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Synthesis of propyl and 2-aminoethyl glycosides of α-D-galactosyl-(1 → 3′)-β-lactoside

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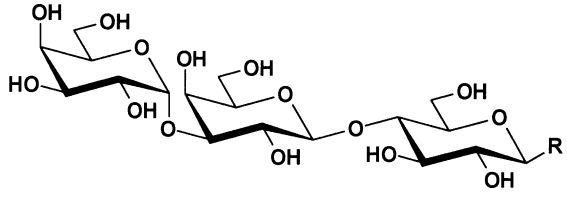
Abstract

Propyl and 2-aminoethyl α-D-galactopyranosyl-(1 → 3′)-β-lactosides (**1** and **2**) were prepared from the corresponding perbenzylated trisaccharide allyl glycoside **6** which, in turn, was obtained by methyl triflate promoted α-galactosylation of benzylated allyl lactoside acceptor **4** with thiogalactoside **3**. Transformation of the allyl moiety in compound **6** into 2-azidoethyl one was achieved by cleavage of the double bond followed by reduction into alcohol **9**, subsequent mesylation, and mesylate → azide substitution. Alternatively trisaccharide **2** was synthesized using α-galactosylation of selectively benzoylated 2-azidoethyl lactoside **19** with **3** as the key step.

Keywords: Gal(α1,3)Gal epitope; α-Galactosylation; Allyl glycoside; Ozonolysis; Xenotransplantation; *iso*-Globo trisaccharide

1. Introduction

The presence of anti α-D-Gal-(1 → 3)-D-Gal antibodies in human sera constitutes the main obstacle for the xenotransplantation from pig to man.[1,2] In order to study the carbohydrate specificity of these antibodies we have been preparing various oligosaccharides, and neoglycoconjugates and glycodendrimers thereof.[3,4] In this paper we describe preparative synthesis of propyl (**1**, R = OPr) and 2-aminoethyl (**2**, R = $OCH_2CH_2NH_2$) glycosides of the trisaccharide α-D-galactosyl-(1 → 3′)-β-lactoside. Several chemical and enzymatic syntheses of the derivatives related to the trisaccharides **1** and **2** but with R = OAll,[5] SPh,[5] N_3,[5] NHAc,[6] $NHC(O)(CH_2)_4NH_2$,[7] $O(CH_2)_8CO_2Me$,[8] OH,[9,10] and ceramide[11] have been described earlier.



1 R = $OCH_2CH_2CH_3$
2 R = $OCH_2CH_2NH_2$

We anticipated, that appropriately protected trisaccharide allyl glycoside **6** was a versatile precursor of both compounds **1** and **2**: while the former is available from **3** by hydrogenolysis, the latter can be obtained by double bond splitting followed by introduction of amino function procedure.[12,13] Such conversion of allyl aglycon into 2-aminoethyl one seems advantageous over the sequence deallylation → glycosyl donor formation → condensation with protected 2-aminoethanol, because low yields and poor stereoselectivity is

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often observed during glycosylation of such simple alcohols with complex oligosaccharide donors.[14]

The alternative route to **2** included α-galactosylation of selectively protected 2-azidoethyl lactoside **19**. The choice of azido group as a protected equivalent of amino one was dictated by the possibility to use this lactose block in the syntheses of longer oligasaccharide chains of such type, for example pentasaccharide α-D-Gal-(1→3)-β-D-Gal-(1→4)-β-D-GlcNAc-(1→3)-β-D-Gal-(1→4)-β-D-Glc, because azido group is orthogonal to nitrogen protections of many aminosugar synthetic blocks.

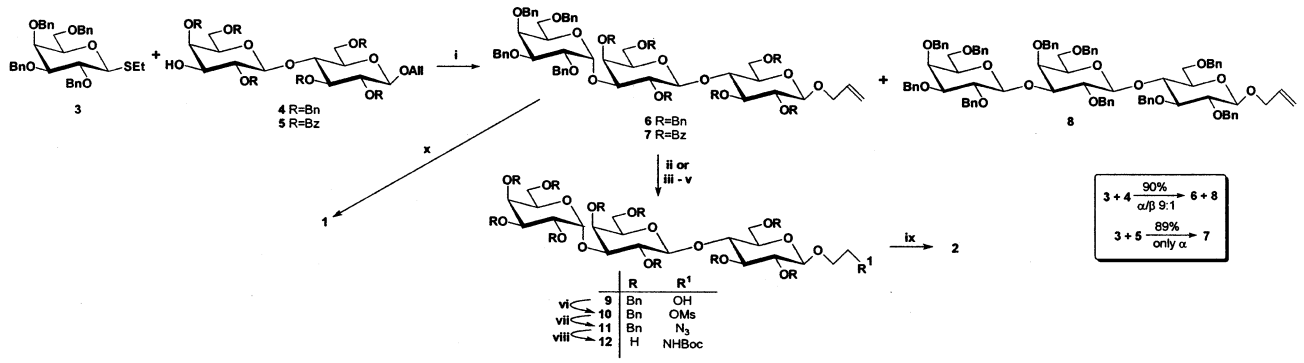
2. Results and discussion

The allyl glycoside **6** was obtained (Scheme 1) by methyl triflate (MeOTf) promoted glycosylation with the known ethyl tetra-*O*-benzyl-1-thio-β-D-galactoside **3**[15] of the readily available allyl hexa-*O*-benzyl-β-lactoside **4**.[16] Similar to the parent examples,[17,18] the reaction afforded 9:1 mixture of compound **6** and its β anomer **8** in 90% combined yield. The α configuration of Gal′ residue in compound **6** was confirmed by the value of $J_{1,2Gal}$ coupling constant 3.2 Hz together with highfield chemical shift of its C-1 carbon 95.98 ppm in comparison with that of β anomer **8** ($J_{1,2Gal'}$ 7.8 Hz, $\delta_{C\text{-}1Gal'}$ 102.55 ppm).

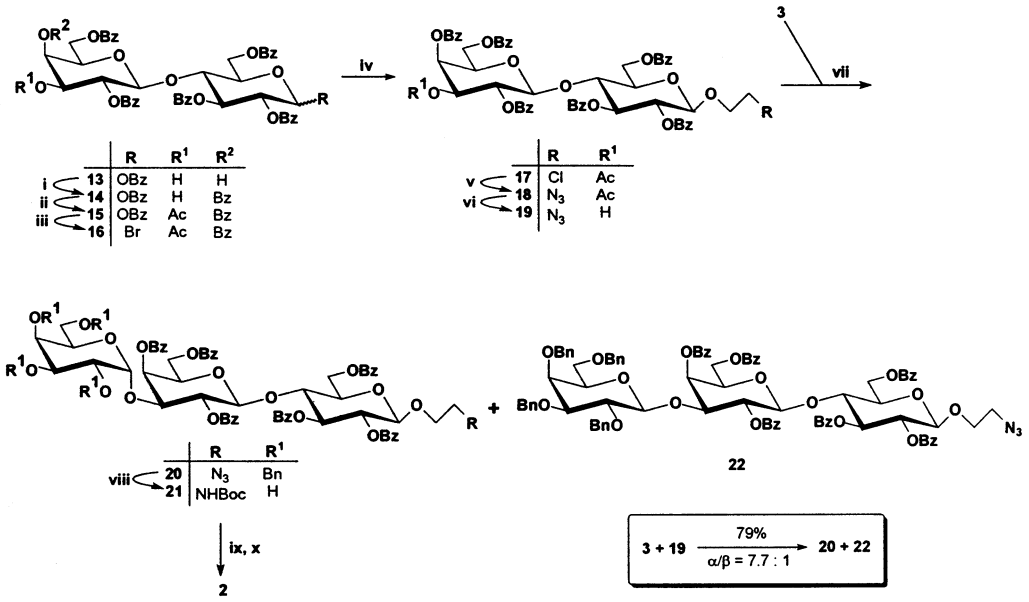
Catalytic hydrogenolysis of **6** afforded the target propyl glycoside **1** in 88% yield. Conversion of allyl aglycon of **6** into 2-azidoethyl one was achieved by ozonolysis of the double bond followed by $NaBH_4$ reduction into the corresponding alcohol **9** in 95% yield. Alternatively, catalytic osmylation followed by periodate oxidation and $NaBH_4$ reduction afforded **9** in 81% yield. Subsequent mesylation (**9**→**10**, 97%), followed by displacement with NaN_3 in the presence of 18-crown-6 at room temperature[19] afforded protected 2-azidoethyl derivative **11** in 89% yield.

However, the perbenzylated 2-azidoethyl glycoside **11** failed to yield aminoethyl glycoside **2** when subjected to catalytic hydrogenolysis. Under both neutral and acidic conditions the azido group hydrogenation occurred within minutes, but debenzylation of the amine thus formed could never be brought to the completion. This might be due to the known ability of amines to influence on benzyl ether hydrogenolysis.[20] Therefore, compound **11** was subjected to hydrogenolysis in the presence of ditertbutyldicarbonate (Boc_2O) to give N-protected polyol **12** in 90% yield. Subsequent deprotection with trifluoracetic acid afforded the target 2-aminoethyl glycoside **2**.

An alternative route to the target spacer-armed glycoside **2** employed glycosylation of 2-azidoethyl hexa-*O*-benzoyl lactoside acceptor **19** with the direct precursor of amino function already present. The benzoyl protections in **19** were chosen instead of benzyl ones in order to simplify further deblocking and improve stereoselectivity of α-galactosylation. Such possibility was confirmed by model condensation of **3** and allyl hexa-*O*-benzoyl-lactoside **5**.[16] In contrast to a 9:1 α/β ratio



Scheme 1. Reagents and conditions: (i) MeOTf, MS-4Å, Et_2O, rt; (ii) O_3, MeOH–CH_2Cl_2, then $NaBH_4$ (95%); (iii) OsO_4, NMMO, acetone–water (87%); (iv) $NaIO_4$, EtOH–MeOH–water; (v) $NaBH_4$, MeOH–CH_2Cl_2 (93%, two steps); (vi) MsCl, Et_3N, CH_2Cl_2 (97%); (vii) NaN_3, 18-crown-6, DMF, rt (89%); (viii) H_2, Pd–C, Boc_2O, EtOAc–EtOH (90%); (ix) CF_3CO_2H, rt (84%); (x) H_2, Pd–C, EtOAc–EtOH.



Scheme 2. Reagents and conditions: (i) $PhC(OEt)_3$, TsOH, benzene, 60 °C, then 80% aq AcOH (74%); (ii) Ac_2O, Py (100%); (iii) HBr, AcOH, CH_2Cl_2 (96%); (iv) $ClCH_2CH_2OH$, AgOTf, CH_2Cl_2 (98%); (v) NaN_3, 18-crown-6, DMF, 70 °C (91%); (vi) MeOH, HCl, CH_2Cl_2 (86%); (vii) MeOTf, MS-4Å, Et_2O, rt (79%); (viii) H_2, Pd–C, Boc_2O, EtOAc–EtOH (86%); (ix) CF_3CO_2H, CH_2Cl_2, rt; (x) NH_3, MeOH–water (99%).

obtained on glycosylation of **4** with **3**, coupling of **3** and **5** under the above mentioned conditions afforded α-linked trisaccharide **7** as the sole product in 89% yield. The α configuration of the Gal′ residue in **7** was deduced from the value of $J_{1,2Gal'}$ coupling constant 2.9 Hz in its ^1H NMR spectrum and from the chemical shift of its C-1 carbon 94.71 ppm in the ^{13}C NMR one.

In order to prepare lactoside acceptor **19**, the readily available diol **13**[21] was converted via orthoester procedure,[22] into heptabenzoate **14** in 74% yield (Scheme 2), which was then 3′-O-acetylated into **15** and then brominated to give **16**. Silver triflate (AgOTf) promoted condensation of glycosyl bromide **16** with 2-chloroethanol afforded β-glycoside **17** in near quantitative yield. Subsequent chlorine displacement in **17** upon treatment with NaN_3 gave 2-azidoethyl glycoside **18** in 91% yield. The two-step procedure was used instead of direct glycosylation of 2-azidoethanol due to its explosive nature. Finally, HCl-catalyzed methanolysis of the acetate ester[23] in **18** afforded mono hydroxy derivative **19** in 86% yield.

In contrast to the stereospecific coupling of **3** and **5**, MeOTf promoted glycosylation of **19** with **3** in Et_2O gave 70% of α-linked **20** and 9% of its β-isomer **22**. Thus a small variation in the aglycon of glycosyl acceptor resulted in substantial change in the stereoselectivity of its glycosylation. Trisaccharide **20** was then deprotected by catalytic hydrogenolysis in the presence of Boc_2O to give **21**, subsequent amine deblocking in **21** with trifluoroacetic acid followed by debenzoylation with ammonia in aqueous methanol to afford the target spacer-armed derivative **2**.

In summary, we demonstrated that allyl glycoside **6** can serve as a convenient precursor of the corresponding spacer-armed derivative, 2-aminoethyl glycoside **2**. The important feature of the approach is that the conversion of allyl glycoside into 2-azidoethyl one does not proceed via glycosylation reaction and thus no control of anomeric stereochemistry is required. Spacer-armed trisaccharide **2** was also synthesized in good yield employing coupling of donor **3** and acceptor **19** as the key step. Conjugation of **2** with various carriers and biological activity studies of the polymers thus obtained will be published elsewhere.

3. Experimental

General methods.—The reagents were purchased from Fluka and Merck, all of the

highest grade available. Molecular Sieves were activated by heating (180 °C) under vacuum (0.1 mmHg) for 5–8 h. Peroxide-free Et_2O was distilled from sodium benzophenone ketyl under Ar and stored over MS-3Å deperox/dehydrate (Fluka). CH_2Cl_2 was washed with 96% H_2SO_4, water, satd aq $NaHCO_3$, dried ($MgSO_4$), distilled twice from P_2O_5 under Ar, and stored over MS-4Å. The catalyst used for hydrogenolysis was 10% Pd–C, oxide form, (Merck–Schuchardt). In glycosylation reactions, Molecular Sieve Union Carbide Type 4Å (Fluka) were used. Column chromatography was performed on Silica gel 60 (Fluka, 70–230 mesh). TLC was performed on Silica Gel 60 F_{254} (E. Merck, Darmstadt, Germany) with detection by dipping the chromatograms into 10% H_3PO_4 in EtOH followed by heating at 180 °C. Amines were also visualized by dipping the chromatograms into 0.017 M ninhydrin solution in (33:1) *n*-butanol–AcOH, followed by heating. For TLC analysis of deblocked oligosaccharides, solvent systems 1:2:1 *n*-butanol–*n*-propanol–0.1 M aq HCl (BPHCl), 1:1:1 MeCN–MeOH–water (AMW), and their combination were used. Optical rotation was measured with JASCO DIP-360 digital polarimeter at 26–30 °C. NMR spectra were recorded with Bruker DRX-500 instrument (500 MHz for ^1H and 125 MHz for ^{13}C), assignments were aided by COSY, TOCSY, APT, and ^1H–^{13}C correlation spectroscopy. Mass spectra were recorded using matrix assisted laser desorption ionization (MALDI)-time of flight (TOF) on VISION 2000 mass spectrometer.

Allyl 2,3,4,6-tetra-O-*benzyl*-α-D-*galactopyranosyl*-(1→3)-*2,4,6-tri*-O-*benzyl*-β-D-*galactopyranosyl*-(1→4)-*2,3,6-tri*-O-*benzyl*-β-D-*glycopyranoside* (**6**) *and allyl 2,3,4,6-tetra*-O-*benzyl*-β-D-*galactopyranosyl*-(1→3)-*2,4,6-tri*-O-*benzyl*-β-D-*galactopyranosyl*-(1→4)-*2,3,6-tri*-O-*benzyl*-β-D-*glycopyranoside* (**8**).—A solution of **3** (625 mg, 1.07 mmol) and **4** (660 mg, 0.72 mmol) in dry Et_2O (25 mL) was stirred with freshly activated MS-4Å (1.5 g) during 1 h under Ar, MeOTf (0.58 mL, 5.3 mmol) was added, and stirring was continued for 20 h at rt. Et_3N (3 mL) was added, the reaction mixture was filtered through a pad of Celite, diluted with CH_2Cl_2 (200 mL), washed with water, 10% aq NaOH, water, 10% aq H_2SO_4, water, dried and concentrated. Chromatography (benzene→9:1 benzene–EtOAc) of the residue on a column of silica gel (150 g) afforded (in order of elution) β-glycoside **8** (93 mg, 9%) and α-glycoside **6** (842 mg, 81%) as colorless oils.

α-Glycoside **6**: R_f 0.32 (9:1, benzene–EtOAc); $[\alpha]_D$ 39° (*c* 0.5, $CHCl_3$); NMR ($CDCl_3$): ^1H, δ 3.28–3.62 (m, 9 H), 3.65–3.87 (m, 5 H), 3.91–4.05 (m, 3 H), 4.11–4.20 (m, 2 H), 4.23–4.59 (m, 12 H), 4.60–5.17 (m, 12 H), 5.22 (broaden d, 1 H, *J* 9.9 Hz, $OCH_2CH{=}CH_2$), 5.25 (d, 1 H, $J_{1,2}$ 3.2 Hz, H-1Gal′), 5.38 (broaden d, 1 H, *J* 17.8 Hz, $OCH_2CH{=}CH_2$), 5.99 (m, 1 H, $OCH_2CH{=}CH_2$), 7.09–7.42 (m, 50 H, arom); ^{13}C, δ 95.98 (C-1Gal′), 102.71 (C-1Glc), 102.97 (C-1Gal), 117.13 ($OCH_2CH{=}CH_2$), 134.22 ($OCH_2CH{=}CH_2$). Anal. Calcd for $C_{91}H_{96}O_{16}$: C, 75.60; H, 6.69. Found C, 75.45; H 6.73.

β-Glycoside **8**: R_f 0.33 (9:1 benzene–EtOAc); $[\alpha]_D$ 5° (*c* 0.5, $CHCl_3$); NMR ($CDCl_3$): ^1H, δ 3.30–3.91 (m, 14 H), 3.93–4.58 (m, 17 H), 4.59 (d, 1 H, $J_{1,2}$ 7.8 Hz, H-1Gal′), 4.61 (d, 1 H, $J_{1,2}$ 8 Hz, H-1Glc), 4.66 (d, 1 H, $J_{1,2}$ 7.6 Hz, H-1Gal), 4.68–5.17 (m, 10 H), 5.20 (broaden d, 1 H, *J* 10 Hz, $OCH_2CH{=}CH_2$), 5.36 (broaden d, 1 H, *J* 16.9 Hz, $OCH_2CH{=}CH_2$), 6.02 (m, 1 H, $OCH_2CH{=}CH_2$), 7.09–7.42 (m, 50 H, arom); ^{13}C, δ 102.55 (C-1Glc), 103.81 (C-1Gal, C-1Gal′), 116.99 ($OCH_2CH{=}CH_2$), 134.09 ($OCH_2CH{=}CH_2$). Anal. Calcd for $C_{91}H_{96}O_{16}$: C, 75.60; H, 6.69. Found C, 75.51; H 6.55.

Propyl α-D-*galactopyranosyl*-(1→3)-β-D-*galactopyranosyl*-(1→4)-β-D-*glycopyranoside* (**1**).—To a solution of **6** (36 mg, 0.025 mmol) in EtOAc (3 mL) and EtOH (6 mL) Pd–C (10 mg) was added, the mixture was degassed under vacuum with stirring, refilled with H_2, and stirred for 2 days under H_2 at rt. The mixture was filtered through Celite, and the pad was washed thoroughly with distilled water. The filtrate and washings were concentrated and the residue was subjected to gel-filtration (elution with 0.1 M aq AcOH) on a column (V_o = 180 mL) of TSK HW-40 S gel to afford **1** (12 mg, 88%) as a foam: R_f 0.4 (BPHCl); $[\alpha]_D$ 97° (*c* 0.5, water); ^1H NMR (D_2O): the spectrum was identical to that of **2**

(see below), except the absence of two-proton signal at δ 3.31 (CH_2NH_2), and the presence of three-proton triplet at δ 0.91 (OCH_2CH_2-CH_3) and two-proton multiplet at δ 1.62 ($OCH_2CH_2CH_3$); MALDI-TOF-MS: Calcd for $[C_{21}H_{38}O_{16}+Na]^+$: 569.2. Found 569.6.

2-Azidoethyl 2,3,4,6-tetra-O-*benzyl*-α-D-*galactopyranosyl*-(1→3)-*2,4,6-tri*-O-*benzyl*-β-D-*galactopyranosyl*-(1→4)-*2,3,6-tri*-O-*benzyl*-β-D-*glycopyranoside* (**11**).—(a) To a solution of *N*-methyl morpholine *N*-oxide (36 mg, 0.26 mmol) and **6** (322 mg, 0.22 mmol) in acetone (5 mL) and water (1 mL) 0.02 M solution of OsO_4 in *t*-BuOH (0.5 mL) was added, and the mixture was stirred for 20 h at rt. H_2S was then bubbled at 0 °C for 5 min, the black precipitate was filtered off through Celite, the pad was washed thoroughly with acetone. Combined filtrate and washings were concentrated and filtered through a short column of silica gel with 2:3 toluene–acetone as eluent to give 287 mg (87%) of the expected diol as an oil: R_f 0.45 in 2:3 toluene–acetone. It was dissolved in 17 mL of 12:4:1 EtOH–MeOH–water mixture and treated with $NaIO_4$ (80 mg, 0.37 mmol) for 5 h at rt with stirring. The reaction mixture was then diluted with CH_2Cl_2 (100 mL), washed with water, and concentrated to afford the expected aldehyde as an oil: R_f 0.28 in 4:1 toluene–EtOAc. It was dissolved in CH_2Cl_2 (10 mL) and MeOH (20 mL), and $NaBH_4$ (76 mg, 2 mmol) was added portionwise at 0 °C, and stirring was continued 20 h. Satd aq NH_4Cl (10 mL) and CH_2Cl_2 (100 mL) were added, the reaction mixture was washed with water, dried, and concentrated to give crude alcohol **9** (261 mg, 93%, 81% from **6**, R_f 0.3 in 4:1 toluene–EtOAc), which was mesylated at 0 °C with MsCl (0.07 mL, 0.6 mmol) and Et_3N (1 mL) in dry CH_2Cl_2 (5 mL) for 1 h. The reaction mixture was then poured into satd aq $NaHCO_3$ (30 mL) and extracted with CH_2Cl_2 (3 × 50 mL), the combined extracts were washed with water, dried and concentrated. Chromatography (benzene→6:1 benzene–EtOAc) on a column of silica gel (50 g) afforded the expected mesylate **10** (266 mg, 97%) as a colorless oil: R_f 0.57 in 5:1 toluene–EtOAc. It was stirred with NaN_3 (130 mg, 2 mmol) and 18-crown-6 (5 mg, 0.02 mmol) in DMF (3 mL) for 3 days at rt. The mixture was then diluted with EtOAc (100 ml), washed with water and concentrated. Chromatography (9:2 toluene–EtOAc) on a column of silica gel (50 g) gave the expected azide **11** (229 mg, 89%, 70% overall from **6**) as colorless oil: R_f 0.61 in 5:1 toluene–EtOAc; $[\alpha]_D$ 37° (*c* 0.5, $CHCl_3$); NMR ($CDCl_3$): ^1H, the spectrum was identical to that of **3**, except the disappearance of three one-proton signals at δ 5.99 ($OCH_2CH{=}CH_2$), 5.38 ($OCH_2CH{=}CH_2$), 5.22 ($OCH_2CH{=}CH_2$), and the presence of two one-proton multiplets at δ 3.31–3.54 (CH_2N_3); ^{13}C: the spectrum was identical to that of **6**, except the disappearance of the signals at δ 117.13 ($OCH_2CH{=}CH_2$) and 134.22 ($OCH_2CH{=}CH_2$) and the presence of the signal at δ 50.73 (CH_2N_3). Anal. Calcd for $C_{90}H_{95}O_{16}N_3$: C, 73.30; H, 6.49; N, 2.85. Found C, 73.48; H, 6.52; N, 2.76.

(b) Ozone was bubbled through a solution of **6** (100 mg, 0.07 mmol) in dry MeOH (5 mL) and CH_2Cl_2 (2.5 mL) at −70 °C until blue color persisted, the excess was then purged out with Ar until decolorization, and $NaBH_4$ (53 mg, 1.4 mmol) was added with stirring at the same temperature, and reaction mixture was allowed to attain 0 °C in a Dewar flask (ca. 2 h). Another portion of $NaBH_4$ (27 mg, 0.7 mmol) was then added, the mixture was stirred for 0.5 h at rt, and then processed as described above to afford the crude alcohol **9** (96 mg, 95%), which was used for the preparation of **11** without further purification.

Allyl 2,3,4,6-tetra-O-*benzyl*-α-D-*galactopyranosyl*-(1→3)-*2,4,6-tri*-O-*benzoyl*-β-D-*galactopyranosyl*-(1→4)-*2,3,6-tri*-O-*benzoyl*-β-D-*glycopyranoside* (**7**).—A solution of **3** (43 mg, 0.075 mmol) and **5** (50 mg, 0.049 mmol) in dry Et_2O (1 mL) was stirred with freshly activated MS-4Å (150 mg) during 1 h, MeOTf (0.04 mL, 0.37 mmol) was added, and stirring was continued for 20 h at rt. Et_3N (0.4 mL) was added, the reaction was filtered through a pad of Celite, diluted with CH_2Cl_2 (50 mL), washed with 10% aq H_2SO_4, water, satd aq $NaHCO_3$, water, dried and concentrated. Chromatography (benzene→10:1 benzene–EtOAc) of the residue on a column of silica gel (50 g) afforded a single product, α-glycoside **7** (67 mg, 89%) as white foam: R_f 0.36

in 9:1 toluene–EtOAc; $[\alpha]_D$ 25° (*c* 1, $CHCl_3$); NMR ($CDCl_3$): ^1H, see Table 1 for carbohydrate ring protons; δ 4.07 (dd, 1 H, J_{gem} 12, J_{vic} 5 Hz, $OCH_2CH{=}CH_2$), 4.22, 4.25, 4.27 (3 d, 3 H, $PhCH_2$), 4.29 (dd, 1 H, J_{vic} 3 Hz, $OCH_2CH{=}CH_2$), 4.37, 4.38, 4.41, 4.42 (4 d, 4 H, $PhCH_2$), 4.67 (d, 1 H, $PhCH_2$), 5.10 (broaden d, 1 H, *J* 9.7 Hz, $OCH_2CH{=}CH_2$), 5.18 (broaden d, 1 H, *J* 17.2 Hz, $OCH_2CH{=}CH_2$), 5.79 (m, 1 H, $OCH_2CH{=}CH_2$), 6.99–7.72 (m, 38 H, arom), 7.87–8.12 (m, 12 H, ortho-protons of Bz); ^{13}C, δ 61.50, 62, 57 (C-6Glc, C-6Gal), 94.71 (C-1Gal′), 99.67, 101.13 (C-1Gal, C-1Glc), 117.74 ($OCH_2CH{=}CH_2$). Anal. Calcd for $C_{91}H_{84}O_{22}$: C, 71.45; H, 5.54. Found C, 71.42; H, 5.68.

2,4,6-Tri-O-*benzoyl*-β-D-*galactopyranosyl*-(1→4)-*1,2,3,6-tetra*-O-*benzoyl*-α,β-D-*glycopyranose* (**14**).—A solution of **13** (3.54 g, 3.67 mmol, ca. 1.3:1 α/β mixture according to ^1H NMR), triethylorthobenzoate (3.5 mL) and TsOH (35 mg) in dry benzene (20 mL) and CH_2Cl_2 (4 mL) was heated at 60 °C for 2 days in tightly closed flask, then 80% aq AcOH (25 mL) was added, and the biphasic mixture was stirred vigorously for 3 h at rt. The reaction mixture was diluted with CH_2Cl_2 (200 mL), washed with water, satd aq $NaHCO_3$, dried and concentrated. Chromatography (toluene → 3:2 toluene–EtOAc) on a column of silica gel (250 g) afforded heptabenzoate **14** (2.9 g, 74%) as white foam which was ca. 5:1 α/β mixture (^1H NMR): R_f 0.42 (10:1 toluene–MeOH); $[\alpha]_D$ 42° (*c* 1, $CHCl_3$); NMR (data for α anomer, $CDCl_3$): ^1H, δ 4.05 (dd, 1 H, $J_{2,3}$ 9, $J_{3,4}$ 1 Hz, H-3Gal), 4.89 (d, 1 H, $J_{1,2}$ 7.9 Hz, H-1Gal), 5.43 (dd, 1 H, H-2Gal), 5.55 (broaden s, 1 H, H-4Gal), 5.67 (dd, 1 H, $J_{1,2}$ 3.5, $J_{2,3}$ 10.3 Hz, H-2Glc), 6.22 (t, 1 H, $J_{2,3} = J_{3,4}$ 7.6 Hz, H-3Glc), 6.83 (d, 1 H, H-1Glc), 7.12–7.72 (m, 21 H, arom), 7.89–8.13 (m, 14 H, arom); ^{13}C, δ 61.42, 62.01 (C-6Glc, C-6Gal), 89.79 (C-1Glc), 100.71 (C-1Gal). Anal. Calcd for $C_{61}H_{50}O_{18}$: C, 68.41; H, 4.70. Found C, 68.70; H, 4.70.

2-Chloroethyl 3-O-*acetyl*-*2,4,6-tri*-O-*benzoyl*-β-D-*galactopyranosyl*-(1→4)-*2,3,6-tetra*-O-*benzoyl*-β-D-*glycopyranoside* (**17**).—The heptabenzoate **14** (2.79 g, 2.6 mmol) was acetylated with Ac_2O (2.35 mL, 20 mmol) in Py (8 mL) (20 h, rt), MeOH was added, the mixture was coevaporated with toluene, dried in vacuo to give compound **15** (2.89 g, 100%) as white foam: R_f 0.58 in 10:1, toluene–MeOH. To a solution of monoacetate **15** (2.78 g, 2.5 mmol) in dry CH_2Cl_2 (4 ml) a solution of HBr in AcOH (33% w/v, 6 mL) was added at 0 °C. The reaction mixture was kept 1 h at rt, and then poured into crushed ice and extracted rapidly with CH_2Cl_2 (3 × 70 mL). The organic phase was then immediately washed with cold satd aq $NaHCO_3$, dried ($MgSO_4$), and concentrated to give bromide **16** (2.57 g, 96%) as white foam: R_f 0.64 in 10:1 toluene–MeOH; NMR ($CDCl_3$): ^1H, see Table 1 for carbohydrate ring protons; δ 1.82 (s, 3 H,

Table 1
Chemical shifts (δ, ppm) and coupling constants (*J*, Hz) for carbohydrate ring protons in ^1H NMR spectra of compounds **2**, **7**, **16**, **17**, **19** in the solvent specified

Compound (solvent)	Residue	H-1 ($J_{1,2}$)	H-2 ($J_{2,3}$)	H-3 ($J_{3,4}$)	H-4 ($J_{4,5}$)	H-5 ($J_{5,6a}$)	H-6a ($J_{6a,6b}$)	H-6b ($J_{6b,5}$)
2 (D_2O)	Glc	4.58 (8)	3.43 (8.3)	3.72	3.73	3.66 (>1)	4.2 (12.5)	3.88 (5)
	Gal	4.56 (7.8)	3.71	3.82 (2.7)	4.22 (0)	3.77	3.85	3.82
	Gal′	5.18 (3.8)	3.90 (10.3)	3.97 (3.1)	4.05 (0)	4.22 (6.1)	3.78	3.78 (6.1)
7 ($CDCl_3$)	Glc	4.77 (8)	5.50 (9.5)	5.79 (9.5)	4.18 (9.5)	3.84 (0)	4.58 (11.7)	4.50 (4.8)
	Gal	4.65 (7.9)	5.63 (10.1)	3.98 (3.2)	5.64 (0)	3.65 (6.2)	3.21 (8)	3.13 (6.2)
	Gal′	5.08 (2.9)	3.85 (10.1)	3.46 (2.5)	3.21 (0)	3.52 (4.3)	3.79 (11.6)	3.43 (4.3)
16 ($CDCl_3$)	Glc	6.73 (4)	5.26 (9.1)	6.15 (9.1)	4.36 (9.1)	3.83	4.59	4.59
	Gal	4.89 (7.9)	5.59 (9.4)	5.21 (3.5)	5.61 (0)	4.40	3.82	3.72
17 ($CDCl_3$)	Glc	4.80 (7.8)	5.48 (9.6)	5.83 (9.6)	4.28 (9.6)	3.85 (1)	4.65 (12.2)	4.49 (4.4)
	Gal	4.86 (7.9)	5.57 (10.4)	5.22 (3.4)	5.63 (0)	3.84	3.78	3.78
19 ($CDCl_3$)	Glc	4.91 (8.1)	5.51 (9.5)	5.79 (9.5)	4.21 (9.5)	3.88 (1.6)	4.66 (12)	4.58 (4.7)
	Gal	4.89 (8.3)	5.38 (9.9)	3.99 (2)	5.51 (0)	3.68	3.49	3.49

Table 2
Chemical shifts (δ, ppm) for carbohydrate ring carbons in ^{13}C NMR spectra of compounds **2** and **17** in the solvent specified

Compound (solvent)	Residue	C-1	C-2	C-3	C-4	C-5	C-6
2 (D_2O)	Glc	103.19	73.90	75.49	79.71	75.95	61.21
	Gal	104.07	70.77	78.43	66.04	76.27	62.22
	Gal′	96.66	69.41	70.50	70.36	72.04	62.16
17 ($CDCl_3$)	Glc	101.17	71.57	72.75	75.91	73.08	62.21
	Gal	100.96	69.69	70.99	67.37	71.29	60.99

OAc), 7.08–7.65 (m, 18 H, arom), 7.93–8.15 (m, 12 H, arom); ^{13}C, δ 20.44 (CH_3CO), 60.87, 61.39 (C-6Glc, C-6Gal), 86.62 (C-1Glc), 101.04 (C-1Gal). A solution of the bromide **16** (2.5 g, 2.3 mmol) and freshly distilled 2-chloroethanol (3.9 mL, 58.3 mmol) in dry CH_2Cl_2 (20 mL) was stirred under Ar with freshly activated MS-4Å (2 g) for 1 h, then cooled to 0 °C and powdered AgOTf (1.2 g, 4.7 mmol) was added. After stirring for 2 h at 0 °C the reaction was quenched by addition of Et_3N (5 mL), filtered through Celite, diluted with CH_2Cl_2 (200 mL), washed with satd aq $NaHCO_3$, 3 M aq $Na_2S_2O_3$, water, dried and concentrated. Chromatography (toluene → 6:1 toluene–acetone) of the residue on a column of silica gel (250 g) afforded **17** (2.46 g, 98%) as white foam: R_f 0.28 in 40:1 toluene–MeOH (double elution); $[\alpha]_D$ 20° (*c* 1, $CHCl_3$); NMR ($CDCl_3$): ^1H, see Table 1 for carbohydrate ring protons; δ 1.8 (s, 3 H, OAc), 3.51 (m, 2 H, CH_2Cl), 3.75 (m, OCH_2CH_2Cl), 4.02 (m, 1 H, OCH_2CH_2Cl), 7.09–7.69 (m, 18 H, arom), 7.91–8.12 (m, 12 H, arom); ^{13}C, see Table 2 for carbohydrate ring carbons; δ 20.33 (CH_3CO), 42.04 (CH_2Cl), 69.81 (OCH_2CH_2Cl), 164.61, 165.13, 165.20, 165.31, 165.40, 165.69 (6 PhCO), 169.94 (CH_3CO). Anal. Calcd for $C_{58}H_{51}O_{18}Cl$: C, 65.02; H, 4.79; Cl, 3.31. Found C, 65.08; H, 4.78; Cl, 3.30.

*2-Azidoethyl 3-*O*-acetyl-2,4,6-tri-*O*-benzoyl-β-*D*-galactopyranosyl-(1→4)-2,3,6-tetra-*O*-benzoyl-β-*D*-glycopyranoside* (**18**).—A mixture of **17** (2.33 g, 2.17 mmol), NaN_3 (1.4 g, 21.7 mmol) and 18-crown-6 (0.058 g, 0.22 mmol) in amine-free, dry DMF (10 mL) was heated, with stirring for 24 h at 70 °C, then diluted with EtOAc (200 mL), washed with water, dried ($MgSO_4$) and concentrated. Chromatography (toluene → 15:1 toluene–acetone) of the residue on a column of silica gel (200 g) afforded **18** (2.13 g, 91%) as white foam: R_f 0.52 in 9:1 toluene–acetone; $[\alpha]_D$ 23° (*c* 1, $CHCl_3$); NMR ($CDCl_3$): ^1H, the spectrum was identical to that of **17**, except the disappearance of two-proton signal at δ 3.51 (CH_2Cl) and the presence of two one-proton multiplets at δ 3.23 and 3.34 (CH_2N_3); ^{13}C, the spectrum was identical to that of **17**, except the disappearance of the signal at δ 42.04 (CH_2Cl) and the presence of the signal at δ 50.42 (CH_2N_3). Anal. Calcd for $C_{58}H_{51}O_{18}N_3$: C, 64.62; H, 4.77; N, 3.89. Found C, 64.62; H, 4.89; N, 3.71.

*2-Azidoethyl 2,4,6-tri-*O*-benzoyl-β-*D*-galactopyranosyl-(1→4)-2,3,6-tetra-*O*-benzoyl-β-*D*-glycopyranoside* (**19**).—The reagent was prepared by dropwise addition, at 0 °C, of acetyl chloride (2 mL, 28 mmol) to anhydrous MeOH (20 mL). After 10 min, the reagent was added to a solution of compound **18** (2.29 g, 2.14 mmol) in dry CH_2Cl_2 (10 mL). After 5 h at rt the reaction mixture was poured into ice-cold water and extracted with CH_2Cl_2 (200 mL). The organic phase was then washed with satd aq $NaHCO_3$ and water, dried, and concentrated. Chromatography (toluene → 6:1 toluene–acetone) of the residue on a column of silica gel (200 g) afforded **19** (1.88 g, 86%) as white foam: R_f 0.33 in 9:1 toluene–acetone; $[\alpha]_D$ 5° (*c* 1, $CHCl_3$); NMR ($CDCl_3$): ^1H, see Table 1 for carbohydrate ring protons; δ 2.9 (broaden s, 1 H, OH), 3.28 (m, 1 H, CH_2N_3), 3.38 (m, 1 H, CH_2N_3), 3.67 (m, 1 H, $OCH_2CH_2N_3$), 3.99 (m, $OCH_2CH_2N_3$), 7.12–7.73 (m, 18 H, arom), 7.88–8.09 (m, 12 H, arom); ^{13}C, δ 50.53 (CH_2N_3), 61.56, 62.51 (C-6Glc, C-6Gal), 100.56, 101.09 (C-1Glc, C-1Gal). Anal. Calcd for $C_{56}H_{49}O_{17}N_3$: C, 64.92;

H, 4.77; N, 4.06. Found C, 65.13; H, 4.73; N, 4.02.

2-Azidoethyl 2,3,4,6-tetra-O-*benzyl*-α-D-*galactopyranosyl*-(1→3)-*2,4,6-tri*-O-*benzoyl*-β-D-*galactopyranosyl*-(1→4)-*2,3,6-tri*-O-*benzoyl*-β-D-*glycopyranoside* (**20**) *and 2-azidoethyl 2,3,4,6-tetra*-O-*benzyl*-β-D-*galactopyranosyl*-(1→3)-*2,4,6-tri*-O-*benzoyl*-β-D-*galactopyranosyl*-(1→4)-*2,3,6-tri*-O-*benzoyl*-β-D-*glycopyranoside* (**22**).—A solution of **3** (0.42 g, 0.72 mmol) and **19** (0.5 g, 0.48 mmol) in dry Et_2O (10 mL) was stirred with freshly activated MS-4Å (1.5 g) during 1 h, MeOTf (0.4 mL, 3.6 mmol) was added, and stirring was continued for 2 h at rt. Et_3N (2 mL) was added, the reaction mixture was filtered through a pad of Celite, diluted with CH_2Cl_2 (100 mL), washed with 10% aq H_2SO_4, water, satd aq $NaHCO_3$, water, dried and concentrated. Chromatography (toluene→25:1 toluene–acetone) of the residue on a column of silica gel (150 g) afforded (in order of elution) α-glycoside **20** (526 mg, 70%) and β-glycoside **22** (67 mg, 9%) as white foams.

α-Glycoside **20**: R_f 0.27 (20:1, toluene–acetone); $[\alpha]_D$ 35° (*c* 1, $CHCl_3$); NMR ($CDCl_3$): ^{1}H, the spectrum was identical to that of **7**, except the absence of the signals of allyl moiety at δ 4.07 ($OCH_2CH{=}CH_2$), 4.29 ($OCH_2CH{=}CH_2$), 5.10 ($OCH_2CH{=}CH_2$), 5.18 ($OCH_2CH{=}CH_2$), 5.79 ($OCH_2CH{=}CH_2$), and the presence of one-proton multiplets at 3.24 (CH_2N_3), 3.37 (CH_2N_3), 3.65 ($OCH_2CH_2N_3$), 3.95 ($OCH_2CH_2N_3$); ^{13}C, δ 50.39 (CH_2N_3), 61.32, 62.23 (C-6Glc, C-6Gal), 94.49 (C-1Gal′), 101.00 (C-1Gal, C-1Glc). Anal. Calcd $C_{90}H_{83}O_{22}N_3$: C, 69.35; H, 5.37; N, 2.69; Found C, 69.08; H, 5.40; N, 2.37.

β-Glycoside **22**: R_f 0.25 (20:1, toluene–acetone); $[\alpha]_D$ 8° (*c* 1, $CHCl_3$); NMR ($CDCl_3$): ^{1}H, δ 4.69 (d, 1 H, $J_{1,2}$ 7.9 Hz, H-1Gal′) 4.73 (d, 1 H, $J_{1,2}$ 7.8 Hz, H-1Gal), 4.75 (d, 1 H, $J_{1,2}$ 8.2 Hz, H-1Glc), 4.81 (d, 1 H, *J* 12 Hz, $PhCH_2$), 5.50 (t, 1 H, H-2Glc), 5.61–5.77 (m, 3 H, H-2Gal, H-4Gal, H-3Glc), 6.91–7.69 (m, 38 H, arom), 7.78–8.21 (m, 12 H, ortho-protons of Bz); ^{13}C, δ 50.4 (CH_2N_3), 61.99, 62.39 (C-6Glc, C-6Gal), 100.82, 101.00, 103.96 (C-1Gal, C-1Glc, C-1Gal′). Anal. Calcd $C_{90}H_{83}O_{22}N_3$: C, 69.35; H, 5.37; N, 2.69; Found C, 69.14; H, 5.53; N; 2.39.

*2-(*tert*-Butoxycarbonylamino)ethyl* α-D-*galactopyranosyl*-(1→3)-*2,4,6-tri*-O-*benzoyl*-β-D-*galactopyranosyl*-(1→4)-*2,3,6-tri*-O-*benzoyl*-β-D-*glycopyranoside* (**21**).—To a solution of **20** (0.87 g, 0.56 mmol) and Boc_2O (0.3 g, 1.4 mmol) in EtOAc (16 mL) and EtOH (48 mL) was added Pd–C (50 mg), the mixture was degassed under vacuum with stirring, refilled with hydrogen, and stirred for 20 h under H_2 at rt. At this point, TLC (9:1, toluene–acetone) indicated the presence of one major product, 2-(*tert*-butoxycarbonylamino)ethyl 2,3,4,6-tetra-*O*-benzyl-α-D-galactopyranosyl-(1→3)-2,4,6-tri-*O*-benzoyl-β-D-galactopyranosyl-(1→4)-2,3,6-tri-*O*-benzoyl-β-D-glycopyranoside (R_f 0.43). New 50 mg portions of Pd–C were added every 24 h, and after stirring for 3 days at rt the reaction mixture was filtered through Celite, the pad was washed thoroughly with linear gradient from EtOAc to EtOH, and the filtrate and washings were concentrated. Chromatography (CH_2Cl_2→10:1 CH_2Cl_2–MeOH) of the residue on a column of silica gel (100 g) afforded **21** (0.62 g, 86%) as white foam: R_f 0.14 in 30:1 CH_2Cl_2–MeOH; $[\alpha]_D$ 35° (c 1, $CHCl_3$); NMR ($CDCl_3$–CD_3OD, 10:1): ^{1}H, δ 1.25 (s, 9 H, *t*-Bu), 4.08 (dd, 1 H, $J_{2,3}$ 10.1, $J_{3,4}$ 2.9 Hz, H-3Gal), 4.12 (t, 1 H, $J_{3,4} = J_{4,5}$ 9.5 Hz, H-4Glc), 4.53 (m, 2 H, H-6aGlc, H-6bGlc), 4.67(d, 1 H, $J_{1,2}$ 8 Hz, H-1Glc), 4.71 (d, 1 H, $J_{1,2}$ 8.1 Hz, H-1Gal), 5.08 (d, 1 H, $J_{1,2}$ 3.7 Hz, H-1Gal′), 5.41 (m, 2 H, H-2Gal, H-2Glc), 5.61 (d, 1 H, H-4Gal), 5.74 (t, 1 H, $J_{2,3} = J_{3,4}$ 9.5 Hz), 7.11–7.73 (m, 18 H, arom), 7.91–8.12 (m, 12 H, arom); ^{13}C, δ 28.16 (*t*-Bu), 40.14 (CH_2NHBoc), 60.84, 62.29 (C-6Glc, C-6Gal, C-6Gal′), 96.95 (C-1Gal′), 100.88, 101.23 (C-1Glc, C-1Gal). Anal. Calcd for $C_{67}H_{69}O_{24}N$: C, 63.25; H, 5.47; N, 1.1. Found C, 63.23; H, 5.72; N, 1.15.

2-Aminoethyl α-D-*galactopyranosyl*-(1→3)-β-D-*galactopyranosyl*-(1→4)-β-D-*glycopyranoside* (**2**).—(a) To a solution of **21** (0.55 g, 0.43 mmol) in CH_2Cl_2 (10 mL) CF_3CO_2H (5 mL) was added. After 1 h at rt the reaction mixture was coevaporated with toluene (5 × 10 mL) and dried in vacuo. The residue was dissolved in MeOH (30 mL), concd aq NH_3 (ca 25%, 30 mL) was added, and the reaction mixture was heated in tightly closed flask at

50 °C for 24 h, then concentrated, dried in vacuo, dissolved in water, filtered, and concentrated. Gel-filtration (elution with water) of the residue on a column (2.5 × 100 cm) of Sephadex G-10 gel ($V_o = 180$ mL) followed by rechromatography (elution with 0.1 M aq AcOH) of mixed fractions on a column of TSK HW-40S gel (1.5 × 100 cm, $V_o = 60$ mL) afforded **2** (0.23 g, 99%) as amorphous mass: R_f 0.3 (3:2, BPHCl–AMW); $[\alpha]_D$ 47° (*c* 1, water); NMR (D_2O): ^1H, see Table 1 for carbohydrate ring protons; δ 3.31 (t, 2 H, *J* 5 Hz, CH_2NH_2), 3.98 (m, $OCH_2CH_2NH_2$), 4.18 (m, 1 H, $OCH_2CH_2NH_2$); ^{13}C, see Table 2 for carbohydrate ring carbons; δ 40.63 (CH_2NH_2), 67.03 ($OCH_2CH_2NH_2$); MALDI-TOF-MS: Calcd for $[C_{20}H_{37}O_{16}N + Na + H]^+$: 571.2. Found 571.4.

(b) Compound **6** (0.21 g, 0.14 mmol) was subjected to hydrogenolysis in EtOAc (3 mL) and EtOH (9 mL) in the presence of Boc_2O (0.15 g, 0.7 mmol) as described for **20**. After the completion of the reaction, the mixture was filtered through Celite, and the pad was washed thoroughly with MeOH. The filtrate and washings were concentrated, the residue was dissolved in water (20 mL), washed with EtOAc (2 × 10 mL), and then lyophilized to afford **12** (75 mg, 90%): R_f 0.5 (BPHCl). Compound **12** thus obtained (7 mg, 0.01 mmol) was dissolved in CF_3CO_2H (0.5 mL) and, after 0.5 h at rt, concentrated and dried in vacuo. After treatment with Amberlyst A-26 anion exchange resin (OH^- form) in water, the residue was purified by gel-filtration as above to afford **2** (5 mg, 84%), which was identical in all respect to the material, prepared by deprotection of **21**.

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References

1. Cooper, D. K. C.; Good, A. H.; Koren, E.; Oriol, R.; Malcolm, A. J.; Ippolito, R. M.; Neethling, F. A.; Ye, Y.; Romano, E.; Zuhdi, N. *Transplant. Immunol.* **1993**, *1*, 198–205.
2. Galili, U. *Immunol. Today* **1993**, *14*, 480–482.
3. Tsvetkov, D. E.; Cheshev P. E.; Tuzikov, A. B.; Pazynina, G. V.; Bovin, N. V.; Rieben, R.; Nifant'ev, N.E. *Mendeleev Commun.* **1999**, 47–50.
4. Rieben, R.; Bovin, N. V.; Korchagina, E. Y.; Oriol, R.; Nifant'ev, N. E.; Tsvetkov, D. E.; Daha, M. R.; Mohacsi, P. J.; Joziasse, D. H. *Glycobiology* **2000**, *10* (2), 141–148.
5. Fang, J.; Li, J.; Chen, X.; Zhang, Y.; Wang, J.; Guo, Z.; Zhang, W.; Yu, L.; Brew, K.; Wang, P. G. *J. Am. Chem. Soc.* **1998**, *120*, 6635–6638.
6. Zhang, W.; Wang, J.; Li, J.; Yu, L.; Wang, P. G. *J. Carbohydr. Chem.* **1999**, *18* (8), 1009–1017.
7. Wang, J.-Q.; Chen, X.; Zhang, W.; Zacharek, S.; Chen, Y.; Wang, P. G. *J. Am. Chem. Soc.* **1999**, *121*, 8174–8181.
8. Sujino, K.; Malet, C.; Hindsgaul, O.; Palcic, M. M. *Carbohydr. Res.* **1998**, *305*, 483–489.
9. Sarkar, A. K.; Matta, K. L. *Carbohydr. Res.* **1992**, *233*, 245.
10. Singh, S.; Scigelova, M.; Crout, D. H. G. *Chem. Commun.* **1999**, *20*, 2065–2066.
11. Koike, K.; Sugimoto, M.; Sato, S.; Ito, Y.; Nakahara, Y.; Ogawa, T. *Carbohydr. Res.* **1987**, *163*, 189–208.
12. Kornilov, A. V.; Sherman, A. A.; Kononov, L. O.; Shashkov, A. S.; Nifant'ev, N. E. *Carbohydr. Res.* **2000**, *329*, 717–730.
13. Dubber, M.; Lindhorst, T. K. *Carbohydr. Res.* **1998**, *310*, 35–41 and references cited therein.
14. Wilstermann, M.; Kononov, L. O.; Nilsson, U.; Ray, A. K.; Magnusson, G. *J. Am. Chem. Soc.* **1995**, *117*, 4742–4754.
15. Kihlberg, J. O.; Leigh, D. A.; Bundle, D. A. *J. Org. Chem.* **1990**, *55*, 2860–2863.
16. Kononov, L. O.; Kornilov, A. V.; Sherman, A. A.; Zyryanov, E. V.; Zatonsky, G. V.; Shashkov, A. S.; Nifant'ev, N. E. *Bioorgan. Khim.* **1998**, *24*, 608–622.
17. Lonn, H. *J. Carbohydr. Chem.* **1987**, *6* (2), 301–306.
18. Zhu, T.; Boons, G. -J. *J. Chem. Soc., Perkin Trans. 1* **1998**, 857–861.
19. Bundle, D. R.; Gerken, M.; Peters, T. *Carbohydr. Res.* **1988**, *174*, 239–251.
20. Czech, B. P.; Bartsch, R. A. *J. Org. Chem.* **1984**, *49*, 4076–4078 and references cited therein.
21. Baer, H. H.; Abbas, S. A. *Carbohydr. Res.* **1980**, *84*, 53–60.
22. Kochetkov, N. K.; Nifant'ev, N. E.; Backinowsky, L. V. *Tetrahedron* **1987**, *43*, 3109–3121.
23. Byramova, N. E.; Ovchinnikov, M. V.; Backinowsky, L. V.; Kochetkov, N. K. *Carbohydr. Res.* **1983**, *124*, C8–C11.