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CARBOHYDRATE RESEARCH

Synthesis of carboxyl-reduced analogues related to the *Chlamydia*-specific Kdo trisaccharide epitope

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Abstract

The disaccharides allyl *O*-(sodium 3-deoxy-α-D-*manno*-2-octulopyranosylonate)-(2 → 4)-3-deoxy-α-D-*manno*-2-octulopyranoside (**8**), allyl *O*-(3-deoxy-α-D-*manno*-2-octulopyranosyl)-(2 → 8)-(sodium 3-deoxy-α-D-*manno*-2-octulopyranosidonate) (**24**), and allyl *O*-(sodium 3-deoxy-α-D-*manno*-2-octulopyranosylonate)-(2 → 8)-3-deoxy-α-D-*manno*-2-octulopyranoside (**35**), and the trisaccharides allyl *O*-(sodium 3-deoxy-α-D-*manno*-2-octulopyranosylonate)-(2 → 8)-(sodium 3-deoxy-α-D-*manno*-2-octulopyranosylonate)-(2 → 4)-3-deoxy-α-D-*manno*-2-octulopyranoside (**13**) and allyl *O*-(3-deoxy-α-D-*manno*-2-octulopyranosyl)-(2 → 8)-(sodium 3-deoxy-α-D-*manno*-2-octulopyranosylonate)-(2 → 4)-(sodium 3-deoxy-α-D-*manno*-2-octulopyranosidonate) (**30**) were prepared. The ketosidic linkages were formed in good yields and high stereoselectivity by $BF_3 \cdot Et_2O$-catalyzed reaction of the per-*O*-acetylated 3-deoxy-α-D-*manno*-2-octulopyranosyl fluoride derivative (**16**) with 8-*O*-SiBu^{t}Me$_2$ derivatives **19** and **21**. Coupling reactions using the Kdo monosaccharide bromide derivative **4** or the α-(2 → 8)-linked Kdo disaccharide bromide derivatives **9** and **26** were performed under Helferich conditions in MeCN or $MeNO_2$, respectively. The disaccharide halides were prepared in good overall yields starting from the readily available allyl β-glycoside of Kdo. The deprotected oligosaccharides correspond to the genus-specific lipopolysaccharide epitope of *Chlamydia* and part structures thereof, containing the carboxyl-reduced Kdo-residues at the distal and proximal position of the Kdo trisaccharide epitope, respectively.

Key words: Kdo; *Chlamydia*; Lipopolysaccharide, 3-Deoxy-D-*manno*-2-octulosonic acid derivatives

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1. Introduction

Chlamydiae, comprising the species *C. psittaci, C. trachomatis,* and *C. pneumoniae,* are pathogenic intracellular parasites responsible for a variety of acute and chronic diseases in animals and humans [1]. Chlamydial lipopolysaccharide (LPS) located at the cell surface of these unique bacteria represents a genus-specific antigen [2]. Its carbohydrate backbone is composed of the pentasaccharide structure α-Kdo*p*-(2 → 8)-α-Kdo*p*-(2 → 4)-α-Kdo*p*-(2 → 6)-β-D-GlcN-(1 → 6)-D-GlcN [3–6], the Kdo trisaccharide terminus constituting the immunodominant part [7]. Glycoconjugates containing the synthetic [8] tetrasaccharide α-Kdo*p*-(2 → 8)-α-Kdo*p*-(2 → 4)-α-Kdo*p*-(2 → 6)-β-D-GlcNAc have been shown to exhibit similar serological specificities as chlamydial LPS [9].

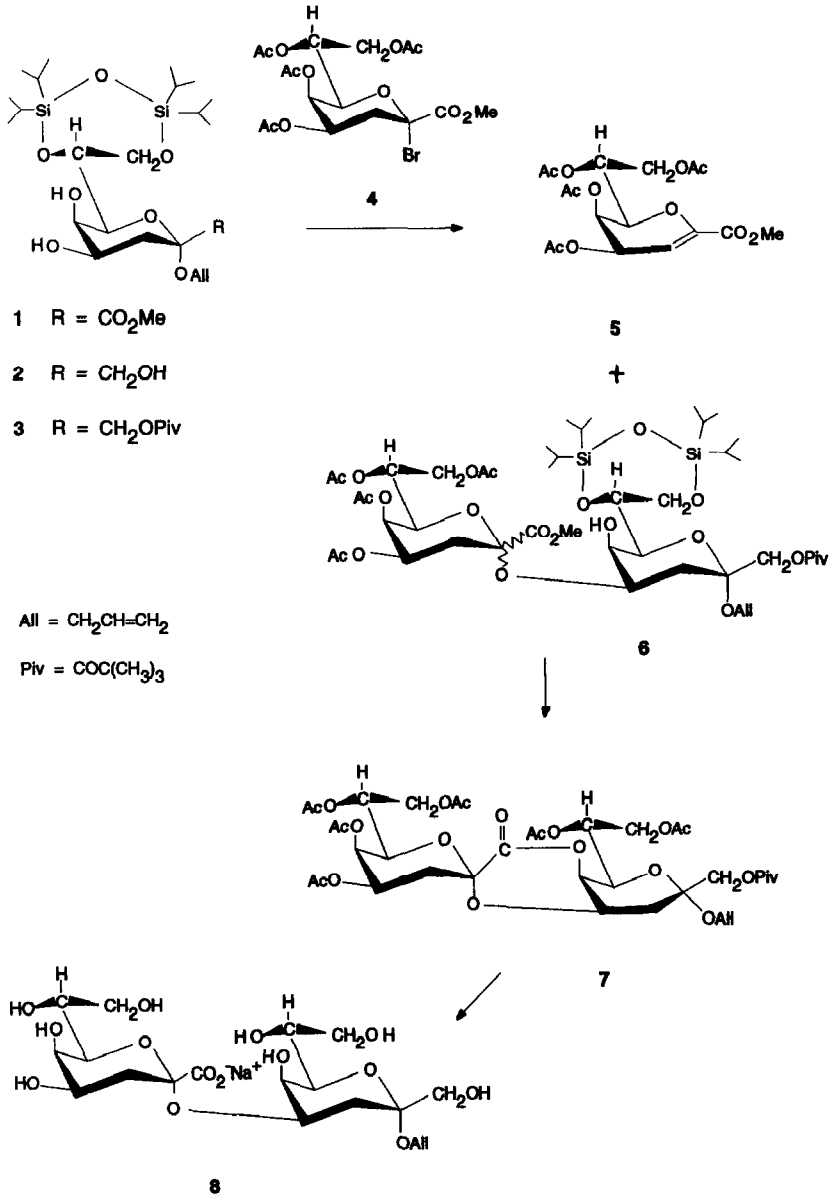
For a further definition of epitope specificities of poly- and mono-clonal antibodies directed against enterobacterial [10] as well as chlamydial LPS, we set out to synthesize oligosaccharides containing carboxyl-reduced Kdo-residues. These derivatives may serve as model oligosaccharides to study the potential involvement of the different carboxylic groups of Kdo di- and tri-saccharides in the binding of the antibodies. Furthermore, they may be exploited for conformational studies using NOE effects of the $-CH_2OH$ group as well as for the ^{13}C NMR assignment of C-1 resonances in Kdo-oligosaccharides. The compounds were prepared as allyl glycosides, which allows for the subsequent preparation of glycopolymers and neoglycoproteins [11–13], respectively.

2. Results and discussion

For the synthesis of the oligosaccharide derivatives containing the carboxyl-reduced Kdo-moiety at the proximal part of the Kdo-region, the previously [14] described 7,8-*O*-TIPS [1]-protected Kdo-derivative **1** was reduced with $NaBH_4$ in MeOH to give the triol **2** in 85% yield. The primary OH-group of **2** was then protected as the pivalic ester **3** [$(CH_3)_3CCOCl$–pyridine, −20°C] in 54% yield; higher acylated by-products were conventionally converted back into the triol derivative **2** for subsequent use.

The diol derivative **3** was coupled with 1.2 equivalents of the Kdo bromide derivative **4** [15] in $MeNO_2$, using a 3:1 mixture of $Hg(CN)_2$–$HgBr_2$ as catalyst, which afforded a 35% yield of the glycal ester derivative **5** [16] and a 61% yield of the α- and β-(2 → 4)-linked disaccharide derivatives **6** as a mixture. The α-to-β ratio of 4:1 was deduced from the intensity of the ^1H NMR signals [17] attributable to H-4′ (5.30 ppm for the α isomer and 4.88 ppm for the β isomer). Separation of the isomers was achieved following removal of the silyl ether group by Bu_4NF in THF [18] and *O*-acetylation (Ac_2O–pyridine), which furnished the α-(2′ → 4)-linked disaccharide derivative **7** in 70% yield. Lactone formation was

[1] TIPS = 1,1,3,3-tetraisopropyldisiloxane-1,3-diyl.



Scheme 1.

evident from the lack of the Me-ester signal and the downfield shift of H-5 to 5.09 ppm. Zemplén *O*-deacylation and hydrolysis of the methyl ester and lactone group by aqueous NaOH afforded allyl *O*-(sodium 3-deoxy-α-D-*manno*-2-octulopyranosylonate)-(2 → 4)-3-deoxy-α-D-*manno*-2-octulopyranoside (**8**) in 97% yield.

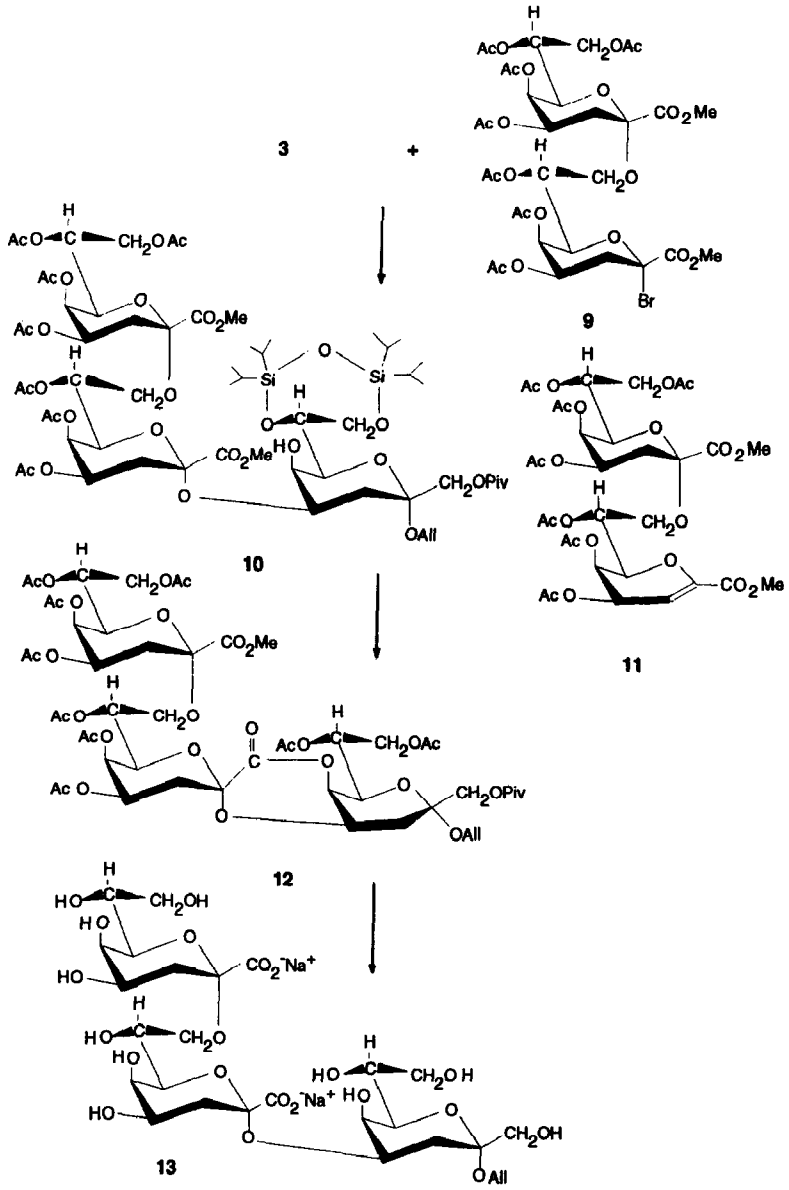
The previously [19] reported disaccharide bromide derivative **9** was treated with

the diol **3**, using either $MeNO_2$ or MeCN as solvent and 3:1 $Hg(CN)_2$–$HgBr_2$ as catalyst. Use of MeCN as solvent afforded the disaccharide glycal ester **11** in 45% yield together with 11% of trisaccharide derivatives. In $MeNO_2$, however, a 4:1 mixture of the α- and β-(2′ → 4)-linked trisaccharide derivatives was obtained in 29% yield, from which the α-(2′ → 4)-linked compound **10** could be separated by LC. Similarly to **6**, removal of the TIPS-group from **10** by the action of Bu_4NF in THF and *O*-acetylation resulted in the formation of the α-(2′ → 4)-trisaccharide lactone **12** in 80% yield. The ^1H NMR spectrum of **12** contained only one methyl signal due to an ester group, but three downfield-shifted signals attributable to H-5 protons. Sequential treatment of **12** with 0.1 M methanolic NaOMe and 0.2 M aq NaOH furnished the target trisaccharide allyl *O*-(sodium 3-deoxy-α-D-*manno*-2-octulopyranosylonate)-(2 → 8)-(sodium 3-deoxy-α-D-*manno*-2-octulopyranosylonate)-(2 → 4)-3-deoxy-α-D-*manno*-2-octulopyranoside (**13**) in 86% yield.

For the synthesis of Kdo-oligosaccharides containing the carboxyl-reduced Kdo-moiety at the terminal position, the glycosyl donors **16** and **26** were prepared from the readily accessible [20] allyl β-glycoside **14**. The allyl group was isomerized [21] to the propenyl group using $\{Ir(COD)[PCH_3(C_6H_5)_2]_2\}PF_6$ in THF and then hydrolyzed with aq I_2 in THF [22], which afforded the octulopyranose derivative **15** in 66% overall yield. Subsequent conversion of **15** into the fluoride **16** was accomplished in 90% yield by the action of diethylaminosulfur trifluoride (DAST) [23] in CH_2Cl_2.

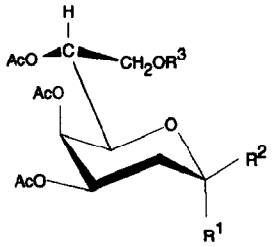
For the synthesis of the α-(2 → 8)-linked disaccharide derivatives, the readily available allyl β-glycoside **17** [11] was transformed into the reducing derivative **18** in 45% yield by treatment with activated $\{Ir(COD)[PCH_3(C_6H_5)_2]_2\}PF_6$ and hydrolysis of the propenyl glycoside under controlled conditions (I_2–THF–collidine). Alternatively, the allyl group could be removed by reaction with SeO_2 in acetic acid–1,4-dioxane [24] at 100°C which gave **18** in 32% yield and recovered starting material **17** (12%). *O*-Acetylation (Ac_2O–pyridine) of **18** afforded the 8-*O*-$SiBu^tMe_2$ derivative **19** in quantitative yield. Cleavage of the silyl ether group using 2% HF in MeCN [25] furnished the glycosyl acceptor derivative **20** (85%) which was immediately used for the glycosylation reaction to avoid extensive 7 → 8 *O*-acetyl migration. $Hg(CN)_2$-promoted coupling of **20** with 2 equivalents of the Kdo bromide derivative **4** in $MeNO_2$–$Hg(CN)_2$ afforded a 70% yield of a mixture containing α- and β-(2 → 8)-linked disaccharide derivatives, which was separated on silica gel (1:1 1-pentanol–hexane) to give the α-(2 → 8)-linked disaccharide derivative **22** [19] in 41% yield. This reaction sequence provides an alternative route to the disaccharide synthon **22** and avoids the use of the previously described allyl α-glycoside of Kdo [11] as the starting material.

$BF_3 \cdot Et_2O$-catalyzed reaction [26] of the fluoride **16** with the 8-*O*-$SiBu^tMe_2$ derivative **21** [11] in MeCN afforded the α-(2 → 8)-linked disaccharide derivative **23** in 64% yield and with excellent stereoselectivity. The ^1H NMR data of **23** indicated the expected downfield shift of the signals attributable to H-7 and H-7′, whereas H-8a and H-8b occurred in the upfield region, thus confirming the (2 → 8) linkage. The assignment of the α-anomeric configuration was tentatively based on the value of the optical rotation ($[\alpha]_D^{20}$ + 83°) which is similar to the reported value



Scheme 2.

($[\alpha]_D^{20} + 87°$) of the corresponding Kdo-disaccharide. The chemical shift difference between H-3*e* and H-3*a*, which normally indicates the anomeric configuration of Kdo-residues [17], is not suitable for assigning the anomeric configuration of the carboxyl-reduced analogues since both H-3 protons occur at similar chemical shifts. The α-D-anomeric configuration was then definitely assigned following removal of the ester groups from **23**, as described for **7** and **12**, which afforded allyl *O*-(3-deoxy-α-D-*manno*-2-octulopyranosyl)-(2 → 8)-(sodium 3-deoxy-α-D-*manno*-2-



14 $R^1 = CH_2OAc$, $R^2 = OAll$, $R^3 = Ac$

15 $R^1 = OH$, $R^2 = CH_2OAc$, $R^3 = Ac$

16 $R^1 = F$, $R^2 = CH_2OAc$, $R^3 = Ac$

17 $R^1 = CO_2Me$, $R^2 = OAll$, $R^3 = SiBu^tMe_2$

18 $R^1 = OH$, $R^2 = CO_2Me$, $R^3 = SiBu^tMe_2$

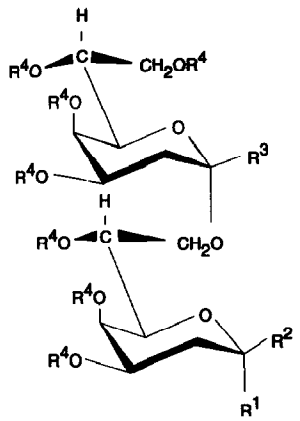
19 $R^1 = OAc$, $R^2 = CO_2Me$, $R^3 = SiBu^tMe_2$

20 $R^1 = OAc$, $R^2 = CO_2Me$, $R^3 = H$

21 $R^1 = OAll$, $R^2 = CO_2Me$, $R^3 = SiBu^tMe_2$

octulopyranosidonate) (**24**) in 70% yield. The ^{13}C NMR chemical shifts of **24** (Table 2) are in close agreement with an α-(2 → 8) linkage since a β-linked octulopyranosyl residue should reveal a downfield shift of the corresponding C-6 signal and an upfield shift of C-1 and C-3 [20].

For the synthesis of the trisaccharide derivative **30**, the per-*O*-acetylated 8-*O*-$SiBu^tMe_2$ derivative **19** was coupled with the octulopyranosyl fluoride **16** in the presence of $BF_3 \cdot Et_2O$ in MeCN. Thus, the crystalline disaccharide derivative **25** was obtained in a yield similar to **23** (59%), the main by-products arising from hydrolysis of **16** and **19**. Treatment of **25** with $TiBr_4$ in CH_2Cl_2 furnished the unstable disaccharide bromide **26** (96%), which was immediately used for the glycosylation of the 7,8-*O*-carbonyl derivative **27** [11], using 1:1 $Hg(CN)_2$–$HgBr_2$ as catalyst in MeCN. The α-(2′ → 4)-linked trisaccharide derivative **28** was obtained in 17% yield, together with a small proportion of the corresponding β isomer which was separated by silica gel chromatography; **28** was converted into the 5-*O*-acetyl derivative **29** to confirm the structural assignments. Upon *O*-acetylation, H-5 experiences the expected downfield shift to 5.25 ppm, whereas the chemical shift of H-4′ is in agreement with the α-anomeric configuration of the respective Kdo-residue (5.12 ppm). Zemplén *O*-deacylation and alkaline hydrolysis of the methyl ester groups finally gave allyl *O*-(3-deoxy-α-D-*manno*-2-octulopyranosyl)-(2 → 8)-(sodium 3-deoxy-α-D-*manno*-2-octulopyranosylonate)-(2 → 4)-(sodium 3-deoxy-α-D-*manno*-2-octulopyranosidonate) (**30**) in 64% yield.



22 R^1 = OAc , R^2 = R^3 = CO_2Me , R^4 = Ac

23 R^1 = OAll , R^2 = CO_2Me , R^3 = CH_2OAc , R^4 = Ac

24 R^1 = OAll , R^2 = $CO_2^-Na^+$, R^3 = CH_2OH , R^4 = H

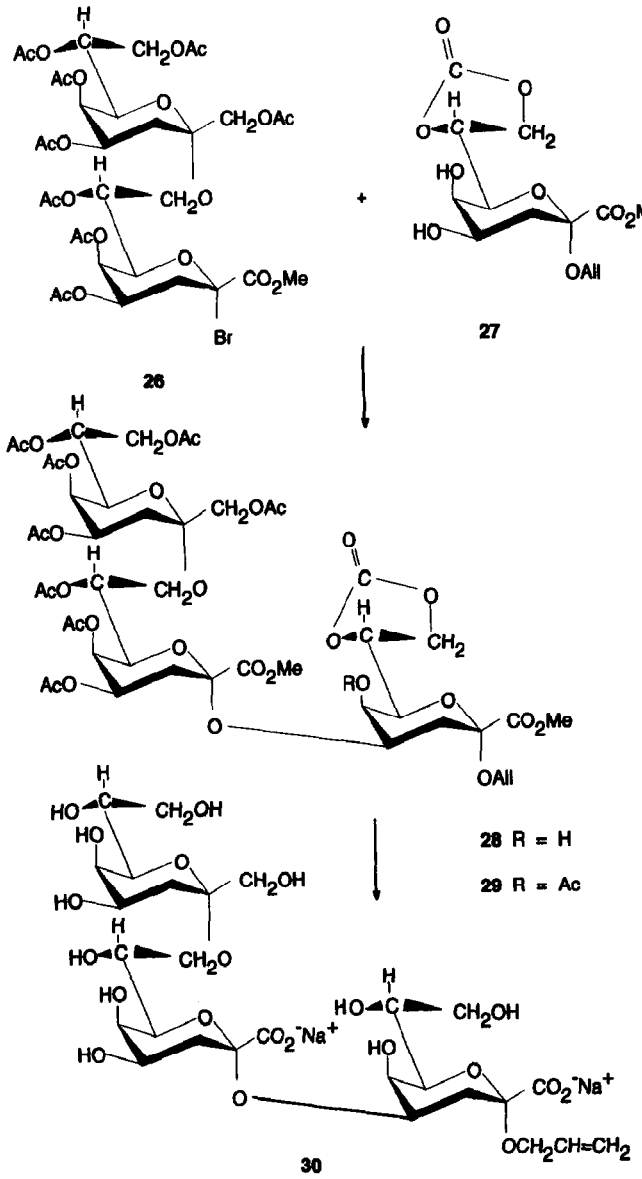
25 R^1 = OAc , R^2 = CO_2Me , R^3 = CH_2OAc , R^4 = Ac

26 R^1 = Br , R^2 = CO_2Me , R^3 = CH_2OAc , R^4 = Ac

Along similar lines, the disaccharide derivative **35** was prepared from the 7,8-*O*-TIPS derivative **3**. Reaction of **3** with diphosgene–*sym*-collidine in THF [27] afforded the 4,5-*O*-carbonyl derivative **31** in 88% yield. Cleavage of the Si-ether groups by the action of Bu_4NF in THF gave the 7,8-diol **32** in 82% yield. Glycosylation of **32** with the Kdo bromide derivative **4** catalyzed by 3:1 $Hg(CN)_2$–$HgBr_2$ in $MeNO_2$ proceeded in a regioselective fashion. Thus, the α-(2 → 8)-linked disaccharide derivative **33** was obtained as the main product (23% yield). To prove the presence of the (2 → 8) linkage, an aliquot of **33** was *O*-acetylated to give **34** in 96% yield. Accordingly, the ^1H NMR signal of H-7 was shifted downfield to 5.23 ppm. Deprotection of **33** as described for **7** and **12** afforded allyl *O*-(sodium 3-deoxy-α-D-*manno*-2-octulopyranosylonate)-(2 → 8)-3-deoxy-α-D-*manno*-2-octulopyranoside (**35**) in 84% yield.

^1H and ^{13}C NMR data (Tables 1 and 2) compare favourably with previously reported values for Kdo oligosaccharides [4], thus confirming the structural and configurational assignments, and indicating a similar overall conformation.

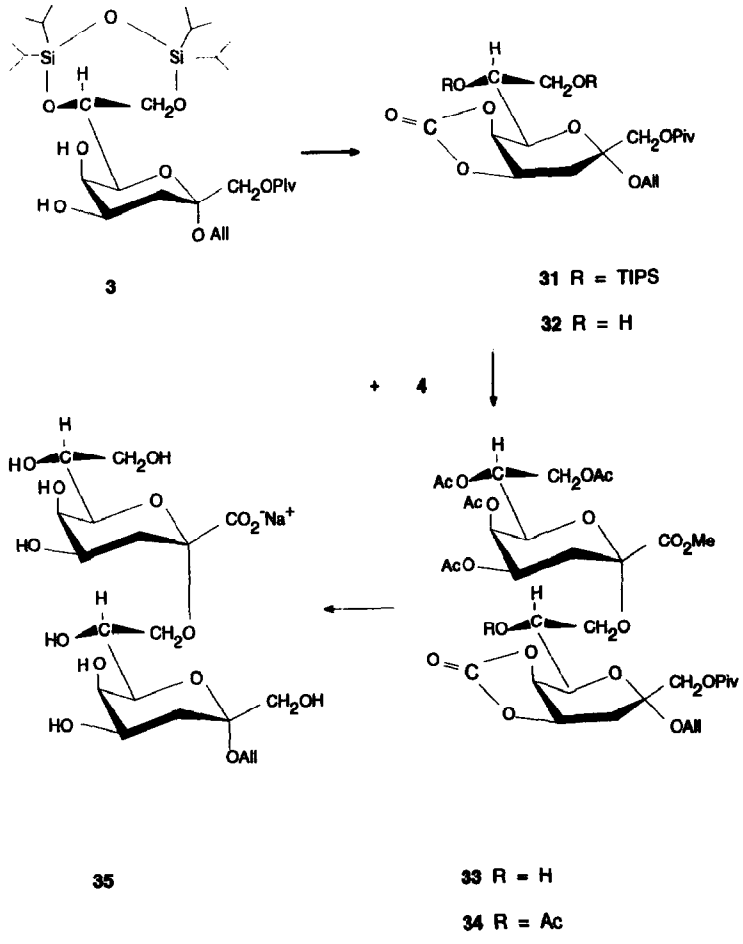
By comparison, the disaccharide derivatives **8** and **35** exhibit — with the exception of the C-1, C-2, and C-3 signals of the carboxyl-reduced Kdo moieties — almost identical ^{13}C NMR chemical shifts. A similar observation holds true for the



Scheme 3.

data of the trisaccharide derivative **13**, which reveal a small downfield shift (−0.6 ppm) of C-8′ at the internal Kdo unit *b*. The most prominent deviations are observed for the oligosaccharide derivatives **24** and **30** containing a terminal, carboxyl-reduced Kdo residue, which notably affects C-5, C-6, C-7, and C-8 of unit *b*.

Furthermore, the chemical shifts of the carboxylic groups of Kdo-oligosaccharides could be assigned. Within the disaccharide derivatives, the terminal Kdo



Scheme 4.

unit *a* shows a downfield shift of C-1, which is a further confirmation of the similar topology of α-(2 → 4)- and α-(2 → 8)-linked Kdo-disaccharides [4,28]. Interestingly, the downfield shift for C-1 to ~ 177.0 ppm is consistently observed for the internal Kdo-unit *b* in the Kdo-trisaccharide derivatives **13** and **30**, as well as in other synthetic or natural oligosaccharides containing the *Chlamydia*-specific Kdo-trisaccharide epitope [5]. Following completion of this series of Kdo-reduced oligosaccharides, the immunochemical characterization of BSA-conjugates derived from the allyl glycosides will be published elsewhere.

3. Experimental

General methods.—These were as described recently [6]. Column sizes for *A*, *B*, and *C* are 24 × 1, 31 × 2.5, and 44 × 3.7 cm, respectively. ^{1}H NMR chemical shift

Table 1
^{1}H NMR chemical shifts (δ) and $J_{H,H}$ values (Hz, first-order values) [a] for compounds **8**, **13**, **24**, **30**, and **35**

Proton	**8**	**13**	**24**	**30**	**35**
Unit *a*					
α-Kdo-(2 →					
H-1a			3.73 (12.3)	3.76 (12.3)	
H-1b			3.47	3.46	
H-3*a*		1.84 (12.2	1.76 (11.9, 13.1)	1.90	~ 1.80 (11.7)
H-3*e*		2.08 (5.3)	2.02 (5.2)	1.99	2.05 (4.4)
H-4		4.15 (2.8)	4.09 (3.1)	4.05	4.07
H-5		4.05	4.04 (1.0)	4.06	3.99 (2.9)
H-6		3.74 (9.5)	3.66 (9.3)	3.79 (9.0)	3.60
H-7		3.98	3.84	3.85	3.94
H-8a		3.96	3.85	3.60	3.90 (2.8)
H-8b		3.73 (6.5)	3.60 (7.3, 12.3)	n.d.[b]	~ 3.63
Unit *b*					
→ 8)-α-Kdo-(2 →					
H-1a					3.70
H-1b					3.51
H-3*a*	1.80 (− 12.4, 13.3)	1.84 (12.2)	1.80 (11.9, − 13.1)	1.80 (12.2, 12.2)	1.80 (11.7)
H-3*e*	2.15 (4.9)	2.14 (4.6)	2.06 (5.0)	2.14 (4.5)	1.97 (13.2)
H-4	4.11 (3.0)	4.12	4.05 (3.1)	~ 4.10	4.9 (3.0)
H-5	4.04 (1.0)	4.07	4.02 (0.7)	4.06	4.06
H-6	3.62 (8.5)	3.70 (5.5)	3.61 (10.0)	3.58	3.62
H-7	3.97	4.18 (4.5)	4.05	~ 4.10	3.94
H-8a	3.97	3.73 (10.0)	3.91 (6.9)	~ 3.90	~ 3.62
H-8b	3.75	3.50 (8.5)	3.47 (10.9)	3.48 (9.3)	3.51
Unit *c*					
→ 4)-α-Kdo-(2 → OAll)					
H-1a	3.72 (12.3)	3.71			
H-1b	3.51	3.53			
H-3*a*	1.94	1.93		1.78 (11.7)	
H-3*e*	1.94	1.93		2.01 (5.4, − 13.1)	
H-4	4.13 (2.6)	4.09		4.13	
H-5	4.10 (1.0)	4.11		4.08	
H-6	3.61 (9.6)	3.58 (9.5)		3.55 (8.8)	
H-7	3.87	3.86 (2.7)		~ 3.93	
H-8a	~ 3.88	3.87		n.d.	
H-8b	3.59	3.60 (6.8, 11.8)		~ 3.68 (6.0, 11.3)	

[a] 300-MHz ^{1}H NMR spectra were recorded at 24°C for solutions in D_2O using sodium 3-(trimethylsilyl)propionate-*2,2,3,3-d*$_4$ (δ = 0.00) as internal standard.
[b] n.d., Not determined.

Table 2
^{13}C NMR chemical shifts * (δ) based on C,H-correlation experiments for compounds **8**, **13**, **24**, **30**, and **35**

Carbon	8	13	24	30	35
Unit *a*					
α-Kdo-(2 →					
C-1		176.05	63.75	64.18	176.61
C-2		100.77 [b]	101.16 [c]	101.24 [e]	101.44 [g]
C-3		35.27	33.68	33.82	34.81
C-4		66.99	66.90	66.89 [f]	66.76
C-5		67.41	67.04 [d]	67.24	67.03
C-6		72.25	72.14	71.62	72.36 [h]
C-7		70.31	70.11	70.18	70.01
C-8		64.05	64.04	64.11	63.92
Unit *b*					
→ 8)-α-Kdo-(2 →					
C-1	177.00	176.95	176.11	176.80	63.88
C-2	100.26 [a]	100.86 [b]	101.01 [c]	101.08 [e]	101.33 [g]
C-3	35.50	35.57	35.00	35.56	33.58
C-4	66.93	66.84	66.80	66.80 [f]	66.88 [i]
C-5	67.22	67.93	66.90 [d]	67.24	66.85 [i]
C-6	73.26	73.15	72.62	73.65	72.17 [h]
C-7	70.73	71.03	68.68	69.93	68.34
C-8	64.13	65.23	63.45	63.97	65.89
Unit *c*					
→ 4)-α-Kdo-(2 → OAll)					
C-1	63.95	64.20		176.09	
C-2	101.58 [a]	101.56		100.49	
C-3	32.87	32.86		34.41	
C-4	69.52	70.18		69.93	
C-5	65.05	65.23		65.15	
C-6	72.23	72.13		72.27	
C-7	70.30	70.44		70.51	
C-8	63.95	64.05		64.11	
Allyl group					
C-1	62.66	62.69	65.24	65.33	62.61
C-2	135.21	135.55	134.67	135.36	134.82
C-3	118.14	117.67	118.43	118.21	118.13

* 75.47-MHz ^{13}C NMR spectra were recorded for solutions in D_2O at 24°C using 1,4-dioxane ($\delta = 67.40$) as external standard.
[a–i] Assignments may be reversed.

values for $=CH_2$ protons of the allyl group were observed between 5.10 and 5.30 ppm.

*Allyl 3-deoxy-7,8-O-(1,1,3,3-tetraisopropyldisiloxane-1,3-diyl)-α-*D-manno*-2-octulopyranoside* (**2**).—A solution of **1** (560 mg, 1.05 mmol) in dry MeOH (15 mL) was treated with $NaBH_4$ (240 mg, 6.3 mmol) for 3 h at 0°C. Dowex 50 resin (H^+ form) was added until neutral pH, and the mixture was filtered. The filtrate was evaporated 4 times with addition of MeOH (5 mL) and purified on silica gel (*B*,

EtOAc) which afforded **2** (448 mg, 85%) as a syrup; $[\alpha]_D^{20}$ + 35° (*c* 0.5, $CHCl_3$); ^1H NMR ($CDCl_3$): δ 5.89 (m, 1 H, =CH–), 4.21 (dt, 1 H, $J_{7,6} \simeq J_{7,8b} \simeq 7.5$, $J_{7,8a} \sim 1.6$ Hz, H-7), 4.12 (dd, 1 H, $J_{8a,8b} \sim -12.0$ Hz, H-8a), 4.02 (m, 2 H, H-4,5), 4.00 and 3.93 (m, 2 H, OCH_2), 3.77 (dd, 1 H, H-8b), 3.62–3.52 (m, 2 H, H-1a,1b), 3.46 (dd, 1 H, $J_{5,6} \sim 0.5$ Hz, H-6), 2.74 (d, 1 H), 2.16 (d, 1 H) and 1.84 (br s, 1 H, OH), 2.01 (dd, 1 H, $J_{3e,4} \sim 6.3$, $J_{3e,3a} \sim -13.2$ Hz, H-3*e*), 1.92 (dd, 1 H, $J_{3a,4} \sim 11.5$ Hz, H-3*a*), and 1.10–1.00 [m, 28 H, 4 $(CH_3)_2CHSi$]. Anal. Calcd for $C_{23}H_{46}O_8Si_2$: C, 54.51; H, 9.15. Found: C, 54.27; H, 9.01.

*Allyl 3-deoxy-1-*O*-pivaloyl-7,8-*O*-(1,1,3,3-tetraisopropyldisiloxane-1,3-diyl)-α-*D*-manno-2-octulopyranoside* (**3**).—A solution of **2** (80 mg, 0.16 mmol) in dry pyridine (5 mL) was stirred with pivaloyl chloride (20 μL, 0.162 mmol) at −20°C for 18 h. A second portion of pivaloyl chloride (20 μL) was added and the solution was kept at −20°C for 48 h. The solution was coevaporated three times with addition of toluene (10 mL) and taken to dryness. The residue was purified on silica gel (*B*, 4:1 toluene–EtOAc) which gave **3** (50 mg, 54%) as a syrup; $[\alpha]_D^{20}$ + 32° (*c* 1.0, $CHCl_3$); ^1H NMR ($CDCl_3$): δ 5.85 (m, 1 H, =CH–), 4.19 (dt, 1 H, $J_{7,6} \sim 7.0$, $J_{7,8b} \sim 7.5$, $J_{7,8a} \sim 1.5$ Hz, H-7), 4.24 and 3.95 (AB, $J_{AB} \sim 12.0$ Hz, H-1a,1b), 4.08 (dd, 1 H, $J_{8a,8b} \sim -12.0$ Hz, H-8a), 4.02 (br s, 1 H, H-5), 4.04–3.86 (m, 3 H, H-4, OCH_2), 3.79 (dd, 1 H, H-8b), 3.48 (dd, 1 H, $J_{6,5} \sim 0.5$ Hz, H-6), 2.75 (br s, 1 H) and 2.14 (br s, 1 H, OH), 2.08 (dd, 1 H, $J_{3e,4} \sim 5.5$, $J_{3e,3a} \sim -13.0$ Hz, H-3*e*), 1.80 (t, 1 H, $J_{3a,4} \sim 12.5$ Hz, H-3*a*), 1.22 [m, 9 H, $(CH_3)_3C$], and 1.09–1.02 [m, 28 H, 4 $(CH_3)_2CHSi$]. Anal. Calcd for $C_{28}H_{54}O_9Si_2$: C, 56.91; H, 9.21. Found: C, 56.44, H 9.04.

Allyl O*-(methyl 4,5,7,8-tetra-*O*-acetyl-3-deoxy-α- and -β-*D*-manno-2-octulopyranosylonate)-(2 → 4)-3-deoxy-1-*O*-pivaloyl-7,8-*O*-(1,1,3,3-tetraisopropyldisiloxane-1,3-diyl)-α-*D*-manno-2-octulopyranoside* (**6**).—A suspension of **3** (40 mg, 0.07 mmol), $Hg(CN_2)$ (80 mg, 0.32 mmol), $HgBr_2$ (38 mg, 0.1 mmol), and 4A molecular sieves (300 mg) in dry $MeNO_2$ (5 mL) was stirred for 30 min at room temperature. A solution of **4** (168 mg, 0.35 mmol) in $MeNO_2$ (3 mL) was added dropwise for 2 h. Stirring was continued for 18 h, and the suspension was diluted with CH_2Cl_2 (50 mL) and filtered over Celite. The filtrate was washed three times with aq 10% KI, then satd aq. $NaHCO_3$, and dried ($MgSO_4$). The organic layer was taken to dryness, and the residue was purified on a column of silica gel (*B*, 2:1 hexane–EtOAc), giving **6** as a syrup. Yield: 41 mg (61%); ^1H NMR ($CDCl_3$): δ 5.83 (m, 1 H, =CH–), 5.38 (br s, 1 H, H-5′), 5.30 (ddd, 1 H, $J_{4',5'} \sim 3.0$, $J_{4'3'a} \sim 12.5$, $J_{4'3'e} \sim 5.0$ Hz, H-4′), 5.26 (ddd, 1 H, H-7′), 4.88 (ddd, H-4′, β isomer), 4.75 (dd, 1 H, $J_{7',8'a} \sim 2.5$, $J_{8'a,8'b} \sim -12.0$ Hz, H-8′a), 4.20 (m, 1 H, H-7), 4.21 (ddd, 1 H, H-4), 4.14 (m, 1 H, H-8a), 4.13 and 4.05 (AB, 2 H, $J_{AB} \sim 12.0$ Hz, H-1a,1b), 4.07 (dd, 1 H, $J_{6',5'} \sim 1.5$, $J_{6',7'} \sim 9.5$ Hz, H-6′), 4.02 (dd, 1 H, $J_{8'b,7'} \sim 5.8$ Hz, H-8′b), 3.95–3.90 (m, 2 H, OCH_2), 3.85 (br s, 1 H, H-5), 3.80 (s, 3 H, CO_2Me), 3.68 (dd, 1 H, $J_{8a,8b} \sim -12.0$, $J_{8b,7} \sim 7.5$ Hz, H-8b), 3.32 (d, 1 H, $J_{6,7} \sim 8.0$ Hz, H-6), 2.69 (d, OH, β isomer), 2.39 (dd, 3′*e*, β isomer), 2.35 (d, 1 H, 5-OH), 2.29 (dd, 1 H, $J_{3'e,3'a} \sim -13.0$ Hz, H-3′*e*), 2.12 (t, 1 H, H-3*a*), ~ 2.08 (t, 1 H, H-3′*a*), 2.08, 2.05, and 1.98 (3 s, 12 H, 4 Ac), 1.86 (dd, 1 H, $J_{3e,3a} \sim -12.5$, $J_{3e,4} \sim 5.0$ Hz, H-3*e*), 1.23 [s, 9 H,

$(CH_3)_3C$], and 1.05–0.99 [m, 28 H, 4 $(CH_3)_2CHSi$]. Anal. Calcd for $C_{45}H_{76}O_{20}Si_2$: C, 54.42; H, 7.71. Found: C, 54.22; H, 7.59.

Further elution of the column with 1:1 hexane–EtOAc afforded **5**. Yield: 75 mg (53%, based on **4**).

Allyl O-*(4,5,7,8-tetra*-O-*acetyl-3-deoxy-α*-D-manno-*2-octulopyranosylonic acid)-(2 → 4)-7,8-di*-O-*acetyl-3-deoxy-1*-O-*pivaloyl-α*-D-manno-*2-octulopyranoside 1',5-lactone* (**7**).—A solution of **6** (30 mg, 0.03 mmol) and 1.1 M Bu_4NF in THF (60 μL, 0.060 mmol) in THF (5 mL) was stirred for 3 h at 0°C. The solution was taken to dryness, and the residue was dissolved in dry pyridine (5 mL) and treated with a catalytic amount of 4-dimethylaminopyridine and Ac_2O (0.3 mL) for 15 h at room temperature. Solvents were removed in vacuo and the residue left after coevaporation with toluene (10 mL) was chromatographed on silica gel (*A*, 2:1 toluene–EtOAc). Pooling and evaporation of the main fraction gave **7** as a syrup. Yield: 17 mg (70%); $[\alpha]_D^{20}$ + 58° (*c* 1.4, $CHCl_3$); ^{1}H NMR ($CDCl_3$): δ 5.86 (m, 1 H, =CH–), 5.36 (br s, 1 H, H-5'), 5.31 (m, 1 H, H-4'), 5.29 (m, 1 H, H-7'), 5.11 (dt, 1 H, H-7), 5.09 (br s, 1 H, H-5), 4.74 (dd, 1 H, $J_{8'a,8'b} \sim -12.5$, $J_{8'a,7'} \sim 2.3$ Hz, H-8'a), 4.44 (ddd, 1 H, $J_{4,5} \sim 3.8$, $J_{4,3e} \sim 5.7$, $J_{4,3a} \sim 11.6$ Hz, H-4), 4.37 (dd, 1 H, $J_{6,5} \sim 1.3$, $J_{6,7} \sim 9.5$ Hz, H-6), 4.36 (dd, 1 H, $J_{8a,8b} \sim -12.5$, $J_{8a,7} \sim 2.0$ Hz, H-8a), 4.26 and 4.02 (AB, 2 H, $J_{AB} \sim 12.0$ Hz, H-1a,1b), 4.18 (dd, 1 H, $J_{8b,7} \sim 3.0$ Hz, H-8b), 4.12 (dd, 1 H, $J_{8'b,7'} \sim 3.4$ Hz, H-8'b), 4.00–3.97 (m, 3 H, H-6', OCH_2), 2.63 (t, 1 H, $J_{3'a,3'e} \simeq J_{3'a,4'} \simeq 13.0$ Hz, H-3'*a*), 2.20 (dd, 1 H, $J_{3e,3a} \sim -13.0$ Hz, H-3*e*), 2.09, 2.05, 2.04, 2.03, and 1.99 (5 s, 18 H, 6 Ac), 1.89 (dd, 1 H, $J_{3'e,4'} \sim 4.0$ Hz, H-3'*e*), 1.69 (dd, 1 H, H-3*a*), and 1.22 [s, 9 H, $(CH_3)_3C$]. Anal. Calcd for $C_{36}H_{50}O_{20}$: C, 53.86; H, 6.28. Found: C, 54.13; H, 6.03.

Allyl O-*(sodium 3-deoxy-α*-D-manno-*2-octulopyranosylonate)-(2 → 4)-3-deoxy-α*-D-manno-*2-octulopyranoside* (**8**).—A solution of **7** (12.3 mg, 15.3 μmol) in dry MeOH was stirred with 0.1 M methanolic NaOMe (0.5 mL) for 5 h at room temperature. Dowex 50 (H^+) resin was added to neutral pH, the suspension was filtered, and the filtrate was taken to dryness. A solution of the residue in water (3 mL) was treated with 0.2 M NaOH (1.5 mL) for 2 h at room temperature. Dowex 50 (H^+) resin was added to pH 8.5 and the resin was removed by filtration. The residue obtained upon lyophilization of the filtrate was purified on a Bio-Gel P-2 column (2.5 × 100 cm, water). Yield of **8**: 7.6 mg (97%); $[\alpha]_D^{20}$ + 69° (*c* 0.8, H_2O); ^{1}H NMR (D_2O): δ 5.99 (m, 1 H, =CH–), 5.37 (dq, 1 H, $=CH_{2trans}$), 5.26 (dq, 1 H, $=CH_{2cis}$), and 4.07 (m, 2 H, OCH_2).

Allyl O-*(methyl 4,5,7,8-tetra*-O-*acetyl-3-deoxy-α*-D-manno-*2-octulopyranosylonate)-(2 → 8)-(methyl 4,5,7-tri*-O-*acetyl-3-deoxy-α*-D-manno-*2-octulopyranosylonate)-(2 → 4)-3-deoxy-1*-O-*pivaloyl-7,8*-O-*(1,1,3,3-tetraisopropyldisiloxane-1,3-diyl)-α*-D-manno-*2-octulopyranoside* (**10**) *and* O-*(methyl 4,5,7,8-tetra*-O-*acetyl-3-deoxy-α*-D-manno-*2-octulopyranosylonate)-(2 → 8)-(methyl 4,5,7-tri*-O-*acetyl-2,6-anhydro-2,3-dideoxy*-D-manno-*2-octenonate)* (**11**).—A suspension of **3** (110 mg, 0.18 mmol), $Hg(CN)_2$ (81 mg, 0.32 mmol), $HgBr_2$ (39 mg, 0.11 mmol), and 4A molecular sieves (0.5 g) in dry $MeNO_2$ (5 mL) was stirred for 30 min at room temperature under N_2. A solution of **9** (300 mg, 0.36 mmol) in $MeNO_2$ (2 mL) was added dropwise during 30 min and stirring was continued for 20 h, CH_2Cl_2 (50 mL) was added, the

suspension was filtered over Celite, and the filtrate was washed with aq 10% KI and satd aq $NaHCO_3$, and dried ($MgSO_4$). Purification on silica gel (*C*, 1:1 toluene–EtOAc) of the residue obtained upon evaporation afforded first crude **10**, and then **11** as a syrup. Yield for **11**: 90 mg (33% based on **9**); $[\alpha]_D^{20}$ + 28° (*c* 0.9, $CHCl_3$); ^{1}H NMR ($CDCl_3$): δ 5.93 (t, 1 H, $J_{3,4} \simeq {}^4J_{3,5} \simeq 2.0$ Hz, H-3), 5.72 (ddd, 1 H, $J_{4,5} \sim 4.6$, $^4J_{4,6} \sim 1.3$ Hz, H-4), 5.47 (ddd, 1 H, $J_{5,6} \sim 1.0$ Hz, H-5), 5.34 (br s, 1 H, H-5′), 5.26 (ddd, 1 H, $J_{7',8'a} \sim 2.3$, $J_{7',8'b} \sim 4.9$, $J_{7',6'} \sim 9.7$ Hz, H-7′), 5.18 (ddd, 1 H, $J_{4',3'e} \sim 6.0$, $J_{4',5'} \sim 2.9$, $J_{4',3'a} \sim 11.2$ Hz, H-4′), 5.14 (ddd, 1 H, $J_{7,8a} \sim 2.4$, $J_{7,8b} \sim 3.6$, $J_{7,6} \sim 9.5$ Hz, H-7), 4.61 (dd, 1 H, $J_{8'a,8'b} \sim -12.2$ Hz, H-8′a), 4.44 (dd, 1 H, H-6), 4.21 (dd, 1 H, $J_{6',5'} \sim 1.4$ Hz, H-6′), 4.18 (dd, 1 H, H-8′b), 3.84–3.77 (m, 2 H, H-8a, H-8b), 3.84 (s, 3 H) and 3.80 (s, 3 H, 2 CO_2Me), 2.13 (dd, 1 H, H-3′*e*), ~ 2.10 (t, 1 H, H-3′*a*), 2.10, 2.09, 2.07, 2.04, 2.03, 2.01, and 1.96 (7 s, 21 H, 7 Ac). Anal. Calcd for $C_{32}H_{42}O_{21}$: C, 50.40; H, 5.55. Found: C, 50.58; H, 5.35.

Further purification of **10** was achieved by LC on Lichrosorb Si 60 (10 μm) using 3:2 toluene–EtOAc as eluant. Pooling and evaporation of the fractions containing the faster moving component afforded **10** as a syrup. Yield: 58 mg (23%); $[\alpha]_D^{20}$ + 55° (*c* 1.0, $CHCl_3$); ^{1}H NMR ($CDCl_3$): δ 5.87 (m, 1 H, =CH–) 5.37 (br s, 1 H, H-5′), 5.34 (br s, 1 H, H-5″), 5.33 (m, 1 H, H-7′), 5.25 (ddd, 1 H, $J_{4',5'} \sim 3.0$, $J_{4',3'a} \sim 12.1$ Hz, H-4′), 5.21 (m, 1 H, H-7″), 5.13 (ddd, 1 H, $J_{4'',5''} \sim 3.0$, $J_{4'',3''a} \sim 12.3$, $J_{4'',3''e} \sim 5.3$ Hz, H-4″), 4.51 (dd, 1 H, $J_{8''a,7''} \sim 2.5$, $J_{8''a,8''b} \sim -12.3$ Hz, H-8″a), 4.23 (dd, 1 H, $J_{8''b,7''} \sim 4.7$ Hz, H-8″b), 4.20 (ddd, 1 H, $J_{7,6} \sim 8.2$, $J_{7,8b} \sim 7.6$ Hz, H-7), 4.14 (dd, 1 H, H-8a), 4.14 and 4.00 (AB, 2 H, $J_{AB} \sim 11.8$ Hz, H-1a,1b), 4.10 (m, 1 H, H-4), 4.06 (dd, 1 H, $J_{6'',5''} \sim 1.3$, $J_{6'',7''} \sim 9.7$ Hz, H-6″), 4.02 (dd, 1 H, $J_{6',5'} \sim 1.5$, $J_{6',7'} \sim 7.8$ Hz, H-6′), 4.00–3.90 (m, 3 H, H-8′a, OCH_2), 3.85 (br s, 1 H, H-5), 3.78 (s, 6 H, 2 CO_2Me), 3.68 (dd, 1 H, $J_{8a,8b} \sim -12.0$ Hz, H-8b), 3.64 (dd, 1 H, $J_{8'a,8'b} \sim -12.0$ Hz, H-8′b), 3.32 (dd, 1 H, H-6), 2.46 (d, 1 H, $J_{5,OH} \sim 3.1$ Hz, OH), 2.27 (dd, 1 H, $J_{3'e,4'} \sim 5.4$, $J_{3'e,3'a} \sim -13.1$ Hz, H-3′*e*), 2.15–2.03 (m, 4 H, H-3*a*,3″*e*,3″*a*,3′*a*), 2.11, 2.10, 2.08, 2.07, 2.00, 1.96, and 1.95 (7 s, 21 H, 7 Ac), 1.75 (dd, 1 H, $J_{3e,3a} \sim -13.4$, $J_{3e,4} \sim 5.3$ Hz, H-3*e*), 1.22 [s, 9 H, $(CH_3)_3C$], and 1.08–1.00 [m, 28 H, 4 $(CH_3)_2CHSi$]. Anal. Calcd for $C_{60}H_{96}O_{30}Si_2$: C, 53.24; H, 7.15. Found: C, 53.76; H, 7.31.

Allyl O-*(methyl 4,5,7,8-tetra*-O-*acetyl-3-deoxy-α-*D-manno-*2-octulopyranosylonate)-(2 → 8)-(4,5,7-tri*-O-*acetyl-3-deoxy-α-*D-manno-*octulopyranosylonic acid)-(2 → 4)-7,8-di*-O-*acetyl-3-deoxy-1-*O-*pivaloyl-α-*D-manno-*2-octulopyranoside 1′,5-lactone* (**12**).—A solution of **10** (20 mg, 0.014 mmol) in dry THF (5 mL) was stirred with 1.1 M Bu_4NF in THF (40 μL) for 2 h at room temperature. The solution was taken to dryness, the residue was dissolved in pyridine (5 mL) and stirred with acetic anhydride (0.4 mL), and a catalytic amount of 4-dimethylaminopyridine for 48 h at 0°C. The solvents were removed by coevaporation with toluene and the product was isolated by silica gel chromatography (*A*, 1:1 toluene–EtOAc) which gave **12** as a syrup. Yield: 13 mg (80%); $[\alpha]_D^{20}$ + 64° (*c* 0.5, $CHCl_3$); ^{1}H NMR ($CDCl_3$): δ 5.86 (m, 1 H, =CH–), 5.38 (br s, 1 H, H-5′), 5.35 (br s, 1 H, H-5″), 5.34 (ddd, 1 H, H-7), 5.25 (m, 1 H, H-4′), 5.24 (m, 1 H, H-7′), 5.17 (m, 1 H, H-4″), 5.16 (m, 2 H, $=CH_{2cis}$, H-7″), 5.10 (br d, 1 H, H-5), 4.68 (dd, 1 H, $J_{8a,7} \sim 2.3$, $J_{8a,8b} \sim -12.5$ Hz, H-8a), 4.57 (ddd, 1 H, $J_{4,5} \sim 3.5$, $J_{4,3e} \sim 5.3$ Hz, H-4), 4.51 (dd, 1

H, $J_{8'',7''} \sim 2.5$, $J_{8''a,8''b} \sim -12.3$ Hz, H-8''a), 4.32 (dd, 1 H, $J_{6',5'} < 1.0$, $J_{6',7'} \sim 8.0$ Hz, H-6'), 4.27 (dd, 1 H, $J_{8''b,7''} \sim 3.3$ Hz, H-8''b), 4.22 (dd, 1 H, $J_{8b,7} \sim 4.4$ Hz, H-8b), 4.24 and 4.04 (AB, 2 H, $J_{AB} \sim 11.8$ Hz, H-1a,1b), 4.14 (dd, 1 H, $J_{6,5} \sim 1.5$, $J_{6,7} \sim 8.0$ Hz, H-6), 4.12 (dd, 1 H, $J_{6'',5''} \sim 1.2$, $J_{6'',7''} \sim 9.0$ Hz, H-6''), 4.00 (m, 2 H, OCH_2), 3.81 (s, 3 H, CO_2Me), 3.76 (dd, 1 H, $J_{8'a,8'b} \sim -11.1$, $J_{8'a,7'} \sim 3.5$ Hz, H-8'a), 3.56 (dd, 1 H, $J_{8'b,7'} \sim 6.9$ Hz, H-8'b), 2.68 (t, 1 H, $J_{3'a,3'e} \simeq J_{3'a,4'} \simeq 13.0$ Hz, H-3'*a*), 2.20–2.10 (m, 3 H, H-3*e*,3''*e*,3''*a*), 2.11, 2.09, 2.08, 2.06, 2.04, 2.01, 1.99, and 1.97 (8 s, 27 H, 9 Ac), 1.86 (dd, 1 H, $J_{3'e,4'} \sim 4.4$ Hz, H-3'*e*), 1.67 (t, 1 H, $J_{3a,4} \simeq J_{3a,3e} \simeq 12.5$ Hz, H-3*a*), and 1.22 [s, 9 H, $(CH_3)_3C$]. Anal. Calcd for $C_{51}H_{70}O_{30}$: C, 52.67; H, 6.07. Found: C, 52.66; H, 5.84.

Allyl O-*(sodium 3-deoxy-α-*D-manno-*2-octulopyranosylonate)-(2 → 8)-(sodium 3-deoxy-α-*D-manno-*2-octulopyranosylonate)-(2 → 4)-3-deoxy-α-*D-manno-*2-octulopyranoside* (**13**).—A solution of **12** (15.1 mg) in dry MeOH (5 mL) was stirred with 0.1 M methanolic NaOMe (1 mL) for 3 h at room temperature. Dowex 50 (H^+) resin was added to neutral pH, the suspension was filtered, and the filtrate was evaporated to dryness. A solution of the residue in water (3 mL) was treated with 0.2 M NaOH (2 mL) for 4 h. The pH was adjusted to 8.5 by adding Dowex 50 (H^+) resin, and the filtrate obtained upon removal of the resin was concentrated and purified on a Bio-Gel P-2 column. Yield of **13**: 7.9 mg (86%); amorphous powder; $[\alpha]_D^{20} + 71°$ (*c* 0.7, H_2O); ^1H NMR (D_2O): δ 6.00 (m, 1 H, =CH–), 5.35 (dq, 1 H, $=CH_{2trans}$), 5.24 (dq, 1 H, $=CH_{2cis}$), 4.05 (m, 2 H, OCH_2).

*1,4,5,7,8-Penta-*O*-acetyl-3-deoxy-*D*-manno-2-octulopyranose* (**15**).—A solution of $\{Ir(COD)[PCH_3(C_6H_5)_2]_2\}PF_6$ (10 mg) in dry THF (20 mL) was purged with oxygen-free N_2, evacuated at aspirator pressure, and placed under H_2 at atmospheric pressure, until a slightly yellow color of the solution was obtained. H_2 was removed in vacuo, dry N_2 was admitted, and a solution of **14** (115 mg, 0.25 mmol) in dry THF (5 mL) was added. After 2 h at room temperature, the solution was concentrated, the residue was taken up in CH_2Cl_2 (50 mL), and the solution was washed with satd aq $NaHCO_3$ and dried (Na_2SO_4). The residue obtained upon removal of the solvent was stirred in 4:1 THF–H_2O (10 mL) containing iodine (100 mg) for 10 min. CH_2Cl_2 (50 mL) was added, and the solution was washed with aq 20% $Na_2S_2O_3$, then satd aq $NaHCO_3$, dried (Na_2SO_4), and concentrated. Purification of the residue on silica gel (*B*, 3:2 toluene–EtOAc) afforded **15** as a syrup. Yield: 77 mg (66%); $[\alpha]_D^{20} + 57°$ (*c* 1.0, $CHCl_3$); ^1H NMR ($CDCl_3$): δ 5.39–5.34 (m, 2 H, H-4,5), 5.08 (ddd, 1 H, $J_{7,8a} \sim 3.9$, $J_{7,8b} \sim 2.7$, $J_{7,6} \sim 9.9$ Hz, H-7), 4.33 (dd, 1 H, $J_{8a,8b} \sim -12.2$ Hz, H-8a), 4.25 (dd, 1 H, H-8b), 4.21 (dd, 1 H, $J_{6,5} \sim 1.0$ Hz, H-6), 4.30 and 3.99 (AB, 2 H, $J_{AB} \sim 11.5$ Hz, H-1a,1b), 3.29 (d, 1 H, OH), 2.14, 2.09, 2.08, 2.02, and 1.99 (5 s, 15 H, 5 Ac), and 1.92 (m, 2 H, H-3*e*,3*a*). Anal. Calcd for $C_{18}H_{26}O_{12}$: C, 49.77; H, 6.03. Found: C, 49.56; H, 6.03.

*1,4,5,7,8-Penta-*O*-acetyl-3-deoxy-α-*D*-manno-2-octulopyranosyl fluoride* (**16**).—A solution of **15** (344 mg, 0.79 mmol) in dry CH_2Cl_2 (10 mL) was treated with diethylaminosulfur trifluoride (0.35 mL) for 2 h at 0°C. The solution was washed with ice-cold satd aq $NaHCO_3$, dried ($MgSO_4$), and concentrated. Chromatography of the residue (*B*, 1:1 toluene–EtOAc) furnished **16** as crystals. Yield: 310 mg (90%); mp 99°C (hexane–EtOAc); $[\alpha]_D^{20} + 46°$ (*c* 1.0, $CHCl_3$); ^1H NMR ($CDCl_3$): δ

5.41 (br s, 1 H, H-5), 5.31 (ddd, 1 H, $J_{4,3a} \sim 12.2$, $J_{4,3e} \sim 5.3$, $J_{4,5} \sim 3.0$ Hz, H-4), 5.14 (m, 1 H, H-7), 4.42 (dd, 1 H, $J_{8a,8b} \sim -12.3$, $J_{8a,7} \sim 2.3$ Hz, H-8a), 4.30 (dd, 1 H, $J_{6,5} \sim 1.5$ Hz, H-6), 4.24 and 4.20 (d, 2 H, OCH_2), 4.15 (dd, 1 H, $J_{8b,7} \sim 4.5$ Hz, H-8b), 2.19–1.90 (m, 2 H, H-3*a*,3*e*), 2.13, 2.09, 2.08, 2.02, and 2.00 (5 s, 15 H, 5 Ac). Anal. Calcd for $C_{18}H_{25}FO_{11}$: C, 49.54; H, 5.77. Found: C, 49.52; H, 5.97.

*Methyl 4,5,7-tri-*O*-acetyl-8-*O*-*tert*-butyldimethylsilyl-3-deoxy-*D-manno-2-*octulopyranosonate* (**18**).—*Method 1.* A solution of **17** (3.8 g, 7.2 mmol) in dry THF (20 mL) was added to a solution of activated $\{Ir(COD)[PCH_3(C_6H_5)_2]_2\}PF_6$ in THF (20 mL) under dry N_2 for 3 h at room temperature. Work-up as described for **15** gave a syrup, which was dissolved in 4:1 THF–H_2O (10 mL) and treated with I_2 (2.7 g) and 2,4,6-trimethylpyridine (0.1 mL) for 1 h at room temperature. Silica gel (2 g) was added and the suspension was stirred overnight, then filtered and washed with EtOAc (100 mL). The organic layer was washed with aq 10% Na_2SO_3 and satd aq $NaHCO_3$, dried ($MgSO_4$), and concentrated. Purification of the residue on silica gel (*C*, 4:1 toluene–EtOAc) gave **18** as colorless crystals. Yield: 1.56 g (45%); mp 102°C (hexane–EtOAc); $[\alpha]_D^{20} + 45°$ (*c* 1.0, $CHCl_3$); ^1H NMR ($CDCl_3$): δ 5.41–5.34 (m, 2 H, H-4,5), 4.98 (ddd, 1 H, $J_{7,6} \sim 9.8$, $J_{7,8a} \sim 2.5$, $J_{7,8b} \sim 3.0$ Hz, H-7), 4.46 (dd, 1 H, $J_{6,5} \sim 1.2$ Hz, H-6), 3.87 (s, 3 H, CO_2Me), 3.73 (m, 2 H, H-8a,8b), 2.45 (t, 1 H, $J_{3a,3e} \sim -12.5$, $J_{3a,4} \sim 12.5$ Hz, H-3*a*), 2.10, 2.01, and 1.98 (3 s, 9 H, 3 Ac), 1.89 (ddd, 1 H, $J_{3e,4} \sim 5.0$, $J_{3e,5} \sim 1.0$ Hz, H-3*e*), 0.88 [s, 9 H, $(CH_3)_3C$], and 0.03–0.00 [s, 6 H, $Si(CH_3)_2$]. Anal. Calcd for $C_{21}H_{36}O_{11}Si$: C, 51.20; H, 7.37. Found: C, 51.16; H, 7.28.

Method 2. A suspension of **17** (1.6 g, 3 mmol), 4A molecular sieves (1 g), acetic acid (1 mL), and SeO_2 (100 mg) in dry 1,4-dioxane was kept at reflux temperature for 5 h. After cooling to room temperature and addition of CH_2Cl_2 (50 mL), the mixture was filtered over Celite. The filtrate was washed with satd aq $NaHCO_3$, dried ($MgSO_4$), concentrated, and purified by silica gel chromatography, which gave **18** (460 mg, 32%) and unreacted **17** (182 mg, 12%).

*Methyl 2,4,5,7-tetra-*O*-acetyl-8-*O*-*tert*-butyldimethylsilyl-3-deoxy-α-D-*manno-2-*octulopyranosonate* (**19**).—A solution of **18** (430 mg, 0.87 mmol) in dry pyridine (10 mL) was stirred with 4-dimethylaminopyridine (20 mg) and acetic anhydride (0.45 mL) for 4 h at room temperature. The solution was taken to dryness by coevaporation with toluene. A solution of the residue in CH_2Cl_2 (100 mL) was washed with satd aq $NaHCO_3$, dried ($MgSO_4$), and concentrated. Purification of the residue on silica gel (*C*, 3:1 toluene–EtOAc) afforded **19** as a syrup. Yield: 462 mg (99%); $[\alpha]_D^{20} + 66°$ (*c* 0.8, $CHCl_3$); ^1H NMR ($CDCl_3$): δ 5.40 (br s, 1 H, H-5), 5.34 (ddd, 1 H, $J_{4,5} \sim 3.2$, $J_{4,3a} \sim 11.2$, $J_{4,3e} \sim 6.3$ Hz, H-4), 5.02 (dt, 1 H, $J_{7,8a} \simeq J_{7,8b} \simeq 2.6$, $J_{7,6} \sim 9.6$ Hz, H-7), 4.32 (dd, 1 H, $J_{6,5} \sim 1.3$ Hz, H-6), 3.83 (dd, 1 H, $J_{8a,8b} \sim -11.6$ Hz, H-8a), 3.80 (s, 3 H, CO_2CH_3), 3.74 (dd, 1 H, H-8b), 2.22 (m, 2 H, H-3*a*,3*e*), 2.11, 2.09, and 2.00 (3 s, 12 H, 4 Ac), 0.88 [s, 9 H, $(CH_3)_3C$], 0.03 and 0.02 [s, 6 H, $(CH_3)_2Si$]. Anal. Calcd for $C_{23}H_{38}O_{12}Si$: C, 51.67; H, 7.16. Found: C, 52.01; H, 6.99.

O-*(Methyl 4,5,7,8-tetra-*O*-acetyl-3-deoxy-α-D-*manno-2-octulopyranosylonate)-(2 → 8)-(methyl 2,4,5,7-tetra-*O*-acetyl-3-deoxy-α-D-*manno-2-octulopyranosonate)* (**22**). —A solution of **19** (2.6 g, 4.9 mmol) in dry MeCN (8 mL) was stirred with 2% HF

in MeCN (7 mL) for 1 h at room temperature. $NaHCO_3$ (1 g) was added and the mixture was taken to dryness. The residue was dissolved in CH_2Cl_2 (50 mL) and water. The organic layer was dried ($MgSO_4$) and evaporated to dryness, giving **20** as a syrup. Yield: 1.87 g (91%). The syrup was dried in vacuo for 2 h and dissolved in dry $MeNO_2$ (5 mL); $Hg(CN)_2$ (3 g, 1.2 mmol) and 4A molecular sieves (1 g) were added under N_2, and the suspension was stirred for 20 min at room temperature. A solution of **4** (4 g, 8.3 mmol) in dry $MeNO_2$ (5 mL) was added dropwise during 3 h and stirring was continued for 48 h. CH_2Cl_2 (50 mL) was added and the suspension was filtered over Celite. The filtrate was washed with aq 10% KI and satd aq $NaHCO_3$, dried (Na_2SO_4), and concentrated. The residue was chromatographed on silica gel (*C*, 1:1 toluene–EtOAc) which afforded first **5** (375 mg) and then **22** (2.53 g, 70%). Further purification of **22** was achieved by chromatography using 1:1 1-pentanol–hexane as eluant which afforded **22** as a syrup. Yield: 1.5 g (41%); $[\alpha]_D^{20} + 88°$ (*c* 1.0, $CHCl_3$); lit. [19]: $[\alpha]_D^{20} + 90°$ (*c* 0.86, $CHCl_3$); ^1H NMR data were identical to those reported [19].

Allyl O-*(1,4,5,7,8-penta*-O-*acetyl-3-deoxy-α*-D-manno-*2-octulopyranosyl)-(2 → 8)-(methyl 4,5,7-tri*-O-*acetyl-3-deoxy-α*-D-manno-*2-octulopyranosidonate)* (**23**).—A suspension of **16** (77 mg, 0.18 mmol), **21** (126 mg, 0.24 mmol), and 4A molecular sieves (1 g) in dry MeCN (5 mL) was stirred for 20 min at 0°C under N_2. $BF_3 \cdot Et_2O$ (0.5 mL) was added. After 2 h, triethylamine (0.5 mL) was added, and the suspension was filtered over Celite and washed with CH_2Cl_2 (50 mL). The organic layer was washed with satd aq $NaHCO_3$, dried ($MgSO_4$), and concentrated. Purification by silica gel chromatography (*B*, 2:1 toluene–EtOAc) afforded **23** as a syrup. Yield: 95 mg (64%); $[\alpha]_D^{20} + 83°$ (*c* 1.0, $CHCl_3$); ^1H NMR ($CDCl_3$); δ 5.88 (m, 1 H, =CH–), 5.33 (ddd, 1 H, $J_{4,5} \sim 3.0$, $J_{4,3e} \sim 4.9$ Hz, H-4), 5.33–5.30 (m, 2 H, H-5,5′), 5.29 (m, 2 H, H-7, $=CH_{2trans}$), 5.10 (ddd, 1 H, $J_{7',8'a} \sim 2.5$, $J_{7',8'b} \sim 4.0$, $J_{7',6'} \sim 9.6$ Hz, H-7′), 5.09 (ddd, 1 H, $J_{4',5'} \sim 3.0$, $J_{4',3'e} \sim 6.1$ Hz, H-4′), 4.54 (dd, 1 H, $J_{8'a,8'b} \sim -12.3$ Hz H-8′a), 4.12–3.94 (m, 7 H, H-1′a,1′b,6,6′,8′b, OCH_2), 3.90 (dd, 1 H, $J_{8a,7} \sim 2.2$, $J_{8a,8b} \sim -11.4$ Hz, H-8a), 3.82 (s, 3 H, CO_2Me), 3.62 (dd, 1 H, $J_{8b,7} \sim 6.2$ Hz, H-8b), 2.22 (dd, 1 H, $J_{3e,3a} \sim -12.8$ Hz, H-3*e*), 2.14–1.92 (m, 3 H, H-3*a*,3′*e*,3′*a*), 2.13, 2.10, 2.09, 2.08, 2.07, 2.00, 1.97 and 1.95 (8 s, 24 H, 8 Ac). Anal. Calcd for $C_{36}H_{50}O_{23}$: C, 51.79; H, 6.04. Found: C, 51.21; H, 6.09.

Allyl O-*(3-deoxy-α*-D-manno-*2-octulopyranosyl)-(2 → 8)-(sodium 3-deoxy-α*-D-manno-*2-octulopyranosidonate)* (**24**).—A solution of **23** (46 mg, 55 μmol) in dry MeOH (5 mL) was stirred with 0.1 M methanolic NaOMe (0.5 mL) for 3 h at room temperature. Dowex 50 (H^+) resin was added to neutral pH, the resin was filtered off, and the filtrate was taken to dryness. A solution of the residue in water (3 mL) was treated with 0.2 M NaOH (2.0 mL) for 2 h at room temperature and for 15 h at 4°C. The pH of the solution was adjusted to 8.5 by adding Dowex 50 (H^+) resin, the suspension was filtered, and the filtrate was lyophilized. Final purification on a Fractogel TSK 40S column (1.6 × 100 cm, water) afforded **24** as an amorphous powder. Yield: 19.7 mg (70%); $[\alpha]_D^{20} + 68°$ (*c* 1.0, H_2O); ^1H NMR (D_2O): δ 5.97 (m, 1 H, =CH–), 5.35 (dq, 1 H, $=CH_{2trans}$), 5.25 (dq, $=CH_{2cis}$), 3.93 (m, 2 H, OCH_2). Anal. Calcd for $C_{19}H_{31}NaO_{14} \cdot 2H_2O$: C, 42.07; H, 6.43. Found: C, 41.64; H, 6.50.

O-*(1,4,5,7,8-Penta*-O-*acetyl-3-deoxy-α*-D-manno-*2-octulopyranosyl)-(2 → 8)-(methyl 2,4,5,7-tetra*-O-*acetyl-3-deoxy-α*-D-manno-*2-octulopyranosonate)* (**25**).—A solution of **16** (158 mg, 0.36 mmol) and **19** (170 mg, 0.32 mmol) in dry MeCN (5 mL) was stirred with 4A molecular sieves (1 g) for 20 min under N_2. $BF_3 \cdot Et_2O$ (0.5 mL) was added at 0°C and the suspension was stirred for 3 h. Triethylamine (0.5 mL) and CH_2Cl_2 (50 mL) were added and the mixture was filtered over Celite. The filtrate was washed with satd aq $NaHCO_3$, dried ($MgSO_4$), and concentrated. The residue was purified on silica gel (*C*, 2:1 toluene–EtOAc) which yielded **25** (157 mg, 59%) as colorless crystals; mp 133°C (hexane–EtOAc); $[\alpha]_D^{20}$ + 73° (*c* 1.0, $CHCl_3$); ^{1}H NMR ($CDCl_3$): δ 5.39 (dd, 1 H, $J_{5,4} \sim 2.9$, $J_{5,6} \sim 1.5$ Hz, H-5), 5.34 (br s, 1 H, H-5′), 5.28 (ddd, 1 H, $J_{4,3e} \sim 8.0$, $J_{4,3a} \sim 10.5$ Hz, H-4), 5.18 (ddd, 1 H, $J_{7,8a} \sim 2.2$, $J_{7,8b} \sim 4.3$, $J_{7,6} \sim 9.8$ Hz, H-7), 5.15 (ddd, 1 H, H-4′), 5.13 (ddd, 1 H, $J_{7',8'a} \sim 2.4$, $J_{7',8'b} \sim 4.9$, $J_{7',6'} \sim 9.7$ Hz, H-7′), 4.48 (dd, 1 H, $J_{8'a,8'b} \sim -12.2$ Hz, H-8′a), 4.27 (dd, 1 H, H-6), 4.18 and 4.06 (AB, 2 H, $J_{AB} \sim 12.0$ Hz, H-1′a,1′b), 4.12 (dd, 1 H, H-8′b), 4.02 (dd, 1 H, $J_{6',5'} \sim 1.4$ Hz, H-6′), 3.80 (s, 3 H, CO_2Me), 3.79 (dd, 1 H, $J_{8a,8b} \sim -11.3$ Hz, H-8a), 3.53 (dd, H-8b), 2.30 (d, 2 H, H-3*e*,3*a*), 2.18, 2.09, 2.07, 2.04, 2.01, 1.99 and 1.96 (7 s, 27 H, 9 Ac), 2.01 (m, 1 H, H-3′*e*), and 1.92 (t, 1 H, $J_{3'a,3'e} \simeq J_{3'a,4'} \simeq 12.8$ Hz, H-3′*a*). Anal. Calcd for $C_{35}H_{48}O_{23}$: C, 50.24; H, 5.78. Found: C, 50.16; H, 5.57.

Allyl O-*(1,4,5,7,8-penta*-O-*acetyl-3-deoxy-α*-D-manno-*2-octulopyranosyl)-(2 → 8)-(methyl 4,5,7-tri*-O-*acetyl-3-deoxy-α*-D-manno-*2-octulopyranosylonate)-(2 → 4)-(methyl 7,8*-O-*carbonyl-3-deoxy-α*-D-manno-*2-octulopyranosidonate)* (**28**).—A solution of **25** (70 mg, 0.084 mmol) in dry CH_2Cl_2 (10 mL) was stirred with $TiBr_4$ (360 mg, 1 mmol) for 20 h at 4°C. The solution was diluted with CH_2Cl_2 (50 mL), washed with ice-cold satd aq $NaHCO_3$, dried ($MgSO_4$), and evaporated to dryness, giving **26** as a slightly yellow syrup. Yield: 69 mg (96%). A suspension of **27** (125 mg, 0.393 mmol), $Hg(CN)_2$ (30 mg, 0.12 mmol), $HgBr_2$ (45 mg, 0.125 mmol), and 4A molecular sieves (1 g) in dry MeCN (5 mL) was stirred for 20 min under N_2 at room temperature. Then a solution of freshly prepared **26** (69 mg, 0.08 mmol) in MeCN (2 mL) was added and stirring was continued for 40 h. After addition of EtOAc (50 mL), the mixture was filtered over Celite, and the filtrate was washed with aq 10% KI, then satd aq $NaHCO_3$, and dried ($MgSO_4$). Concentration afforded a syrup which was chromatographed on silica gel (*C*, 1:2 toluene–EtOAc) to give **28** as a syrup. Yield: 15 mg (17%); ^{1}H NMR ($CDCl_3$): δ 5.86 (m, 1 H, =CH–), 5.39 (dt, 1 H, $J_{7',8'a} \sim 2.2$, $J_{7',8'b} \simeq J_{7',6'} \simeq 9.0$ Hz, H-7′), 5.35 and 5.28 (br s, 2 H, H-5′,5″), 5.19 (ddd, 1 H, H-4′), 5.17 (m, 1 H, H-7″), 5.10 (ddd, 1 H, $J_{4'',5''} \sim 2.9$, $J_{4'',3''e} \sim 5.9$, $J_{4'',3''a} \sim 10.9$ Hz, H-4″), 4.93 (ddd, 1 H, $J_{7,8a} \sim 6.9$, $J_{7,8b} \sim 8.6$, $J_{7,6} \sim 3.4$ Hz, H-7), 4.77 (dd, 1 H, $J_{8a,8b} \sim -8.9$ Hz, H-8a), 4.55 (t, 1 H, H-8b), 4.46 (dd, 1 H, $J_{8''a,7''} \sim 2.4$, $J_{8''a,8''b} \sim -12.1$ Hz, H-8″a), 4.34 and 4.03 (AB-system, 2 H, $J_{AB} \sim 12.0$ Hz, H-1″a,1″b), 4.21 (dd, 1 H, $J_{8''b,7''} \sim 5.4$ Hz, H-8″b), 4.16 (ddd, 1 H, $J_{4,5} \sim 3.0$, $J_{4,3e} \sim 5.2$, $J_{4,3a} \sim 12.0$ Hz, H-4), 4.02–3.96 (m, 5 H, H-6,6″,8′a, OCH_2), 3.90–3.83 (m, 2 H, H-5,6′), 3.85 (s, 3 H) and 3.78 (s, 3 H, CO_2Me), 3.51 (dd, 1 H, $J_{8'b,7'} \sim 9.0$, $J_{8'a,8'b} \sim -9.8$ Hz, H-8′b), 2.69 (d, 1 H, $J_{5,OH} \sim 3.5$ Hz, OH), 2.20–1.96 (m, 6 H, H-3*e*,3*a*,3′*e*,3′*a*,3″*e*,3″*a*), 2.12, 2.11, 2.08, 2.02, 1.98, and 1.96 (6 s, 24 H, 8 Ac). Anal. Calcd for $C_{62}H_{86}O_{30}$: C, 56.79; H, 6.61. Found: C, 56.41; H, 6.66.

O-Acetylation of **28**.—A solution of **28** (10.4 mg, 9.5 μmol), 4-dimethylaminopyridine, and Ac_2O (5 μL) in dry pyridine (5 mL) was stirred overnight at room temperature. The solution was coevaporated three times with addition of toluene (5 mL) and concentrated. Purification of the residue on silica gel (*A*, 1:2 toluene–EtOAc) afforded **29** as a syrup. Yield: 7.1 mg (66%); ^{1}H NMR ($CDCl_3$): δ 5.87 (m, 1 H, =CH–), 5.41 (dt, 1 H, $J_{7',8'a} \simeq J_{7',8'b} \simeq 2.6$, $J_{7',6'} \sim 10.0$ Hz, H-7'), 5.31 (m, 2 H, H-5',5''), 5.25 (m, 1 H, H-5), 5.12 (ddd, 1 H, $J_{4',5'} \sim 2.1$, $J_{4',3'e} \sim 4.7$, $J_{4',3'a} \sim 12.1$ Hz, H-4'), 5.12 (ddd, 1 H, $J_{7,6} \sim 4.4$, $J_{7,8a} \sim 6.4$, $J_{7,8b} \sim 8.4$ Hz, H-7), 4.61 (dd, 1 H, $J_{8a,8b} \sim -8.4$ Hz, H-8a), 4.57 (ddd, 1 H, $J_{4,5} \sim 2.9$, $J_{4,3e} \sim 6.0$, $J_{4,3a} \sim 10.8$ Hz, H-4), 4.50 (dd, 1 H, $J_{8''a,7''} \sim 2.5$, $J_{8''a,8''b} \sim -12.2$ Hz, H-8''a), 4.39 (t, 1 H, H-8b), 4.26 (dd, 1 H, $J_{8''b,7''} \sim 4.7$ Hz, H-8''b), 4.27 and 4.09 (AB, 2 H, $J_{AB} \sim 12.0$ Hz, H-1''a,1''b), 4.17 (dd, 1 H, $J_{6,5} \sim 1.3$ Hz, H-6), 4.03 (m, 2 H, OCH_2), 4.01 (dd, 1 H, $J_{6'',5''} \sim 0.9$ Hz, H-6''), 3.95 (dd, 1 H, $J_{8'a,8'b} \sim -10.1$ Hz, H-8'a), 3.85 (dd, 1 H, $J_{6',5'} \sim 1.3$ Hz, H-6'), 3.85 (s, 3 H) and 3.79 (s, 3 H, 2 CO_2Me), 3.51 (t, 1 H, H-8'b), 2.20–1.91 (m, 6 H, H-3*e*,3*a*,3'*e*,3'*a*,3''*e*,3''*a*), 2.13, 2.11, 2.10, 2.09, 2.07, 2.00, 1.97, and 1.95 (8 s, 24 H, 8 Ac). Anal. Calcd for $C_{64}H_{88}O_{31}$: C, 56.80; H, 6.55. Found: C, 56.91; H, 6.46.

Allyl O-*(3-deoxy-α-*D-manno-*2-octulopyranosyl)-(2 → 8)-(sodium 3-deoxy-α-*D-manno-*2-octulopyranosylonate-)-(2 → 4)-(sodium 3-deoxy-α-*D-manno-*2-octulopyranosidonate)* (**30**).—A solution of **29** (7.1 mg, 6.3 μmol) in dry MeOH (5 mL) was stirred with 0.2 M methanolic NaOMe (0.3 mL) for 4 h at room temperature. Work-up as described for **8** gave a syrup, which was treated with 0.2 M NaOH (1 mL) for 4 h at room temperature. Adjustment of the pH to 8.5 by addition of Dowex 50 (H^+) resin, filtration, and concentration of the solution furnished a syrup which was desalted on a Fractogel column. Yield: 3.0 mg (64%) of **30**, amorphous powder; $[\alpha]_D^{20} + 88°$ (*c* 0.3, H_2O); ^{1}H NMR (D_2O): δ 5.96 (m, 1 H, =CH–), 5.32 (dq, 1 H, $=CH_{2trans}$), 5.19 (dq, 1 H, $=CH_{2cis}$), and 3.90 (m, 2 H, OCH_2).

*Allyl 4,5-*O*-carbonyl-3-deoxy-1-*O*-pivaloyl-7,8-*O*-(1,1,3,3-tetraisopropyldisiloxane-1,3-diyl)-α-*D-manno-*2-octulopyranoside* (**31**).—A solution of **3** (247 mg, 0.42 mmol) and *sym*-collidine (0.5 mL) in dry THF (15 mL) was cooled to −20°C under N_2. A solution of diphosgene (60 μL, 0.5 mmol) in THF (2 mL) was added dropwise during 30 min. MeOH (0.5 mL) was added after 4 h, and the solution was concentrated and applied on to a column of silica gel (*C*). Elution with 10:1 → 8:1 toluene–EtOAc afforded **31** as a syrup. Yield: 227 mg (88%); $[\alpha]_D^{20} + 3°$ (*c* 1.1, $CHCl_3$); ^{1}H NMR ($CDCl_3$): δ 5.84 (m, 1 H, =CH–), 5.04 (dt, 1 H, $J_{4,3a} \simeq J_{4,3e} \simeq 4.0$, $J_{4,5} \sim 8.4$ Hz, H-4), 4.93 (dd, 1 H, $J_{5,6} \sim 1.8$ Hz, H-5), 4.43 and 3.89 (AB, 2 H, $J_{AB} \sim 12.2$ Hz, H-1a,1b), 4.20 (ddd, 1 H, $J_{7,6} \sim 9.2$, $J_{7,8a} \sim 1.9$, $J_{7,8b} \sim 6.3$ Hz, H-7), 4.14 (dd, 1 H, $J_{8a,8b} \sim -12.2$ Hz, H-8a), 4.04 (m, 1 H) and 3.92 (m, 1 H, OCH_2), 3.77 (dd, 1 H, H-8b), 3.74 (dd, 1 H, H-6), 2.56 (dd, 1 H, $J_{3a,3e} \sim -16.0$ Hz, H-3*e*), 1.91 (ddd, 1 H, $J_{3a,H\text{-}1a} \sim 1.0$ Hz, H-3*a*), 1.22 [s, 9 H, $(CH_3)_3C$], and 1.09–1.00 [m, 28 H, 4 $(CH_3)_2CHSi$]. Anal. Calcd for $C_{29}H_{52}O_{10}Si_2$: C, 56.46; H, 8.49. Found: C, 56.74; H, 8.57.

*Allyl 4,5-*O*-carbonyl-3-deoxy-1-*O*-pivaloyl-α-*D-manno-*2-octulopyranoside* (**32**).—A solution of **31** (211 mg, 0.34 mmol) in dry THF (10 mL) was stirred with 1.1 M

Bu_4NF in THF (0.62 mL, 0.682 mmol) for 1 h at 0°C. Evaporation of the solvent and purification of the residue by silica gel chromatography (*B*, EtOAc) furnished **32** as a syrup. Yield: 105 mg (82%); $[\alpha]_D^{20}$ + 34° (*c* 0.9, $CHCl_3$); ^1H NMR ($CDCl_3$): δ 5.86 (m, 1 H, =CH–), 5.09 (dt, 1 H, $J_{4,3a} \simeq J_{4,3e} \simeq 4.3$, $J_{4,5} \sim 8.2$ Hz, H-4), 5.01 (dd, 1 H, $J_{5,6} \sim 1.5$ Hz, H-5), 4.49 (AB, 1 H, $J_{AB} \sim 12.0$ Hz, H-1a), 4.05 (m, 1 H, OCH_2), 3.95–3.90 (m, 4 H, H-1b,6,7, OCH_2), 3.86 (dd, 1 H, $J_{8a,7} \sim 2.5$ Hz, H-8a), 3.69 (dd, 1 H, $J_{8b,7} \sim 4.2$, $J_{8a,8b} \sim -11.5$ Hz, H-8b), 2.49 (dd, 1H, $J_{3e,3a} \sim -15.8$ Hz, H-3*e*), 1.99 (ddd, $J_{3a,1a} \sim 1.0$ Hz, H-3*a*), and 1.22 [s, 9 H, $(CH_3)_3C$]. Anal. Calcd for $C_{17}H_{26}O_9$: C, 54.54; H, 7.00. Found: C, 54.33; H, 6.88.

Allyl O-*(methyl 4,5,7,8-tetra*-O-*acetyl-3-deoxy-α*-D-manno-*2-octulopyranosylonate)-(2 → 8)-4,5*-O-*carbonyl-3-deoxy-1*-O-*pivaloyl-α*-D-manno-*2-octulopyranoside* (**33**).—A suspension of **32** (91 mg, 0.24 mmol), $Hg(CN)_2$ (60 mg, 0.24 mmol), $HgBr_2$ (29 mg, 0.08 mmol), and 4A molecular sieves (1 g) in dry $MeNO_2$ (5 mL) was stirred for 20 min at room temperature. A solution of **4** (133 mg, 0.28 mmol) in $MeNO_2$ (2 mL) was added dropwise over a period of 2 h and stirring was continued for 18 h. CH_2Cl_2 (50 mL) was added and the suspension was filtered over Celite. The filtrate was washed with aq 10% KI and satd aq $NaHCO_3$, dried ($MgSO_4$), and concentrated. Silica gel chromatography (*C*, 3:1 → 1:1 toluene–EtOAc) furnished **33** as a syrup. Yield: 44 mg (23%); $[\alpha]_D^{20}$ + 50° (*c* 1.0, $CHCl_3$); ^1H NMR ($CDCl_3$): δ 5.87 (m, 1 H, =CH–), 5.35 (dd, 1 H, $J_{5',6'} \sim 1.5$ Hz, H-5′), 5.25 (ddd, 1 H, $J_{4',5'} \sim 3.0$ Hz, H-4′), 5.22 (m, 1 H, H-7′), 5.06 (dt, 1 H, $J_{4,3a} \simeq J_{4,3e} \simeq 4.4$, $J_{4,5} \sim 8.0$ Hz, H-4), 5.00 (dd, 1 H, $J_{5,6} \sim 1.8$ Hz, H-5), 4.56 (dd, 1 H, $J_{8'a,7'} \sim 2.4$, $J_{8'a,8'b} \sim -12.2$ Hz, H-8′a), 4.41 and 3.91 (AB, 2 H, $J_{AB} \sim 12.0$ Hz, H-1a,1b), 4.15 (dd, 1 H, $J_{8'b,7'} \sim 3.9$ Hz, H-8′b), 4.12 (dd, 1 H, $J_{6',7'} \sim 9.8$ Hz, H-6′), 4.04–3.96 (m, 3 H, H-7, OCH_2), 3.88 (dd, 1 H, $J_{6,7} \sim 9.3$ Hz, H-6), 3.84 (s, 3 H, CO_2CH_3), 3.67 (m, 2 H, H-8a,8b), 2.44 (dd, 1 H, $J_{3e,3a} \sim -15.5$ Hz, H-3*e*), 2.15–2.03 (m, 3 H, H-3*a*,3′*e*,3′*a*), 2.10, 2.07, 2.01, and 1.98 (4 s, 12 H, 4 Ac), and 1.21 [s, 9 H, $(CH_3)_3C$]. Anal. Calcd for $C_{34}H_{48}O_{20}$: C, 52.58; H, 6.23. Found: C, 52.47; H, 6.14.

O-*Acetylation of* **33**.—A solution of **33** (6.9 mg) and a catalytic amount of 4-dimethylaminopyridine in pyridine (5 mL) was stirred with Ac_2O (0.3 mL) for 16 h at room temperature. The solution was coevaporated three times with addition of toluene and the residue was chromatographed on silica gel (*A*, 1:1 toluene–EtOAc) which furnished **34** as a syrup. Yield: 7 mg (96%); $[\alpha]_D^{20}$ + 42° (*c* 0.7, $CHCl_3$); ^1H NMR ($CDCl_3$): δ 5.88 (m, 1 H, =CH–), 5.32 (br s, 1 H, H-5′), 5.23 (ddd, 1 H, H-7′), 5.20 (ddd, 1 H, H-4), 5.13 (ddd, 1 H, $J_{7,8a} \sim 3.0$, $J_{7,8b} \sim 5.3$, $J_{7,6} \sim 7.2$ Hz, H-7), 5.03 (dt, 1 H, $J_{4,3a} \simeq J_{4,3e} \simeq 5.2$, $J_{4,5} \sim 7.8$ Hz, H-4), 4.82 (dd, 1 H, $J_{5,6} \sim 2.2$ Hz, H-5), 4.61 (dd, 1 H, $J_{7',8'a} \sim 2.5$, $J_{8'a,8'b} \sim -12.3$ Hz, H-8′a), 4.41 and 3.94 (AB, 2 H, $J_{AB} \sim 12.1$ Hz, H-1a,1b), 4.21 (dd, 1 H, H-6), 4.13 (dd, 1 H, $J_{8'b,7'} \sim 4.5$ Hz, H-8′b), 4.04 (m, 2 H, OCH_2), 4.04 (dd, 1 H, $J_{6',7'} \sim 9.6$, $J_{6',5'} \sim 1.3$ Hz, H-6′), 3.89 (dd, 1 H, $J_{8a,8b} \sim -11.6$ Hz, H-8a), 3.82 (s, 3 H, CO_2CH_3), 3.71 (dd, 1 H, H-8a), 2.37 (dd, 1 H, $J_{3e,3a} \sim -15.5$ Hz, H-3*e*), 2.20 (dd, 1 H, $J_{3'e,4'} \sim 5.0$, $J_{3'e,3'a} \sim -13.0$ Hz, H-3′*e*), 2.09 (m, 2 H, H-3*a*,3′*a*), 2.13, 2.09, 2.08, 2.00 and 1.96 (5 s, 15 H, 5 Ac), and 1.21 [s, 9 H, $(CH_3)_3C$]. Anal. Calcd for $C_{36}H_{50}O_{21}$: C, 52.81; H, 6.16. Found: C, 52.75; H, 6.13.

Allyl O-*(sodium 3-deoxy-α-*D-manno-*2-octulopyranosylonate)-(2 → 8)-3-deoxy-α-*D-manno-*2-octulopyranoside* (**35**).—A solution of **33** (15.4 mg, 0.02 mmol) in dry MeOH (5 mL) was stirred with 0.1 M methanolic NaOMe (0.5 mL) for 2.5 h at room temperature. Treatment as described for **8** gave a residue which was taken up in H_2O (5 mL) and stirred with 0.2 M NaOH (2.0 mL) for 4.5 h at room temperature. Adjustment of pH and purification, as for **8**, afforded **35** as an amorphous powder. Yield: 8.4 mg (84%); $[\alpha]_D^{20} + 67°$ (*c* 0.5, H_2O); ^1H NMR (D_2O): δ 5.97 (m, 1 H, =CH–), 5.36 (dq, 1 H, $=CH_{2trans}$), and 5.27 (dq, 1 H, $=CH_{2cis}$), 4.05 (m, 2 H, OCH_2). Anal. Calcd for $C_{19}H_{31}NaO_{14}$: C, 45.06; H, 6.17. Found: C, 44.70; H, 6.02.

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