cl_2 (1 mL) was added catalytic amount of sodium methoxide, and the mixture was stirred for 5 h at room temperature, and then neutralized with Amberlite IR-120 (H^+) resin and filtered. The resin was washed with MeOH and the combined filtrate and washings were concentrated. The residue was chromatographed on a column of silica gel (30 g) with 25:1 CH_2Cl_2-MeOH to give **14** (163 mg, quantitative) as an amorphous mass: $[\alpha]_D$ -63° (*c* 0.4, $CHCl_3$); ^1H NMR ($CDCl_3$) δ 1.61 (d, 3H, $J_{5,6}$ = 6.6 Hz, H-6c), 5.22 (d, 1H, $J_{1,2}$ = 3.3 Hz, H-1c), 7.22-7.78 (m, 29H, aromatic).

Anal. Calcd for $C_{61}H_{65}NO_{16}$ (1068.2): C,68.59; H, 6.13; N, 1.31. Found: C,68.48; H, 5.92; N, 1.30.

Benzyl *O*-(β-D-Galactopyranosyl)-(1→3)-*O*-[2,3,4-tri-*O*-benzyl-α-L-fucopyranosyl-(1 → 4)]-2-acetamido-6-*O*-benzyl-2-deoxy-β-D-glucopyranoside (15). To a solution of **14** (360 mg, 0.34 mmol) in aq 80% EtOH (4 mL) was added hydrazine hydrate (0.34 mL), the mixture was refluxed for 5 h. After cooling the mixture in ice bath, the precipitate was filtered off, and washed with MeOH. The filtrate and washings were combined, and concentrated. The residue thus obtained was then treated with acetic anhydride (0.16 mL) in MeOH (3 mL) for 4 h at room temperature. The reaction mixture was then concentrated to a syrup which was chromatographed on a column of silica gel (30 g) with 25:1 CH_2Cl_2-MeOH, to give **15** (330 mg, quantitative) as an amorphous mass: $[\alpha]_D$ -67° (*c* 1.5, $CHCl_3$); ^1H NMR ($CDCl_3$) δ 1.22 (d, 3H, $J_{5,6}$ = 6.4 Hz, H-6c), 2.00 (s, 3H, AcN), 5.25 (d, 1H, $J_{1,2}$ = 3.5 Hz, H-1c), and 7.23-7.31 (m, 25H, 5Ph).

Anal. Calcd for $C_{55}H_{65}NO_{15}$ (980.1): C, 67.47; H, 6.68; N, 1.43. Found: C, 67.27; H, 6.41; N, 1.15.

Benzyl *O*-(β-D-Galactopyranosyl)-(1→3)-*O*-[2,3,4-tri-*O*-benzyl-α-L-fucopyranosyl-(1→4)]-2,6-di-*O*-benzyl-β-D-glucopyranoside (16). To a solution of **13** (1.3 g, 0.9 mmol) in MeOH (13 mL) and THF (6 mL) was added catalytic amount of sodium methoxide, and the mixture was stirred for a day at room temperature. It was then neutralized with Amberlite IR-120 (H^+) resin and filtered. A workup similar to that described for **14** gave **16** (820 mg, 89%) as an amorphous

mass: $[\alpha]_D$ -64° (*c* 1.1, $CHCl_3$); ^1H NMR ($CDCl_3$) δ 1.12 (d, 3H, H-6c), 5.14 (d, 1H, H-1c), and 7.25-7.77 (m, 30H, 6Ph).

Anal. Calcd for $C_{60}H_{68}O_{15}$ (1029.2): C, 70.02; H, 6.66. Found: C, 69.95; H, 6.45.

***O*-(β-D-Galactopyranosyl)-(1→3)-*O*-[α-L-fucopyranosyl-(1→4)]-2-acetamido-2-deoxy-D-glucopyranose (17).** Compound **15** (50 mg, 0.05 mmol) in EtOH (1.3 mL) and AcOH (0.2 mL) was hydrogenolyzed in the presence of 10% Pd-C (50 mg) for a day at 45 °C, then the mixture was filtered, and concentrated. Chromatography (MeOH) of the residue on Sephadex LH-20 (80 g) gave **17** (21 mg, 78%) as an amorphous mass: $[\alpha]_D$ -32° (*c* 0.5, MeOH) [ref. 14, -45.1° (*c* 1, water)]; ^1H NMR (CD_3OD) δ 1.19 (d, 3H, $J_{5,6}$ = 6.6 Hz, H-6c), 1.99 (s, 3H, AcN), 4.39 (d, 0.19H, $J_{1,2}$ = 7.3 Hz, H-1b of β-anomer), 4.45 (d, 0.81H, $J_{1,2}$ = 7.3 Hz, H-1b of α-anomer), 4.64 (d, 0.19H, $J_{1,2}$ = 8.1 Hz, H-1a of β-anomer), 4.89 (q, 1H, H-5c), 4.99 (d, 1H, $J_{1,2}$ = 2.6 Hz, H-1c) and 5.04 (d, 0.81H, $J_{1,2}$ = 4.0 Hz, H-1a of α-anomer). FAB-MS (negative ion mode): *m/z* 528.2 $(M-H)^-$. Average mass of M-H was 528.4877 for $C_{20}H_{34}NO_{15}$.

Anal. Calcd for $C_{20}H_{35}NO_{15}$ (529.5): C, 45.37; H, 6.66; N, 2.65. Found: C, 45.11; H, 6.58; N, 2.61.

***O*-(β-D-Galactopyranosyl)-(1→3)-*O*-[α-L-fucopyranosyl-(1→4)]-β-D-glucopyranose (18).** Compound **16** (100 mg, 0.1 mmol) in EtOH (2.5 mL) was hydrogenolyzed in the presence of 20% $Pd(OH)_2$-C (100 mg) for a day at room temperature. A workup similar to that described for **17** gave **18** (41 mg, 86%) as an amorphous mass: $[\alpha]_D$ -39° (*c* 0.8, MeOH); ^1H NMR (CD_3OD) δ 1.18 (d, 3H, $J_{5,6}$ = 6.59 Hz, H-6c), 4.51 (d, 0.55H, $J_{1,2}$ = 7.9 Hz, H-1b of β-anomer), 4.70 (d, 0.45H, $J_{1,2}$ = 7.7 Hz, H-1b of α-anomer), 4.74 (d, 0.55H, $J_{1,2}$ = 7.7 Hz, H-1a of β-anomer), 4.89 (q, 1H, J = 6.6 Hz, H-5c), 5.02 (d, 1H, $J_{1,2}$ = 3.7 Hz, H-1c), and 5.11 (d, 0.45H, $J_{1,2}$ = 3.7 Hz, H-1a of α-anomer). FAB-MS (negative ion mode): *m/z* 487.2 $(M-H)^-$. Average mass of M-H was 487.4351 for $C_{18}H_{31}O_{15}$.

Anal. Calcd for $C_{18}H_{32}O_{15}$ (488.4): C, 44.26; H, 6.60. Found: C, 44.09; H, 6.31.

Benzyl *O*-(3,4-*O*-Isopropylidene-β-D-galactopyranosyl)-(1→3)-*O*-[2,3,4-tri-*O*-benzyl-α-L-fucopyranosyl-(1→4)]-2-acetamido-6-*O*-benzyl-2-deoxy-β-D-glucopyranoside (19). To a solution of **15** (140 mg, 0.14 mmol) in CH_3CN (1.5 mL) were added 2,2-dimethoxypropane (40 μL) and a catalytic amount of *p*-toluenesulfonic acid (*p*-TsOH). The mixture was stirred for 4 h at room temperature, then neutralized with Amberlite IR-410 (OH^-) and filtered. The resin was washed with MeOH and the combined filtrate and washings were concentrated. The residue was chromatographed on a column of silica gel (30 g) with 40:1 CH_2Cl_2-MeOH, to give **19** (98 mg, 67%) as an amorphous mass with the corresponding 4,6-*O*-isopropylidene derivative (26%). Compound **19** had $[\alpha]_D$ -62° (*c* 1.3, $CHCl_3$); ^1H NMR (CD_3OD) δ 1.12 (d, 3H, $J_{5,6}$ = 6.4 Hz, H-6c), 1.31,1.37 (2s, 6H, Me_2C), 1.91 (s, 3H, AcN), 4.36 (d, 1H, $J_{1,2}$ = 8.2 Hz, H-1b), 5.09 (d, 1H, $J_{1,2}$ = 3.5 Hz, H-1c), and 7.2-7.4 (m, 25H, 5Ph).

Anal. Calcd for $C_{58}H_{69}NO_{15}$ (1020.2): C, 68.29; H, 6.82; N, 1.37. Found: C, 68.14; H, 6.70; N, 1.25.

Benzyl *O*-(2,6-Di-*O*-benzyl-3,4-*O*-isopropylidene-β-D-galactopyranosyl)-(1→3)-*O*-[2,3,4-tri-*O*-benzyl-α-L-fucopyranosyl-(1→4)]-2-acetamido-6-*O*-benzyl-2-deoxy-β-D-glucopyranoside (20). To a solution of **19** (63.7 mg, 0.06 mmol) in dry DMF (1 mL), was added sodium hydride (6 mg, 0.15 mmol). After the reagent had dissolved, benzyl bromide was added, and the mixture was stirred for 1 h at 0 °C. The precipitate was filtered off and washed with MeOH. The combined filtrate and washings were concentrated to a syrup which was chromatographed on a column of silica gel (30 g) with 1:2 AcOEt-hexane to give **20** (52 mg, 70%) as an amorphous mass: $[\alpha]_D$ -35° (*c* 1.0, $CHCl_3$); ^1H NMR ($CDCl_3$) δ 1.04 (d, 3H, $J_{5,6}$ = 6.4 Hz, H-6c), 1.29, 1.33, (2s, 6H, Me_2C), 1.62 (s, 3H, AcN), 5.17 (d, 1H, $J_{1,2}$ = 3.7 Hz, H-1c), 6.24 (d, 1H, $J_{NH,2}$ = 7.9 Hz, NH), and 7.15-7.4 (m, 35H, 7Ph).

Anal. Calcd for $C_{72}H_{81}NO_{15}$ (1200.4): C, 72.04; H, 6.80; N, 1.17. Found: C, 71.96; H, 6.52; N, 1.14.

Benzyl *O*-(3,4-*O*-Isopropylidene-β-D-galactopyranosyl)-(1→3)-*O*-[2,3,4-tri-*O*-benzyl-α-L-fucopyranosyl-(1→4)]-2,6-di-*O*-benzyl-β-D-glucopyranoside (21). To a solution of **16** (100 mg, 0.1 mmol) in CH_3CN (1 mL) was added 2,2-dimethoxypropane (27 μL) and a catalytic amount of camphorsulfonic acid (CSA), and the mixture was stirred for 2 h at room temperature. A workup similar to that described for **19** gave **21** (65 mg, 63%) as an amorphous mass with the corresponding 4,6-*O*-isopropylidene derivative (32%). Compound **21** had $[\alpha]_D$ -48° (*c* 1.3, $CHCl_3$); ^1H NMR ($CDCl_3$) δ 1.11 (d, 3H, $J_{5,6}$ = 6.6 Hz, H-6c), 1.33,1.42 (2s, 6H, Me_2C), 3.94 (dd, 1H, H-2c), 5.14 (d, 1H, $J_{1,2}$ = 3.5 Hz, H-1c), and 7.24-7.40 (m, 30H, 6Ph).

Anal. Calcd for $C_{63}H_{72}O_{15}$ (1069.3): C, 70.77; H, 6.79. Found: C, 70.58; H, 6.73.

Benzyl *O*-(2,6-Di-*O*-benzyl-3,4-*O*-isopropylidene-β-D-galactopyranosyl)-(1→3)-*O*-[2,3,4-tri-*O*-benzyl-α-L-fucopyranosyl-(1→4)]-2,6-di-*O*-benzyl-β-D-glucopyranoside (22). To a solution of **21** (200 mg, 0.2 mmol) in dry DMF (2 mL), was added sodium hydride (22 mg, 0.6 mmol). After the reagent had dissolved, benzyl bromide (0.73 mL) was added, and the mixture was stirred for 1 h at room temperature. A workup similar to that described for **20** gave **22** (220 mg, 94%) as an amorphous mass: $[\alpha]_D$ -2° (*c* 1.2, $CHCl_3$); ^1H NMR ($CDCl_3$) δ 1.05 (d, 3H, $J_{5,6}$ = 6.6 Hz, H-6c), 1.30,1.35 (2s, 6H, Me_2C), 5.10 (d, 1H, $J_{1,2}$ = 3.5 Hz, H-1c), 7.19-7.35 (m, 40H, 8Ph).

Anal. Calcd for $C_{77}H_{84}O_{15}$ (1249.5): C, 74.02; H, 6.78. Found: C, 73.82; H, 6.77.

Benzyl *O*-(2,6-Di-*O*-benzyl-β-D-galactopyranosyl)-(1→3)-*O*-[2,3,4-tri-*O*-benzyl-α-L-fucopyranosyl-(1→4)]-2-acetamido-6-*O*-benzyl-2-deoxy-β-D-glucopyranoside (23). A solution of **20** (52 mg, 0.04 mmol) in 80% aq AcOH (1 mL) was heated for 3 h at 45 °C, and concentrated to give **23** (50 mg, quantitative) as an amorphous mass: $[\alpha]_D$ -41° (*c* 1.1, $CHCl_3$); ^1H NMR ($CDCl_3$) δ 1.10 (d, 3H, $J_{5,6}$ = 6.41 Hz, H-6c), 1.62 (s, 3H, AcN), 5.21 (d, 1H, $J_{1,2}$ = 3.8 Hz, H-1c), and 7.21-7.34 (m, 35H, 7Ph).

Anal. Calcd for $C_{69}H_{77}NO_{15}$ (1160.4): C, 71.42; H, 6.69; N, 1.21. Found: C, 71.25; H, 6.49; N, 1.07.

Benzyl *O*-(2,6-Di-*O*-benzyl-β-D-galactopyranosyl)-(1→3)-*O*-[2,3,4-tri-*O*-benzyl-α-L-fucopyranosyl-(1→4)]-2,6-di-*O*-benzyl-β-D-glucopyranoside (24). To a solution of **22** (447 mg, 0.36 mmol) in MeOH (15 mL) was added catalytic amount of *p*-TsOH, and the mixture was stirred for 3 h at 45 °C. A workup similar to that described for **19** to give **24** (369 mg, 85%) as an amorphous mass: $[\alpha]_D$ -43° (*c* 0.9, $CHCl_3$); ^1H NMR ($CDCl_3$) δ 1.20 (d, 3H, $J_{5,6}$ = 6.59 Hz, H-6c), 4.43 (d, 1H, $J_{1,2}$ = 7.7 Hz, H-1a), 5.04 (d, 1H, $J_{1,2}$ = 7.3 Hz, H-1b), 5.11 (d, 1H, $J_{1,2}$ = 3.5 Hz, H-1c), and 7.17-7.35 (m, 40H, 8Ph).

Anal. Calcd for $C_{74}H_{80}O_{15}$ (1209.4): C, 73.49; H, 6.67. Found: C,73.25; H, 6.62.

Benzyl *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*-benzyl-β-D-galactopyranosyl)-(1→3)-*O*-[2,3,4-tri-*O*-benzyl-α-L-fucopyranosyl-(1→4)]-2-acetamido-6-*O*-benzyl-2-deoxy-β-D-glucopyranoside (26). To a solution of **23** (104 mg, 0.09 mmol) and **25** (110 mg, 0.18 mmol) in dry CH_3CN (2 mL) was added MS-4Å (0.2 g), and the mixture was stirred for 8 h at room temperature, then it was cooled to -35 °C. NIS (84 mg, 0.38 mmol) and TfOH (6 μL, 0.06 mmol) were added to the cooled mixture, and it was stirred for 3 h at -35 °C and then neutralized with Et_3N. A workup similar to that described for **7** gave **26** (76 mg, 52%) as an amorphous mass: $[\alpha]_D$ -53° (*c* 0.72, $CHCl_3$); ^1H NMR ($CDCl_3$) δ 1.12 (d, 3H, $J_{5,6}$ = 6.4 Hz, H-6c), 1.65, 1.88, 2.00, 2.01, 2.02, 2.10 (6s, 18H, 4AcO, 2AcN), 2.54 (dd, 1H, J_{gem} = 13, $J_{3eq,4}$ = 4.4 Hz, H-3d*eq*), 3.76 (s, 3H, CO_2Me), 5.18 (d, 1H, $J_{1,2}$ = 3.5 Hz, H-1c), 5.34 (dd, 1H, $J_{6,7}$ = 2.4, $J_{7,8}$ = 8.3 Hz, H-7d), 5.42 (m, 1H, H-8d), 5.17, 6.12 (2d, 2H, NH), and 7.23-7.37 (m, 35H, 7Ph).

Anal. Calcd for $C_{89}H_{104}N_2O_{27}$ (1633.8): C, 65.43; H, 6.42; N, 1.71. Found: C, 65.42; H, 6.41; N, 1.56.

A sample of **26** (10 mg) was acetylated with acetic anhydride (0.2 mL) and pyridine (0.2 mL) to give the corresponding acetate as an amorphous mass, which showed a narrow doublet ($J_{3,4}$ = 3.0 Hz, H-4b) at δ 5.03 in the ^1H NMR ($CDCl_3$) spectrum.

Benzyl *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*-benzyl-β-D-galactopyranosyl)-(1 → 3)-*O*-[2,3,4-tri-*O*-benzyl-α-L-fucopyranosyl-(1→4)]-2,6-di-*O*-benzyl-β-D-glucopyranoside (27). To a solution of **24** (100 mg, 0.08 mmol) and **25** (104 mg, 0.18 mmol) in dry CH_3CN (2 mL) was added MS-4Å (0.2 g), and the mixture was stirred for 8 h at room temperature, then it was cooled to -35 °C. NIS (80 mg, 0.36 mmol) and TfOH (6 μL, 0.14 mmol) were added to the cooled mixture, and the mixture was stirred for 4 h at -35 °C and then neutralized with Et_3N. A workup similar to that described for **7** gave **27** (82 mg, 59%) as an amorphous mass: $[\alpha]_D$ -32° (*c* 1.6, $CHCl_3$); ^1H NMR ($CDCl_3$) δ 1.21 (d, 3H, $J_{5,6}$ = 6.4 Hz, H-6d), 1.90, 1.92, 1.96, 2.00, 2.10 (5s, 15H, 4AcO, AcN), 2.49 (dd, 1H, J_{gem} = 13, $J_{3eq,4}$ = 4.5 Hz, H-3d*eq*), 3.82 (s, 3H, CO_2Me), 4.46 (d, 1H, $J_{1,2}$ = 8.3 Hz, H-1a), 5.04 (d, 1H, $J_{1,2}$ = 7.9 Hz, H-1b), 5.08 (d, 1H, $J_{1,2}$ = 2.4 Hz, H-1c), and 7.15-7.40 (m, 40H, 8Ph).

Anal. Calcd for $C_{94}H_{107}NO_{27}$ (1682.9): C, 67.09; H, 6.41; N, 0.83. Found: C, 66.92; H, 6.24; N, 0.69.

Benzyl *O* - (5 - Acetamido - 3,5 - dideoxy - D - *glycero* - α - D - *galacto* - 2 - nonulopyranosylonic acid) - (2→3) - *O* - (2,6 -di -*O*-benzyl-β-D-galacto-pyranosyl)-(1 → 3)-*O*-[2,3,4-tri-*O*-benzyl-α-L-fucopyranosyl-(1 → 4)]-2-acetamido-6-*O*-benzyl-2-deoxy-β-D-glucopyranoside (28). To a solution of **26** (37 mg, 0.02 mmol) in MeOH (2 mL) was added catalytic amount of sodium methoxide, and the mixture was stirred for a day at room temperature. 0.2M-KOH (0.5 mL) was added to the mixture and stirring was continued for 6 h at room temperature. The solution was neutralized with Amberlite IR-120 (H^+) resin and filtered. The resin was washed with MeOH and the combined filtrate and washings were concentrated. The residue was chromatographed on a column of silica gel (30 g)

with 20:1 CH_2Cl_2-MeOH, to give **28** (30 mg, 91%) as an amorphous mass: $[\alpha]_D$ -61° (*c* 0.4, $CHCl_3$); ^1H NMR ($CDCl_3$) δ 1.01 (d, 3H, $J_{5,6}$ = 6.4 Hz, H-6c), 1.86, 1.98 (2s, 6H, 2AcN), 2.80 (dd, 1H, J_{gem} = 13, $J_{3eq,4}$ = 4 Hz, H-3d*eq*), 5.01 (d, 1H, $J_{1,2}$ = 3.8 Hz, H-1c), and 7.10-7.29 (m, 35H, 7Ph).

Anal. Calcd for $C_{80}H_{94}N_2O_{23}$ (1451.6): C, 66.19; H, 6.53; N, 1.93. Found: C, 65.90 H, 6.41; N, 1.74.

Benzyl *O*-(5-Acetamido-3,5-dideoxy-D-*glycero*-α-D-*galacto*-2-nonulopyranosylonic acid)-(2→3)-*O*-(2,6-di-*O*-benzyl-β-D-galactopyranosyl)-(1→3)-*O*-[2,3,4-tri-*O*-benzyl-α-L-fucopyranosyl-(1→4)]-2,6-di-*O*-benzyl-β-D-glucopyranoside (29). To a solution of **27** (86 mg, 0.05 mmol) in MeOH (2 mL) was added a catalytic amount of sodium methoxide, and the mixture was stirred for a day at room temperature. 0.2M KOH (0.5 mL) was added to the mixture, and the stirring was continued for a day at room temperature. The solution was neutralized with Amberlite IR-120 (H^+) resin and filtered. A workup similar to that described for **28** gave **29** (60 mg, 78%) as an amorphous mass: $[\alpha]_D$ -31° (*c* 1.20, $CHCl_3$); ^1H NMR (CD_3OD) δ 1.23 (d, 3H, $J_{5,6}$ = 6.4 Hz, H-6c), 1.94 (t, 1H, $J_{gem} = J_{3ax,4}$ =13 Hz, H-3d*ax*), 2.04 (s, 3H, AcN), 2.92 (dd, 1H, J_{gem} = 13, $J_{3eq,4}$ =4.5 Hz, H-3d*eq*), 4.35 (d, 1H, $J_{1,2}$ = 7.9 Hz, H-1a), 4.96 (d, 1H, $J_{1,2}$ = 7.9 Hz, H-1b), 5.02 (d, 1H, $J_{1,2}$ = 3.5 Hz, H-1c), and 7.15-7.48 (m, 40H, 8Ph).

Anal. Calcd for $C_{85}H_{97}NO_{23}$ (1500.7): C, 68.03; H, 6.52; N, 0.93. Found: C, 67.78; H, 6.39; N, 0.92.

***O*-(5-Acetamido-3,5-dideoxy-D-*glycero*-α-D-*galacto*-2-nonulopyranosylonic acid)-(2→3)-*O*-(β-D-galactopyranosyl)-(1→3)-*O*-[α-L-fucopyranosyl-(1→4)]-2-acetamido-2-deoxy-D-glucopyranose (30).** Compound **28** (37 mg, 0.03 mmol) in THF (1 mL) and H_2O (1 mL) was hydrogenolyzed in the presence of 20% $Pd(OH)_2$-C (10 mg) for a day at room temperature, then filtered, and concentrated. Chromatography (MeOH) of the residue on Sephadex LH-20 (80 g) gave **30** (23 mg, quantitative) as an amorphous mass: $[\alpha]_D$ -33° (*c* 0.8, CH_3OH); ^1H NMR (CD_3OD) δ 1.18 (d, 3H, $J_{5,6}$ = 6.4 Hz, H-6c), 1.98, 2.03 (2s, 6H, 2AcN), 2.82 (dd, 1H, J_{gem} = 12, $J_{3eq,4}$ = 4.4 Hz, H-3d*eq*), 4.39 (d, 0.27H, $J_{1,2}$ =7.5 Hz,

H-1b of β-anomer), 4.45 (d, 0.73H, $J_{1,2}$ = 7.2 Hz, H-1b of α-anomer), 4.63 (d, 0.27H, $J_{1,2}$ = 7.9 Hz, H-1a of β-anomer), 4.91 (q, 1H, H-5c), 4.99 (d, 0.73H, $J_{1,2}$ = 3.1 Hz, H-1c of α-anomer) and 5.03 (d, 0.73H, $J_{1,2}$ = 4 Hz, H-1a of α-anomer). FAB-MS (negative ion mode): *m/z* 819.3 $(M-H)^-$. Average mass of M-H was 819.7455 for $C_{31}H_{51}N_2O_{23}$.

Anal. Calcd for $C_{31}H_{52}N_2O_{23}$ (820.8): C, 45.37; H, 6.39; N, 3.41. Found: C, 45.12; H, 6.15; N, 3.22.

***O*-(5-Acetamido-3,5-dideoxy-D-*glycero*-α-D-*galacto*-2-nonulopyranosylonic acid)-(2→3)-*O*-(β-D-galactopyranosyl)-(1→3)-*O*-[α-L-fucopyranosyl-(1→4)]-β-D-glucopyranose (31).** Compound **29** (58 mg, 0.04 mmol) in THF (1 mL) and H_2O (1 mL) was hydrogenolyzed in the presence of 20% $Pd(OH)_2$-C (10 mg) for a day at room temperature, and the mixture was filtered. A workup similar to that described for **30** gave **31** (28 mg, 93%) as an amorphous mass: $[\alpha]_D$ -17° (*c* 0.6, MeOH); ^1H NMR (CD_3OD) δ 1.16 (d, 3H, $J_{5,6}$ = 6.2 Hz, H-6c), 2.00 (s, 3H, AcN), 2.85 (dd, 1H, Jgem = 13, $J_{3eq,4}$ = 4 Hz, H-3d*eq*), 4.50 (d, 0.56H, $J_{1,2}$ = 7.7 Hz, H-1b of β-anomer), 4.73 (d, 0.44H, $J_{1,2}$ = 7.7 Hz, H-1b of α-anomer), 4.77 (d, 0.56H, $J_{1,2}$ = 7.7 Hz, H-1a of β-anomer), 5.01 (~t, 1H, $J_{1,2}$ = 3~4 Hz, H-1c of two anomers are overlapping), and 5.11 (d, 0.44H, $J_{1,2}$ = 3.5 Hz, H-1a of α-anomer). FAB-MS (negative ion mode): *m/z* 778.3 $(M-H)^-$. Average mass of M-H was 778.6930 for $C_{29}H_{48}NO_{23}$.

Anal. Calcd for $C_{29}H_{49}NO_{23}$ (779.7): C, 44.67; H, 6.33; N, 1.80. Found: C, 44.64; H, 6.30; N, 1.50.

Benzyl *O*-(6-*O*-Benzoyl-3,4-*O*-isopropylidene-β-D-galactopyranosyl)-(1→3)-*O*-[2,3,4-tri-*O*-benzyl-α-L-fucopyranosyl-(1→4)]-2-acetamido-6-*O*-benzyl-2-deoxy-β-D-glucopyranoside (32). To a stirred solution of **19** (140 mg, 0.14 mmol) in CH_2Cl_2 (1.4 mL) and pyridine (0.1 mL) was added benzoyl chloride (0.21 mmol) in CH_2Cl_2 (0.5 mL) dropwise at -50 °C, and the stirring was continued for 1 h at -50 °C. A workup similar to that described for **5** and column chromatography (100:1 CH_2Cl_2-MeOH) on silica gel gave **32** (80 mg, 52%) together with **33** (8%) and **34** (38%). Compound **32** had $[\alpha]_D$ -53° (*c* 1.7, $CHCl_3$);

^{1}H NMR ($CDCl_3$) δ 1.10 (d, 3H, $J_{5,6}$ = 6.2 Hz, H-6c), 1.35, 1.52, 1.53 (3S, 9H, Me_2C and AcN), 5.14 (d, 1H, $J_{1,2}$ = 3.7 Hz, H-1c), 6.68 (d, 1H, $J_{NH,2}$ = 8.3 Hz, NH), 7.20-7.45 (m, 25H of 5Bn and 3H of Bz), and 8.00 (d, 2H, J = 7.33, *o*-position of Bz).

Anal. Calcd for $C_{65}H_{73}NO_{16}$ (1124.3): C, 69.44; H, 6.54; N, 1.25. Found: C, 69.35; H, 6.26; N, 1.11.

Benzyl *O*-(6-*O*-Benzoyl-β-D-galactopyranosyl)-(1→3)-*O*-[2,3,4-tri-*O*-benzyl-α-L-fucopyranosyl-(1→4)]-2-acetamido-6-*O*-benzyl-2-deoxy-β-D-glucopyranoside (35). A mixture of **32** (96.5 mg, 0.088 mmol) and 80% aq AcOH (1 mL) was stirred for a day at 45 °C. The solvent was removed by evaporation (with toluene) to give **35** (91.3 mg, quantitative) as an amorphous mass: $[\alpha]_D$ -55° (*c* 1.6, $CHCl_3$); ^{1}H NMR ($CDCl_3$) δ 1.12 (d, 3H, $J_{5,6}$ = 6.2 Hz, H-6c), 1.58 (S, 3H, AcN), 5.12 (d, 1H, $J_{1,2}$ = 3.7 Hz, H-1c), 6.75 (d, 1H, $J_{NH,2}$ = 8.3 Hz, NH), 7.20-7.45 (m, 25H of 5Bn and 3H of Bz), and 7.99 (d, 2H, J = 7.2 Hz, *o*-position of Bz).

Anal. Calcd for $C_{62}H_{69}NO_{16}$ (1084.2): C, 68.68; H, 6.41; N, 1.29. Found: C, 68.56; H, 6.30; N, 1.10.

Benzyl *O*-(Methyl 5-Acetamido-4,7,8,9-tetra-*O*-acetyl-3,5-dideoxy-D-*glycero*-α-D-*galacto*-2-nonulopyranosylonate)-(2→3)-*O*-(6-*O*-benzoyl-β-D-galactopyranosyl)-(1 → 3)-*O*-[2,3,4-tri-*O*-benzyl-α-L-fucopyranosyl-(1→4)]-2-acetamido-6-*O*-benzyl-2-deoxy-β-D-glucopyranoside (36). To a solution of **35** (80.6 mg, 0.08 mmol) and **25** (89 mg, 0.15 mmol) in dry CH_3CN (1 mL) was added MS-4Å (0.1 g), and the mixture was stirred for 8 h at room temperature, then it was cooled to -35 °C. NIS (69 mg, 0.3 mmol) and TfOH (5 μL, 0.06 mmol) were added to the cooled mixture, and it was stirred for 3 h at -35 °C and then neutralized with Et_3N. A workup similar to that described for **7** and column chromatography (40:1 CH_2Cl_2-MeOH) on silica gel to give **36** (80 mg, 69%) as an amorphous mass: $[\alpha]_D$ -41° (*c* 0.9, $CHCl_3$); ^{1}H NMR ($CDCl_3$) δ 1.18 (d, 3H, $J_{5,6}$ = 6.5 Hz, H-6c), 1.50, 1.88, 2.00 (×2), 2.09, 2.14 (6s, 18H, 2AcN and 4AcO), 1.95 (t, 1H, J = 13 Hz, H-3d*ax*), 2.57 (dd, 1H, J_{gem} = 13, $J_{3eq,4}$ = 4.5 Hz, H-3d*eq*), 3.77 (s, 3H, CO_2Me), and 7.05-7.50 and 8.06 (m+d, 30H, 6Ph).

Anal. Calcd for $C_{82}H_{96}N_2O_{28}$ (1557.7): C, 63.23; H, 6.21; N, 1.80. Found: C, 63.06; H, 6.01; N, 1.67.

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