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Synthesis of the methyl α-glycosides of some isomalto-oligosaccharides specifically deoxygenated at position C-3

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Abstract

Methyl α-isomaltoside and methyl α-isomaltotrioside specifically deoxygenated at position C-3 of various glucopyranosyl units were synthesized by condensation of either 1,6-di-*O*-acetyl-2,4-di-*O*-benzyl-3-deoxy-α,β-D-*ribo*-hexopyranose (**7**) or 1,6-di-*O*-acetyl-2,3,4-tri-*O*-benzyl-α,β-D-glucopyranose [mediated by silver perchlorate and tin(IV) chloride] with suitably blocked derivatives of methyl α-D-glucopyranoside, its 3-deoxy analog (**6**), or methyl 3′-deoxy α-isomaltoside (**10**), respectively. © 1996 Published by Elsevier Science Ltd.

Keywords: Glycosides, methyl; Glycosides, synthesis; Oligosaccharides, α-isomalto-; Sugars, deoxygenated

1. Introduction

To probe for possible H-bonding interactions between ligands and antidextran antibodies [1,2], we have already prepared isomalto di- and tri-saccharides that are deoxygenated at locations 2 and 4 of the glucosyl residues [3–6]. Finally, we herein present a general procedure for preparing the methyl glycosides of α-isomalto-oligosaccharides specifically deoxygenated at C-3 of various glucopyranosyl units.

2. Results and discussion

The glycosidation procedure published by Mukaiyama and co-workers [7–10], using 1-*O*-acetyl glycosyl donors with a nonparticipating group at position C-2, trimethylsily-

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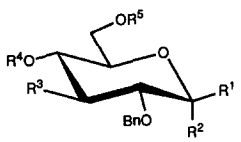
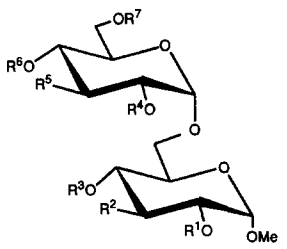
lated glycosyl acceptors, and a combination of tin(IV) chloride and silver perchlorate as promotors, is very effective and stereoselective for 1,2-*cis* glycoside formation. We decided to use this method for the synthesis of methyl α-isomalto-oligosaccharides deoxygenated at position C-3. As a glycosyl donor we used 1,6-di-*O*-acetyl-2,4-di-*O*-benzyl-3-deoxy-α,β-D-*ribo*-hexopyranose (**7**). Methyl 2-*O*-benzyl-4,6-*O*-benzylidene-3-deoxy-α-D-*ribo*-hexopyranoside [4] was hydrolyzed with HCl (5%) in methanol offering compound **1** [11]. Derivative **1** was benzylated giving methyl 2,4,6-tri-*O*-benzyl-3-deoxy-α-D-*ribo*-hexopyranoside [12], which, after acetolysis, yielded glycosyl donor **7** (89.5%) [13]. The glycosyl acceptor **6** was prepared from compound **1** which was selectively acetylated at position O-6 using acetyl chloride and *sym*-collidine [14] (−40 °C, 40 min), giving **3** (92%), which, after benzoylation, afforded methyl 6-*O*-acetyl-4-*O*-benzoyl-2-*O*-benzyl-3-deoxy-α-D-*ribo*-hexopyranoside (**4**). Derivative **4** was deacetylated with HCl (5%) in methanol to produce compound **5** (94%) and then silylated with trimethylchlorosilane to afford the glycosyl acceptor (**6**).



	R1	R2	R3	R4	R5
1	H	OMe	H	H	H
2	H	OMe	H	Bn	Bn
3	H	OMe	H	H	Ac
4	H	OMe	H	Bz	Ac
5	H	OMe	H	Bz	H
6	H	OMe	H	Bz	TMS
7	OAc, H		H	Bn	Ac

Methyl 2,3,4-tri-*O*-benzyl-6-*O*-trimethylsilyl-α-D-glucopyranoside [10] was coupled (0 °C, 24 h) with di-*O*-acetyl derivative **7** [mediated with tin(IV) chloride and silver perchlorate] affording disaccharide **8** (89.5%). After deacetylation with sodium methoxide in toluene and methanol, compound **9** was isolated and debenzylated to give disaccharide **11** in quantitative yield. Derivative **9** was also silylated with trimethylchlorosilane (2.5 h, room temperature), giving nucleophile **10** (92.3%). Condensation [tin(IV) chloride, silver perchlorate, 0 °C, 24 h] of derivative **6** with 1,6-di-*O*-acetyl-2,3,4-tri-*O*-benzyl-α,β-D-glucopyranose [15] gave disaccharide **12** (89.5%). Deacetylation of compound **12** with sodium methoxide in toluene and methanol (room temperature, 20 min) afforded partially *O*-deacylated disaccharide **13** (80%), but after 5 h the fully *O*-deacylated derivative **14** (91%) was isolated. Compound **13** was also silylated with trimethylchlorosilane (room temperature, 20 h) to give nucleophile **15**. Compound **14** was debenzylated to give the unsubstituted product **16** in quantitative yield. Nucleophile **6** was condensed with donor **7** (0 °C, 24 h) in the presence of tin(IV) chloride and silver perchlorate to provide disaccharide **17** (87%). When compound **17** was *O*-deacyl-

ated with sodium methoxide in toluene and methanol for 2 h at room temperature, the partially *O*-deacylated product **18** (79%) was isolated. After prolonging that treatment to 16 h, only fully *O*-deacylated product **19** (94%) was found. Debenzylation of derivative **19** resulted in the formation of methyl 3-deoxy-α-D-*ribo*-hexopyranosyl-(1 → 6)-3-deoxy-α-D-*ribo*-hexopyranoside (**20**).



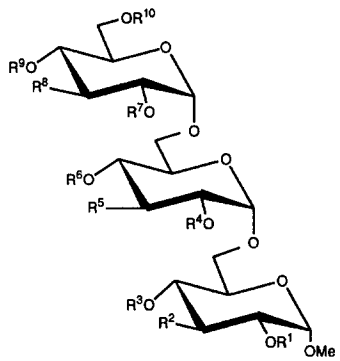
	R1	R2	R3	R4	R5	R6	R7
8	Bn	OBn	Bn	Bn	H	Bn	Ac
9	Bn	OBn	Bn	Bn	H	Bn	H
10	Bn	OBn	Bn	Bn	H	Bn	TMS
11	H	OH	H	H	H	H	H
12	Bn	H	Bz	Bn	OBn	Bn	Ac
13	Bn	H	Bz	Bn	OBn	Bn	H
14	Bn	H	H	Bn	OBn	Bn	H
15	Bn	H	Bz	Bn	OBn	Bn	TMS
16	H	H	H	H	OH	H	H
17	Bn	H	Bz	Bn	H	Bz	Ac
18	Bn	H	Bz	Bn	H	Bz	H
19	Bn	H	H	Bn	H	H	H
20	H	H	H	H	H	H	H

Nucleophile **15** was condensed with 1,6-di-*O*-acetyl-2,3,4-tri-*O*-benzyl-α,β-D-glucopyranose [15] [tin(IV) chloride, silver perchlorate, 0 °C, 20 h] to yield trisaccharide **21** (88%). Deacylation of **21** with sodium methoxide in toluene and methanol at room temperature gave either **22** (81% after 1.5 h) or **23** (90% after 24 h). After debenzylation of **23**, the target methyl α-D-glucopyranosyl-(1 → 6)-α-D-glucopyranosyl-(1 → 6)-3-deoxy-α-D-*ribo*-hexopyranoside (**24**) [4] was isolated in quantitative yield.

Our results on deacylation of saccharides **12**, **17**, and **21** show that Zemplén deacylation can be used to selectively remove the acyl group from position 6 when there is another *O*-acyl function in position 4 while position 3 is deoxygenated. This observation — that an *O*-acyl group at position 4 of a carbohydrate moiety is also more stable to the condition of Zemplén *O*-deacylation than the one in position 6 when positions 2 and 3 are, respectively, *O*-benzylated and deoxygenated — can be added to those already published [6,16].

Condensation (0 °C, 19 h) of nucleophile **10** with 1,6-di-*O*-acetyl-2,3,4-tri-*O*-benzyl-α,β-D-glucopyranose [15] in the presence of tin(IV) chloride and silver perchlorate

afforded derivative **25** (89%), which was subsequently deacetylated (sodium methoxide, toluene, methanol) to give **26** (92%) and fully deblocked trisaccharide **27** in quantitative yield after debenzylation. Methyl 2,3,4-tri-*O*-benzyl-6-*O*-trimethylsilyl-α-D-glucopyranosyl-(1 → 6)-2,3,4-tri-*O*-benzyl-α-D-glucopyranoside [9] was condensed with **7** (0 °C, 24 h) in the presence of tin(IV) chloride and silver perchlorate to provide **28** (84%). Deacetylation with sodium methoxide in toluene and methanol yielded compound **29** (92%), which was debenzylated to give deprotected trisaccharide **30** (95%).



	R^1	R^2	R^3	R^4	R^5	R^6	R^7	R^8	R^9	R^{10}
21	Bn	H	Bz	Bn	OBn	Bn	Bn	OBn	Bn	Ac
22	Bn	H	Bz	Bn	OBn	Bn	Bn	OBn	Bn	H
23	Bn	H	H	Bn	OBn	Bn	Bn	OBn	Bn	H
24	H	H	H	H	OH	H	H	OH	H	H
25	Bn	OBn	Bn	Bn	H	Bn	Bn	OBn	Bn	Ac
26	Bn	OBn	Bn	Bn	H	Bn	Bn	OBn	Bn	H
27	H	OH	H	H	H	H	H	OH	H	H
28	Bn	OBn	Bn	Bn	OBn	Bn	Bn	H	Bn	Ac
29	Bn	OBn	Bn	Bn	OBn	Bn	Bn	H	Bn	H
30	H	OH	H	H	OH	H	H	H	H	H

The structures of all compounds were confirmed by NMR spectroscopy.

3. Experimental

General methods.—Optical rotations were measured at 25 °C with a Perkin–Elmer automatic polarimeter, Model 241 MC. All reactions were monitored by thin-layer chromatography (TLC) on precoated slides of Silica Gel GF_{254} (Analtech). Detection was effected by charring with 5% sulfuric acid in ethanol or, when applicable, with UV

light. Preparative chromatography was performed by elution from columns of Silica Gel-60 (E. Merck, No. 9385). ^{1}H and ^{13}C NMR spectra were measured at ambient temperature using a Varian FX 300 or Varian Gemini spectrometer, operating at 300 MHz for protons and 75 MHz for ^{13}C. Chemical shifts recorded for solutions in $CDCl_3$ and D_2O were measured, respectively, from internal Me_4Si and methanol (δ_C 49.0). Proton signal assignments were made by COSY or homonuclear decoupling experiments. The nonequivalent geminal proton resonating at a lower field is denoted Ha and the one resonating at a higher field is denoted Hb. Cumulative runs of ^{1}H NMR spectra (minimally 128) failed to show any extraneous peaks, thus indicating purity. Carbon signal assignments were based on heteronuclear shift-correlated 2D experiments (HETCOR). Chemical-ionization mass spectra (CIMS), using ammonia as the reactive gas, were obtained with a Finnigan 1015 D spectrometer. The fast-atom bombardment mass spectra (FABMS) were recorded on a JEOL SX102 instrument with Xe as the bombarding gas and "magic-bullet" as the matrix. Reactions requiring anhydrous conditions were performed under dry nitrogen using common laboratory glassware, and reagents and solvents were handled with gas-tight syringes. Solutions in organic solvents were dried with anhydrous sodium sulfate and concentrated at 2 kPa and 40 °C.

For the glycosidation reaction, a solution of tin(IV) chloride (M in heptane) was added to silver perchlorate suspended in ether, and the mixture was shielded from light and stirred at room temperature. After 1 h, the mixture was cooled to 0 °C, and an ethereal solution of the appropriate aldosyl 1-acetate, together with the primary *O*-trimethylsilyl derivative selected, were added. When starting material was no longer detected (TLC), the mixture was extracted with satd aq sodium bicarbonate and water, dried with sodium sulfate, concentrated and purified on a column of silica gel.

For trimethylsilylation, suitably protected samples were dissolved in anhydrous dichloromethane, and imidazole was added. The reaction mixture was cooled to 0–5 °C and trimethylchlorosilane was added dropwise. When starting material was no longer detected (TLC), the mixture was filtered, the filtrate was extracted with satd aq sodium bicarbonate, water, dried, concentrated, and purified on a column of silica gel.

For deacylations, samples were dissolved in toluene and anhydrous methanol. Sodium methoxide in methanol (M) was added, and the reaction mixture was stirred at room temperature. When starting material was no longer detected (TLC), the mixture was neutralized with Amberlite IR 120 (H^+), filtered, concentrated, and purified on a column of silica gel.

For debenzylations, samples were dissolved in 95% ethanol, and Pd–C (5%) suspended in 95% ethanol was added. The reaction mixture was stirred under hydrogen at room temperature until starting material was no longer detected (TLC). The mixture was filtered through Celite (caution: fire hazard!), and the filtrate was concentrated and purified on a column of silica gel.

*Methyl 2-O-benzyl-3-deoxy-α-*D-ribo-*hexopyranoside* (**1**).—Methyl 4,6-*O*-benzylidene-2-*O*-benzyl-3-deoxy-α-D-*ribo*-hexopyranoside [4] (3.1 g, 8.7 mmol) was dissolved in 5% HCl (31 mL) in methanol. The mixture was stirred for 20 min at the end of which time no starting was detected (TLC, 4:1 toluene–acetone). After neutralization with Amberlite IR 400 (OH^-) and concentration, the residue was purified on silica gel (2.5:1 toluene–acetone) giving 2.1 g of compound **1** [11] (91%). ^{1}H NMR ($CDCl_3$): δ 4.57 (d,

1 H, $J_{1,2}$ 3 Hz, H-1), 4.51 (dd, 2 H, J_{gem} 12.4 Hz, CH_2Ph), 3.69 (m, 2 H, H-6a, H-6b), 3.50–3.38 (m, 3 H, H-5, H-4, H-2), 3.33 (s, 3 H, OCH_3), 2.95 (br s, 2 H, OH), 2.13–2.08 (m, 1 H, H-3a), 1.84–1.73 (m, 1 H, H-3b); ^{13}C NMR ($CDCl_3$): δ 97.97 (C-1), 73.55 (C-2), 71.99 (C-5), 70.88 (CH_2Ph), 65.51 (C-4), 62.11 (C-6), 54.81 (OCH_3), 32.86 (C-3); CIMS: *m/z* 328 ($[M + NH_4]^+$).

*Methyl 6-O-acetyl-2-O-benzyl-3-deoxy-α-*D-ribo*-hexopyranoside* (**3**).—Derivative **1** (0.1 g, 0.37 mmol) was dissolved in *sym*-collidine (1.5 mL), cooled to −40 °C, and acetyl chloride (0.026 mL) was added dropwise. After 40 min no starting material could be detected (TLC, 4:1 toluene–acetone). The mixture was evaporated with toluene, dissolved in CH_2Cl_2, extracted with satd aq $NaHCO_3$, water, dried with Na_2SO_4, concentrated and purified (silica gel, 5:1 toluene–acetone) offering 0.11 g of compound **3** (91.7%). ^1H NMR ($CDCl_3$): δ 7.83–7.23 (m, 5 H, Ph), 5.20 (d, 1 H, $J_{1,2}$ 3 Hz, H-1), 5.10 (dd, 2 H, J_{gem} 12.6 Hz, CH_2Ph), 4.87 (d, 2 H, H-6a, H-6b), 4.26–4.21 (m, 1 H, H-5), 4.14–4.01 (m, 2 H, H-2, H-4), 3.93 (s, 3 H, OCH_3), 2.97–2.47 (m, 5 H, H-3a, H-3b, $COCH_3$); ^{13}C NMR ($CDCl_3$): δ 170.02 ($COCH_3$), 96.42 (C-1), 73.25 (C-2), 70.35 (2 C) (CH_2Ph, C-5), 63.82 (C-4), 63.21 (C-6), 53.95 (OCH_3), 33.13 (C-3), 23.39 ($COCH_3$); CIMS: *m/z* 328 ($[M + NH_4]^+$).

*Methyl 6-O-acetyl-4-O-benzoyl-2-O-benzyl-3-deoxy-α-*D-ribo*-hexopyranoside* (**4**).—Derivative **3** (1 g, 2.4 mmol) was dissolved in pyridine (30 mL), and benzoyl chloride (0.35 mL, 3 mmol) was added. The reaction mixture was stirred at room temperature overnight, after which time no starting material could be detected. Toluene was added, the reaction mixture was concentrated, and the residue was dissolved in dichloromethane and extracted with satd aq sodium bicarbonate, water, dried with sodium sulfate, and purified on a column of silica gel (7:1 toluene–acetone) giving 1.25 g (93.3%) of **4**: $[\alpha]_D$ +67.4° (*c* 0.433, $CHCl_3$); ^1H NMR ($CDCl_3$): δ 7.94–7.18 (m, 5 H, Ph), 4.91 (m, 1 H, H-4), 4.64–4.49 (m, 3 H, H-1, CH_2Ph), 4.13 (d, 2 H, H-6a, H-6b), 3.84 (m, 1 H, H-5), 3.60 (m, 1 H, H-2), 3.40 (s, 3 H, OCH_3), 2.40 (m, 1 H, H-3a), 1.95 (br s, 4 H, H-3b, $COCH_3$); ^{13}C NMR ($CDCl_3$): δ 170.74 ($COCH_3$), 165.32 (*C*OPh), 97.36 (C-1), 72.95 (C-2), 71.18 (CH_2Ph), 67.81, 67.16 (C-4, C-5), 62.93 (C-6), 55.16 (OCH_3), 29.80 (C-3), 20.71 ($COCH_3$); CIMS: *m/z* 432 ($[M + NH_4]^+$). Anal. Calcd for $C_{23}H_{26}O_7$: C, 66.65; H, 6.32. Found: C, 66.46; H, 6.27.

*Methyl 4-O-benzoyl-2-O-benzyl-3-deoxy-α-*D-ribo*-hexopyranoside* (**5**).—Derivative **4** (2 g, 4.8 mmol) was dissolved in toluene (60 mL) and HCl in methanol (5%, 16 mL) was added. The mixture was stirred for 2 h at room temperature, then showing the absence of starting material (TLC, 6:1 toluene–acetone). Purification on a column of silica gel (7:1 toluene–acetone) gave **5** (1.7 g, 94.4%): $[\alpha]_D$ +33.1° (*c* 1.337, $CHCl_3$); ^1H NMR ($CDCl_3$): δ 7.96–7.08 (m, 10 H, 2 Ph), 4.95 (m, 1 H, $J_{3a,4}$ 4.9, $J_{3b,4}$ 11.3, $J_{4,5}$ 11.3 Hz, H-4), 4.65 (d, 1 H, $J_{1,2}$ 3.3 Hz, H-1), 4.53 (d, 2 H, J_{gem} 12.5 Hz, CH_2Ph), 3.75–3.71 (m, 1 H, H-5), 3.64–3.53 (m, 3 H, H-6a, H-6b, H-2), 3.39 (s, 3 H, OCH_3), 2.38–2.31 (m, 1 H, H-3a), 2.10–1.98 (m, 1 H, H-3b); ^{13}C NMR ($CDCl_3$): δ 97.26 (C-1), 73.10 (C-2), 70.10 (C-5), 71.11 (CH_2Ph), 70.10 (C-5), 66.79 (C-4), 61.33 (C-6), 55.08 (OCH_3), 29.62 (C-3); CIMS: *m/z* 390 ($[M + NH_4]^+$).

*Methyl 4-O-benzoyl-2-benzyl-3-deoxy-6-O-trimethylsilyl-α-*D-ribo*-hexopyranoside* (**6**).—Compound **5** (1.8 g) was silylated as described in the General methods section, using CH_2Cl_2 (80 mL), imidazole (0.51 g, 5.7 mmol), and trimethylchlorosilane (0.72

mL, 5.7 mmol). The mixture was stirred overnight (monitored by TLC, 6:1 toluene–acetone). After work-up and purification by silica gel column chromatography, 2 g of derivative **6** was obtained (93%): $[\alpha]_D$ +49.3° (*c* 1.07, $CHCl_3$); ^1H NMR ($CDCl_3$): δ 7.95–7.11 (m, 5 H, Ph), 4.91 (m, 1 H, H-4), 4.66 (d, 1 H, $J_{1,2}$ 3 Hz, H-1), 4.57 (dd, 2 H, J_{gem} 12.2 Hz, CH_2Ph), 3.79 (m, 1 H, H-5), 3.65–3.54 (m, 3 H, H-6a, H-6b, H-2), 3.39 (s, 3 H, OCH_3), 2.41 (m, 1 H, H-3a), 1.92 (m, 1 H, H-3b), −0.25 [s, 9 H, Si(CH_3)$_3$]; ^{13}C NMR ($CDCl_3$): δ 97.36 (C-1), 73.17 (C-2), 71.14 (*C*H_2Ph), 70.41 (C-5), 67.18 (C-4), 61.66 (C-6), 55.04 (O*C*H_3), 29.80 (C-3), −0.64 [Si(*C*H_3)$_3$]; CIMS: *m/z* 462 ([M + NH_4]$^+$).

*1,6-Di-*O*-acetyl-2,3-di-*O*-benzyl-3-deoxy-α,β-*D-ribo*-hexopyranose* (**7**).—Methyl glycoside **2** (0.1 g, 0.22 mmol) was dissolved in Ac_2O (1 mL), and H_2SO_4 (0.5%) in Ac_2O (0.12 mL) was added. The mixture was stirred at room temperature for 30 min, when the reaction was complete (TLC, 5:1 toluene–EtOAc). Saturated aq $NaHCO_3$ was added, and the mixture was vigorously stirred for 30 min, then extracted with CH_2Cl_2 (3 times). The organic layer was washed with water, dried, and concentrated, and the residue was purified on a column of silica gel (7:1 toluene–EtOAc) giving compound **7** (0.085 g, 89.5%) [13]: $[\alpha]_D$ +85.2° (*c* 0.725, $CHCl_3$); α:β = 2.2:1; CIMS: *m/z* 446 ([M + NH_4]$^+$).

*Methyl 6-*O*-acetyl-2,4-di-*O*-benzyl-3-deoxy-α-*D-ribo*-hexopyranosyl-(1 → 6)-2,3,4-tri-*O*-benzyl-α-*D*-glucopyranoside* (**8**).—Disaccharide **8** was prepared as described under General methods, using a solution of M tin(IV) chloride in heptane (0.117 mL), silver perchlorate (0.0234 g, 0.117 mmol), acetate **7** (1 g, 2.3 mmol), and methyl 2,3,4-tri-*O*-benzyl-6-*O*-trimethylsilyl-α-D-glucopyranoside [9] (1.5 g, 2.8 mmol). After 24 h the reaction was completed (TLC, 4:1 toluene–EtOAc). Purification on a column of silica gel (4:1 toluene–EtOAc) gave **8** (1.7 g, 89.5%): $[\alpha]_D$ +77.5° (*c* 1.058, $CHCl_3$); ^1H NMR ($CDCl_3$): δ 7.31–7.25 (m, 25 H, 5 Ph), 4.97–4.51 (m, 11 H, H-1, 5 CH_2Ph), 4.93 (br d, 1 H, $J_{1',2'}$ 2.7 Hz, H-1), 4.56 (d, 1 H, $J_{1,2}$ 3.6 Hz, H-1), 4.20 (br d, 2 H, H-6'a, H-6'b), 3.98 (br dd, 1 H, H-3), 3.86–3.37 (m, 8 H, H-6a, H-5, H-6b, H-4', H-4, H-2', H-5', H-2), 3.34 (s, 3 H, OCH_3), 2.34–2.31 (m, 1 H, H-3'a), 1.88 (m, 1 H, H-3'b); ^{13}C NMR ($CDCl_3$): δ 170.85 (*C*OCH_3), 97.91, 95.99 (C-1, C-1'), 82.10 (C-3), 80.04 (C-2), 77.85 (C-4), 75.62, 75.03 (*C*H_2Ph), 73.54 (C-2'), 73.32 (*C*H_2Ph), 71.36, 70.51 (C-5, C-5'), 70.29 (*C*H_2Ph), 69.16 (C-4') 65.82 (C-6), 63.33 (C-6'), 55.10 (O*C*H_3), 29.88 (C-3'), 20.80 (CO*C*H_3); CIMS: *m/z* 850 ([M + NH_4]$^+$). Anal. Calcd for $C_{50}H_{56}O_{11}$: C, 72.10; H, 6.78. Found: C, 72.02; H, 6.74.

*Methyl 2,4-di-*O*-benzyl-3-deoxy-α-*D-ribo*-hexopyranosyl-(1 → 6)-2,3,4-tri-*O*-benzyl-α-*D*-glucopyranoside* (**9**).—Disaccharide **8** (1.3 g, 1.56 mmol) was deacetylated as described under General methods, using toluene (50 mL), anhyd MeOH (50 mL), and NaOMe (M, 0.1 mL). The mixture was stirred for 8 h (monitored by TLC, 6:1 toluene–acetone). After work-up and column chromatography on silica gel (5:1 toluene–acetone) 1.15 g of compound **9** was obtained (93.5%): $[\alpha]_D$ +81° (*c* 1.085, $CHCl_3$); ^1H NMR ($CDCl_3$): δ 7.29–7.21 (m, 25 H, 5 Ph), 4.95–4.37 (m, 12 H, H-1, H-1', 5 CH_2Ph), 3.97 (br dd, 1 H, H-3), 3.80 (dd, 1 H, H-6a), 3.73–3.62 (m, 8 H, H-4', H-6b, H-5, H-4, H-6'a, H-2, H-5', H-6'b), 3.42 (br dd, 1 H, H-2'), 3.30 (s, 3 H, OCH_3), 2.29 (m, 1 H, H-3'a), 1.88 (m, 1 H, H-3'b); ^{13}C NMR ($CDCl_3$): δ 97.45, 95.77 (C-1, C-1'), 81.84 (C-3), 79.86 (C-2), 77.56 (C-4), 75.38, 74.80 (*C*H_2Ph), 73.63 (C-2'), 73.11

(CH_2Ph), 71.90, 71.06 (C-5, C-5′), 70.39, 70.30 (CH_2Ph), 70.13 (C-4′), 65.53 (C-6), 61.82 (C-6′), 54.90 (OCH_3), 29.69 (C-3). CIMS: m/z 808 ($[M + NH_4]^+$). Anal. Calcd for $C_{48}H_{54}O_{10}$: C, 72.89; H, 6.88. Found: C, 72.96; H, 6.87.

*Methyl 2,3-di-*O*-benzyl-3-deoxy-6-*O*-trimethylsilyl-α-*D*-ribo-hexopyranosyl-(1 → 6)-2,3,4-tri-*O*-benzyl-α-*D*-glucopyranoside* (**10**).—Disaccharide **9** (0.6 g, 0.76 mmol) was silylated as described under General methods using CH_2Cl_2 (40 mL), imidazole (0.12 g, 1.76 mmol), trimethylchlorosilane (0.12 mL, 0.94 mmol). After 2.5 h, no starting material could be detected (TLC, 6:1 toluene–acetone). Purification on a column of silica gel (7:1 toluene–acetone) gave **10** (0.6 g, 92.3%): $[\alpha]_D$ +66.6° (*c* 1.08, $CHCl_3$); ^{1}H NMR ($CDCl_3$): δ 7.30–7.21 (m, 25 H, 5 Ph), 4.99–4.57 (m, 10 H, 5 CH_2Ph), 4.92 (d, 1 H, $J_{1',2'}$ 3.4 Hz, H-1′), 4.53 (d, 1 H, $J_{1,2}$ 4 Hz, H-1), 3.97 (br dd, 1 H, H-3), 3.87 (dd, 1 H, H-6a), 3.79–3.40 (m, 7 H, H-4′, H-6′b, H-4, H-6b, H-5, H-5′, H-2′), 3.42 (br dd, 1 H, $J_{2',3'}$ 9.7 Hz, H-2′), 3.33 (s, 3 H, OCH_3), 2.29 (m, 1 H, H-3′a), 1.89 (m, 1 H, H-3′b), 0.07 [s, 9 H, Si(CH_3)$_3$]; ^{13}C NMR ($CDCl_3$): δ 97.87, 96.03 (C-1, C-1′), 82.08 (C-3), 80.04, (C-2), 77.83 (C-4), 75.54, 74.97 (CH_2Ph), 73.76 (C-2′), 73.30 (CH_2Ph), 71.76, 71.32 (C-5, C-5′), 70.44, 70.36 (CH_2Ph), 70.30 (C-4′), 65.58, (C-6), 61.43 (C-6′), 55.00 (OCH_3), 30.06 (C-3′), −0.44 [Si(CH_3)$_3$]. CIMS: m/z 880 ($[M + NH_4]^+$).

*Methyl 3-deoxy-α-*D*-ribo-hexopyranosyl-(1 → 6)-α-*D*-glucopyranoside* (**11**).—Disaccharide **10** (0.1 g, 0.14 mmol) was debenzylated as described under General methods for 20 h at room temperature (monitored by TLC, 2:1:1 2-propanol–water–EtOAc) filtrated, and concentrated. The product was purified on column of silica gel offering 0.04 g of **11**. Neither the ^{1}H nor ^{13}C NMR spectrum revealed signals that would indicate the presence of an aromatic residue. Compound **11** had $[\alpha]_D$ +134.5° (*c* 1.061, H_2O); ^{1}H NMR (D_2O): δ 4.74 (d, 1 H, $J_{1',2'}$ 3.4 Hz, H-1′), 4.71 (d, 1 H, $J_{1,2}$ 3.7 Hz, H-1), 3.90 (dd, 1 H, $J_{5,6a}$ 4.2, $J_{6a,6b}$ 11 Hz, H-6a), 3.74–3.40 (m, 10 H, H-5, H-2′, H-6′a, H-6b, H-3, H-5, H-4′, H-2, H-6′b, H-4), 3.32 (s, 3 H, OCH_3), 2.08–2.03 (m, 1 H, H-3a), 1.73–1.62 (m, 1 H, H-3b); ^{13}C NMR (D_2O): δ 99.38 (C-1), 96.74 (C-1′), 73.39 (C-3), 72.56 (C-2′), 71.18 (C-2), 70.21 (C-5), 69.47 (C-4), 66.59 (C-4′), 65.28 (C-6), 64.11 (C-5′), 60.52 (C-6′), 55.17 (OCH_3), 34.40 (C-3′). CIMS: m/z 358 ($[M + NH_4]^+$).

*Methyl 6-*O*-acetyl-2,3,4-tri-*O*-benzyl-α-*D*-glucopyranosyl-(1 → 6)-4-*O*-benzoyl-2-*O*-benzyl-3-deoxy-α-*D*-ribo-hexopyranoside* (**12**).—This disaccharide was prepared as described under General methods, using a heptane solution of tin(IV) chloride (M, 0.113 mL), silver perchlorate (0.023 g, 0.113 mmol), 1,6-di-*O*-acetyl-2,3,4-tri-*O*-benzyl-α,β-D-glucopyranose [15] (1.44 g, 2.4 mmol), and methyl 4-*O*-benzoyl-2-di-*O*-benzyl-6-*O*-trimethylsilyl-3-*O*-deoxy-α-D-*ribo*-hexopyranoside (**6**) (1 g, 2.25 mmol). After 24 h the reaction was completed (TLC, 3:1 heptane–EtOAc). Purification on a column of silica gel (4:1 heptane–EtOAc) gave **12** (1.7 g, 89.5%): $[\alpha]_D$ +77° (*c* 1.15, $CHCl_3$); ^{1}H NMR ($CDCl_3$): δ 7.96–7.16 (m, 25 H, 5 Ph), 4.96 (m, 1 H, H-4), 4.89–4.40 (m, 8 H, 4 CH_2Ph), 4.65 (d, 1 H, $J_{1,2}$ 3.7 Hz, H-1), 4.52 (d, 1 H, $J_{1',2'}$ 4 Hz, H-1′), 4.04–4.00 (m, 3 H, H-6′a, H-6′b, H-5), 3.90 (br dd, 1 H, H-3′), 3.81 (m, 1 H, H-5′), 3.64 (dd, 1 H, $J_{5,6a}$ 6.2, $J_{6a,6b}$ 11 Hz, H-6a), 3.53–3.44 (m, 2 H, H-2, H-6b), 3.42–3.40 (m, 2 H, H-4′, H-6b), 3.40 (s, 3 H, OCH_3), 2.22 (m, 1 H, H-3a), 1.93 (m, 1 H, H-3b), 1.90 (s, 3 H, COCH_3); ^{13}C NMR ($CDCl_3$): δ 170.65 ($COCH_3$), 165.21 (*C*OPh), 97.06, 96.76 (C-1, C-1′), 81.59 (C-3′), 79.87 (C-2′), 77.02 (C-4′), 75.51, 74.58 (CH_2Ph), 73.12 (C-2), 72.78, 71.02 (CH_2Ph), 68.89 (C-5), 68.49 (C-5′), 67.36 (C-4), 66.59 (C-6), 62.81

(C-6′), 55.12 (OCH_3), 29.91 (C-3), 20.68 ($COCH_3$). CIMS: m/z 864 ($[M + NH_4]^+$). Anal. Calcd for $C_{50}H_{54}O_{12}$: C, 70.91; H, 6.43. Found: C, 70.89; H, 6.46.

*Methyl 2,3,4-tri-*O*-benzyl-α-*D*-glucopyranosyl-(1 → 6)-4-*O*-benzoyl-2-*O*-benzyl-3-deoxy-α-*D*-ribo-hexopyranoside* (**13**).—Disaccharide **12** (0.2 g, 0.24 mmol) was deacetylated as described under General methods, using toluene (15 mL), anhyd MeOH (15 mL), and NaOMe (M, 0.1 mL). When only traces of starting material could be detected (20 min; TLC, 6:1 toluene–acetone), the mixture was purified on a column of silica gel (4:1 toluene–acetone) giving derivative **13** (0.15 g, 80%): $[\alpha]_D$ +70.2° (*c* 2.07, $CHCl_3$); ^{1}H NMR ($CDCl_3$): δ 7.97–7.11 (m, 25 H, 4 Ph), 5.03–4.94 (m, 1 H, H-4), 4.89–4.40 (m, 10 H, H-1, H-1′, 4 CH_2Ph), 4.04–3.99 (m, 1 H, H-5), 4.39–3.88 (m, 1 H, H-3′), 3.68–3.63 (m, 2 H, H-5′, H-6a), 3.55–3.37 (m, 6 H, H-2, H-2′, H-4′, H-6′b, H-6a), 3.41 (s, 3 H, OCH_3), 2.45–2.28 (m, 1 H, H-3a), 1.99–1.91 (m, 1 H, H-3b); ^{13}C NMR ($CDCl_3$): δ 165.02 (*C*OPh), 96.88 (2 C) (C-1, C-1′), 81.26 (C-3′), 79.78 (C-2′), 77.01 (C-4′), 75.21, 74.43 (*C*H_2Ph), 72.97 (C-2), 72.60, 70.83 (*C*H_2Ph), 70.57 (C-5′), 68.75 (C-5), 67.20 (C-4), 66.61 (C-6), 61.37 (C-6′), 54.91 (O*C*H_3), 29.67 (C-3). CIMS: m/z 822 ($[M + NH_4]^+$).

*Methyl 2,3,4-tri-*O*-benzyl-α-*D*-glucopyranosyl-(1 → 6)-2-di-*O*-benzyl-3-deoxy-α-*D*-ribo-hexopyranoside* (**14**) .—Disaccharide **12** (0.2 g, 0.24 mmol) was deacetylated as described under General methods, using toluene (15 mL), anhyd MeOH (15 mL), and NaOMe (M, 0.1 mL). When only traces of starting material were left (5 h; TLC, 6:1 toluene–acetone), the mixture was purified on a column of silica gel (4:1 toluene–acetone) giving derivative **14** (0.15 g, 90.9%): $[\alpha]_D$ +50.1° (*c* 1.116, $CHCl_3$); ^{1}H NMR ($CDCl_3$): δ 7.97–7.06 (m, 20 H, 4 Ph), 4.87–4.23 (m, 10 H, H-1, H-1′, 4 CH_2Ph), 3.91–3.81 (m, 1 H, H-3′), 3.66–3.31 (m, 10 H, H-5′, H-6a, H-6′a, H-6′b, H-6b, H-5, H-2′, H-4, H-4′, H-2), 3.31 (s, 3 H, OCH_3), 2.12 (m, 1 H, H-3a), 1.80 (m, 1 H, H-3b); ^{13}C NMR ($CDCl_3$): δ 97.61, 96.87 (C-1, C-1′), 81.77 (C-3′), 79.59 (C-2′), 77.20 (C-4′), 75.57, 74.89 (*C*H_2Ph), 73.41 (2 C) (C-2, CH_2Ph), 73.25 (*C*H_2Ph), 71.12 (C-5′), 70.81 (CH_2Ph), 69.83 (C-5), 69.44 (C-6), 68.09 (C-4), 61.60 (C-6′), 54.92 (O*C*H_3), 32.42 (C-3). CIMS: m/z 718 ($[M + NH_4]^+$).

*Methyl 6-*O*-trimethylsilyl-2,3,4-tri-*O*-benzyl-α-*D*-glucopyranosyl-(1 → 6)-4-*O*-benzoyl-2-*O*-benzyl-3-deoxy-α-*D*-ribo-hexopyranoside* (**15**).—Disaccharide **15** (0.5 g, 0.62 mmol) was silylated using CH_2Cl_2 (60 mL), imidazole (0.067 g, 0.74 mmol), and chlorotrimethylsilane (0.09 mL, 0.74 mmol) for 20 h. After purification (silica gel, 8:1 toluene–acetone) 0.5 g of **15** (91.7%) was obtained: $[\alpha]_D$ +34.2° (*c* 1.106, $CHCl_3$); ^{1}H NMR ($CDCl_3$): δ 7.97–7.16 (m, 25 H, 5 Ph), 5.01 (m 1 H, H-4), 4.98–4.42 (m, 10 H, H-1, H-1′, 4 CH_2Ph), 4.02 (m, 1 H, H-5), 3.91 (br dd, 1 H, H-3′), 3.69 (dd, 1 H, H-6a), 3.59–3.44 (m, 7 H, H-6′a, H-6b, H-4′, H-2, H-5′, H-6′b, H-2′), 3.41 (s, 3 H, OCH_3), 2.24 (m, 1 H, H-3a), 1.93 (m, 1 H, H-3b), −0.05 [s, 9 H, Si(CH_3)$_3$]; ^{13}C NMR ($CDCl_3$): δ 165.17 (*C*OPh), 97.12, 96.97 (C-1, C-1′), 81.72 (C-3′), 80.00 (C-2′), 77.01 (C-4′), 75.49, 74.43 (*C*H_2Ph), 73.19 (C-2), 72.78 (*C*H_2Ph), 71.15 (C-5′), 71.08 (*C*H_2Ph), 68.93 (C-5), 67.50 (C-4), 66.36 (C-6), 61.09 (C-6′), 55.13 (O*C*H_3), 29.96 (C-3), −0.48 [Si(*C*H_3)$_3$]. CIMS: m/z 894 ($[M + NH_4]^+$).

*Methyl α-*D*-glucopyranosyl-(1 → 6)-3-deoxy-α-*D*-ribo-hexopyranoside* (**16**) .—Disaccharide **14** (0.1 g, 0.14 mmol), was debenzylated for 16 h as described under General methods and monitored by TLC (2:1:1 2-propanol–H_2O–EtOAc). Purification (silica

gel, 2:1:1.75 2-propanol–H_2O–EtOAc) gave disaccharide **16** (0.047 g, 95.9%). Neither the ^1H nor ^{13}C NMR spectrum revealed signals that would indicate the presence of an aromatic residue. Compound **16** had $[\alpha]_D$ +182.3° (*c* 0.458 H_2O); ^1H NMR (D_2O): δ 4.87 (d, 1 H, $J_{1,2}$ 3.6 Hz, H-1), 4.64 (d, 1 H, $J_{1',2'}$ 3.6 Hz, H-1'), 3.91 (dd, 1 H, H-6a), 3.79–3.62 (m, 7 H, H-5, H-6'a, H-2, H-5', H-6b, H-6'b, H-4), 3.48 (dd, 1 H, H-2'), 3.37 (s, 3 H, OCH_3), 3.38 (m, 1 H, H-4'), 2.11 (m, 1 H, H-3a), 1.64 (m, 1 H, H-3b); ^{13}C NMR (D_2O): δ 98.85, 98.34 (C-1, C-1'), 73.59 (C-3'), 72.28, 72.00 (C-2', C-5'), 71.37 (C-2), 69.97 (C-4'), 66.72 (C-5), 65.96 (C-6), 64.40 (C-4), 60.92 (C-6'), 55.45 (OCH_3), 35.26 (C-3). FABMS: *m/z* 341 $[M]^+$, 363 $[M + Na]^+$.

Methyl 6-O-acetyl-2,4-di-O-benzyl-3-deoxy-α-D-ribo-hexopyranosyl-(1 → 6)-4-O-benzoyl-2-O-benzyl-3-deoxy-α-D-ribo-hexopyranoside (**17**).—Disaccharide **17** was prepared as described under General methods, using a heptane solution of tin(IV) chloride (M, 0.04 mL), silver perchlorate (0.008 g, 0.04 mmol), acetate **7** (0.37 g, 0.086 mmol), and methyl 4-*O*-benzoyl-2-*O*-benzyl-6-*O*-trimethylsilyl-3-deoxy-α-D-*ribo*-hexopyranoside (**6**) (0.37 g, 0.84 mmol). After 24 h the reaction was completed (TLC, 2:1 hexane–EtOAc). Purification on a column of silica gel (4:1 heptane–EtOAc) gave **17** (0.54 g, 87.1%): $[\alpha]_D$ +115.2° (*c* 1.3, $CHCl_3$); ^1H NMR ($CDCl_3$): δ 7.97–7.20 (m, 10 H, 2 Ph), 4.96 (m, 1 H, H-4), 4.72, 4.64 (br d, 2 H, H-1, H-1'), 4.58–4.29 (m, 6 H, 3 CH_2Ph), 4.10–4.03 (m, 3 H, H-5, H-6'a, H-6'b), 3.80–3.68 (m, 2 H, H-5', H-6a), 3.57–3.50 (m, 2 H, H-2, H-2'), 3.41–3.36 (m, 4 H, OCH_3, H-6b), 3.27 (m, 1 H, H-4'), 2.44–2.37, 2.30–2.26 (m, 2 H, H-3a, H-3'a), 2.02–1.75 (m, 5 H, H-3b, H-3'b, COCH_3); ^{13}C NMR ($CDCl_3$): δ 170.67 (*C*OCH$_3$), 165.22 (*C*OPh), 96.97, 95.65 (C-1, C-1'), 73.57, 73.10 (C-2, C-2'), 71.11 (C-4'), 71.01, 70.75, 70.03 (*C*H$_2$Ph), 68.91, 68.85 (C-5, C-5'), 67.38 (C-4), 66.04 (C-6), 63.13 (C-6'), 55.06 (O*C*H$_3$), 29.93, 29.54 (C-3, C-3'), 20.72 (CO*C*H$_3$). CIMS: *m/z* 758 ($[M + NH_4]^+$). Anal. Calcd for $C_{43}H_{48}O_{11}$: C, 69.71; H, 6.53. Found: C, 69.57; H, 6.57.

Methyl 2,3-di-O-benzyl-3-deoxy-α-D-ribo-hexopyranosyl-(1 → 6)-4-O-benzoyl-2-O-benzyl-3-deoxy-α-D-ribo-hexopyranoside (**18**).—Disaccharide **17** (0.2 g, 0.27 mmol) was deacetylated for 2 h using toluene (15 mL), MeOH (15 mL), and NaOMe (M, 0.1 mL) (monitored by TLC, 6:1 toluene–acetone). After purification (silica gel, 2.5:1 toluene–acetone) compound **18** was obtained (0.15 g, 79.4%): $[\alpha]_D$ +118.7° (*c* 1.015, $CHCl_3$); ^1H NMR ($CDCl_3$): δ 7.95–7.16 (m, 20 H, 4 Ph), 4.93 (br ddd, 1 H, H-4), 4.67(d, 1 H, $J_{1,2}$ 2.9 Hz, H-1), 4.63 (d, 1 H, $J_{1',2'}$ 3 Hz, H-1'), 4.55–4.32 (m, 6 H, 3 CH_2Ph), 4.04–3.99 (m, 1 H, H-6a), 3.71–3.27 (m, 9 H, H-6'a, H-5', H-4, H-5, H-6'b, H-6b, H-2, H-2', H-4'), 3.40 (s, 3 H, OCH_3), 2.42–2.18 (m, 2 H, H-3a, H-3'a), 2.00–1.75 (m, 2 H, H-3b, H-3'b); ^{13}C NMR ($CDCl_3$): δ 165.33 (COPh), 97.08, 95.96 (C-1, C-1'), 73.87, 73.22 (C-2, C-2'), 72.04 (C-4'), 71.12 (*C*H$_2$Ph), 71.04 (C-5'), 70.79, 70.44 (*C*H$_2$Ph), 69.02 (C-5), 67.52 (C-4), 66.42 (C-6), 62.18 (C-6'), 55.17 (O*C*H$_3$), 29.99, 29.63 (C-3, C-3'). CIMS: *m/z* 716 ($[M + NH_4]^+$).

Methyl 2,3-di-O-benzyl-3-deoxy-α-D-ribo-hexopyranosyl-(1 → 6)-2-O-benzyl-3-deoxy-α-D-ribo-hexopyranoside (**19**).—Disaccharide **17** (0.3 g, 0.2 mmol) was deacetylated for 16 h using toluene (20 mL), MeOH (20 mL), and NaOMe (M, 0.1 mL) (monitored by TLC, 6:1 toluene–acetone). After purification (silica gel, 4:1 toluene–acetone) compound **19** was obtained (0.12 g, 93.8%): $[\alpha]_D$ +89° (*c* 0.908, $CHCl_3$); ^1H NMR ($CDCl_3$): δ 7.29–7.20 (m, 15 H, 3 Ph), 4.73 (d, 1 H, $J_{1,2}$ 3.3 Hz, H-1), 4.58 (d, 1

H, $J_{1',2'}$ 3.3 Hz, H-1'), 4.56–4.35 (m, 6 H, 3 CH_2Ph), 3.91 (dd, 1 H, H-6a), 3.76 (br dd, 1 H, H-6'a), 3.63–3.35 (m, 8 H, H-5', H-4, H-5, H-6'b, H-6b, H-2, H-2', H-4'), 3.35 (s, 3 H, OCH_3), 2.30–2.11 (m, 3 H, H-3a, H-3'a, O*H*), 1.88–1.73 (m, 2 H, H-3b, H-3'b); ^{13}C NMR ($CDCl_3$): δ 96.90, 96.33 (C-1, C-1'), 73.44, 73.36 (C-2, C-2'), 71.94 (C-4'), 71.44 (C-5'), 70.83 (2 C), 70.60 (*C*H_2Ph), 70.07 (C-5), 68.73 (C-6), 67.72 (C-4), 62.04 (C-6'), 54.93 (O*C*H_3), 32.50 (C-3), 29.73 (C-3'). CIMS: *m/z* 612 ([M + NH_4]$^+$). Anal. Calcd for $C_{34}H_{42}O_9$: C, 66.67; H, 7.12. Found: C, 68.70; H, 7.19.

*Methyl 3-deoxy-α-*D-ribo-*hexopyranosyl-(1 → 6)-3-deoxy-α-*D-ribo-*hexopyranoside* (**20**).—Disaccharide **19** (0.12 g, 0.2 mmol) was debenzylated for 20 h as described under General methods. When no starting material remained (TLC, 2:1:1.5 2-propanol–H_2O–EtOAc) the mixture was purified (silica gel, 2:1:1.75 2-propanol–H_2O–EtOAc) giving **20** (0.059 g, 90.8%). Neither the ^{1}H nor ^{13}C NMR spectrum revealed signals that would indicate the presence of an aromatic residue: [α]$_D$ +104.5 ° (*c* 1.909, H_2O); ^{1}H NMR (D_2O): δ 4.70 (d, 1 H, $J_{1',2'}$ 3.4 Hz, H-1'), 4.59 (d, 1 H, $J_{1,2}$ 3.5 Hz, H-1), 3.84 (dd, 1 H, $J_{5,6a}$ 4.3, $J_{6a,6b}$ 11.3 Hz, H-6a), 3.71–3.48 (m, 9 H, H-2', H-2, H-5', H-5, H-6'a, H-6'b, H-6b, H-4, H-4', H-6b), 3.31 (s, 3 H, OCH_3), 2.08–2.00 (m, 2 H, H-3a, H-3'a), 1.70–1.52 (m, 2 H, H-3b, H-3'b); ^{13}C NMR (D_2O): δ 98.98, 97.38 (C-1, C-1'), 73.17, 71.65 (C-2, C-2'), 67.25, 66.90 (C-5, C-5'), 66.02 (C-6), 64.78, 64.69 (C-4, C-4'), 61.20 (C-6'), 55.62 (O*C*H_3), 34.40, 35.08 (C-3, C-3'). FABMS: *m/z* 325 [M]$^+$, 347 [M + Na]$^+$.

*Methyl 6-*O*-acetyl-2,3,4-tri-*O*-benzyl-α-*D*-glucopyranosyl-(1 → 6)-2,3,4-tri-*O*-benzyl-α-*D*-glucopyranosyl-(1 → 6)-4-*O*-benzoyl-2-*O*-benzyl-3-deoxy-α-*D-ribo-*hexopyranoside* (**21**).—Compound **21** was prepared as described under General methods, using a heptane solution of tin(IV) chloride (M, 0.03 mL), silver perchlorate (0.006 g, 0.03 mmol), derivative **15** (0.5 g, 0.6 mmol) and 1,6-di-*O*-acetyl-2,3,4-tri-*O*-benzyl-α,β-D-glucopyranose [15] (0.42 g, 0.7 mmol). The mixture was stirred for 20 h (TLC monitoring used, 2:1 hexane–EtOAc). After purification on a column of silica gel (3:1 hexane–EtOAc) 0.64 g of **15** was obtained (87.7%): [α]$_D$ +93.2° (*c* 0.842, $CHCl_3$); ^{1}H NMR ($CDCl_3$): δ 7.97–7.1 (m, 40 H, 8 Ph), 5.02–4.95 (m, 1 H, H-4), 4.94–4.38 (m, 17 H, H-1, H-1', H-1'', 7 CH_2Ph), 4.08 (m, 2 H, H-6''a, H-6''b), 4.02–3.98 (m, 1 H, H-5), 3.92–3.85 (m, 2 H, H-3', H-3''), 3.73–3.51 (m, 4 H, H-6'a, H-6a, H-5', H-5''), 3.52–3.29 (m, 7 H, H-6'b, H-4', H-6b, H-4'', H-2, H-2', H-2''), 3.40 (s, 3 H, OCH_3), 2.41 (m, 1 H, H-3a), 1.90 (s, 3 H, COCH_3), 2.00–1.90 (m, 1 H, H-3b); ^{13}C NMR ($CDCl_3$): δ 170.65 (*C*OCH_3), 165.22 (*C*OPh), 97.13, (C-1), 97.04, 96.93 (C-1', C-1''), 81.62, 81.51 (C-3', C-3''), 80.19, 79.87 (C-2', C-2''), 77.32, 77.01 (C-4', C-4''), 75.50, 74.86, 74.68 (*C*H_2Ph), 73.27 (C-2), 72.79, 71.95, 71.08 (*C*H_2Ph), 70.54, 69.05 (C-5', C-5''), 68.55 (C-5), 67.46 (C-4), 66.54, 65.45 (C-6, C-6'), 62.86 (C-6''), 55.14 (O*C*H_3), 29.94 (C-3), 20.78 (CO*C*H_3). CIMS: *m/z* 1296 ([M + NH_4]$^+$). Anal. Calcd for $C_{77}H_{82}O_{17}$: C, 72.28; H, 6.46. Found: C, 72.03; H, 6.02.

*Methyl 2,3,4-tri-*O*-benzyl-α-*D*-glucopyranosyl-(1 → 6)-2,3,4-tri-*O*-benzyl-α-*D*-glucopyranosyl-(1 → 6)-4-*O*-benzoyl-2-*O*-benzyl-3-deoxy-α-*D*-ribo-hexopyranoside* (**22**).—Compound **21** (0.05 g, 0.04 mmol) was deacetylated as described under General methods using toluene (10 mL), MeOH (10 mL), and NaOMe (M, 0.01 mL). After 1.5 h no starting material was detected (TLC, 6:1 toluene–acetone). The reaction mixture was neutralized with Amberlite IR 120 (H^+), filtered, concentrated, and purified on column

of silica gel (6:1 toluene–acetone) giving 0.039 g (81.2%) of **22**: $[\alpha]_D$ +96.5° (*c* 0.808, $CHCl_3$); ^1H NMR ($CDCl_3$): δ 7.96–7.12 (m, 40 H, 8 Ph), 4.93 (m, 1 H, H-4), 4.89–4.38 (m, 17 H, H-1, H-1′, H-1″, 7 CH_2Ph), 4.02–3.97 (m, 1 H, H-5), 3.90–3.85 (m, 2 H, H-3′, H-3″), 3.73–3.28 (m, 13 H, H-6″a, H-6″b, H-3″, H-6a, H-6′a, H-5′, H-5″, H-2, H-6b, H-6′b, H-2′, H-2″, H-4′, H-4″), 3.40 (s, 3 H, OCH_3), 2.39 (m, 1 H, H-3a), 1.93 (m, 1 H, H-3b); ^{13}C NMR ($CDCl_3$): δ 165.27 (*C*OPh), 97.13 (2 C), 97.05 (C-1, C-1′, C-1″), 81.67, 81.46 (C-3′, C-3″), 80.23, 80.05 (C-2′, C-2″), 77.37 (2 C) (C-4′, C-4″), 75.49 (2 C), 74.97, 74.74, (*C*H_2Ph), 73.29 (C-2), 72.91, 72.09, 71.14 (*C*H_2Ph), 70.77, 70.67, 69.08 (C-5, C-5′, C-5″), 67.53 (C-4), 66.70, 65.50, (C-6, C-6′), 61.89 (C-6″), 55.20 (O*C*H_3), 30.01 (C-3). CIMS: *m/z* 1255 ($[M + NH_4]^+$).

*Methyl 2,3,4-tri-O-benzyl-α-*D*-glucopyranosyl-(1 → 6)-2,3,4-tri-O-benzyl-α-*D*-glucopyranosyl-(1 → 6)-2-O-benzyl-3-deoxy-α-*D*-*ribo*-hexopyranoside* (**23**).—Compound **21** (0.4 g, 0.31 mmol) was deacetylated as described under General methods using toluene (10 mL), MeOH (10 mL), and NaOMe (M, 0.01 mL). After 24 h no starting material was detected (TLC, 6:1 toluene–acetone). The reaction mixture was neutralized with Amberlite IR 120 (H^+), filtered, concentrated, and purified on column of silica gel (6:1 toluene–acetone) giving 0.354 g (90.4%) of **22**: $[\alpha]_D$ +67° (*c* 0.642, $CHCl_3$); ^1H NMR ($CDCl_3$): δ 8.03–7.16 (m, 35 H, 7 Ph), 4.94–4.44 (m, 17 H, H-1, H-1′, H-1″, 7 CH_2Ph), 3.97–3.88 (m, 2 H, H-3′, H-3″), 3.81 (dd, 1 H, H-6a), 3.76–3.35 (m, 13 H, H-5, H-5′, H-6′a, H-6″a, H-6b, H-6′b, H-6″b, H-5″, H-4′, H-4″, H-2, H-2′, H-2″), 3.33 (s, 3 H, OCH_3), 2.07–2.02 (m, 1 H, H-3a), 1.86–1.75 (m, 2 H, H-3b, O*H*), 1.64 (br s, 1 H, O*H*); ^{13}C NMR ($CDCl_3$): δ 97.22, 97.08, 96.91 (C-1, C-1′, C-1″), 81.99, 81.42 (C-3′, C-3″), 80.10, 79.74 (C-2′, C-2″), 77.66, 77.29 (C-4′, C-4″), 75.64, 75.47, 74.97 (2 C), (*C*H_2Ph), 73.41 (C-2), 73.28, 72.59 (*C*H_2Ph), 70.81 (2 C) 69.69 (C-5, C-5′, C-5″), 69.42 (C-6), 68.12 (C-4), 66.29, (C-6′), 61.74 (C-6″), 54.95 (O*C*H_3), 32.47 (C-3). CIMS: *m/z* 1150 ($[M + NH_4]^+$). Anal. Calcd for $C_{68}H_{76}O_{15}$: C, 72.07; H, 6.76. Found: C, 71.92; H, 6.73.

*Methyl α-*D*-glucopyranosyl-(1 → 6)-α-*D*-glucopyranosyl-(1 → 6)-3-deoxy-α-*D*-*ribo*-hexopyranoside* (**24**).—Trisaccharide **22** (0.2 g, 0.18 mmol) was debenzylated for 20 h as described under General methods. After purification (silica gel, 2:1:1.75 2-propanol–EtOAc–H_2O) compound **24** (0.081 g, 91%) was isolated: $[\alpha]_D$ +151.8° (*c* 1.008, H_2O) [4].

*Methyl 6-O-acetyl-2,3,4-tri-O-benzyl-α-*D*-glucopyranosyl-(1 → 6)-2,4-di-O-benzyl-3-deoxy-α-*D*-*ribo*-hexopyranosyl-(1 → 6)-2,3,4-tri-O-benzyl-α-*D*-glucopyranoside* (**25**).—Trisaccharide **25** was prepared as described under General methods using tin(IV) chloride in heptane (M, 0.03 mL), silver perchlorate in ether (0.006 g, 0.03 mmol), and ethereal solutions of disaccharide **10** (0.55 g, 0.65 mmol), and 1,6-di-*O*-acetyl-2,3,4-tri-*O*-benzyl-α,β-D-glucopyranose [15] (0.45 g, 0.75 mmol). After 19 h the reaction was completed (TLC, 4:1 toluene–EtOAc), and the mixture was extracted with satd aq $NaHCO_3$, water, then dried, filtered, concentrated, and purified on a column of silica gel (6:1 toluene–EtOAc) giving **25** (0.72 g, 88.9%): $[\alpha]_D$ +80.9° (*c* 0.45, $CHCl_3$); ^1H NMR ($CDCl_3$): δ 7.25–7.22 (m, 40 H, 8 Ph), 4.95–4.29 (m, 19 H, H-1, H-1′, H-1″, 8 CH_2Ph), 4.14 (br s, 2 H, H-6″a, H-6″b), 3.94 (dd, 2 H, H-3, H-3″), 3.85–3.41 (m, 11 H, H-5″, H-6a, H-6′a, H-6″b, H-5, H-5′, H-6b, H-6′b, H-4, H-4′, H-6b, H-6′b, H-2, H-2″), 3.37 (br dd, 1 H, $J_{1',2'}$ 3.4, $J_{2',3'a}$ 9.7 Hz, H-2′), 3.27 (s, 3 H, OCH_3), 2.22–2.20 (m, 1

H, H-3'a), 1.93 (s, 3 H, COCH_3), 1.81 (m, 1 H, H-3'b); ^{13}C NMR ($CDCl_3$): δ 170.72 (*C*OCH$_3$), 97.94, 96.68, 95.97 (C-1, C-1', C-1''), 82.09, 81.75 (C-3, C-3''), 80.12 (2 C) (C-2, C-2''), 77.85, 77.19 (C-4, C-4''), 75.56, 75.04, 74.96, (*C*H$_2$Ph), 74.04 (C-2'), 73.34, 72.11 (*C*H$_2$Ph), 71.47, 71.02 (C-5, C-5'), 70.59 (C-4'), 70.43 (2 C) (*C*H$_2$Ph), 68.54 (C-5''), 65.59 (2 C) (C-6, C-6'), 62.99 (C-6''), 55.06 (O*C*H$_3$), 30.16 (C-3'), 20.80 (CO*C*H$_3$). CIMS: *m/z* 1284 ([M + NH$_4$]$^+$). Anal. Calcd for $C_{77}H_{84}O_6$: C, 73.08; H, 6.69. Found: C, 73.11; H, 6.65.

*Methyl 2,3,4-tri-*O*-benzyl-α-*D*-glucopyranosyl-(1 → 6)-2,4-di-*O*-benzyl-3-deoxy-α-*D*-ribo-hexopyranosyl-(1 → 6)-2,3,4-tri-*O*-benzyl-α-*D*-glucopyranoside* (**26**).—Trisaccharide **25** (0.25 g, 0.2 mmol) was deacetylated for 3 h using toluene (30 mL), anhyd MeOH (30 mL), and NaOMe (0.1 mL) (monitored by TLC, 6:1 toluene–acetone). After purification (silica gel, 2:1 hexane–EtOAc) compound **32** (0.22 g, 91.7%) was obtained: $[\alpha]_D$ +80.6° (*c* 1.242, $CHCl_3$); ^{1}H NMR ($CDCl_3$): δ 7.27–7.14 (m, 40 H, 8 Ph), 4.97–4.38 (m, 19 H, 8 C*H*$_2$Ph, H-1, H-1', H-1''), 3.96 (m, 2 H, H-3, H-3''), 3.88–3.31 (m, 14 H, H-6a, H-6'a, H-5, H-5', H-5'', H-6b, H-6'b, H-6''a, H-6''b, H-2, H-2'', H-2'), 3.31 (s, 3 H, OC*H*$_3$), 2.29–2.23 (m 1 H, H-3'a), 1.96–1.81 (m, 1 H, H-3'b); ^{13}C NMR ($CDCl_3$): δ 97.86, 96.66, 95.92 (C-1, C-1', C-1''), 82.00, 81.57 (C-3, C-3''), 80.16, 80.02 (C-2, C-2''), 77.76, 77.43 (C-4, C-4''), 75.49, 75.41, 74.93 (2 C) (*C*H$_2$Ph), 73.97 (C-2'), 73.25, 72.13, (*C*H$_2$Ph), 71.40, 70.89, 70.65 (C-5, C-5', C-5''), 70.48, 70.38 (*C*H$_2$Ph), 70.32 (C-4'), 65.56 (2 C) (C-6, C-6'), 61.75 (C-6''), 54.98 (O*C*H$_3$), 30.07 (C-3'). FABMS: *m/z* 1245 ([M + Na]$^+$).

*Methyl α-*D*-glucopyranosyl-(1 → 6)-3-deoxy-α-*D*-ribo-hexopyranosyl-(1 → 6)-α-*D*-glucopyranoside* (**27**).—Trisaccharide **26** (0.15 g, 0.12 mmol) was debenzylated for 20 h at room temperature (monitored by TLC, 2:1:1 2-propanol–H_2O–EtOAc). After filtration and concentration of the filtrate, the product was purified (silica gel, 2:1:1.75 2-propanol–H_2O–EtOAc) offering 0.058 g of **26** (95.2%). Neither the ^{1}H nor ^{13}C NMR spectrum revealed signals that would indicate the presence of an aromatic residue. Compound **27** had $[\alpha]_D$ +122.3° (*c* 0.6, H_2O); ^{1}H NMR (D_2O): δ 4.85 (d, 1 H, $J_{1'',2''}$ 3.6 Hz, H-1''), 4.75 (d, 1 H, $J_{1',2'}$ 3.5 Hz, H-1'), 4.72 (d, 1 H, $J_{1,2}$ 3.6 Hz, H-1), 4.01 (m, 2 H, H-6a, H-6'a), 3.75–3.53 (m, 13 H, H-2', H-4', H-3, H-6''a, H-6'b, H-6b, H-6''b, H-4, H-4'', H-3'', H-5, H-5', H-5''), 3.49–3.40 (m, 2 H, H-2, H-2''), 3.32 (s, 3 H, OCH_3), 2.10–2.06 (m, 1 H, H-3'a), 1.85–1.63 (m, 1 H, H-3'b); ^{13}C NMR (D_2O): δ 99.49, 97.87, 96.89 (C-1, C-1', C-1''), 73.54, 73.23 (C-3, C-3''), 71.91 (C-5''), 71.63 (C-2''), 71.30 (C-2), 71.14 (C-5), 70.25, 69.61 (C-4, C-4'), 66.63 (C-2'), 65.65, 65.47 (C-6, C-6'), 64.15 (C-4'), 60.55 (C-6''), 55.28 (O*C*H$_3$), 34.91 (C-3'). CIMS: *m/z* 520 ([M + NH$_4$]$^+$).

*Methyl 2,4-di-*O*-benzyl-3-deoxy-α-*D*-ribo-hexopyranosyl-(1 → 6)-2,3,4-tri-*O*-benzyl-α-*D*-glucopyranosyl-(1 → 6)-2,3,4-tri-*O*-benzyl-α-*D*-glucopyranoside* (**28**).—Compound **28** was prepared as described under General methods, using a heptane solution of tin(IV) chloride (M, 0.03 mL), silver perchlorate (0.006 g, 0.03 mmol), and ethereal solutions of acetate **7** (0.26 g, 0.6 mmol) and with methyl 6-*O*-trimethylsilyl-2,3,4-tri-*O*-benzyl-α-*D*-glucopyranosyl-(1 → 6)-2,3,4-tri-*O*-benzyl-α-*D*-glucopyranoside [9] (0.52 g, 0.54 mmol). The mixture was stirred overnight (monitored by TLC, 2:1, hexane–EtOAc). After work-up and column chromatography on silica gel (4:1 hexane–EtOAc) 0.56 g of trisaccharide **28** (83.6%) was obtained: $[\alpha]_D$ +84.3° (*c* 0.75, $CHCl_3$); ^{1}H NMR

($CDCl_3$): δ 7.30–7.16 (m, 40 H, 8 Ph), 4.96–4.33 (m, 19 H, H-1, H-1′, H-1″, 8 CH_2Ph), 4.18 (br s, 2 H, H-6″a, H-6″b), 3.95 (br dd, 2 H, H-3, H-3′), 3.92–3.63 (m, 8 H, H-4″, H-6a, H-6′a, H-5, H-5′, H-5″, H-4, H-4′), 3.40–3.34 (m, 3 H, H-2, H-2′, H-2″), 3.30 (s, 3 H, OCH_3), 2.37–2.01 (m, 1 H, H-3″a), 1.95–1.86 (m, 4 H, COCH_3, H-43′b); ^{13}C NMR ($CDCl_3$): δ 170.83 (*C*OCH_3), 97.89 (C-1), 96.96, 95.93 (C-1′, C-1″), 82.05, 81.55 (C-3, C-3′), 80.17, 80.08, 80.12 (C-2, C-2′), 77.72, 77.64 (C-4, C-4′), 75.64, 75.30, 74.95, 74.89, (*C*H_2Ph), 73.57 (C-2″), 73.28, 72.30 (*C*H_2Ph), 71.31, 70.56, 70.41 (C-5, C-5′, C-5″), 70.41, 70.27 (*C*H_2Ph), 69.11 (C-4″), 65.69, 65.61 (C-6, C-6′), 63.28 (C-6″), 55.06 (O*C*H_3), 29.85 (C-3″), 20.77 (CO*C*H_3). FABMS: *m/z* 1287 ([M + Na]$^+$). Anal. Calcd for $C_{77}H_{84}O_{16}$: C, 73.08; H, 6.69. Found: C, 72.79; H, 6.61.

*Methyl 2,4-di-*O*-benzyl-3-deoxy-α-*D*-*ribo*-hexopyranosyl-(1 → 6)-2,3,4-tri-*O*-benzyl-α-*D*-glucopyranosyl-(1 → 6)-2,3,4-tri-*O*-benzyl-α-*D*-glucopyranoside* (**29**).—Trisaccharide **28** (0.25 g, 0.2 mmol) was deacetylated for 18 h using toluene (30 mL), anhyd MeOH (30 mL), and NaOMe (0.1 mL) (monitored by TLC, 6:1 toluene–acetone). After purification (silica gel, 2:1 hexane–acetone) compound **29** (0.22 g, 91.7%) was obtained: $[\alpha]_D$ +30.3° (*c* 1.233, $CHCl_3$); ^{1}H NMR ($CDCl_3$): δ 7.29–7.14 (m, 40 H, 8 Ph), 5.23–4.36 (m, 19 H, H-1, H-1′, H-1″, 8 CH_2Ph), 3.93 (br dd, 2 H, H-3, H-3′), 3.90–3.60 (m, 9 H, H-5, H-6″a, H-6a, H-6′a, H-5′, H-5″, H-6″b, H-6b, H-6′b), 3.39–3.35 (m, 4 H, H-4″, H-2, H-2′, H-2″), 3.29 (s, 3 H, OCH_3), 2.30–2.00 (m, 1 H, H-3″a), 1.93–1.81 (m, 1 H, H-3″b), 1.70 (br s, 1 H, O*H*) ^{13}C NMR ($CDCl_3$): δ 97.90, 97.01, 95.88 (C-1, C-1′, C-1″), 82.08, 81.56 (C-3, C-3′), 80.19, 80.07 (C-2, C-2′), 77.73, 77.76 (C-4, C-4′), 75.67, 75.31, 74.94 (2 C) (*C*H_2Ph), 73.82 (C-2″), 73.32, 72.37 (*C*H_2Ph), 72.25 (C-4″), 71.07 70.57 (2 C) (C-5, C-5′, C-5″), 70.39 (*C*H_2Ph), 65.81, 65.61 (C-6, C-6′), 62.31 (C-6″), 55.11 (O*C*H_3), 29.87 (C-3″). FABMS: *m/z* 1246 ([M + Na]$^+$). Anal. Calcd for $C_{75}H_{82}O_{15}$: C, 73.63; H, 6.76. Found: C, 73.37; H, 6.73.

*Methyl 3-deoxy-α-*D*-*ribo*-hexopyranosyl-(1 → 6)-α-*D*-glucopyranosyl-(1 → 6)-α-*D*-glucopyranoside* (**30**).—Trisaccharide **29** (0.15 g, 0.123 mmol) was debenzylated as described under General methods. When no starting material remained (20 h; TLC, 2:1:1.5 2-propanol–H_2O–EtOAc) the mixture was purified on a column of silica gel (2:1:1.75 2-propanol–H_2O–EtOAc) affording compound **30** (0.058 g, 95.1%): $[\alpha]_D$ +79.8° (*c* 0.942, H_2O); ^{1}H NMR (D_2O): δ 4.79 (d, 1 H, $J_{1,2}$ 3.6 Hz, H-1), 4.67 (d, 1 H, H-1″), 4.64 (d, 1 H, $J_{1'',2''}$ 3.8 Hz, H-1″), 3.86–3.79 (m, 2 H, H-6a, H-6′a), 3.76–3.31 (m, 16 H, H-5, H-5′, H-2″, H-3, H-3″, H-4″, H-6″a, H-6b, H-6′b, H-5″, H-6″b, H-2, H-2′, H-2″, H-4, H-4′), 3.25 (s, 3 H, OCH_3), 2.05–1.96 (m, 1 H, H-3″a), 1.66–1.55 (m, 1 H, H-3″b); ^{13}C NMR (D_2O): δ 99.90 (C-1), 98.94, 98.32 (C-1′, C-1″), 73.91, 73.83 (2 C) (C-3, C-3′, C-2″), 71.92, 71.69 (C-2, C-2′), 70.86 (C-5′), 70.49 (C-5), 70.06, 69.98 (C-4, C-4′), 69.37 (C-5″), 67.76 (C-3″), 66.03 (2 C) (C-6, C-6′), 64.11 (C-6″), 55.68 (O*C*H_3), 34.61 (C-4″). CIMS: *m/z* 520 ([M + NH_4]$^+$).

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