Carbohydrate Research, 253 (1994) 121–139
Elsevier Science B.V., Amsterdam

Synthesis of three tetrasaccharides containing 3-*O*-methyl-D-mannose, as model compounds for xylose-containing carbohydrate chains from N-glycoproteins

Jos G.M. van der Ven, Jac C.H.M. Wijkmans, Johannis P. Kamerling * and Johannes F.G. Vliegenthart

Bijvoet Center, Department of Bio-Organic Chemistry, Utrecht University, P.O. Box 80.075, NL-3508 TB Utrecht (Netherlands)

(Received April 30th, 1993; accepted July 6th, 1993)

ABSTRACT

The synthesis is reported of methyl 3,6-di-*O*-(3-*O*-methyl-α-D-mannopyranosyl)-2-*O*-β-D-xylopyranosyl-β-D-mannopyranoside (**2**), methyl 6-*O*-α-D-mannopyranosyl-3-*O*-(3-*O*-methyl-α-D-mannopyranosyl)-2-*O*-β-D-xylopyranosyl-β-D-mannopyranoside (**3**), and methyl 3-*O*-α-D-mannopyranosyl-6-*O*-(3-*O*-methyl-α-D-mannopyranosyl)-2-*O*-β-D-xylopyranosyl-β-D-mannopyranoside (**4**). The various methyl β-D-Man*p* acceptor derivatives were prepared from the corresponding methyl β-D-Glc*p* derivatives via oxidation–reduction. All glycosyl donors were coupled using the trichloroacetimidate method at −40°C in dichloromethane with trimethylsilyl triflate as a catalyst. Methyl-3-*O*-benzyl-4,6-*O*-benzylidene-β-D-mannopyranoside (**7**) was condensed with 2,3,4-tri-*O*-acetyl-α-D-xylopyranosyl trichloroacetimidate (**8**). Regioselective reductive 4,6-*O*-benzylidene ring-opening on the resulting disaccharide derivative, followed by acetylation, and hydrogenation gave methyl 4-*O*-acetyl-2-*O*-(2,3,4-tri-*O*-acetyl-β-D-xylopyranosyl)-β-D-mannopyranoside (**12**). Coupling of **12** with 2,4,6-tri-*O*-acetyl-3-*O*-methyl-α-D-mannopyranosyl trichloroacetimidate (**18**) afforded tetrasaccharide derivative **19**, and subsequent *O*-deacetylation gave **2**. Methyl 3-*O*-benzyl-4,6-*O*-prop-2-enylidene-β-D-mannopyranoside (**22**) was condensed with 2,3,4-tri-*O*-acetyl-α-D-xylopyranosyl trichloroacetimidate (**8**). Regioselective reductive 4,6-*O*-prop-2-enylidene ring-opening on the resulting disaccharide derivative, followed by acetylation, and deallylation at O-6 gave methyl 4-*O*-acetyl-3-*O*-benzyl-2-*O*-(2,3,4-tri-*O*-acetyl-β-D-xylopyranosyl)-β-D-mannopyranoside (**26-a**), which was either condensed with 2,3,4,6-tetra-*O*-acetyl-α-D-mannopyranosyl trichloroacetimidate (**27**) or **18**, to give trisaccharide derivatives **28** or **31**, respectively. Debenzylation of **28** followed by condensation with **18** gave, after *O*-deacetylation, **3**, whereas debenzylation of **31** followed by condensation with **27** gave, after *O*-deacetylation, **4**.

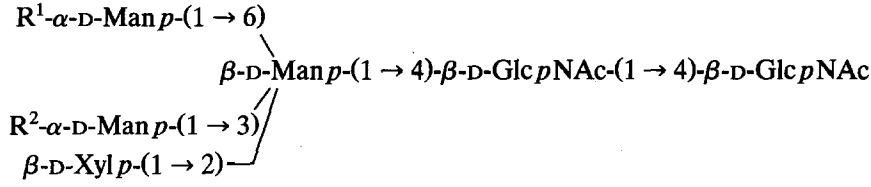
INTRODUCTION

Methylated monosaccharide residues only rarely occur in N-linked carbohydrate chains of glycoproteins. So far, 3-*O*-methyl-D-mannose has been found in hemocyanin of *Lymnaea stagnalis*[1,2] and in N-glycoproteins of the dimorphic fungus

* Corresponding author.

SSDI 0008-6215(93)E0280-E

Mucor rouxii[3]. In the hemocyanin, 3-*O*-methyl-α-D-mannose forms an integral part of the core element which also contains a β-D-xylose residue (1 → 2)-linked to β-D-mannose[1,2,4], whereas novel extensions, including the occurrence of 3-*O*-methyl-β-D-galactose, were established[2] (**1**).



1

(*i*) $R^1 = R^2 =$ 3-*O*-Me

(*ii*) $R^1 =$ 3-*O*-Me-β-D-Gal*p*-(1 → 3)-β-D-Gal*p*NAc-(1 → 4)-β-D-Glc*p*NAc-(1 → 2) and $R^2 =$ 3-*O*-Me

(*iii*) $R^1 =$ H and $R^2 =$ 3-*O*-Me-β-D-Gal*p*-(1 → 3)-β-D-Gal*p*NAc-(1 → 4)-β-D-Glc*p*NAc-(1 → 2)

(*iv*) $R^1 = R^2 =$ 3-*O*-Me-β-D-Gal*p*-(1 → 3)-β-D-Gal*p*NAc-(1 → 4)-β-D-Glc*p*NAc-(1 → 2)

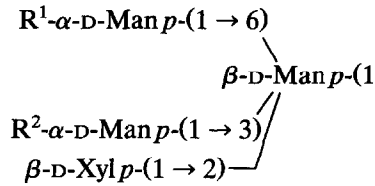
(*v*) $R^1 =$ α-L-Fuc*p*-(1 → 2)-β-D-Gal*p*-(1 → 3)-β-D-Gal*p*NAc-(1 → 4)-β-D-Glc*p*NAc-(1 → 2) and $R^2 =$ 3-*O*-Me

(*vi*) $R^1 =$ H and $R^2 =$ α-L-Fuc*p*-(1 → 2)-β-D-Gal*p*-(1 → 3)-β-D-Gal*p*NAc-(1 → 4)-β-D-Glc*p*NAc-(1 → 2)

(*vii*) $R^1 = R^2 =$ α-L-Fuc*p*-(1 → 2)-β-D-Gal*p*-(1 → 3)-β-D-Gal*p*NAc-(1 → 4)-β-D-Glc*p*NAc-(1 → 2)

(*viii*) $R^1 =$ 3-*O*-Me-β-D-Galp-(1 → 3)-β-D-Gal*p*NAc-(1 → 4)-β-D-Glc*p*NAc-(1 → 2) and $R^2 =$ α-L-Fuc*p*-(1 → 2)-β-D-Gal*p*-(1 → 3)-β-D-Gal*p*NAc-(1 → 4)-β-D-Glc*p*NAc-(1 → 2)

As a part of our program concerning the biosynthesis and conformation analysis of these types of glycans[5–7], the synthesis of some related oligosaccharide elements has been reported[8,9]. Here, we describe the synthesis of the tetrasaccharides **2**, **3**, and **4**, containing either one or two 3-*O*-methyl-α-D-mannose residues, representing the branching part of the core structure in which the β-D-mannose configuration is mimicked as a methyl glycoside. It should be noted that **4** is not a structural element of *L. stagnalis* hemocyanin.



2 $R^1 = R^2 =$ 3-*O*-Me
3 $R^1 =$ H, $R^2 =$ 3-*O*-Me
4 $R^1 =$ 3-*O*-Me, $R^2 =$ H

RESULTS AND DISCUSSION

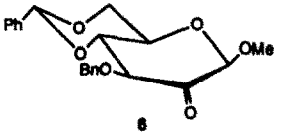
For the synthesis of tetrasaccharide **2**, methyl 4-*O*-acetyl-2-*O*-(2,3,4-tri-*O*-acetyl-β-D-xylopyranosyl)-β-D-mannopyranoside (**12**) and 2,4,6-tri-*O*-acetyl-3-*O*-methyl-α-D-mannopyranosyl trichloroacetimidate (**18**) where chosen as building blocks. The

preparation of methyl β-D-Man*p*, or β-D-mannopyranosides in general, can be accomplished via 'direct' or 'indirect' methods[8–10]. Because the synthesis of xylose-containing carbohydrate chains using the indirect method via oxidation–reduction has proved to be very convenient in our hands[8,9], this strategy was also followed in the present report. Thus, methyl 3-*O*-benzyl-β-D-glucopyranoside[11] was benzylidenated using α,α-dimethoxytoluene and *p*-toluenesulfonic acid to give crystalline **5** (75%). Oxidation of **5** using 2:1 dimethyl sulfoxide–acetic anhydride gave **6** and a small amount of a by-product. Evaporation of the reagents followed by treatment of the residue with sodium borohydride afforded **7** (66% from **5**) and some **5** (10% from **5**). The by-product in the oxidation of **5**, probably methyl 3-*O*-benzyl-4,6-*O*-benzylidene-2-*O*-methylthiomethyl-β-D-glucopyranoside[12], could easily be separated from the reaction products after the reduction. Its amount can be minimized by using acetic anhydride free from acetic acid[13]. Stereoselective xylosylation of **7** proceeded satisfactorily using 2,3,4-tri-*O*-acetyl-α-D-xylopyranosyl trichloroacetimidate (**8**)[9,14] in dichloromethane at −40°C, with trimethylsilyl triflate as a catalyst, to give exclusively the β-linked disaccharide derivative **9** in 75% yield. Regioselective reductive ring-opening of the 4,6-benzylidene acetal, using sodium cyanoborohydride and hydrochloric acid in tetrahydrofuran[15] (→ **10**, 67%), followed by treatment with pyridine–acetic anhydride (→ **11**, 99%) and subsequent hydrogenation using 10% Pd–C gave **12** in 90% yield.

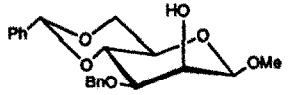
The synthesis of the 3-*O*-methyl-D-mannose donor (**18**) involved also the application of the oxidation–reduction method, whereby benzyl 4,6-*O*-isopropylidene-3-*O*-methyl-β-D-glucopyranoside (**13**) was converted into the corresponding *manno* derivative (**15**). Isopropylidenation of benzyl 3-*O*-methyl-β-D-glucopyranoside[16], using 2,2-dimethoxypropane and *p*-toluenesulfonic acid, yielded crystalline **13** (88%), which was oxidised using 2:1 dimethyl sulfoxide–acetic anhydride to give **14** in its keto and *gem*-diol form (79%), as shown by ^{13}C NMR spectroscopy. Reduction of this mixture with sodium borohydride afforded **15** (79%) and some **13** (7%). Then compound **15** was de-isopropylidenated and acetylated (→ **16**, 93%), hydrogenolysed (→ **17**, 97%), and treated with trichloroacetonitrile in the presence of 1,8-diazabicyclo[5.4.0]undec-7-ene[17] to afford **18** (73%). Coupling of **18** with **12** in dichloromethane (1 h, −40°C), using trimethylsilyl triflate as a catalyst, gave tetrasaccharide derivative **19** in 71% yield. Finally, Zemplén deacetylation of **19** afforded **2** (90%). For ^1H NMR structural-reported-group data, see Table I.

For the synthesis of the tetrasaccharides **3** and **4**, having a 3-*O*-methyl-α-D-mannose residue linked either 1 → 3 or 1 → 6, the 4,6-benzylidene acetal in compound **9** was changed for a 4,6-(prop-2-enylidene) acetal[18]. Regioselective reductive ring-opening and acetylation gives a synthon with an allyl group at O-6 and a benzyl group at O-3, making the regiospecific introduction of 3-*O*-methyl-α-D-mannose and α-D-mannose residues possible. To this end, methyl 3-*O*-benzyl-β-D-glucopyranoside[11] was treated with acrolein dimethyl acetal and *p*-toluenesulfonic acid in *N*,*N*-dimethylformamide[18] to give crystalline **20** (75%). Oxidation of **20** using 2:1 dimethyl sulfoxide–acetic anhydride gave **21**, in its keto and *gem*-diol

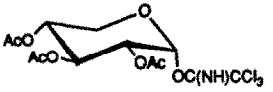
5



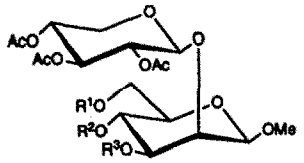
6



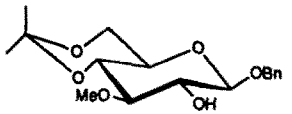
7



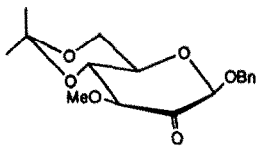
8



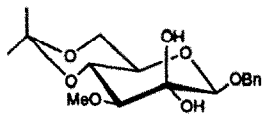
9 R^1, R^2 = CHPh, R^3 = Bn
10 R^1 = R^3 = Bn, R^2 = H
11 R^1 = R^3 = Bn, R^2 = Ac
12 R^1 = R^3 = H, R^2 = Ac

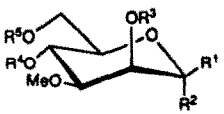


13

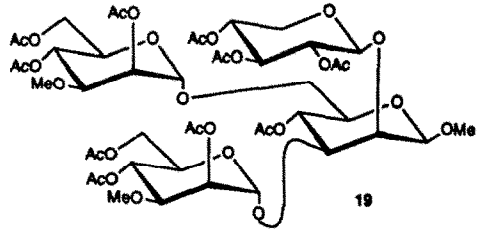


14

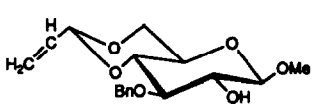




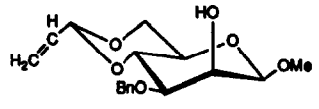
15 R^1 = OBn, R^2 = R^3 = H, R^4, R^5 = $C(CH_3)_2$
16 R^1 = OBn, R^2 = H, R^3 = R^4 = R^5 = Ac
17 R^1, R^2 = H, OH, R^3 = R^4 = R^5 = Ac
18 R^1 = H, R^2 = OC(NH)CCl_3, R^3 = R^4 = R^5 = Ac



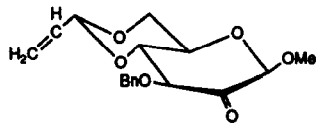
19

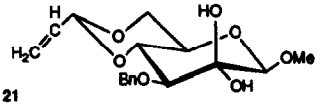


20

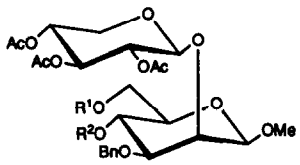


22

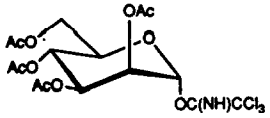




21



23 R^1, R^2 = CHCH=CH_2
24 R^1 = All, R^2 = H
25 R^1 = All, R^2 = Ac
26-a R^1 = H, R^2 = Ac
26-b R^1 = Ac, R^2 = H



27

form. After evaporation of the reagents, the residue, still containing a small amount of by-product (see above), was directly treated with sodium borohydride to afford **22** (56% from **20**) and **20** (11% from **20**). Xylosylation of **22** with **8** in dichloromethane at −40°C, using trimethylsilyl triflate as a catalyst, gave **23** (89%). Regioselective reductive ring-opening of the 4,6-(prop-2-enylidene) acetal, using sodium cyanoborohydride and hydrochloric acid in tetrahydrofuran (→ **24**, 69%), followed by treatment with pyridine–acetic anhydride gave **25** (98%). De-allylation of **25** using the Wilkinson catalyst in the presence of 1,4-diazabicyclo[2.2.2]octane[19] followed by hydrolysis yielded one spot in TLC (**26-a**). However, during column chromatography, acetyl migration in the β-D-mannose residue occurred from O-4 → O-6, and the 4-*O*-acetyl derivative **26-a** could be isolated in only 53% yield, together with the undesired 6-*O*-acetyl derivative **26-b** (40%). This problem could be overcome by direct glycosylation after work-up, as is shown for the synthesis of **31**.

Condensation of compound **26-a** with **27** in dichloromethane (1 h, −40°C), using trimethylsilyl triflate as a catalyst (→ **28**, 77%), followed by hydrogenolysis of the benzyl ether of the resulting trisaccharide derivative gave acceptor **29** (98%), which was mannosylated with **18** in dichloromethane (trimethylsilyl triflate, 1.5 h,

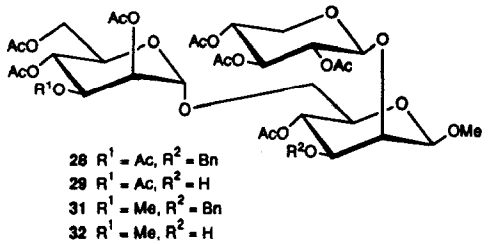
TABLE I

300-MHz ^{1}H NMR data of the tetrasaccharides **2–4**, together with those of reference compound methyl 3,6-di-*O*-α-D-mannopyranosyl-2-*O*-β-D-xylopyranosyl-β-D-mannopyranoside[8] (**R**)

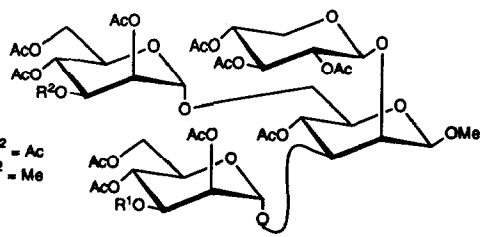
Residue	Reporter group (J)	δ (ppm)/J (Hz)			
		2	**3**	**4**	**R**
β-Man	H-1 [a]	4.689	4.682	4.687	4.681
	H-2 ($J_{2,3}$)	4.203 (2.3)	4.197 (2.1)	4.200 (2.3)	4.197 (2.8)
	CH_3O	3.532	3.526	3.531	3.523
Xyl	H-1 ($J_{1,2}$)	4.488 (7.4)	4.482 (7.4)	4.483 (7.4)	4.474 (7.5)
α-Man-(1 → 6)	H-1 ($J_{1,2}$)	4.948 (1.8)	4.903 (1.7)	4.945 (1.8)	4.900 (1.8)
	H-2 ($J_{2,3}$)	4.263 (3.2)	n.d. [b]	4.258 (3.0)	4.010 (3.5)
	CH_3O	3.459		3.457	
α-Man-(1 → 3)	H-1 ($J_{1,2}$)	5.183 (1.5)	5.180 (1.5)	5.141 (1.4)	5.138 (1.8)
	H-2 ($J_{2,3}$)	4.303 (2.9)	4.294 (n.d.)	4.043 (3.3)	4.035 (3.4)
	CH_3O	3.445	3.445		

[a] Because of the very small $J_{1,2}$ value, H-1 is observed as a singlet. [b] Not determined.

−40°C) to afford tetrasaccharide derivative **30** (61%). Zemplén deacetylation then gave compound **3** (96%). Trisaccharide derivative **31** was prepared in 51% yield by condensation of non-purified **26-a** (see above) with **18** in dichloromethane, using trimethylsilyl triflate as a catalyst (1 h, −40°C). Hydrogenolysis of **31** (→ **32**, 98%) and subsequent glycosylation of **32** with **27** gave tetrasaccharide derivative **33** (70%), which after Zemplén deacetylation afforded **4** (96%). For ^{1}H NMR structural-reporter-group data of **3** and **4**, see Table I.



28 R^1 = Ac, R^2 = Bn
29 R^1 = Ac, R^2 = H
31 R^1 = Me, R^2 = Bn
32 R^1 = Me, R^2 = H



30 R^1 = Me, R^2 = Ac
33 R^1 = Ac, R^2 = Me

TABLE II

Coupling constants (J, Hz) between the skeleton protons of the xylose residue in protected oligosaccharides synthesised in this study

Compound	$J_{1,2}$	$J_{2,3}$	$J_{3,4}$	$J_{4,5eq}$	$J_{4,5ax}$	$J_{5,5}$
9	6.1	8.1	7.9	4.7	7.5	−12.0
10	6.3	8.0	8.0	4.8	8.0	−11.9
12	6.9	n.d. [a]	n.d.	5.1	n.d.	−11.8
19	7.1	9.1	n.d.	5.6	9.0	−12.3
23	5.6	7.7	7.7	4.6	7.4	−12.0
24	6.3	8.2	8.0	4.8	8.0	−12.9
25	n.d.	n.d.	n.d.	3.4	n.d.	−12.0
26-a	n.d.	n.d.	n.d.	3.5	4.7	−12.4
26-b	7.0	9.0	8.8	5.1	8.8	−11.8
28	n.d.	n.d.	n.d.	3.5	4.9	−12.3
29	6.7	8.6	n.d.	n.d.	8.8	−11.9
30	n.d.	n.d.	n.d.	5.2	8.2	−11.6
31	4.7	6.5	n.d.	5.5	n.d.	−12.3
33	5.8	n.d.	7.1	4.4	7.1	n.d.

[a] Not determined.

Evaluation of the ^{1}H NMR spectra of the compounds containing a protected β-D-xylopyranose residue showed that the J values between the skeleton protons vary to some extent (Table II). Taking into account especially the $J_{1,2}$, $J_{4,5ax}$, and $J_{4,5eq}$ values, it can be concluded that these variations have to reflect changes in conformation of the xylose residue. This behaviour is not uncommon for protected β-D-Xyl$p$ derivatives, and quite often $^1C_4$(D) ⇔ $^4C_1$(D) conformational equilibria are suggested in case of small $J_{1,2}/J_{4,5ax}/J_{4,5eq}$ values, explained by the anomeric effect which balances the destabilising effect of the three axially oriented O-acetyl groups on the Xyl$p$ ring[9,20–26]. In this context it has to be mentioned that distortions of the $^4C_1$(D) chair can also lead to deviating J values.

EXPERIMENTAL

General methods.—The ^{1}H (300 and 360 MHz) and ^{13}C (APT, 50 MHz) NMR spectra were recorded at 25°C with a Bruker AC 300, WP 200, or HX 360 spectrometer. Chemical shifts (δ) are given in ppm relative to the signal for internal Me_4Si ($CDCl_3$) or sodium 4,4-dimethyl-4-silapentane-1-sulfonate (D_2O; indirectly to internal acetone, δ 2.225) for ^{1}H, and to the signal for internal Me_4Si ($CDCl_3$; indirectly to $CDCl_3$, δ 76.9) or external Me_4Si (D_2O; indirectly to internal acetone, δ 31.55) for ^{13}C. Column chromatography was performed on Kieselgel 60 (Merck, < 230 mesh) and fractions were monitored by TLC on Kieselgel 60 F_{254} (Merck) by detection with UV light and then charring with H_2SO_4. Optical rotations were measured for solutions in $CHCl_3$, unless otherwise stated, at 20°C with a Perkin–Elmer 241 polarimeter, using a 10-cm 1-mL cell. Melting points

were determined with a Mettler FP 51 instrument. In the work-up procedures, washings were carried out three times with appropriate quantities of water or aq 5% $NaHCO_3$ unless indicated otherwise. Solvents were evaporated under reduced pressure at 40°C (bath) unless indicated otherwise. All solvents were distilled from the appropriate drying agents.

Methyl 3-O-benzyl-4,6-O-benzylidene-β-D-glucopyranoside (**5**).—To a solution of methyl 3-*O*-benzyl-β-D-glucopyranoside[11] (1.8 g, 6.3 mmol) in *N*,*N*-dimethylformamide (17 mL) and α,α-dimethoxytoluene (1.8 mL, 12 mmol) was added *p*-toluenesulfonic acid monohydrate (150 mg). After stirring for 1 h under reduced pressure (20 mmHg), TLC (95:5 CH_2Cl_2–acetone) indicated the reaction to be complete, and solid $NaHCO_3$ was added. The mixture was diluted with CH_2Cl_2 (300 mL), washed with water, dried ($MgSO_4$), filtered, and concentrated. The residue was crystallised from EtOH to give **5** (1.8 g, 75%); mp 181°C; $[\alpha]_D$ −38° (*c* 1); R_f 0.60; lit[27] mp 182–183°C; $[\alpha]_D$ −51° (*c* 0.86, $CHCl_3$). NMR data ($CDCl_3$): ^1H, δ 7.48–7.25 (m, 10 H, 2 Ph), 5.576 (s, 1 H, PhC*H*), 4.974 and 4.792 (2 d, each 1 H, PhCH_2O), 4.364 (dd, 1 H, $J_{6a,5}$ 5.0, $J_{6a,6b}$ −10.5 Hz, H-6a), 4.328 (d, 1 H, $J_{1,2}$ 7.6 Hz, H-1), 3.804 (t, 1 H, $J_{4,3} = J_{4,5} = 10.2$ Hz, H-4), 3.572 (s, 3 H, CH_3O), 2.442 (d, 1 H, $J_{HO\text{-}2,2}$ 2.2 Hz, HO-2); ^{13}C, δ 137.1, 128.8–127.7, and 125.9 ($C_6H_5CH_2O$ and C_6H_5CHO), 104.1 (Ph*C*H), 101.1 (C-1), 81.3, 80.1, 74.1, and 66.2 (C-2,3,4,5), 74.5 and 68.6 (PhCH_2O and C-6), 57.3 (CH_3O). Anal. Calcd for $C_{21}H_{24}O_6$: C, 67.73; H, 6.50. Found: C, 67.67; H, 6.65.

Methyl 3-O-benzyl-4,6-O-benzylidene-β-D-mannopyranoside (**7**).—A solution of **5** (1.2 g, 3.2 mmol) in 1:2 acetic anhydride–Me_2SO (22 mL) was stirred for 20 h. TLC (95:5 CH_2Cl_2–acetone) then showed the ulose **6** (R_f 0.50–0.72) and a faster moving product (R_f 0.93). The mixture was concentrated, and toluene (3 × 15 mL) was evaporated from the residue, which was then further concentrated in vacuo (bath < 60°C) to yield **6**, isolated as a yellow solid (1.2 g). A purified sample gave: $[\alpha]_D$ −80° (*c* 1); lit[27] $[\alpha]_D$ −81° (*c* 1, $CHCl_3$). NMR data ($CDCl_3$): ^1H, δ 7.51–7.30 (m, 10 H, 2 Ph), 5.587 (s, 1 H, PhC*H*), 4.970 and 4.764 (2 d, each 1 H, PhCH_2O), 4.780 (s, 1 H, H-1), 4.460 (dd, 1 H, $J_{6a,5}$ 4.7, $J_{6a,6b}$ − 10.3 Hz, H-6a), 4.240 (dd, 1 H, $J_{3,4}$ 10.3 Hz, H-3), 3.761 (m, 1 H, H-5), 3.601 (s, 3 H, CH_3O); ^{13}C, δ 188.1 (C-2), 137.1, 136.7, 129.0–127.8, and 125.9 ($C_6H_5CH_2O$ and C_6H_5CHO), 101.4 and 100.9 (C-1 and Ph*C*H), 81.9, 81.8, and 66.3 (C-3,4,5), 73.1 and 68.4 (PhCH_2O and C-6), 56.9 (CH_3O).

To a solution of **6** (1.0 g, 2.7 mmol) in 1:1 CH_2Cl_2–MeOH (20 mL) containing Kieselgel 60 (70–230 mesh, 0.5 g) was added $NaBH_4$ (0.4 g, 11 mmol) in portions during 30 min at 0°C. After 30 min, TLC (95:5 CH_2Cl_2–acetone) showed the formation of **5** (R_f 0.60) and **7** (R_f 0.41) in the ratio ~1:7. The mixture was diluted with CH_2Cl_2 (250 mL), filtered, washed with water, dried ($MgSO_4$), filtered, and concentrated. Column chromatography (95:5 CH_2Cl_2–acetone) of the residue gave **5** (100 mg, 10%), and then **7** (660 mg, 66%), both isolated as white solids (yields calculated from **5**). Compound **7**: mp 119°C (from EtOH); $[\alpha]_D$ −28° (*c* 1); lit[27] mp 119–120°C (EtOH); $[\alpha]_D$ −33° (*c* 0.86, $CHCl_3$). NMR data

($CDCl_3$): ^1H, δ 7.52–7.20 (m, 10 H, 2 Ph), 5.614 (s, 1 H, PhC*H*), 4.871 and 4.777 (2 d, each 1 H, PhCH_2O), 4.431 (bs, 1 H, H-1), 4.344 (dd, 1 H, $J_{6a,5}$ 4.9, $J_{6a,6b}$ −10.5 Hz, H-6a), 3.657 (dd, 1 H, $J_{3,2}$ 3.3, $J_{3,4}$ 9.6 Hz, H-3), 3.565 (s, 3 H, CH_3O), 3.355 (m, 1 H, H-5), 2.529 (d, 1 H, $J_{HO\text{-}2,2}$ 1.2 Hz, HO-2); ^{13}C, δ 137.8, 137.3, 128.8–127.7, and 125.9 ($C_6H_5CH_2O$ and C_6H_5CH), 101.3 (C-1 and PhC*H*), 78.3, 76.5, 69.7, and 66.7 (C-2,3,4,5), 72.4 and 68.4 (C-6 and PhCH_2O), 57.1 (CH_3O). Anal. Calcd for $C_{21}H_{24}O_6$: C, 67.73; H, 6.50. Found: C, 67.48; H, 6.61.

Methyl 3-O-benzyl-4,6-O-benzylidene-2-O-(2,3,4-tri-O-acetyl-β-D-xylopyranosyl)-β-D-mannopyranoside (**9**).—A solution of **7** (568 mg, 1.5 mmol) and 2,3,4-tri-*O*-acetyl-α-D-xylopyranosyl trichloroacetimidate[14] (**8**; 977 mg, 2.3 mmol) in CH_2Cl_2 (10 mL) containing powdered 4A molecular sieves (5.5 g) was stirred for 30 min under N_2. Then a solution of trimethylsilyl triflate (65 μL) in CH_2Cl_2 (12 mL) was added dropwise at −40°C, and after 2 h, when TLC showed the disappearance of **7** and the formation of **9** (R_f 0.76, 95:5 CH_2Cl_2–acetone), pyridine (1 mL) was added. The mixture was filtered through Celite, then concentrated, and toluene (3 × 10 mL) was evaporated from the residue. Two-fold column chromatography [first 95:5 CH_2Cl_2–acetone, then 1:1 light petroleum (bp 40–60°C)–EtOAc] of the residue gave **9**, isolated as a white foam (740 mg, 75%); $[\alpha]_D$ −96° (*c* 1); R_f 0.46 [1:1 light petroleum (bp 40–60°C)–EtOAc]. NMR data ($CDCl_3$): ^1H, δ 7.51–7.26 (m, 10 H, 2 Ph), 5.591 (s, 1 H, PhC*H*), 5.189 (t, 1 H, $J_{3',4'}$ 7.9 Hz, H-3'), 5.058 (dd, 1 H, $J_{2',3'}$ 8.1 Hz, H-2'), 4.933 (m, 1 H, $J_{4',5'eq}$ 4.7 Hz, H-4'), 4.930 (d, 1 H, $J_{1',2'}$ 6.1 Hz, H-1'), 4.763 (s, 2 H, PhCH_2O), 4.315 (s, 1 H, H-1), 4.155 (d, 1 H, $J_{2,3}$ 3.0 Hz, H-2), 3.564 (dd, 1 H, $J_{3,4}$ 9.9 Hz, H-3), 3.462 (s, 3 H, CH_3O), 3.378 (dd, 1 H, $J_{5'ax,4'}$ 7.5, $J_{5'ax,5'eq}$ −12.0 Hz, H-5'*ax*), 3.279 (m, 1 H, $J_{5,6a}$ 4.8, $J_{5,6b}$ 9.9 Hz, H-5), 2.074, 2.056, and 2.047 (3 s, each 3 H, 3 Ac); ^{13}C, δ 169.7 (2 C) and 169.2 (3 *C*OCH_3), 138.1, 137.4, 128.7–127.4, and 125.9 ($C_6H_5CH_2O$ and C_6H_5CH), 102.3, 101.3, and 100.6 (C-1,1' and PhC*H*), 78.0, 76.0, 74.9, 70.3, 70.0, 68.8, and 67.4 (C-2,3,4,5,2',3',4'), 71.5, 68.4, and 61.4 (C-6,5' and PhCH_2O), 56.8 (CH_3O), 20.7 (CO*C*H_3). Anal. Calcd for $C_{32}H_{38}O_{13}$: C, 60.94; H, 6.07. Found: C, 60.43; H, 6.00.

Methyl 3,6-di-O-benzyl-2-O-(2,3,4-tri-O-acetyl-β-D-xylopyranosyl)-β-D-mannopyranoside (**10**).—A solution of **9** (627 mg, 1.0 mmol) and sodium cyanoborohydride (750 mg, 12 mmol) in tetrahydrofuran (18 mL) containing 3A molecular sieves (2.0 g) was stirred for 30 min under N_2. Then a saturated solution of HCl in diethyl ether was added until the evolution of gas ceased, and the mixture was stirred for 30 min. TLC (95:5 CH_2Cl_2–acetone) then showed the conversion of **9** (R_f 0.76) into **10** (R_f 0.22). The mixture was diluted with CH_2Cl_2 (200 mL), filtered through Celite, washed with water, aq 5% $NaHCO_3$, and water, dried ($MgSO_4$), filtered, and concentrated. Column chromatography (95:5 CH_2Cl_2–acetone) of the residue gave **10**, isolated as a white solid (421 mg, 67%); $[\alpha]_D$ −101° (*c* 1). NMR data ($CDCl_3$): ^1H, δ 7.38–7.27 (m, 10 H, 2 Ph), 5.175 (t, 1 H, $J_{3',4'}$ 8.0 Hz, H-3'), 4.996 (dd, 1 H, $J_{2',3'}$ 8.0 Hz, H-2'), 4.917 (m, 1 H, $J_{4',5'eq}$ 4.8, $J_{4',5'ax}$ 8.0 Hz, H-4'), 4.902 (d, 1 H, $J_{1',2'}$ 6.3 Hz, H-1'), 4.799 and 4.495 (2 d, each 1 H, PhCH_2O), 4.602 and 4.557 (2 d, each 1 H, PhCH_2O), 4.267 (s, 1 H, H-1), 4.228

(dd, 1 H, $J_{5'eq,5'ax}$ −11.9 Hz, H-5′*eq*), 4.150 (d, 1 H, $J_{2,3}$ 2.9 Hz, H-2), 3.821 (dd, 1 H, $J_{6a,5}$ 3.3, $J_{6a,6b}$ −10.4 Hz, H-6a), 3.743 (m, 1 H, $J_{4,5}$ 9.4 Hz, H-4), 3.658 (dd, 1 H, $J_{6b,5}$ 6.4 Hz, H-6b), 3.472 (s, 3 H, CH_3O), 3.401 (m, 1 H, H-5), 3.356 (dd, 1 H, H-5′*ax*), 3.289 (dd, 1 H, $J_{3,4}$ 9.4 Hz, H-3), 2.527 (d, 1 H, $J_{HO-4,4}$ 1.9 Hz, HO-4), 2.047, 2.011, and 1.989 (3 s, each 3 H, 3 Ac); ^{13}C, δ 169.9, 169.7, and 169.3 (3 $COCH_3$), 138.0, 137.5, and 128.3–127.5 ($C_6H_5CH_2O$), 101.5 and 100.6 (C-1,1′), 79.5, 75.1, 72.4, 70.0, 68.9, and 67.5 (2 C) (C-2,3,4,5,2′,3′,4′), 73.3, 70.6, 70.4, and 61.4 (C-6,5′ and 2 PhCH_2O), 56.6 (CH_3O), 20.6 ($COCH_3$). Anal. Calcd for $C_{32}H_{40}O_{13}$: C, 60.75; H, 6.37. Found: C, 60.52; H, 6.42.

*Methyl 4-*O*-acetyl-3,6-di-*O*-benzyl-2-*O*-(2,3,4-tri-*O*-acetyl-β-*D*-xylopyranosyl)-β-*D*-mannopyranoside* (**11**).—A solution of **10** (336 mg, 0.52 mmol) in 1:1 pyridine–acetic anhydride (30 mL) was stirred for 16 h at room temperature, and toluene (3 × 15 mL), EtOH (3 × 15 mL), and CH_2Cl_2 (3 × 15 mL) were evaporated from the residue, to give **11**, isolated as a yellow solid (350 mg, 99%); R_f 0.60 (95:5 CH_2Cl_2–acetone). NMR data ($CDCl_3$): ^1H, δ 7.35–7.16 (m, 10 H, 2 Ph), 5.145 (t, 1 H, $J_{4,3} = J_{4,5} = 9.7$ Hz, H-4), 4.711 and 4.492 (2 d, each 1 H, PhCH_2O), 4.528 (s, 2 H, PhCH_2O), 4.290 (s, 1 H, H-1), 4.152 (d, 1 H, $J_{2,3}$ 3.0 Hz, H-2), 3.480 (s, 3 H, CH_3O), 2.101, 2.071, 2.050, and 1.946 (4 s, each 3 H, 4 Ac); ^{13}C, δ 137.6 and 128.2–127.4 ($C_6H_5CH_2O$), 101.4 and 99.0 (C-1,1′), 73.5, 70.7, 70.1, and 59.6 (C-6,5′ and 2 PhCH_2O), 56.7 (CH_3O), 20.6 ($COCH_3$). Anal. Calcd for $C_{34}H_{42}O_{14}$: C, 60.53; H, 6.27. Found: C, 60.29; H, 6.45.

*Methyl 4-*O*-acetyl-2-*O*-(2,3,4-tri-*O*-acetyl-β-*D*-xylopyranosyl)-β-*D*-mannopyranoside* (**12**).—To a solution of **11** (375 mg, 0.58 mmol) in 1:1 EtOH–EtOAc (12 mL) were added acetic acid (0.3 mL) and 10% Pd–C (250 mg). Hydrogenolysis was performed at atmospheric pressure for 1 h, the mixture was filtered and concentrated, and toluene (3 × 10 mL) was evaporated from the residue, to yield **12**, isolated as a white solid (249 mg, 90%); R_f 0.76 (9:1 CH_2Cl_2–MeOH). NMR data ($CDCl_3$): ^1H, δ 4.745 (d, 1 H, $J_{1',2'}$ 6.9 Hz, H-1′), 4.380 (s, 1 H, H-1), 4.136 (dd, 1 H, $J_{5'eq,4'}$ 5.1, $J_{5'eq,5'ax}$ −11.8 Hz, H-5′*eq*), 4.000 (d, 1 H, $J_{2,3}$ 3.1 Hz, H-2), 3.493 (s, 3 H, CH_3O), 2.846 and 2.810 (2 bs, each 1 H, HO-3,6), 2.104, 2.060, 2.058, and 2.052 (4 s, each 3 H, 4 Ac); ^{13}C, δ 170.5 and 169.8–169.6 ($COCH_3$), 101.1 (C-1,1′), 77.8, 74.2, 71.1, 70.5 (2 C), 69.0, and 68.5 (C-2,3,4,5,2′,3′,4′), 61.8 and 61.3 (C-6,5′), 56.9 (CH_3O), 20.8, 20.6, and 20.5 (2 C) (4 $COCH_3$). Anal. Calcd for $C_{20}H_{30}O_{14}$: C, 48.58; H, 6.12. Found: C, 48.42; H, 6.33.

*Benzyl 4,6-*O*-isopropylidene-3-*O*-methyl-β-*D*-glucopyranoside* (**13**).—To a solution of benzyl 3-*O*-methyl-β-D-glucopyranoside[16] (6.0 g, 21.1 mmol) in 2,2-dimethoxypropane (50 mL) was added *p*-toluenesulfonic acid monohydrate (100 mg), and the mixture was stirred for 45 min. TLC (95:5 CH_2Cl_2–acetone) then showed the reaction to be complete, and solid $NaHCO_3$ was added. The mixture was diluted with CH_2Cl_2 (300 mL), washed with water, dried ($MgSO_4$), filtered, and concentrated. The residue was crystallised from EtOH to give **13** (6.0 g, 88%); $[\alpha]_D$ −69° (*c* 1); mp 108°C; R_f 0.43 (95:5 CH_2Cl_2–acetone). NMR data ($CDCl_3$): ^1H, δ 7.37–7.31 (m, 5 H, Ph), 4.911 and 4.632 (2 d, each 1 H, PhCH_2O), 4.448 (d, 1 H,

$J_{1,2}$ 7.7 Hz, H-1), 3.944 (dd, 1 H, $J_{6a,5}$ 5.4, $J_{6a,6b}$ −10.5 Hz, H-6a), 3.811 (t, 1 H, $J_{6b,5}$ 10.5 Hz, H-6b), 3.661 (t, 1 H, $J_{4,3} = J_{4,5} = 9.4$ Hz, H-4), 3.598 (s, 3 H, CH_3O), 3.505 (m, 1 H, $J_{2,3}$ 8.9 Hz, H-2), 2.399 (d, 1 H, $J_{HO\text{-}2,2}$ 2.2 Hz, HO-2), 1.512 and 1.425 (2 s, each 3 H, CMe_2); ^{13}C, δ 137.0 and 128.3–127.8 ($C_6H_5CH_2O$), 102.0 and 99.1 (C-1 and Me_2C), 82.3, 73.9, 73.7, and 67.0 (C-2,3,4,5), 71.0 and 62.0 (C-6 and $PhCH_2O$), 28.9 and 18.9 [$C(CH_3)_2$]. Anal. Calcd for $C_{17}H_{24}O_6$: C, 62.95; H, 7.46. Found: C, 62.61; H, 7.45.

Benzyl 4,6-O-isopropylidene-3-O-methyl-β-D-mannopyranoside (**15**).—A solution of **13** (5.8 g, 17.9 mmol) in 1:2 acetic anhydride–Me_2SO (100 mL) was stirred for 20 h. TLC (95:5 CH_2Cl_2–acetone) then showed the disappearance of **13** (R_f 0.43), and the formation of ulose **14** (R_f 0.28–0.43) and a faster moving product (R_f 0.66). After partial evaporation of the solvent using toluene (3 × 30 mL), the residue was further concentrated in vacuo (bath < 60°C). Column chromatography (95:5 CH_2Cl_2–acetone) of the residue gave **14**, isolated as a syrup (4.6 g, 79%); $[\alpha]_D$ +20° (*c* 1) for $C\text{-}2_{CO}:C\text{-}2_{C(OH)_2} = 0.2:1$. ^{13}C NMR data ($CDCl_3$): δ 187.7 (C-2 as carbonyl) and 93.6 (C-2 as *gem*-diol).

To a solution of **14** (3.0 g, 9.2 mmol) in 1:1 CH_2Cl_2–MeOH (50 mL) containing Kieselgel 60 (70–230 mesh, 1.0 g) was added $NaBH_4$ (1.4 g, 37 mmol), as described for **7**. After 30 min, TLC (95:5 CH_2Cl_2–acetone) showed the formation of **13** (R_f 0.43) and **15** (R_f 0.17) in the ratio ~1:10. The mixture was diluted with CH_2Cl_2 (300 mL), filtered, washed with water, dried ($MgSO_4$), filtered, and concentrated. Column chromatography [3:2 light petroleum (bp 40–60°C)–EtOAc] of the residue first gave **13** (200 mg, 7%), and then **15** (2.4 g, 79%), both isolated as a white solid. Compound **15**: $[\alpha]_D$ −95° (*c* 1); R_f 0.17. NMR data ($CDCl_3$): ^1H, δ 7.41–7.29 (m, 5 H, Ph), 4.934 and 4.664 (2 d, each 1 H, $PhCH_2O$), 4.523 (s, 1 H, H-1), 4.176 (bd, 1 H, $J_{2,3}$ 3.2 Hz, H-2), 4.084 (t, 1 H, H-4), 3.492 (s, 3 H, CH_3O), 3.278 (dd, 1 H, $J_{3,4}$ 9.3 Hz, H-3), 3.180 (m, 1 H, $J_{5,6a}$ 5.8, $J_{5,6b} = J_{5,4} = 9.8$ Hz, H-5), 2.482 (bs, 1 H, HO-2), 1.527 and 1.431 (2 s, each 3 H, CMe_2); ^{13}C, δ 136.3 and 128.2–127.8 ($C_6H_5CH_2O$), 99.5 and 98.4 (C-1 and Me_2C), 79.4, 70.1, 68.2, and 67.6 (C-2,3,4,5), 70.4 and 61.8 (C-6 and $PhCH_2O$), 57.3 (CH_3O), 28.9 and 18.9 [$C(CH_3)_2$]. Anal. Calcd for $C_{17}H_{24}O_6$: C, 62.95; H, 7.46. Found: C, 63.33; H, 7.31.

Benzyl 2,4,6-tri-O-acetyl-3-O-methyl-β-D-mannopyranoside (**16**).—A solution of **15** (2.2 g, 6.8 mmol) in 1:1 acetic acid–water (20 mL) was boiled under reflux for 45 min, then concentrated, and toluene (3 × 20 mL) was evaporated from the residue. The residue was dissolved in 1:1 pyridine–acetic anhydride (20 mL), stirred for 16 h at room temperature, and concentrated, and toluene (3 × 10 mL), EtOH (3 × 10 mL), and CH_2Cl_2 (3 × 10 mL) were evaporated from the residue to yield **16**, isolated as a yellow syrup (2.6 g, 93%); R_f 0.43 (95:5 CH_2Cl_2–acetone). NMR data ($CDCl_3$): ^1H, δ 7.39–7.32 (m, 5 H, Ph), 5.567 (bd, 1 H, $J_{2,3}$ 3.3 Hz, H-2), 5.132 (t, 1 H, $J_{4,5}$ 9.8 Hz, H-4), 4.893 and 4.665 (2 d, each 1 H, $PhCH_2O$), 4.518 (d, 1 H, $J_{1,2}$ 0.9 Hz, H-1), 4.293 (dd, 1 H, $J_{6b,5}$ 5.9 Hz, H-6b), 4.183 (dd, 1 H, $J_{6a,5}$ 2.7, $J_{6a,6b}$ −12.2 Hz, H-6a), 3.541 (m, 1 H, H-5), 3.335 (s, 3 H, CH_3O), 3.321 (dd, 1 H, $J_{3,4}$ 9.8 Hz, H-3), 2.190, 2.114, and 2.072 (3 s, each 3 H, 3 Ac); ^{13}C, δ

170.5, 170.2, and 169.5 (3 $COCH_3$), 136.3, 128.2, and 127.8 ($C_6H_5CH_2O$), 96.7 (C-1), 79.3, 72.2, 67.4, and 66.8 (C-2,3,4,5), 70.1 and 62.6 (C-6 and $PhCH_2O$), 57.4 (CH_3O), 20.7 and 20.6 (2 C) (3 $COCH_3$). Anal. Calcd for $C_{20}H_{26}O_9$: C, 58.52; H, 6.39. Found: C, 58.24; H, 6.21.

2,4,6-Tri-O-acetyl-3-O-methyl-α-D-mannopyranosyl trichloroacetimidate (**18**).—To a solution of **16** (2.5 g, 6.1 mmol) in 1:1 EtOH–EtOAc (30 mL) were added acetic acid (0.5 mL) and 10% Pd–C (250 mg). Hydrogenolysis, and work-up as described for **6**, gave **17**, isolated as a syrup (1.9 g, 97%); R_f 0.16 (95:5 CH_2Cl_2–acetone). Anal. Calcd for $C_{13}H_{20}O_9$: C, 48.75; H, 6.29. Found: C, 48.12; H, 6.23.

To a solution of **17** (1.9 g, 5.9 mmol) in CH_2Cl_2 (25 mL) and trichloroacetonitrile (7.3 mL, 73 mmol) was added 1,8-diazabicyclo[5.4.0]undec-7-ene (1.0 mL, 6.7 mmol), and the mixture was stirred for 1 h. Then the reaction was complete (TLC 95:5 CH_2Cl_2–acetone, R_f 0.52), and the mixture was concentrated. Column chromatography (95:5 CH_2Cl_2–acetone) of the residue gave **18**, isolated as a yellow syrup (2.0 g, 73%); $[\alpha]_D$ + 23° (*c* 1). NMR data ($CDCl_3$): ^1H, δ 8.799 (s, 1 H, NH), 6.303 (d, 1 H, $J_{1,2}$ 2.0 Hz, H-1), 5.536 (dd, 1 H, $J_{2,3}$ 3.4 Hz, H-2), 5.293 (t, 1 H, $J_{4,5}$ 10.0 Hz, H-4), 4.247 (dd, 1 H, $J_{6b,5}$ 5.4, $J_{6b,6a}$ −12.5 Hz, H-6b), 3.732 (dd, 1 H, $J_{3,4}$ 10.0 Hz, H-3), 3.395 (s, 3 H, CH_3O), 2.204, 2.119, and 2.083 (3 s, each 3 H, 3 Ac); ^{13}C, δ 170.0, 169.3, and 169.2 (3 $COCH_3$), 159.0 ($OCNHCCl_3$), 94.3 (C-1), 90.0 ($OCNHCCl_3$), 76.4, 70.8, 66.4, and 65.7 (C-2,3,4,5), 61.8 (C-6), 57.5 (CH_3O), 20.3 ($COCH_3$). Anal. Calcd for $C_{15}H_{20}O_9NCl_3$: C, 38.77; H, 4.34. Found: C, 38.40; H, 4.45.

Methyl 4-O-acetyl-3,6-di-O-(2,4,6-tri-O-acetyl-3-O-methyl-α-D-mannopyranosyl)-2-O-(2,3,4-tri-O-acetyl-β-D-xylopyranosyl)-β-D-mannopyranoside (**19**).—A solution of **12** (50 mg, 0.1 mmol) and **18** (170 mg, 0.37 mmol) in CH_2Cl_2 (10 mL) containing powdered 4A molecular sieves (1.0 g) was stirred for 30 min under N_2. A solution of trimethylsilyl triflate (40 μL) in CH_2Cl_2 (2 mL) was added dropwise at −40°C, and after 1 h, when TLC showed the disappearance of **12** and a new compound **19** (R_f 0.18, 9:1 CH_2Cl_2–acetone), pyridine (1 mL) was added, the mixture was filtered through Celite and concentrated, and toluene (3 × 10 mL) was evaporated from the residue. Column chromatography (9:1 CH_2Cl_2–acetone) of the residue gave **19**, isolated as a white solid (72 mg, 71%); $[\alpha]_D$ −34° (*c* 1). NMR data ($CDCl_3$): ^1H, δ 5.438 and 5.102 (2 dd, each 1 H, $J_{2'',1''} = J_{2''',1'''} = 1.7$, $J_{2'',3''} = J_{2''',3'''} = 3.4$, H-2″,2‴), 5.028 (dd, 1 H, $J_{2',3'}$ 9.1 Hz, H-2′), 4.908 and 4.814 (bs and d, each 1 H, H-1″,1‴), 4.900 (m, 1 H, H-4′), 4.765 (d, 1 H, $J_{1',2'}$ 7.1 Hz, H-1′), 4.353 (s, 1 H, H-1), 4.275 (dd, 1 H, $J_{5'eq,4'}$ 5.6, $J_{5'eq,5'ax}$ −12.3 Hz, H-5′*eq*), 3.497 and 3.398 (2 s, 3 and 6 H, 3 CH_3O), 3.306 (dd, 1 H, $J_{5'ax,4'}$ 9.0 Hz, H-5′*ax*), 2.148, 2.144, 2.128, 2.098, 2.089, 2.077, 2.068, and 2.043 (8 s, 3,3,3,3,6,6,3,3 H, 10 Ac); ^{13}C, δ 170.5–169.0 ($COCH_3$), 101.3 (2 C), 99.9, and 97.6 (C-1,1′,1″,1‴), 78.5, 76.4, 76.2, 75.9, 72.6, 70.8, 70.3, 69.4, 68.7, 68.5, 68.3, 68.0, 67.8, 67.5, and 67.4 (C-2,3,4,5,2′,3′,4′,2″,3″,4″,5″,2‴,3‴,4‴,5‴), 66.4, 63.0, 62.5, and 61.6 (C-6,5′,6″,6‴), 58.0, 57.6, and 56.7 (3 CH_3O), 20.8–20.5 ($COCH_3$). Anal. Calcd for $C_{46}H_{66}O_{30}$: C, 50.27; H, 6.05. Found: C, 50.15; H, 6.12.

Methyl 3,6-di-O-(3-O-methyl-α-D-mannopyranosyl)-2-O-β-D-xylopyranosyl-β-D-mannopyranoside (**2**).—To a solution of **19** (25 mg, 24 μmol) in MeOH (5 mL) was added NaOMe (pH 10). After 16 h, the solution was neutralised with Dowex-50 (H^+) resin, filtered, and concentrated, and CH_2Cl_2 (3 × 5 mL) was evaporated from the residue, to give **2**, isolated as a white powder (13 mg, 90%); $[\alpha]_D$ + 0.4° (*c* 0.5, H_2O); R_f 0.50 (2:1:1 1-butanol–MeOH–water). ^{13}C NMR data (D_2O): δ 106.4, 103.3, 102.6, and 100.9 (C-1,1′,1″,1‴), 58.2, 57.6, and 57.5 (3 CH_3O). For ^1H NMR data, see Table I.

Methyl 3-O-benzyl-4,6-O-prop-2-enylidene-β-D-glucopyranoside (**20**).—To a solution of methyl 3-*O*-benzyl-β-D-glucopyranoside[11] (11.1 g, 39 mmol) in *N*,*N*-dimethylformamide (33 mL) and acrolein dimethyl acetal (15.9 mL, 134 mmol) was added *p*-toluenesulfonic acid monohydrate (250 mg), and the solution was stirred for 16 h at 60°C. TLC (95:5 CH_2Cl_2–acetone) then showed the reaction to be complete, and triethylamine (2 mL) was added. The mixture was concentrated in vacuo (bath < 60°C), diluted with CH_2Cl_2 (250 mL), washed with water, dried ($MgSO_4$), filtered, and concentrated. Crystallisation of the residue from EtOH gave **20** (9.4 g, 75%); mp 146°C; $[\alpha]_D$ −6° (*c* 1); R_f 0.51 (95:5 CH_2Cl_2–acetone). NMR data ($CDCl_3$): ^1H, δ 7.40–7.28 (m, 5 H, Ph), 5.879 (m, 1 H, H_2C=C*H*CH), 5.509 and 5.345 (2 m, each 1 H, H_2C=CHCH), 5.012 (m, 1 H, H_2C=CHC*H*), 4.948 and 4.771 (2 d, each 1 H, PhCH_2O), 4.287 (d, 1 H, $J_{1,2}$ 7.6 Hz, H-1), 4.248 (dd, 1 H, $J_{6a,5}$ 5.0, $J_{6a,6b}$ −10.5 Hz, H-6a), 3.550 (s, 3 H, CH_3O), 3.351 (m, 1 H, $J_{5,4} = J_{5,6b} = 9.5$ Hz, H-5), 2.386 (d, 1 H, $J_{HO\text{-}2,2}$ 2.1 Hz, HO-2); ^{13}C, δ 138.2 and 128.3–127.7 ($C_6H_5CH_2O$), 133.4 (H_2C=*C*HCH), 118.9 (H_2C=CHCH), 104.0 (H_2C=CH*C*H), 100.3 (C-1), 80.9, 80.0, 74.0, and 66.1 (C-2,3,4,5), 74.4 and 68.2 (C-6 and Ph*C*H_2O), 57.2 (CH_3O). Anal. Calcd for $C_{17}H_{22}O_6$: C, 63.34; H, 6.88. Found: C, 63.31; H, 6.76.

Methyl 3-O-benzyl-4,6-O-prop-2-enylidene-β-D-mannopyranoside (**22**).—A solution of **20** (7.2 g, 22 mmol) in 1:2 acetic anhydride–Me_2SO (10 mL) was stirred for 20 h. TLC (95:5 CH_2Cl_2–acetone) then showed the formation of the ulose **21** (R_f 0.23–0.35) and a faster moving product (R_f 0.87). Work-up as described for **6** gave **21**, isolated as a yellow solid (8.3 g). A purified sample gave $[\alpha]_D$ −50° (*c* 1) for $C\text{-}2_{CO} : C\text{-}2_{C(OH)_2} = 1:1$. ^{13}C NMR data ($CDCl_3$): δ 187.9 (C-2 as carbonyl) and 93.4 (C-2 as *gem*-diol).

To a solution of **21** (7.1 g, 22 mmol) in 1:1 CH_2Cl_2–MeOH (200 mL) containing Kieselgel 60 (70–230 mesh, 3.0 g) was added $NaBH_4$ (2.6 g, 68 mmol), as described for **7**. After 30 min, TLC (95:5 CH_2Cl_2–acetone) showed **20** (R_f 0.51) and **22** (R_f 0.31) in the ratio ~ 1:6. The mixture was diluted with CH_2Cl_2 (300 mL), filtered, washed with water, dried ($MgSO_4$), filtered, and concentrated. Column chromatography [3:2 light petroleum (bp 40–60°C)–EtOAc] of the residue first gave **20** (800 mg, 11%), and then **22** (4.0 g, 56%), both isolated as a white solid (yields calculated from **20**). Compound **22**: $[\alpha]_D$ −16° (*c* 1); R_f 0.18. NMR data ($CDCl_3$): ^1H, δ 7.41–7.31 (m, 5 H, Ph), 5.889 (m, 1 H, H_2C=C*H*CH), 5.518 and 5.344 (2 m, each 1 H, H_2C=CHCH), 5.050 (m, 1 H, H_2C=CHC*H*), 4.851 and 4.746 (2 d, each 1 H,

PhCH_2O), 4.386 (d, 1 H, $J_{1,2}$ 1.2 Hz, H-1), 4.229 (dd, 1 H, $J_{6a,5}$ 4.9, $J_{6a,6b}$ −10.5 Hz, H-6a), 4.090 (m, 1 H, H-2), 3.973 (t, 1 H, $J_{4,5}$ 9.5 Hz, H-4), 3.739 (t, 1 H, $J_{6b,5}$ 10.4 Hz, H-6b), 3.592 (dd, 1 H, $J_{2,3}$ 3.3, $J_{3,4}$ 9.5 Hz, H-3), 3.540 (s, 3 H, CH_3O), 3.251 (m, 1 H, H-5), 2.488 (d, 1 H, $J_{HO\text{-}2,2}$ 1.5 Hz, HO-2); ^{13}C, δ 133.6 (H_2C=CHCH), 128.4 and 127.8 ($C_6H_5CH_2O$), 118.9 (H_2C=CHCH), 101.3 and 100.6 (C-1 and H_2C=CHCH), 77.0, 76.6, 69.6, and 66.7 (C-2,3,4,5), 72.4 and 68.1 (C-6 and PhCH_2O), 57.2 (CH_3O). Anal. Calcd for $C_{17}H_{22}O_6$: C, 63.34; H, 6.88. Found: C, 63.42; H, 6.84.

Methyl 3-O-benzyl-4,6-O-prop-2-enylidene-2-O-(2,3,4-tri-O-acetyl-β-D-xylopyranosyl)-β-D-mannopyranoside (**23**).—A solution of **22** (2.1 g, 6.5 mmol) and 2,3,4-tri-*O*-acetyl-α-D-xylopyranosyl trichloroacetimidate[14] (**8**; 3.6 g, 8.6 mmol) in CH_2Cl_2 (50 mL) containing powdered 4A molecular sieves (5.0 g) was stirred for 30 min under N_2. A solution of trimethylsilyl triflate (300 μL) in CH_2Cl_2 (10 mL) was added dropwise at −40°C. After 75 min, when TLC showed the disappearance of **22** and a new compound **23** (R_f 0.45, 95:5 CH_2Cl_2–acetone), pyridine (1 mL) was added, the mixture was filtered through Celite and concentrated, and toluene (3 × 10 mL) was evaporated from the residue. Column chromatography [1:1 light petroleum (bp 40–60°C)–EtOAc] of the residue afforded **23**, isolated as a white foam (3.4 g, 89%); $[\alpha]_D$ −86° (*c* 1); R_f 0.37. NMR data ($CDCl_3$): ^1H, δ 7.39–7.29 (m, 5 H, Ph), 5.872 (m, 1 H, H_2C=CHCH), 5.505 and 5.326 (2 m, each 1 H, H_2C=CHCH), 5.166 (t, 1 H, $J_{3',2'} = J_{3',4'} = 7.7$ Hz, H-3′), 4.913 (d, 1 H, $J_{1',2'}$ 5.6 Hz, H-1′), 4.738 (s, 2 H, PhCH_2O), 4.302 (dd, 1 H, $J_{5'eq,4'}$ 4.6, $J_{5'eq,5'ax}$ −12.0 Hz, H-5′*eq*), 4.276 (s, 1 H, H-1), 4.177 (dd, 1 H, $J_{6a,5}$ 4.8, $J_{6a,6b}$ −10.4 Hz, H-6a), 4.129 (d, 1 H, $J_{2,3}$ 3.0 Hz, H-2), 3.861 (t, 1 H, $J_{4,3} = J_{4,5} = 9.6$ Hz, H-4), 3.657 (t, 1 H, $J_{6b,5}$ 10.3 Hz, H-6b), 3.506 (dd, 1 H, $J_{3,4}$ 9.9 Hz, H-3), 3.441 (s, 3 H, CH_3O), 3.371 (dd, 1 H, $J_{5'ax,4'}$ 7.4 Hz, H-5′*ax*), 3.181 (m, 1 H, H-5), 2.063, 2.054, and 2.028 (3 s, each 3 H, 3 Ac); ^{13}C, δ 169.8 ($COCH_3$), 138.0 and 128.2–127.5 ($C_6H_5CH_2O$), 133.6 (H_2C=CHCH), 118.8 (H_2C=CHCH), 102.3 and 100.6 (2 C) (C-1,1′ and H_2C=CHCH), 77.7, 76.0, 74.8, 70.2, 69.9, 68.9, and 67.4 (C-2,3,4,5,2′,3′,4′), 71.4, 68.1, and 61.4 (C-6,5′ and PhCH_2O), 56.8 (CH_3O), 20.7 ($COCH_3$). Anal. Calcd for $C_{28}H_{36}O_{13}$: C, 57.93; H, 6.25. Found: C, 57.67; H, 6.28.

Methyl 6-O-allyl-3-O-benzyl-2-O-(2,3,4-tri-O-acetyl-β-D-xylopyranosyl)-β-D-mannopyranoside (**24**).—A solution of **23** (3.2 g, 5.5 mmol) and sodium cyanoborohydride (4.2 g, 67 mmol) in tetrahydrofuran (100 mL) containing 3A molecular sieves (7.5 g) was stirred for 30 min under N_2. A saturated solution of HCl in diethyl ether was added until the evolution of gas ceased, and the mixture was stirred for 2 h. TLC (95:5 CH_2Cl_2–acetone) then showed the conversion of **23** (R_f 0.45) into **24** (R_f 0.23). The mixture was diluted with CH_2Cl_2 (250 mL), filtered through Celite, washed with water, aq 5% $NaHCO_3$, and water, dried ($MgSO_4$), filtered, and concentrated, and MeOH (3 × 25 mL) was evaporated from the residue. Column chromatography (9:1 CH_2Cl_2–acetone) of the residue gave **24**, isolated as a white solid (2.2 g, 69%); $[\alpha]_D$ −111° (*c* 1); R_f 0.42. NMR data ($CDCl_3$): ^1H, δ 7.37–7.26 (m, 5 H, Ph), 5.897 (m, 1 H, H_2C=CHCH$_2$O), 5.280 and

5.174 (2 m, each 1 H, H_2C=CHCH$_2$O), 5.181 (t, 1 H, $J_{3',4'}$ 8.0 Hz, H-3'), 5.002 (dd, 1 H, $J_{2',3'}$ 8.2 Hz, H-2'), 4.924 (m, 1 H, $J_{4',5'eq}$ 4.8, $J_{4',5'ax}$ 8.0 Hz, H-4'), 4.899 (d, 1 H, $J_{1',2'}$ 6.3 Hz, H-1'), 4.803 and 4.494 (2 d, each 1 H, PhCH_2O), 4.260 (s, 1 H, H-1), 4.226 (dd, 1 H, $J_{5'eq,5'ax}$ −12.9 Hz, H-5'*eq*), 4.148 (d, 1 H, $J_{2,3}$ 2.9 Hz, H-2), 4.049 and 4.031 (2 m, each 1 H, H$_2$C=CHCH_2O), 3.776 (dd, 1 H, $J_{6a,5}$ 3.4, $J_{6a,6b}$ −10.5 Hz, H-6a), 3.735 (m, 1 H, H-4), 3.620 (dd, 1 H, $J_{6b,5}$ 6.4 Hz, H-6b), 3.465 (s, 3 H, CH$_3$O), 3.287 (dd, 1 H, $J_{3,4}$ 9.3 Hz, H-3), 2.538 (d, 1 H, $J_{HO\text{-}4,4}$ 1.9 Hz, HO-4), 2.049 (s, 9 H, 3 Ac); ^{13}C, δ 169.8 (2 C) and 169.4 (3 *C*OCH$_3$), 137.5 and 128.4–127.8 (C_6H$_5$CH$_2$O), 134.5 (H$_2$C=*C*HCH$_2$O), 116.9 (H_2C=CHCH$_2$O), 101.5 and 100.6 (C-1,1'), 72.3, 70.6, 70.4, and 61.5 (C-6,5, PhCH_2O, and H$_2$C=CHCH_2O), 56.6 (CH$_3$O), 20.7 (CO*C*H$_3$). Anal. Calcd for $C_{28}H_{38}O_{13}$: C, 57.72; H, 6.57. Found: C, 57.15; H, 6.42.

*Methyl 4-*O*-acetyl-6-*O*-allyl-3-*O*-benzyl-2-*O*-(2,3,4-tri-*O*-acetyl-β-*D*-xylopyranosyl)-β-*D*-mannopyranoside* (**25**).—A solution of **24** (2.1 g, 3.6 mmol) in 1:1 pyridine–acetic anhydride (50 mL) was stirred for 16 h, and toluene (3 × 20 mL), EtOH (3 × 20 mL), and CH_2Cl_2 (3 × 20 mL) were evaporated from the residue to give **25**, isolated as a yellow solid (2.2 g, 98%); R_f 0.56 (95:5 CH_2Cl_2–acetone). NMR data ($CDCl_3$): ^{1}H, δ 7.35–7.27 (m, 5 H, Ph), 5.868 (m, 1 H, H$_2$C=C*H*CH$_2$O), 5.255 and 5.163 (2 m, each 1 H, H_2C=CHCH$_2$O), 5.128 (t, 1 H, $J_{4,3} = J_{4,5}$ = 9.6 Hz, H-4), 4.716 and 4.499 (2 d, each 1 H, PhCH_2O), 4.442 (dd, 1 H, $J_{5'ax/eq,4'}$ 3.4, $J_{5'ax,5'eq}$ −12.0 Hz, H-5'*ax* or H-5'*eq*), 4.281 (s, 1 H, H-1), 4.149 (d, 1 H, $J_{2,3}$ 3.0 Hz, H-2), 4.000 and 3.982 (2 m, each 1 H, H$_2$C=CHCH_2O), 3.469 (s, 3 H, CH$_3$O), 2.141, 2.075, 2.072, and 2.028 (4 s, each 3 H, 4 Ac); ^{13}C, δ 169.7 (3 C) and 169.0 (4 *C*OCH$_3$), 137.6, 128.3, 127.7, and 127.5 (C_6H$_5$CH$_2$O), 134.4 (H$_2$C=*C*HCH$_2$O), 117.1 (H_2C=CHCH$_2$O), 101.4 and 99.0 (C-1,1'), 77.3, 73.9, 72.8, 68.7, 68.2, and 67.8 (2 C) (C-2,3,4,5,2',3',4'), 72.4, 70.7, 70.0, and 59.6 (C-6,5', PhCH_2O, and H$_2$C=CHCH_2O), 56.8 (CH$_3$O), 20.7 (CO*C*H$_3$). Anal. Calcd for $C_{30}H_{40}O_{14}$: C, 57.68; H, 6.45. Found: C, 57.28; H, 6.53.

*Methyl 4-*O*-acetyl-3-*O*-benzyl-2-*O*-(2,3,4-tri-*O*-acetyl-β-*D*-xylopyranosyl)-β-*D*-mannopyranoside* (**26-a**) *and methyl 6-*O*-acetyl-3-*O*-benzyl-2-*O*-(2,3,4-tri-*O*-acetyl-β-*D*-xylopyranosyl)-β-*D*-mannopyranoside* (**26-b**).—To a mixture of **25** (746 mg, 1.2 mmol) and 1,4-diazabicyclo[2.2.2]octane (100 mg) in 8:3:1 EtOH–toluene–water (40 mL) was added tris(triphenylphosphine)rhodium(I) chloride (170 mg), and the mixture was boiled under reflux for 2 h, then cooled, and concentrated. A solution of the residue in acetone (45 mL) and M HCl (5 mL) was boiled under reflux for 30 min, when TLC (9:1 CH_2Cl_2–acetone) showed the conversion of the propenyl analogue of **25** (R_f 0.88) into **26-a** (R_f 0.14) to be complete. The mixture was neutralised with aq 5% NaHCO$_3$, concentrated, diluted with CH_2Cl_2 (100 mL), washed with water, dried (MgSO$_4$), filtered, and concentrated. Column chromatography (8:2 CH_2Cl_2–acetone) of the residue first gave **26-b** (280 mg, 40%); R_f 0.73, then **26-a** (371 mg, 53%); $[\alpha]_D$ −108° (*c* 1); R_f 0.57, both isolated as a white solid. NMR data ($CDCl_3$) for **26-a**: ^{1}H, δ 7.71–7.31 (m, 5 H, Ph), 5.243 (t, 1 H, $J_{4,5}$ 9.8 Hz, H-4), 4.730 and 4.505 (2 d, each 1 H, PhCH_2O), 4.433 and 3.402 (2 dd,

each 1 H, $J_{5'ax/eq,4'}$ 3.5 and 4.7, $J_{5'ax,5'eq}$ −12.6 and −12.4 Hz, H-5′*eq*,5′*ax*), 4.317 (s, 1 H, H-1), 4.164 (d, 1 H, $J_{2,3}$ 2.9 Hz, H-2), 3.487 (dd, 1 H, $J_{3,4}$ 9.8 Hz, H-3), 3.475 (s, 3 H, CH_3O), 3.312 (m, 1 H, H-5), 2.481 (m, 1 H, HO-6), 2.135, 2.082, 2.069, and 2.051 (4 s, each 3 H, 4 Ac); ^{13}C, δ 169.9 and 169.2 ($COCH_3$), 137.5, 128.3, 127.7, and 127.4 ($C_6H_5CH_2O$), 101.5 and 99.2 (C-1,1′), 77.3, 74.5, 72.8, 68.5, 68.0 (2 C), and 67.5 (C-2,3,4,5,2′,3′,4′), 70.6, 61.5, and 59.7 (C-6,5′ and PhCH_2O), 56.9 (CH_3O), 20.8 (3 C) and 20.6 (4 $COCH_3$). NMR data ($CDCl_3$) for **26-b**: ^1H, δ 7.39–7.27 (m, 5 H, Ph), 5.212 (t, 1 H, $J_{3',4'}$ 8.8 Hz, H-3′), 5.026 (dd, 1 H, $J_{2',3'}$ 9.0 Hz, H-2′), 4.957 (m, 1 H, $J_{4',5'ax}$ 8.8, $J_{4',5'eq}$ 5.1 Hz, H-4′), 4.863 (d, 1 H, $J_{1',2'}$ 7.0 Hz, H-1′), 4.809 and 4.479 (2 d, each 1 H, PhCH_2O), 4.256 (s, 1 H, H-1), 4.174 (dd, 1 H, H-5′*eq*), 4.158 (d, 1 H, $J_{2,3}$ 3.0 Hz, H-2), 3.759 (dt, 1 H, $J_{4,5}$ 9.5 Hz, H-4), 3.459 (s, 3 H, CH_3O), 3.336 (dd, 1 H, $J_{5'ax,5'eq}$ −11.8 Hz, H-5′*ax*), 3.283 (dd, 1 H, $J_{3,4}$ 9.2 Hz, H-3), 2.512 (d, 1 H, $J_{HO\text{-}4,4}$ 2.6 Hz, HO-4), 2.124 and 2.038 (2 s, 3 and 9 H, 4 Ac). Anal. Calcd for $C_{27}H_{36}O_{14}$: C, 55.48; H, 6.21. Found **26-a**: C, 55.36; H, 6.26.

*Methyl 4-*O*-acetyl-3-*O*-benzyl-6-*O*-(2,3,4,6-tetra-*O*-acetyl-α-*D*-mannopyranosyl)-2-*O*-(2,3,4-tri-*O*-acetyl-β-*D*-xylopyranosyl)-β-*D*-mannopyranoside* (**28**).—A solution of **26-a** (309 mg, 0.53 mmol) and 2,3,4,6-tetra-*O*-acetyl-α-D-mannopyranosyl trichloroacetimidate[8] (**27**; 345 mg, 0.70 mmol) in CH_2Cl_2 (10 mL), containing powdered 4A molecular sieves (1 g), was stirred for 30 min under N_2. A solution of trimethylsilyl triflate (50 μL) in CH_2Cl_2 (5 mL) was added dropwise at −40°C, and after 1 h, when TLC showed the disappearance of **26-a** and a new product **28** (R_f 0.53, 9:1 CH_2Cl_2–acetone), pyridine (1 mL) was added, the mixture was filtered through Celite and concentrated, and toluene (3 × 10 mL) was evaporated from the residue. Column chromatography (9:1 CH_2Cl_2–acetone) of the residue gave **28**, isolated as a white solid (359 mg, 77%); $[\alpha]_D$ −65° (*c* 1.5). NMR data ($CDCl_3$): ^1H, δ 7.36–7.25 (m, 5 H, Ph), 5.199 (dd, 1 H, $J_{2'',3''}$ 3.0 Hz, H-2″), 4.790 (d, 1 H, $J_{1'',2''}$ 1.8 Hz, H-1″), 4.718 and 4.506 (2 d, each 1 H, PhCH_2O), 4.401 and 3.398 (2 dd, each 1 H, $J_{5'eq/ax,4'}$ 3.5 and 4.9, $J_{5'eq,5'ax}$ − 12.3 Hz, H-5′*ax*,5′*eq*), 4.311 (s, 1 H, H-1), 4.157 (d, 1 H, $J_{2,3}$ 3.0 Hz, H-2), 3.481 (s, 3 H, CH_3O), 2.147, 2.113, 2.104, 2.066, 2.052, 2.014, and 1.978 (7 s, 3,3,3,6,3,3,3 H, 8 Ac); ^{13}C, δ 170.6–168.8 ($COCH_3$), 137.5 and 128.3–127.5 ($C_6H_5CH_2O$), 101.3, 99.2, and 96.9 (C-1,1′,1″), 77.5, 72.9, 72.7, 69.3, 68.9, 68.7, 68.5 (2 C), 68.0 (2 C), and 65.9 (C-2,3,4,5,2′,3′,4′,2″,3″,4″,5″), 70.9, 67.6, 62.1, and 59.8 (C-6,5′,6″ and PhCH_2O), 56.7 (CH_3O), 20.7 ($COCH_3$). Anal. Calcd for $C_{41}H_{54}O_{23}$: C, 53.83; H, 5.95. Found: C, 53.29; H, 6.01.

*Methyl 4-*O*-acetyl-6-*O*-(2,3,4,6-tetra-*O*-acetyl-α-*D*-mannopyranosyl)-2-*O*-(2,3,4-tri-*O*-acetyl-β-*D*-xylopyranosyl)-β-*D*-mannopyranoside* (**29**).—To a solution of **28** (330 mg, 0.37 mmol) in 1:1 EtOH–EtOAc (12 mL) were added acetic acid (0.3 mL) and 10% Pd–C (250 mg). Hydrogenolysis, and work-up as described for **12**, gave **29**, isolated as a white solid (300 mg, 98%); R_f 0.11 (9:1 CH_2Cl_2–acetone). NMR data ($CDCl_3$): ^1H, δ 5.228 (dd, 1 H, $J_{2'',3''}$ 3.2 Hz, H-2″), 4.944 (dd, 1 H, $J_{2',3'}$ 8.6 Hz, H-2′), 4.836 (d, 1 H, $J_{1'',2''}$ 1.8 Hz, H-1″), 4.750 (d, 1 H, $J_{1',2'}$ 6.7 Hz, H-1′),

4.385 (s, 1 H, H-1), 4.001 (d, 1 H, $J_{2,3}$ 3.2 Hz, H-2), 3.504 (s, 3 H, CH_3O), 3.388 (dd, 1 H, $J_{5'ax,4'}$ 8.8, $J_{5'ax,5'eq}$ − 11.9 Hz, H-5′*ax*), 2.156, 2.121, 2.113, 2.064, 2.041, 2.010, and 1.986 (7 s, 3,3,3,3,6,3,3 H, 8 Ac); ^{13}C, δ 170.5–169.4 ($COCH_3$), 100.9 (2 C) and 96.8 (C-1,1′,1″), 77.9, 72.6, 71.0, 70.3, 70.0 (2 C), 69.3, 68.8, 68.3 (2 C), and 65.8 (C-2,3,4,5,2′,3′,4′,2″,3″,4″,5″), 66.8, 62.0, and 61.7 (C-6,5′,6″), 56.8 (CH_3O), 20.5 ($COCH_3$). Anal. Calcd for $C_{34}H_{48}O_{23}$: C, 49.52; H, 5.87. Found: C, 49.16; H, 5.81.

*Methyl 4-*O*-acetyl-6-*O*-(2,3,4,6-tetra-*O*-acetyl-α-*D*-mannopyranosyl)-3-*O*-(2,4,6-tri-*O*-acetyl-3-*O*-methyl-α-*D*-mannopyranosyl)-2-*O*-(2,3,4-tri-*O*-acetyl-β-*D*-xylopyranosyl)-β-*D*-mannopyranoside* (**30**).—A solution of **29** (109 mg, 0.13 mmol) and **18** (140 mg, 0.3 mmol) in CH_2Cl_2 (10 mL) containing powdered 4A molecular sieves (1 g) was stirred for 30 min under N_2. A solution of trimethylsilyl triflate (30 μL) in CH_2Cl_2 (5 mL) was added dropwise at −40°C, and after 1.5 h, when TLC showed the disappearance of **29** and a new compound **30** (R_f 0.49, 9:1 CH_2Cl_2–acetone), pyridine (1 mL) was added. The mixture was filtered through Celite and concentrated, and toluene (3 × 10 mL) was evaporated from the residue. Column chromatography (9:1 CH_2Cl_2–acetone) of the residue afforded **30**, isolated as a white solid (90 mg, 61%); $[\alpha]_D$ −19° (*c* 1). NMR data ($CDCl_3$): ^1H, δ 4.926 (d, 1 H, $J_{1'',2''}$ or $J_{1''',2'''}$ 1.7 Hz, H-1″ or H-1‴), 4.367 (s, 1 H, H-1), 4.308 (dd, 1 H, $J_{5'eq,4'}$ 5.2 Hz, H-5′*eq*), 4.002 (d, 1 H, $J_{2,3}$ 3.0 Hz, H-2), 3.505 and 3.386 (2 s, each 3 H, 2 CH_3O), 3.346 (dd, 1 H, $J_{5'ax,4'}$ 8.2, $J_{5'ax,5'eq}$ −11.6 Hz, H-5′*ax*), 2.155, 2.128, 2.123, 2.085, 2.080, 2.078, 2.047, 2.046, 2.016, and 1.984 (10 s, 6,3,3,3,3,3,3,3,3,3 H, 11 Ac); ^{13}C, δ 170.6–168.9 ($COCH_3$), 101.1, 101.0, 99.9, and 96.9 (C-1,1′,1″,1‴), 67.3, 63.0, 62.1, and 61.3 (C-6,5′,6″,6‴), 58.0 and 56.8 (2 CH_3O), 20.5 ($COCH_3$). Anal. Calcd for $C_{47}H_{66}O_{31}$: C, 50.09; H, 5.90. Found: C, 49.15; H, 5.82.

*Methyl 6-*O*-α-*D*-mannopyranosyl-3-*O*-(3-*O*-methyl-α-*D*-mannopyranosyl)-2-*O*-β-*D*-xylopyranosyl-β-*D*-mannopyranoside* (**3**).—Deacetylation of **30** (24 mg, 22 μmol), as described for **2**, gave **3**, isolated as a white powder (14 mg, 96%); $[\alpha]_D$ +2° (*c* 0.5, H_2O); R_f 0.47 (2:1:1 1-butanol–MeOH–water). ^{13}C NMR data (D_2O): δ 106.5, 103.3, 102.6, and 100.9 (C-1,1′,1″,1‴), 58.2 and 57.4 (2 CH_3O). For ^1H NMR data, see Table I.

*Methyl 4-*O*-acetyl-3-*O*-benzyl-6-*O*-(2,4,6-tri-*O*-acetyl-3-*O*-methyl-α-*D*-mannopyranosyl)-2-*O*-(2,3,4-tri-*O*-acetyl-β-*D*-xylopyranosyl)-β-*D*-mannopyranoside* (**31**).—Compound **25** (200 mg, 0.32 mmol) was converted into **26a** as described above, but the residue after work-up was not purified by column chromatography. A solution of the residue (**26-a**) and **18** (250 mg, 0.54 mmol) in CH_2Cl_2 (10 mL) containing powdered 4A molecular sieves (1 g) was stirred for 30 min under N_2. A solution of trimethylsilyl triflate (50 μL) in CH_2Cl_2 (5 mL) was added dropwise at −40°C, and after 1 h, when TLC showed the disappearance of **26-a** and a new product **31** (R_f 0.23, 9:1 CH_2Cl_2–acetone), pyridine (1 mL) was added, the mixture was filtered through Celite and concentrated, and toluene (3 × 10 mL) was evaporated from the residue. Column chromatography (9:1 CH_2Cl_2–acetone) of the residue gave **31**, isolated as a white solid (155 mg, 51%); $[\alpha]_D$ −63° (*c* 0.3).

NMR data ($CDCl_3$): ^1H, δ 7.37–7.27 (m, 5 H, Ph), 5.371 (dd, 1 H, $J_{2'',3''}$ 3.4 Hz, H-2''), 4.995 (dd, 1 H, $J_{2',3'}$ 6.5 Hz, H-2'), 4.947 (d, 1 H, $J_{1',2'}$ 4.7 Hz, H-1'), 4.811 (d, 1 H, $J_{1'',2''}$ 1.8 Hz, H-1''), 4.727 and 4.480 (2 d, each 1 H, PhCH_2O), 4.298 (s, 1 H, H-1), 4.260 (dd, 1 H, $J_{5'eq,4'}$ 5.5, $J_{5'eq,5'ax}$ −12.3 Hz, H-5'*eq*), 4.167 (d, 1 H, $J_{2,3}$ 3.0 Hz, H-2), 3.481 and 3.365 (2 s, each 3 H, 2 CH_3O), 2.134, 2.099, 2.083, 2.078, 2.059, and 2.034 (6 s, 3,3,3,6,3,3 H, 7 Ac); ^{13}C, δ 170.3–168.8 ($COCH_3$), 137.5, 128.3, and 127.8–127.6 ($C_6H_5CH_2O$), 101.6, 99.8, and 97.4 (C-1,1',1''), 67.4, 70.6, 66.7, 62.5, and 60.4 (C-6,5',6'' and PhCH_2O), 57.7 and 56.7 (2 CH_3O), 20.7 ($COCH_3$).

*Methyl 4-*O*-acetyl-6-*O*-(2,4,6-tri-*O*-acetyl-3-*O*-methyl-α-*D*-mannopyranosyl)-2-*O*-(2,3,4-tri-*O*-acetyl-β-*D*-xylopyransyl)-β-*D*-mannopyranoside* (**32**).—To a solution of **31** (145 mg, 0.16 mmol) in 1:1 EtOH–EtOAc (16 mL) were added acetic acid (0.4 mL) and 10% Pd–C (125 mg). Hydrogenolysis, and work-up as described for **12**, gave **32**, isolated as a white solid (127 mg, 98%); R_f 0.17 (9:1 CH_2Cl_2–acetone). ^{13}C NMR data ($CDCl_3$): δ 170.6, 170.3, 170.0, 169.9, 169.8, 169.6, and 169.0 (7 $COCH_3$), 101.4, 101.2, and 97.5 (C-1,1',1''), 77.7, 76.4, 72.5, 71.3, 70.8, 70.1, 69.3, 68.6 (2 C), 67.9, and 67.4 (C-2,3,4,5,2',3',4',2'',3'',4'',5''), 66.1, 62.5, and 62.1 (C-6,5',6''), 57.7 and 56.8 (2 CH_3O), 20.9 (2 C), 20.7 (3 C), 20.6, and 20.4 (7 $COCH_3$).

*Methyl 4-*O*-acetyl-3-*O*-(2,3,4,6-tetra-*O*-acetyl-α-*D*-mannopyranosyl)-6-*O*-(2,4,6-tri-*O*-acetyl-3-*O*-methyl-α-*D*-mannopyranosyl)-2-*O*-(2,3,4-tri-*O*-acetyl-β-*D*-xylopyranosyl)-β-*D*-mannopyranoside* (**33**).—To a solution of **32** (95 mg, 0.12 mmol) and 2,3,4,6-tetra-*O*-acetyl-α-D-mannopyranosyl trichloroacetimidate[8] (**27**; 65 mg, 0.13 mmol) in CH_2Cl_2 (10 mL) containing powdered 4A molecular sieves (1 g) was added dropwise a solution of trimethylsilyl triflate (50 μL) in CH_2Cl_2 (5 mL) at −40°C, and the mixture was stirred for 1.5 h. TLC (9:1 CH_2Cl_2–acetone) then indicated the disappearance of **32** and a new product **33** (R_f 0.41), and pyridine (1 mL) was added. The mixture was filtered through Celite and concentrated, and toluene (3 × 10 mL) was evaporated from the residue. Column chromatography (85:15 CH_2Cl_2–acetone) of the residue gave **33**, isolated as a white solid (92 mg, 70%); $[\alpha]_D$ −27° (*c* 1); R_f 0.31. NMR data ($CDCl_3$): ^1H, δ 5.421 and 5.042 (2 dd, each 1 H, $J_{2'',3''} = J_{2''',3'''} = 3.4$ Hz, H-2'',2'''), 5.401 (dd, 1 H, $J_{3''',4'''}$ 10.0 Hz, H-3'''), 4.949 and 4.816 (2 d, each 1 H, $J_{1'',2''} = J_{1''',2'''} = 1.7$ Hz, H-1'',1'''), 4.921 (m, 1 H, $J_{4',3'} = J_{4',5'ax} = 7.1$, $J_{4',5'eq}$ 4.4 Hz, H-4'), 4.873 (d, 1 H, $J_{1',2'}$ 5.8 Hz, H-1'), 4.365 (s, 1 H, H-1), 4.168 (d, 1 H, $J_{2,3}$ 4.0 Hz, H-2), 3.494 and 3.398 (2 s, each 3 H, 2 CH_3O), 2.144, 2.140, 2.123, 2.094, 2.089, 2.077, 2.044, 2.039, and 2.004 (9 s, 3,3,3,3,9,3,3,3,3 H, 11 Ac); ^{13}C, δ 170.6–168.7 ($COCH_3$), 101.4, 100.5, 99.3, and 97.5 (C-1,1',1'',1'''), 62.5 (3 C) and 61.0 (C-6,5',6'',6'''), 57.8 and 56.7 (2 CH_3O), 20.9–20.5 ($COCH_3$). Anal. Calcd for $C_{47}H_{66}O_{31}$: C, 50.09; H, 5.90. Found: C, 50.31; H, 6.04.

*Methyl 3-*O*-α-*D*-mannopyranosyl-6-*O*-(3-*O*-methyl-α-*D*-mannopyranosyl)-2-*O*-β-*D*-xylopyranosyl-β-*D*-mannopyranoside* (**4**).—Deacetylation of **33** (40 mg, 36 μmol), as described for **2**, gave **4**, isolated as a white powder (24 mg, 96%); $[\alpha]_D$ +4° (*c* 0.5, H_2O); R_f 0.46 (2:1:1 1-butanol–MeOH–water). ^{13}C NMR data

(D_2O): δ 106.3, 103.3, 102.5, and 100.8 (C-1,1′,1″,1‴), 58.2 and 57.6 (2 CH_3O). For ^1H NMR data, see Table I.

ACKNOWLEDGMENTS

This investigation was supported by the Netherlands Foundation for Chemical Research (SON) with financial aid from the Netherlands Organization for Scientific Research (NWO). We thank Dr. A.M.P. van Steijn for the recording of several ^{13}C NMR spectra.

REFERENCES

1 J.A. van Kuik, R.P. Sijbesma, J.P. Kamerling, J.F.G. Vliegenthart, and E.J. Wood, *Eur. J. Biochem.*, 160 (1986) 621–625.
2 J.A. van Kuik, R.P. Sijbesma, J.P. Kamerling, J.F.G. Vliegenthart, and E.J. Wood, *Eur. J. Biochem.*, 169 (1987) 399–411.
3 G.Z. Lederkremer and A.J. Parodi, *J. Biol. Chem.*, 259 (1984) 12514–12518.
4 J.P. Kamerling, *Pure Appl. Chem.*, 63 (1991) 465–472.
5 J.B. Bouwstra, J. Kerékgyártó, J.P. Kamerling, and J.F.G. Vliegenthart, *Carbohydr. Res.*, 186 (1989) 39–49.
6 B.R. Leeflang, J. Kerékgyártó, J.P. Kamerling, and J.F.G. Vliegenthart, *Carbohydr. Res.*, 208 (1990) 117–126.
7 H. Mulder, H. Schachter, M. de Jong-Brink, J.G.M. van der Ven, J.P. Kamerling, and J.F.G. Vliegenthart, *Eur. J. Biochem.*, 210 (1991) 459–465.
8 J. Kerékgyártó, J.P. Kamerling, J.B. Bouwstra, J.F.G. Vliegenthart, and A. Lipták, *Carbohydr. Res.*, 186 (1989) 51–62.
9 J. Kerékgyártó, J.G.M. van der Ven, J.P. Kamerling, A. Lipták, and J.F.G. Vliegenthart, *Carbohydr. Res.*, 238 (1993) 135–145.
10 H. Paulsen, *Angew. Chem. Int. Ed. Engl.*, 21 (1982) 155–173.
11 P.A. Finan and C.D. Warren, *J. Chem. Soc.*, (1962) 3089–3092.
12 R.F. Butterworth and S. Hanessian, *Synthesis*, (1971) 70–88.
13 P.M. Pojer and S.J. Angyal, *Aust. J. Chem.*, 31 (1978) 1031–1040.
14 M. Mori, Y. Ito, and T. Ogawa, *Carbohydr. Res.*, 191 (1990) 199–224.
15 M. Ek, P.J. Garegg, H. Hultberg, and S. Oscarson, *J. Carbohydr. Chem.*, 2 (1983) 305–311.
16 A.K. Sen, K.K. Sarkar, and N. Banerji, *J. Carbohydr. Chem.*, 7 (1988) 645–654.
17 S. Sato, Y. Ito, T. Nukada, Y. Nakahara, and T. Ogawa, *Carbohydr. Res.*, 167 (1987) 197–210.
18 P.J. Garegg, H. Hultberg, and S. Oscarson, *J. Chem. Soc., Perkin Trans. 1*, (1982) 2395–2397.
19 E.J. Corey and J.W. Suggs, *J. Org. Chem.*, 38 (1973) 3224.
20 O. Kanie, T. Takeda, N. Hada, and Y. Ogihara, *J. Carbohydr. Chem.*, 10 (1991) 561–581.
21 C.V. Holland, D. Horton, and J.S. Jewell, *J. Org. Chem.*, 32 (1967) 1818–1821.
22 H. Paulsen, F. Garrido Espinose, W.P. Trautwein, and K. Heyns, *Chem. Ber.*, 101 (1968) 179–185.
23 L.D. Hall and J.F. Manville, *Carbohydr. Res.*, 4 (1967) 512–515.
24 A. de Bruyn, M. Anteunis, R. van Rijsbergen, M. Claeyssens, and P. Kovác, *J. Carbohydr. Chem.*, 1 (1982/1983) 301–309.
25 P.L. Durette, D. Horton, and N.S. Bhacca, *Carbohydr. Res.*, 10 (1969) 565–577.
26 P.L. Durette and D. Horton, *Carbohydr. Res.*, 18 (1971) 57–80.
27 E.E. Lee, G. Keaveney, and P.S. O'Colla, *Carbohydr. Res.*, 59 (1977) 268–273.