Synthesis of Blood-Group Substances. 6. Synthesis of O-α-L-Fucopyranosyl-(1→2)-O-β-D-galactopyranosyl-(1→4)-O-[α-L-fucopyranosyl-(1→3)]-2-acetamido-2-deoxy-α-D-glucopyranose, the Postulated Lewis d Antigenic Determinant[1]

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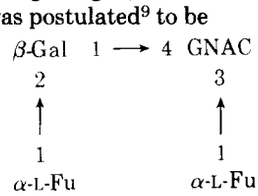
The chemical synthesis of the title tetrasaccharide is reported. It involves condensation of benzyl 2-acetamido-3-O-allyl-6-O-benzyl-2-deoxy-α-D-glucopyranoside (**8**) with 3,4,6-tri-O-benzyl-1,2-O-(*tert*-butoxyethylidene)-α-D-galactopyranose (**11**). After O-deacetylation of **12**, the obtained compound **13** was glycosylated by 2,3,4-tri-O-benzyl-α-L-fucopyranosyl bromide (**22**) using the bromide ion catalyzed reaction. The allyl ether of **23** was cleaved and the resulting trisaccharide **24** condensed again with **22**. The title tetrasaccharide was obtained in crystalline form after catalytic hydrogenolysis of **27**.

Practical syntheses of complex oligosaccharides containing a variety of linkages has represented one of greatest challenges in carbohydrate chemistry. The fascinating oligosaccharidic structures of blood-group substances, as proposed by Kabat,[2] present an attractive target to the synthetic chemists. With the success achieved by Lemieux and Driguez[3] in the synthesis of the terminal trisaccharide units of the human B and Lewis a blood-group antigenic determinants, the onslaught is now launched and other groups[4,5] have taken up the challenge. Our interest in type II blood-group determinants arose after we described[6] a practical synthesis of *N*-acetyllactosamine. The H specific trisaccharide (type II) has recently been obtained by us[5] and, using a similar strategy, we report here the synthesis of a more complex tetrasaccharide. Potapov[7] has discovered an antibody which reacts only with Lewis (a^-b^-) red cells of secretors. The structure of the corresponding antigen, named Lewis d by him and Y by Hakomori,[8] was postulated[9] to be

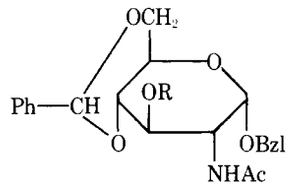


An oligosaccharide containing this complex structure as a terminal nonreducing group has been isolated from blood-group glycoproteins.[10] Despite its similarity to the Lewis b active tetrasaccharide, it was inactive as a Lewis b inhibitor.[11] This tetrasaccharide has been incorporated into the composite structure proposed for the carbohydrate chains in a HLeb substance.[12] As far as we are aware, it has not yet been possible to identify and isolate the title tetrasaccharide and therefore the synthesis of this compound is of interest for immunological studies.[20]

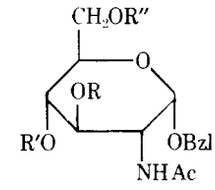
Results and Discussion

We have shown[6,13] that benzyl 2-acetamido-3,6-di-O-benzyl-2-deoxy-α-D-glucopyranoside is an attractive aglycon for the high-yield synthesis of various disaccharides of the type (α or β) × 1→4 *N*-acetylglucosamine.

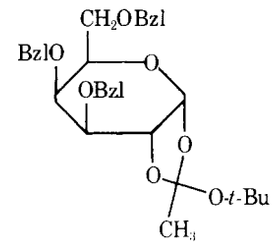
A key compound for the synthesis of the title tetrasaccharide (**28**) was benzyl 2-acetamido-3-O-allyl-6-O-benzyl-2-deoxy-α-D-glucopyranoside (**8**). Benzyl 2-acetamido-4,6-O-benzylidene-2-deoxy-α-D-glucopyranoside[14] was quantitatively converted into its 3-O-allyl derivative (**1**) and, after hydrolysis (60% acetic acid), to benzyl 2-acetamido-3-O-allyl-2-deoxy-α-D-glucopyranoside (**2**). When **2** was treated with *N*-benzoylimidazole in dioxane under reflux, a selective benzoylation took place and benzyl 2-acetamido-3-O-allyl-6-O-benzoyl-2-deoxy-α-D-glucopyranoside (**4**) was obtained in 89% yield. The expected compound **8** was then obtained through a sequence already used[15] for the synthesis of benzyl 2-acetamido-3,6-di-O-benzyl-2-deoxy-α-D-glucopyranoside: after temporary protection of the C-4 hydroxyl group with tetrahydropyranyl ether, the primary position was easily benzylated; acid hydrolysis finally gave benzyl 2-acetamido-3-O-allyl-6-O-benzyl-2-deoxy-α-D-glucopyranoside (**8**), whose ^{1}H NMR spectrum is in full agreement with the structure. The total yield from **2** to **8** was ca. 70%, each intermediate being obtained in pure form and excellent yield after one crystallization. Alternatively, **8** may be obtained after selective benzylation of benzyl 2-acetamido-3-O-allyl-2-deoxy-α-D-glucopyranoside (**2**). It was obtained in 37% yield after chromatographic separation from benzyl 2-acetamido-3-O-allyl-4,6-di-O-benzyl-2-deoxy-α-D-glucopyranoside (**10**).



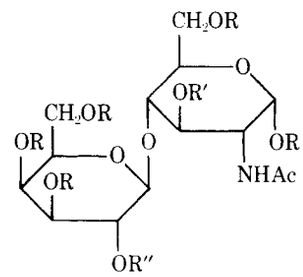
1, R = A



2, R = A; R′ = R″ = H
3, R = A; R′ = R″ = Ac
4, R = A; R′ = H; R″ = Bz
5, R = A; R′ = THP; R″ = Bz
6, R = A; R′ = THP; R″ = OH
7, R = A; R′ = THP; R″ = Bzl
8, R = A; R′ = H; R″ = Bzl
9, R = A; R′ = Ac; R″ = Bzl
10, R = A; R′ = R″ = Bzl

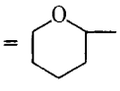


11

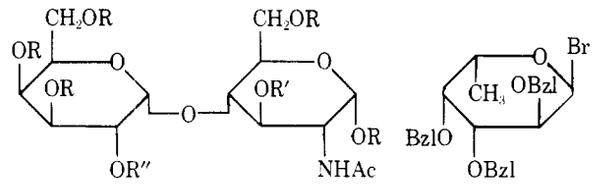


12, R = Bzl; R′ = A; R″ = Ac
13, R = Bzl; R′ = A; R″ = H
14, R = Bzl; R′ = R″ = H
15, R = Bzl; R′ = R″ = Ac
16, R = R′ = R″ = H

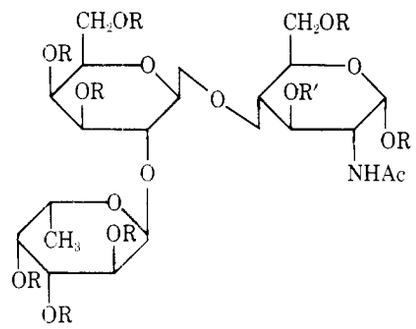
A = $CH_2CH{=}CH_2$
Bz = C_6H_5CO
Bzl = $C_6H_5CH_2$
THP =



Condensation of aglycon 8 with the ortho ester 11[5] (reflux in chlorobenzene in the presence of 2,6-dimethylpyridinium perchlorate[16]) gave a mixture of the two disaccharides 12 and 18. After a chromatographic separation of the starting material 8 from the disaccharidic fractions, 12 was obtained directly by crystallization in 38% yield. The mother liquors were O-deacetylated (sodium methoxide in methanol) to give the α anomer 17 in crystalline form. The formation of a 1,2-cis glycoside, with preservation of the acetate on C-2, during a glycosylation with a benzylated ortho ester has already been observed and discussed during the synthesis of a closely related disaccharide.[5] After O-deacetylation, 12 was converted into crystalline benzyl 2-acetamido-3-*O*-allyl-6-*O*-benzyl-4-*O*-(3,4,6-tri-*O*-benzyl-β-D-galactopyranosyl)-2-deoxy-α-D-glucopyranoside (13). This derivative of lactosamine is properly protected to reach our objective, the two fucopyranosyl residues being introduced successively. Its structure was confirmed by conversion into known *N*-acetyllactosamine[6] after O-deallylation (potassium *tert*-butoxide in dimethyl sulfoxide) and catalytic hydrogenolysis. The structure of 18 was similarly confirmed by transformation into known[5] reducing disaccharide 21.

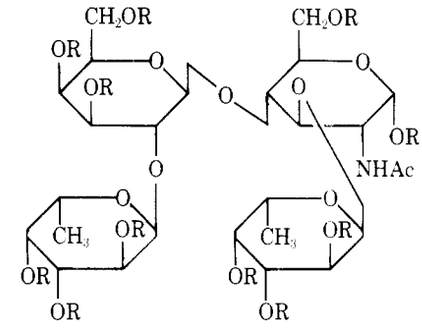


17, R = Bzl; R′ = A; R″ = H
18, R = Bzl; R′ = A; R″ = Ac
19, R = Bzl; R′ = R″ = H
20, R = Bzl; R′ = R″ = Ac
21, R = R′ = R″ = H



23, R = Bzl; R′ = A
24, R = Bzl; R′ = H
25, R = Bzl; R′ = Ac
26, R = R′ = H (α,β)

The bromide ion catalyzed reaction[17] has proven to be an excellent way to obtain an α-L-fucoside.[3,5,13,17,19] Condensation of aglycon 13, with 2,3,4-tri-*O*-benzyl-α-L-fucopyranosyl bromide[18] (22), in 1,2-dichloroethane–*N*,*N*-dimethylformamide in the presence of tetraethylammonium bromide, diisopropylethylamine, and molecular sieves 4 Å gave the protected trisaccharide 23 in excellent yield (91%). The configuration of the newly established glycosidic linkage was demonstrated by ^{1}H NMR. The doublet at δ 5.68 (J = 3.5 Hz) was assigned to the anomeric proton of the L-fucopyranosyl residue, in a cis equatorial–axial relationship to the vicinal proton. After acid hydrolysis, trisaccharide 23 was selectively cleaved to disaccharide 13 and 2,3,4-tri-*O*-benzyl-α-L-fucopyranose.[18] After O-deallylation, 23 was converted into an amorphous alcohol 24. The structure of 24 was established by ^{1}H NMR spectroscopy and by catalytic hydrogenolysis to give the known[5] trisaccharide 26. A new condensation of 24 with 2,3,4-tri-*O*-benzyl-α-L-fucopyranosyl bromide using the



27, R = Bzl
28, R = H

bromide ion catalyzed reaction[17] gave the fully benzylated tetrasaccharide 27 in good yield (80%). The doublet at δ 5.23 (J = 3 Hz) was assigned to the anomeric proton of the newly established glycosidic linkage, showing a cis equatorial–axial relationship to the vicinal proton. Alternatively the tetrasaccharide 27 was obtained (74%) after condensation of the diol 14 with 2,3,4-tri-*O*-benzyl-α-L-fucopyranosyl bromide. A by-product of this reaction was the trisaccharide 24. After catalytic hydrogenolysis in glacial acetic acid and purification of the residue by chromatography on a charcoal–Celite column, the title tetrasaccharide was obtained in crystalline form. ^{1}H NMR spectroscopy and mutarotation strongly suggest the α configuration at the reducing center.

Experimental Section

General Methods. Melting points were determined with capillary tubes on a Büchi apparatus and were not corrected. Optical rotations were measured on a Perkin-Elmer Model 141 polarimeter. IR spectra were recorded with a Jouan-Jasco IRA-1 infrared spectrometer. Nuclear magnetic resonance spectra were obtained in chloroform-*d* solution (Me_4Si as internal standard) or deuterium oxide (Me_4Si as external standard) with a Perkin-Elmer R-32 spectrometer. The indexes respectively refer to: primary, galactose; secondary, fucose bound to galactose; tertiary, fucose bound to glucosamine. Gas–liquid chromatography (GLC) of the per-*O*-(trimethylsilyl) derivatives was performed with a Girdel 3000 apparatus, provided with a flame ionization detector, using a 3.40-m Pyrex column (4% OV-17 on Gas-Chrom Q, 80–100 mesh), programmed for a rise of 10 °C/min from 150 to 300 °C; t_R is given relative to that of hexakis-*O*-(trimethylsilyl)-*myo*-inositol. Purity of products was determined by thin layer chromatography (TLC) on silica gel 60 F 254 (E. Merck). Components were located by spraying with 50% sulfuric acid in ethanol and heating. Column chromatography was performed on silica gel Merck 60, powder 0.063–0.200 mm, which was used without pretreatment. Elemental analyses were obtained from the Service Central de Microanalyse du Centre National de la Recherche Scientifique (Thiais, France).

Benzyl 2-Acetamido-3-*O*-allyl-4,6-*O*-benzylidene-2-deoxy-α-D-glucopyranoside (1). A solution of benzyl 2-acetamido-4,6-*O*-benzylidene-2-deoxy-α-D-glucopyranoside (15 g, 37.5 mmol) in *N*,*N*-dimethylformamide (250 ml) was stirred at room temperature for 20 min with barium oxide (25 g), barium hydroxide octahydrate (7.5 g), and allyl bromide (6.25 ml). The resulting crystalline mass was dissolved by heating and barium oxide was precipitated by addition of pyridine (200 ml). After filtration, the organic phase was evaporated, the last traces of barium oxide being eliminated after dissolution of the residue in the minimum amount of pyridine and filtration. After evaporation of the organic phase, the residue was crystallized from methanol–pyridine–water, giving 15.85 g (95%) of benzyl 2-acetamido-3-*O*-allyl-4,6-*O*-benzylidene-2-deoxy-α-D-glucopyranoside (1): mp 255–256 °C; $[\alpha]^{20}D$ + 125° (*c* 1.0, C_5H_5N); ν_{max} (Nujol) 3340 (NH), 1660, 1570 cm^{-1} (CONH).

Anal. Calcd for $C_{25}H_{29}NO_6$ (439.49): C, 68.62; H, 6.65; N, 3.19. Found: C, 68.74; H, 6.66; N, 3.13.

Benzyl 2-Acetamido-3-*O*-allyl-2-deoxy-α-D-glucopyranoside (2). A suspension of 1 (10 g, 22.7 mmol) in 60% acetic acid (600 ml) was heated at 100 °C for 1 h, then cooled. Following evaporation of the solution the residue was coevaporated several times with water then with toluene and crystallized from 2-propanol, giving 7.36 g (91%) of 2: mp 177–178 °C; $[\alpha]^{20}D$ + 164° (*c* 1.0, MeOH); ν_{max} (Nujol) 3420 (OH), 3340 (NH), 1645, 1560 cm^{-1} (CONH).

Anal. Calcd for $C_{18}H_{25}NO_6$ (351.39): C, 61.52; M, 7.17; N, 3.99. Found: C, 61.67; H, 7.16; N, 3.57.

Benzyl 2-Acetamido-4,6-di-*O*-acetyl-3-*O*-allyl-2-deoxy-α-D-glucopyranoside (3). A solution of **2** (250 mg, 0.71 mmol) in a mixture of pyridine (5 ml) and acetic anhydride (1 ml) was stirred for 3 h at room temperature. Following evaporation of the solution the residue was coevaporated with toluene and crystallized twice from 2-propanol, giving 285 mg (92%) of **3**: mp 159–160 °C; $[\alpha]^{20}D$ +120° (*c* 1.0, MeOH); ν_{max} (Nujol) 3360 (NH), 1750 (OAc), 1660, 1560 cm^{-1} (CONH); ^1H NMR ($CDCl_3$) δ 1.90 (s, 3, NHAc), 2.04, 2.06 (2 s, 6, OAc), 7.30 (s, 5, aromatic).

Anal. Calcd for $C_{22}H_{29}NO_8$ (435.46): C, 60.68; H, 6.71; N, 3.22. Found: C, 60.75; H, 6.70; N, 3.07.

Benzyl 2-Acetamido-3-*O*-allyl-6-*O*-benzoyl-2-deoxy-α-D-glucopyranoside (4). A solution of benzoyl chloride (4.8 g, 34.2 mmol) in dichloromethane (50 ml) was added to a solution of imidazole (4.66 g, 68.53 mmol) in dichloromethane (110 ml). After 15 min at 5 °C, imidazole hydrochloride was removed by filtration. The resulting filtrate was added to a solution of **2** (10 g, 28.5 mmol) in dioxane (200 ml). The mixture was heated under reflux for 36 h and then evaporated to dryness. The residue was dissolved in chloroform (500 ml) and the organic phase washed successively with dilute aqueous sodium bicarbonate and water, dried (Na_2SO_4), and evaporated. The residue was crystallized from ethyl acetate, giving 11.37 g (89%) of benzyl 2-acetamido-3-*O*-allyl-6-*O*-benzoyl-2-deoxy-α-D-glucopyranoside (**4**): mp 161–162 °C; $[\alpha]^{20}D$ +91° (*c* 1.0, $CHCl_3$): ν_{max} (Nujol) 3540 (OH), 3350 (NH), 1720 (OBz), 1645, 1560 (CONH), 708 cm^{-1} (aromatic).

Anal. Calcd for $C_{25}H_{29}NO_7$ (455.49): C, 65.92; H, 6.42; N, 3.08. Found: C, 66.01; H, 6.42; N, 3.22.

This compound was fully resistant to tritylation (trityl chloride in pyridine for 3 days at 100 °C).

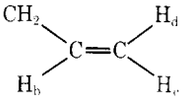
Benzyl 2-Acetamido-3-*O*-allyl-6-*O*-benzoyl-2-deoxy-4-*O*-tetrahydropyranyl-α-D-glucopyranoside (5). A solution of **4** (3 g, 6.59 mmol), 3,4-dihydro-2*H*-pyran (1.5 ml, 16.5 mmol), and *p*-toluenesulfonic acid monohydrate (45 mg) in dioxane (25 ml) was stirred at room temperature for 1 h, then diluted with chloroform (150 ml). The reaction mixture was washed successively with dilute aqueous sodium bicarbonate and water, dried (Na_2SO_4), and evaporated. The residue was crystallized from ether–hexane, giving 3.35 g (93%) of benzyl 2-acetamido-3-*O*-allyl-6-*O*-benzoyl-2-deoxy-4-*O*-tetrahydropyranyl-α-D-glucopyranoside (**5**): mp 119–120 °C; $[\alpha]^{20}D$ +91° (*c* 1.0, $CHCl_3$) (mixture of diastereoisomers); ν_{max} (Nujol) 3350 (NH), 1730 (OBz), 1650, 1550 (CONH), 705 cm^{-1} (aromatic).

Anal. Calcd for $C_{30}H_{37}NO_8$ (539.60): C, 66.71; H, 6.91; N, 2.60. Found: C, 66.83; H, 6.90; N, 2.73.

Benzyl 2-Acetamido-3-*O*-allyl-6-*O*-benzyl-2-deoxy-4-*O*-tetrahydropyranyl-α-D-glucopyranoside (7). A 2 M methanolic solution of sodium methoxide (2 ml) was added to a solution of **5** (3.55 g, 6.21 mmol) in methanol (20 ml) and stirred at room temperature for 1 h, then diluted with chloroform (500 ml). The reaction mixture was washed with water, dried (Na_2SO_4), and evaporated. The residue was crystallized from ether, giving 2.65 g (95%) of benzyl 2-acetamido-3-*O*-allyl-2-deoxy-4-*O*-tetrahydropyranyl-α-D-glucopyranoside (**6**) (mixture of diastereoisomers): ν_{max} (Nujol) 3560 (OH), 3350 (NH), 1650, 1555 (CONH), 720 cm^{-1} (aromatic). A solution of **6** (2.5 g, 5.74 mmol) in *N,N*-dimethylformamide (40 ml) was stirred for 5 h at room temperature with barium oxide (4 g), barium hydroxide octahydrate (1.3 g), and benzyl bromide (1.5 ml, 11.5 mmol). After dilution with chloroform (180 ml), the salts were removed by filtration and the filtrate was evaporated to dryness. To eliminate benzyl bromide, the residue was dissolved in a mixture of pyridine (20 ml) and dioxane (35 ml) and cooled overnight to 0 °C. The resulting precipitate was collected by filtration and the filtrate was evaporated to dryness. The residue was crystallized from ether–hexane, giving 2.57 g (85%) of benzyl 2-acetamido-3-*O*-allyl-6-*O*-benzyl-2-deoxy-4-*O*-tetrahydropyranyl-α-D-glucopyranoside (**7**): mp 118–119 °C; $[\alpha]^{20}D$ + 103° (*c* 1.0, $CHCl_3$) (mixture of diastereoisomers); ν_{max} (Nujol) 3340 (NH), 1650, 1550 (CONH), 725 cm^{-1} (aromatic).

Anal. Calcd for $C_{30}H_{39}NO_7$ (525.62): C, 68.55; H, 7.48; N, 2.67. Found: C, 68.68; H, 7.49; N, 2.64.

Benzyl 2-Acetamido-3-*O*-allyl-6-*O*-benzyl-2-deoxy-α-D-glucopyranoside (8). **6** (2.5 g, 5.74 mmol) was benzylated as described above. The residue was dissolved in 60% acetic acid (50 ml) and heated for 10 min on a boiling water bath. Following evaporation to dryness the residue was coevaporated with water, then with toluene, and crystallized from ethyl acetate–ether, giving 1.96 g (80%) of benzyl 2-acetamido-3-*O*-allyl-6-*O*-benzyl-2-deoxy-α-D-glucopyranoside (**8**): mp 149–150 °C; $[\alpha]^{20}D$ +103° (*c* 1.0, $CHCl_3$); ν_{max} (Nujol) 3500 (OH), 3340 (NH), 1640, 1555 (CONH), 740, 690 cm^{-1} (aromatic); ^1H NMR ($CDCl_3$) δ 1.94 (s, 3, NHAc), 2.90 (OH), 4.48, 4.78 (2 d, AB system, *J* = 12 Hz, CH_2Ar), 4.62 (s, 2, CH_2Ar), 4.92 (d, 1, $J_{1,2}$ = 4 Hz, H-1), 5.17 (m, 1, $J_{c,d}$ = 2 Hz, H_c), 5.27 (m, 1, H_d), 5.66 (d, 1, $J_{NH,2}$ = 9 Hz, NH), 5.93 (m, 1, $J_{b,c}$ = 10 Hz, $J_{b,d}$ = 17 Hz, H_b), 7.37 (s, 10, aromatic). Allyl group:



Anal. Calcd for $C_{25}H_{31}NO_6$ (441.51): C, 68.00; H, 7.08; N, 3.17. Found: C, 68.20; H, 7.16; N, 3.37.

This compound was fully resistant to tritylation (trityl chloride in pyridine for 96 h at 100 °C). **8** (8.65 g, 19.6 mmol) was subsequently prepared from **2** (10 g, 28.5 mmol) without isolating the intermediates **4, 5, 6,** and **7** (yield 69%).

Benzyl 2-Acetamido-4-*O*-acetyl-3-*O*-allyl-6-*O*-benzyl-2-deoxy-α-D-glucopyranoside (9). **8** (0.2 g, 0.45 mmol) was acetylated (pyridine–acetic anhydride), giving 212 mg (97%) of **9** after crystallization from ethyl acetate–ether: mp 149–150 °C; $[\alpha]^{20}D$ +119° (*c* 1.0, $CHCl_3$); ν_{max} (Nujol) 3360 (NH), 1750 (OAc), 1650, 1550 (CONH), 730, 690 cm^{-1} (aromatic).

Anal. Calcd for $C_{27}H_{33}NO_7$ (483.54): C, 67.06; H, 6.88; N, 2.90. Found: C, 67.00; H, 6.82; N, 3.08.

Selective Benzylation of Benzyl 2-Acetamido-3-*O*-allyl-2-deoxy-α-D-glucopyranoside. A solution of **2** (5 g, 14.2 mmol) in *N,N*-dimethylformamide (50 ml) was stirred for 4 h at room temperature with barium oxide (5 g), barium hydroxide octahydrate (1.2 g), and benzyl bromide (2.4 ml, 18.4 mmol). After dilution with chloroform (400 ml), the organic phase was washed successively with 60% aqueous acetic acid, saturated aqueous sodium bicarbonate, and water, dried ($CaCl_2$), and evaporated to dryness. The residue was chromatographed on a column (100 g) using chloroform–acetone (9:1 v/v) which separated benzyl 2-acetamido-3-*O*-allyl-4,6-di-*O*-benzyl-2-deoxy-α-D-glucopyranoside (**10**, 3.18 g, 42%), mp 137.5–138.5 °C (ethyl acetate–hexane), and benzyl 2-acetamido-3-*O*-allyl-6-*O*-benzyl-2-deoxy-α-D-glucopyranoside (**8**), crystallized from ethyl acetate–ether (2.32 g, 37%), mp 148–149.5 °C, identical with the compound previously prepared.

Benzyl 2-Acetamido-3-*O*-allyl-4,6-di-*O*-benzyl-2-deoxy-α-D-glucopyranoside (10). A solution of **2** (1.15 g, 3.27 mmol) in *N,N*-dimethylformamide (25 ml) was stirred for 24 h at room temperature with barium oxide (1.3 g), barium hydroxide octahydrate (450 mg), and benzyl bromide (1.5 ml, 11.5 mmol). Following the treatment described above, a residue was obtained which was crystallized from ether, giving 1.49 g (81%) of benzyl 2-acetamido-3-*O*-allyl-4,6-di-*O*-benzyl-2-deoxy-α-D-glucopyranoside (**10**): mp 137.5–138.5 °C; $[\alpha]^{20}D$ + 102° (*c* 1.0, $CHCl_3$); ν_{max} (Nujol) 3350 (NH), 1655, 1560 (CONH), 725, 690 cm^{-1} (aromatic); ^1H NMR ($CDCl_3$) δ 1.96 (s, 3, NHAc), 4.95 (d, 1, $J_{1,2}$ = 4.5 Hz, H-1), 5.60 (d, 1, $J_{NH,2}$ = 9 Hz, NH), 5.90 (m, 1, $J_{b,c}$ = 10, $J_{b,d}$ = 17 Hz, H_b), 7.30, 7.37 (2 s, 15, aromatic).

Anal. Calcd for $C_{32}H_{37}NO_6$ (531.62): C, 72.29; H, 7.02; N, 2.63. Found: C, 72.00; H, 6.96; N, 2.63.

Benzyl 2-Acetamido-4-*O*-(2-*O*-acetyl-3,4,6-tri-*O*-benzyl-β-D-galactopyranosyl)-3-*O*-allyl-6-*O*-benzyl-2-deoxy-α-D-glucopyranoside (12). A solution of freshly prepared 3,4,6-tri-*O*-benzyl-1,2-*O*-(*tert*-butoxyethylidene)-α-D-galactopyranose (**11**, 3.29 g, 6 mmol) and **8** (1.766 g, 4 mmol) in chlorobenzene (30 ml) was heated at 140 °C under a dry atmosphere of nitrogen. After 15 ml of solvent had been distilled off, a 0.2 M solution of 2,6-dimethylpyridinium perchlorate in 1,2-dichloroethane (1.5 ml) was added and the solvent was continuously distilled off for 1 h at 140 °C, the volume of the reaction mixture being held constant (15 ml) by the dropwise addition of chlorobenzene. After cooling, the reaction mixture was diluted with chloroform (150 ml), washed successively with saturated aqueous sodium bicarbonate and water, dried ($MgSO_4$), and evaporated to dryness. The residue was chromatographed on a column (135 g) using chloroform–acetone (11.5:1 v/v), giving first a disaccharide fraction, then starting material **8** (529 mg, 30% after crystallization from ethyl acetate–ether).

The disaccharide fraction was crystallized from chloroform–ether, giving 1.361 g (38% based on **8**) of **12**: mp 136–137 °C; $[\alpha]^{20}D$ +66.5° (*c* 1.0, $CHCl_3$); ν_{max} (Nujol) 3375 (NH), 1750 (OAc), 1650, 1540 (CONH), 720 cm^{-1} (aromatic); ^1H NMR ($CDCl_3$) δ 1.92, 1.93 (2 s, 6, Ac), 4.45 (d, 1, $J_{1',2'}$ = 8.5 Hz, H-1'), 4.95 (d, 1, $J_{1,2}$ = 4.5 Hz, H-1), 5.58 (d, 1, $J_{NH,2}$ = 9 Hz, NH), 7.30, 7.34 (2 s, 25, aromatic).

Anal. Calcd for $C_{54}H_{61}NO_{12}$ (916.08): C, 70.80; H, 6.71; N, 1.52. Found: C, 70.97; H, 6.64; N, 1.65.

Benzyl 2-Acetamido-3-*O*-allyl-6-*O*-benzyl-4-*O*-(3,4,6-tri-

O-benzyl-α-D-galactopyranosyl)-2-deoxy-α-D-glucopyranoside (17). The mother liquors from the crystallization of **12** were evaporated to dryness. The residue was O-deacetylated (sodium methoxide in methanol), giving, after crystallization from ether, 438 mg (16% based on **8**) of **17**: mp 136–137 °C; $[\alpha]^{20}D$ + 91° (*c* 1.0, $CHCl_3$); ν_{max} (Nujol) 3440 (OH, shoulder), 3390 (NH), 1660, 1535 (CONH), 730, 690 cm^{-1} (aromatic); ^1H NMR ($CDCl_3$) δ 1.92 (s, 3, Ac), 2.95 (d, 1, $J_{OH,2'}$ = 9 Hz, OH), 4.88 (d, 1, $J_{1,2}$ = 4 Hz, H-1), 5.35 (d, 1, $J_{1',2'}$ = 4 Hz, H-1'), 5.63 (d, 1, $J_{NH,2}$ = 9 Hz, NH), 5.94 (m, 1, H_b), 7.32, 7.38 (2 s, 25, aromatic).

Anal. Calcd for $C_{52}H_{59}NO_{11}$ (874.11): C, 71.45; H, 6.80; N, 1.60. Found: C, 71.59; H, 6.72; N, 1.79.

Benzyl 2-Acetamido-4-O-(2-O-acetyl-3,4,6-tri-O-benzyl-α-D-galactopyranosyl)-3-O-allyl-6-O-benzyl-2-deoxy-α-D-glucopyranoside (18). Compound **17** (100 mg, 0.11 mmol) was acetylated (pyridine–acetic anhydride). After treatment, the residue was purified chromatographically on a column (2 g) using chloroform–ether (1:1, v/v), giving 96 mg (92%) of **18** as a colorless glass: $[\alpha]^{20}D$ +93.5° (*c* 1.0, $CHCl_3$); ν_{max} (film) 3320 (NH), 1745 (OAc), 1650, 1540 (CONH), 740, 685 cm^{-1} (aromatic); ^1H NMR ($CDCl_3$) δ 1.93 (s, 3, NHAc), 2.05 (s, 3, OAc), 4.93 (d, 1, $J_{1,2}$ = 4.5 Hz, H-1), 5.60 (m, 2, NH and H-1', $J_{NH,2}$ = 9, $J_{1',2'}$ = 3.5 Hz).

Anal. Calcd for $C_{54}H_{61}NO_{12}$ (916.08): C, 70.80; H, 6.71; N, 1.52. Found: C, 70.90; H, 6.85; N, 1.57.

Benzyl 2-Acetamido-6-O-benzyl-4-O-(3,4,6-tri-O-benzyl-α-D-galactopyranosyl)-2-deoxy-α-D-glucopyranoside (19). A solution of **17** (960 mg, 1.1 mmol) and potassium *tert*-butoxide (740 mg) in dimethyl sulfoxide was stirred and heated at 100 °C in a current of nitrogen for 2 h. After cooling the reaction mixture was poured into iced water (100 ml) and the mixture was extracted with chloroform (90 ml). The extract was washed with water, dried (Na_2SO_4), and evaporated to dryness. The colored oily residue was stirred in acetone–water (20 ml, 9:1 v/v) with yellow mercuric oxide (500 mg). A solution of mercuric chloride (450 mg) in acetone–water (5 ml, 9:1 v/v) was added dropwise for 5 min. The reaction mixture was then filtered and evaporated to dryness. The residue was dissolved in chloroform and the solution washed successively with 10% aqueous potassium iodide and water, dried ($MgSO_4$), and evaporated to dryness. The residue was chromatographed twice on a column (45 g) using chloroform–methanol (24:1, v/v), giving 697 mg (76%) of **19** as a colorless glass: $[\alpha]^{20}D$ + 90° (*c* 1.0, $CHCl_3$); ν_{max} (film) 3350 (broad, NH and OH), 1650, 1545 (CONH), 690 cm^{-1} (aromatic); ^1H NMR ($CDCl_3$) δ 1.93 (s, 3, Ac), 5.00 (d, 1, $J_{1,2}$ = 4 Hz, H-1), 5.21 (d, 1, $J_{1',2'}$ = 3.5 Hz, H-1'), 5.90 (d, 1, $J_{NH,2}$ = 9 Hz, NH), 7.32, 7.35 (2 s, 25, aromatic).

Anal. Calcd for $C_{49}H_{55}NO_{11}$ (833.97): C, 70.57; H, 6.64; N, 1.68. Found: C, 70.38; H, 6.65; N, 1.68.

Benzyl 2-Acetamido-3-O-acetyl-4-O-(2-O-acetyl-3,4,6-tri-O-benzyl-α-D-galactopyranosyl)-6-O-benzyl-2-deoxy-α-D-glucopyranoside (20). Acetylation of **19** (251 mg, 0.3 mmol) with acetic anhydride and pyridine gave 240 mg (86%) of **20** as a colorless glass: $[\alpha]^{20}D$ + 103° (*c* 1.1, $CHCl_3$); ν_{max} (film) 1750 (OAc), 1680, 1510 (CONH), 685 cm^{-1} (aromatic); ^1H NMR ($CDCl_3$) δ 1.87 (s, 3, NHAc), 2.03 (s, 6, OAc), 4.92 (d, 1, $J_{1,2}$ = 4 Hz, H-1), 5.51 (d, 1, $J_{1',2'}$ = 4.5 Hz, H-1'), 5.66 (d, 1, $J_{NH,2}$ = 10 Hz, NH), 7.30–7.37 (m, 25, aromatic).

Anal. Calcd for $C_{53}H_{59}NO_{13}$ (918.05): C, 69.34; H, 6.48; N, 1.52. Found: C, 69.55; H, 6.24; N, 1.36.

2-Acetamido-2-deoxy-4-O-(α-D-galactopyranosyl)-α-D-glucopyranose (21). A solution of **19** (346 mg, 0.41 mmol) in acetic acid (13 ml) was hydrogenolyzed with Pd/C (10%) for 24 h. The reaction mixture was filtered and evaporated to dryness. Crystallization of the residue from 2-propanol–methanol gave 125 mg (79%) of **21**: mp 193–195 °C; $[\alpha]^{20}D$ + 147° (2 min) → + 131° (3 h) (*c* 0.50, water–methanol, 9:1 v/v) [lit.[5] mp 196–198 °C; $[\alpha]^{20}D$ + 151° (2 min) → + 132° (5 h) (*c* 0.40, water–methanol, 9:1 v/v)]; mmp 193–195.5 °C.

Benzyl 2-Acetamido-3-O-allyl-6-O-benzyl-4-O-(3,4,6-tri-O-benzyl-β-D-galactopyranosyl)-2-deoxy-α-D-glucopyranoside (13). A molar solution of sodium methoxide in methanol (1 ml) was added to a solution of **12** (500 mg, 0.55 mmol) in methanol (10 ml) and the mixture was stirred for 12 h at room temperature. After evaporation to dryness, the residue was dissolved in chloroform (50 ml), and the organic phase was washed with water, dried ($MgSO_4$), and evaporated to dryness. The residue was crystallized from ether, giving 451 mg (95%) of **13**: mp 122–123 °C; $[\alpha]^{20}D$ +72.5° (*c* 1.0, $CHCl_3$); ν_{max} (Nujol) 3330, 3280 (OH, NH), 1645, 1560 (CONH), 725, 690 cm^{-1} (aromatic); ^1H NMR ($CDCl_3$) δ 1.93 (s, 3, Ac), 4.92 (d, 1, $J_{1,2}$ = 4 Hz, H-1), 5.57 (d, 1, $J_{NH,2}$ = 9 Hz, NH).

Anal. Calcd for $C_{52}H_{59}NO_{11}$ (874.11): C, 71.45; H, 6.80; N, 1.60. Found: C, 71.33; H, 6.84; N, 1.62.

Benzyl 2-Acetamido-6-O-benzyl-4-O-(3,4,6-tri-O-benzyl-β-D-galactopyranosyl)-2-deoxy-α-D-glucopyranoside (14). Compound **13** (1.22 g, 1.4 mmol) was transformed into **14** as described above for the synthesis of **19**. The residue was chromatographed twice on a column (100 g) using ethyl acetate, giving 908 mg (78%) of **14** as a colorless, glassy mass: $[\alpha]^{20}D$ +61° (*c* 1.0, $CHCl_3$); ν_{max} (film) 3360 (OH, NH), 1650, 1540 (CONH), 690 cm^{-1} (aromatic); ^1H NMR ($CDCl_3$) δ 1.95 (s, 3, Ac), 2.94 (broad s, 1, OH'), 3.35 (dd, 1, $J_{2',3'}$ = 9, $J_{3',4'}$ = 3 Hz, H-3'), 4.30 (d, 1, $J_{1',2'}$ = 9 Hz, H-1'), 5.03 (d, 1, $J_{1,2}$ = 4 Hz, H-1), 5.71 (d, 1, $J_{NH,2}$ = 9 Hz, NH), 7.31–7.38 (m, 25, aromatic).

Anal. Calcd for $C_{49}H_{55}NO_{11}$ (833.97): C, 70.57; H, 6.64; N, 1.68. Found: C, 70.61; H, 6.51; N, 1.76.

Benzyl 2-Acetamido-3-O-acetyl-4-O-(2-O-acetyl-3,4,6-tri-O-benzyl-β-D-galactopyranosyl)-6-O-benzyl-2-deoxy-α-D-glucopyranoside (15). Acetylation of **14** (100 mg, 0.12 mmol) with acetic anhydride in pyridine gave a crude compound. Purification on a column (5 g) using chloroform–ether (7:3 v/v) gave 103 mg (93%) of **15** as a glassy mass: $[\alpha]^{20}D$ +74° (*c* 1.1, $CHCl_3$); ν_{max} (film) 3360 (NH), 1755 (OAc), 1675, 1520 (CONH), 740, 690 cm^{-1} (aromatic); ^1H NMR δ 1.87 (s, 3, NHAc), 1.91, 1.92 (2 s, 6, OAc), 4.47 (d, 1, $J_{1',2'}$ = 9 Hz, H-1'), 4.90 (d, 1, $J_{1,2}$ = 4 Hz, H-1), 5.76 (d, 1, $J_{NH,2}$ = 9 Hz, NH), 7.34 (s, 25, aromatic).

Anal. Calcd for $C_{53}H_{59}NO_{13}$ (918.05): C, 69.34; H, 6.48; N, 1.52. Found; c, 69.23; H, 6.63; N, 1.60.

2-Acetamido-2-deoxy-4-O-(β-D-galactopyranosyl)-α-D-glucopyranose (*N*-Acetyllactosamine) (16). A solution of **14** (100 mg, 0.12 mmol) in acetic acid (10 ml) was hydrogenolyzed with Pd/C (10%, 100 mg) for 60 h. The reaction mixture was filtered and evaporated to dryness. Crystallization of the residue (41 mg) from 2-propanol–methanol gave 36 mg (82%) of **16**: mp 169–170 °C; $[\alpha]^{20}D$ +48° (2 min) → + 29° (3 h) (*c* 0.45, water–methanol, 9:1 v/v) [lit.[6] mp 170–171 °C; $[\alpha]^{20}D$ + 50° → + 28.5° (12 h) (*c* 0.6, water–methanol, 9:1 v/v)].

Benzyl 2-Acetamido-3-O-allyl-6-O-benzyl-4-O-[2-O-(2,3,4-tri-O-benzyl-α-L-fucopyranosyl)-3,4,6-tri-O-benzyl-β-D-galactopyranosyl]-2-deoxy-α-D-glucopyranoside (23). Compound **13** (1.748 g, 2 mmol) was dissolved in *N,N*-dimethylformamide (3 ml) which contained tetraethylammonium bromide (2.10 g, 10 mmol) and molecular sieves 4 Å (1 g). A solution of freshly prepared 2,3,4-tri-O-benzyl-α-L-fucopyranosyl bromide (2.49 g, 5 mmol) in 1,2-dichloroethane (12 ml) and diisopropylethylamine (1.5 ml, 5.25 mmol) was added and the mixture was stirred under dry nitrogen at room temperature for 3 days. After addition of methanol (10 ml), the mixture was stirred for 4 h, the solids were removed by filtration, and the filtrate, after dilution with chloroform (100 ml), was washed twice with water, dried ($MgSO_4$), and evaporated to dryness. The residue was chromatographed twice on a column (220 g), using chloroform–ether (7:3 v/v), giving 2.36 g (91% based on **13**) of **23** as a colorless glass: $[\alpha]^{20}D$ −0.5° (*c* 1.0, $CHCl_3$); ν_{max} (film) 3330 (NH), 1550, 1545 (CONH), 690 cm^{-1} (aromatic); ^1H NMR ($CDCl_3$) δ 1.10 (d, 3, *J* = 7 Hz, CH_3), 1.96 (s, 3, Ac), 5.04 (d, 1, $J_{1,2}$ = 4 Hz, H-1), 5.58 (d, 1, $J_{NH,2}$ = 9 Hz, NH), 5.68 (d, 1, $J_{1'',2''}$ = 3.5 Hz, H-1''), 7.17–7.33 (m, 30, aromatic).

Anal. Calcd for $C_{79}H_{87}NO_{15}$ (1290.56): C, 73.52; H, 6.79; N, 1.08. Found: C, 73.36; H, 6.83; N, 1.13.

The trisaccharide **23** (60 mg) was hydrolyzed for 3.5 h at 100 °C in a mixture of 80% aqueous acetic acid (4 ml) and 1 M hydrochloric acid (1 ml). After cooling, the reaction mixture was poured into iced water and extracted with chloroform (30 ml). The organic phase was washed successively with 5% aqueous sodium bicarbonate and water, dried ($MgSO_4$), and evaporated to dryness. The residue (57 mg) was chromatographed on a column (6 g) using chloroform–acetone (11:1 v/v), giving two compounds: 3,4,6-tri-O-benzyl-α-L-fucopyranose (15 mg, 75%), crystallized from ethyl acetate–ether–hexane, mp 102–103 °C (lit.[18] 102–103 °C); compound **13** (31 mg, 76%), crystallized from ether–hexane, mp 121–123 °C.

Benzyl 2-Acetamido-6-O-benzyl-4-O-[2-O-(2,3,4-tri-O-benzyl-α-L-fucopyranosyl)-3,4,6-tri-O-benzyl-β-D-galactopyranosyl]-2-deoxy-α-D-glucopyranoside (24). The allyl group of compound **23** (2.102 g, 1.63 mmol) was removed as described above for the preparation of **19**. The residue was chromatographed on a column (150 g) using chloroform–ether (7:3 v/v), giving 1.693 g (83%) of **24** as a colorless glass: $[\alpha]^{20}D$ +1.5° (*c* 1.2, $CHCl_3$); ν_{max} (film) 3480 (OH), 3340 (NH), 1660, 1550 (CONH), 690 cm^{-1} (aromatic); ^1H NMR ($CDCl_3$) δ 1.10 (d, 3, *J* = 7 Hz, CH_3), 5.08 (d, 1, $J_{1,2}$ = 3.5 Hz, H-1), 5.66 (d, 1, $J_{NH,2}$ = 9 Hz, NH), 5.73 (d, 1, $J_{1'',2''}$ = 4 Hz, H-1''), 7.25–7.33 (m, 40, aromatic).

Anal. Calcd for $C_{76}H_{83}NO_{15}$ (1250.49): C, 72.99; H, 6.69; N, 1.12; O, 19.12. Found: C, 72.88; H, 6.76; N, 1.04; O, 19.12.

Acetate **25** (pyridine–acetic anhydride): glass; $[\alpha]^{20}D$ +2° (*c* 1.0, $CHCl_3$); ν_{max} (film) 3460 (NH), 1750 (OAc), 1685, 1530 (CONH), 685 cm^{-1} (aromatic); ^1H NMR ($CDCl_3$) δ 1.15 (d, 3, *J* = 7 Hz, CH_3), 4.97

(d, 1, $J_{1,2}$ = 4 Hz, H-1), 5.64 (d, 1, $J_{1'',2''}$ = 4 Hz, H-1''), 5.74 (d, 1, $J_{NH,2}$ = 9.5 Hz, NH), 7.23–7.33 (m, 40, aromatic).

Anal. Calcd for $C_{78}H_{85}NO_{16}$ (1292.53): C, 72.49; H, 6.63; N, 1.08. Found: C, 72.35; H, 6.65; N, 0.93.

***O*-α-L-Fucopyranosyl-(1 → 2)-*O*-β-D-galactopyranosyl-(1 →4)-2-acetamido-2-deoxy-D-glucopyranose (26).** A solution of **24** (20 mg, 1.6×10^{-2} mmol) in acetic acid (1 ml) was hydrogenolyzed with Pd/C (10%, 20 mg) for 72 h. The reaction mixture was filtered and evaporated to dryness, giving **26**, identical with an authentic sample.[5] After sodium borohydride reduction and trimethylsilylation, the compound was homogeneous by GLC, t_R 2.90.

Benzyl 2-Acetamido-6-*O*-benzyl-3-*O*-(2,3,4-tri-*O*-benzyl-α-L-fucopyranosyl)-4-*O*-[2-*O*-(2,3,4-tri-*O*-benzyl-α-L-fucopyranosyl)-3,4,6-tri-*O*-benzyl-β-D-galactopyranosyl]-2-deoxy-α-D-glucopyranoside (27). A. From Compound 24. **24** (1.41 g, 1.127 mmol) was dissolved in *N,N*-dimethylformamide (2 ml) which contained tetraethylammonium bromide (1.05 g, 5 mmol) and molecular sieves 4 Å (1 g). A solution of freshly prepared 2,3,4-tri-*O*-benzyl-α-L-fucopyranosyl bromide (1.24 g, 2.5 mmol) in 1,2-dichloroethane (8 ml) and diisopropylethylamine (0.35 ml, 2.62 mmol) was added and the mixture was stirred under dry nitrogen at room temperature for 3 days. The reaction mixture was worked up as described above for the synthesis of **23.** The residue was chromatographed twice on a column (200 g), using chloroform–acetone (32:1 v/v), giving 1.503 g (80% based on **24**) of **27** as a colorless glass: $[\alpha]^{20}D$ −31.5° (*c* 1.0, $CHCl_3$); ν_{max} (film) 3320 (NH), 1660, 1540 (CONH), 740, 695 cm^{-1} (aromatic); ^1H NMR ($CDCl_3$) δ 1.14 (d, *J* = 7 Hz, CH_3), 1.80 (s, 3, Ac), 4.97 (d, 1, $J_{1,2}$ = 4 Hz, H-1), 5.23 (d, 1, $J_{1''',2'''}$ = 3 Hz, H-1'''), 5.72 (d, 1, $J_{NH,2}$ = 9 Hz, NH), 5.74 (d, 1, $J_{1'',2''}$ = 4 Hz, H-1''), 7.25–7.33 (m, 55, aromatic).

Anal. Calcd for $C_{103}H_{111}NO_{19}$ (1667.01): C, 74.21; H, 6.71; N, 0.84. Found: C, 74.01; H, 6.78; N, 0.94.

B. From Compound 14. **14** (930 mg, 1.12 mmol) was dissolved in *N,N*-dimethylformamide (2 ml) which contained tetraethylammonium bromide (2.10 g, 10 mmol) and molecular sieves 4 Å (1 g). A solution of freshly prepared 2,3,4-tri-*O*-benzyl-α-L-fucopyranosyl bromide (2.49 g, 5 mmol) in 1,2-dichloroethane (8 ml) and diisopropylethylamine (0.7 ml, 5.24 mmol) was added and the mixture was stirred under dry nitrogen at room tempeature for 3 days. The same treatment as above gave 1.383 g (74% based on **14**) of **27** as a colorless glass, identical with the compound prepared from **24.** A compound that migrated more slowly was isolated in pure form and identified as **24** (192 mg, 14%).

The tetrasaccharide **27** (84 mg, 5×10^{-2} mmol) was hydrolyzed as described for the acid hydrolysis of **23.** The residue was chromatographed on a column (10 g) using chloroform–ether (7:3 v/v), giving two compounds: 2,3,4-tri-*O*-benzyl-α-L-fucopyranose (36 mg, 83%), crystallized from ether–hexane, mp 102–103 °C; compound **14** (35 mg, 84%), $[\alpha]^{20}D$ + 62° (*c* 1.0, $CHCl_3$).

***O*-α-L-Fucopyranosyl-(1→2)-*O*-β-D-galactopyranosyl-(1 →4)-*O*-[α-L-fucopyranosyl-(1→3)]-2-acetamido-2-deoxy-α-D-glucopyranose (28).** A solution of **27** (2.638 g, 1.58 mmol) in acetic acid (50 ml) was hydrogenolyzed with Pd/C (10%) (2.5 g) for 8 days. The reaction mixture was filtered and evaporated to dryness. The residue (997 mg) was purified on a charcoal–Celite column (18 × 220 mm, 30 g of 1:1 mixture). Fractions eluted with water–ethanol (19:1 v/v, 2 l.) and water–ethanol (4:1 v/v, 1 l.) were pooled and evaporated to dryness, giving 813 mg (76%) of tetrasaccharide **28.** This compound was pure on paper chromatography (Whatman no. 1) using ethyl acetate–pyridine–water (10:4:3 v/v/v) and showed $R_{lactose}$ 0.41 (aniline phthalate reagent).

A fraction was crystallized from methanol–ethanol, giving **28:** mp 214–216 °C dec; $[\alpha]^{20}D$ −113° (3 min) → −124.5° (18 h) (*c* 0.5, water–methanol, 9:1 v/v); ^1H NMR (D_2O) δ 1.30 (d, 6, *J* = 7 Hz, CH_3), 2.10 (s, 3, Ac), 4.55 (d, 1, $J_{1',2'}$ = 7.5 Hz, H-1'), 5.15 (d, 2, $J_{1,2}$ = 3, $J_{1''',2'''}$ = 3 Hz, H-1 and H-1'''), 5.34 (d, 1, $J_{1'',2''}$ = 3 Hz, H-1'').

Anal. Calcd for $C_{26}H_{45}NO_{19}$ (675.63): C, 46.22; H, 6.71; N, 2.07; O, 44.99. Found: C, 46.33; H, 6.87; N, 2.16; O, 45.01.

Registry No.—**1,** 60920-72-1; **2,** 60920-73-2; **3,** 60920-74-3; **4,** 60920-75-4; (4*R*)-**5,** 60920-76-5; (4*S*)-**5,** 60920-77-6; (4*R*)-**6,** 60920-78-7; (4*S*)-**6,** 60920-79-8; (4*R*)-**7,** 60920-80-1; (4*S*)-**7,** 60920-81-2; **8,** 60920-82-3; **9,** 60920-83-4; **10,** 60920-84-5; **11,** 60920-85-6; **12,** 60920-86-7; **13,** 60920-87-8; **14,** 60920-88-9; **15,** 60920-89-0; **17,** 60920-90-3; **18,** 60920-91-4; **19,** 60920-92-5; **20,** 60920-93-6; **21,** 60966-24-7; **23,** 60920-94-7; **24,** 60920-95-8; **25,** 60920-96-9; **27,** 60920-97-0; **28,** 60966-25-8; benzyl 2-acetamido-4,6-*O*-benzylidene-2-deoxy-α-D-glucopyranoside, 13343-63-0; allyl bromide, 106-95-6; benzoyl chloride, 98-88-4; 3,4-dihydro-2*H*-pyran, 110-87-2; benzyl bromide, 100-39-0; 2,3,4-tri-*O*-benzyl-α-L-fucopyranosyl bromide, 33639-77-9; 2,3,4-tri-*O*-benzyl-α-L-fucopyranose, 33639-75-7.

References and Notes

(1) (a) Synthesis of Blood-Group Substances. 6. For part 5, see J.-P. Cartron, C. Mulet, J. Badet, J.-C. Jacquinet, and P. Sinaÿ, *FEBS Lett.*, **67,** 143 (1976). (b) This work was supported by Centre National de la Recherche Scientifique, Caisse Régionale d'Assurance Maladie du Centre, and Délégation Générale à la Recherche Scientifique et Technique (ASCO, agreement no. 74 7 0973).
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(20) After this manuscript has been submitted for publication, Dr. Henry A. Graham (Ortho Diagnostics, Raritan, N.J.) completed inhibition studies with this tetrasaccharide. It does not inhibit haemagglutination with a goat anti-Le dH serum, supporting the idea that this structure is not the Le d antigenic determinant, as previously postulated.[9]