27. Vinyl Carbanions

Part 36[1])

Synthesis of 3-Deoxy-D-*manno*-2-octulosonic Acid (KDO) and Derivatives

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(29.VIII.88)

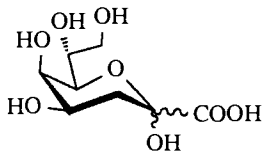
The β-*C*-lithiated acrylamide **3A** has been proven to be an ideal pyruvate β-carbanion equivalent useful in a highly diastereoselective KDO synthesis. The starting material **3** was prepared from pyruvate diethyl acetal in four convenient steps. Direct lithiation with 2 equiv. of LDA generated the dilithiated species **3A** quantitatively. Reaction with 2,3:4,5-di-*O*-isopropylidene-D-arabinose (**11**) was highly D-*manno*-selective. The product **12** was obtained readily from the reaction mixture *via* crystallization. Ring closure to the butenolide **13**, subsequent PhS-group removal with Bu_3SnH and pyridinium bromide, and hydrogenolytic debenzylation afforded the known butenolide **19**; this KDO precursor gives KDO in two convenient steps. Butenolide **19** was also transformed *via* two high-yielding steps into the 4,5:7,8-di-*O*-cyclohexylidene-KDO derivative **22**, a valuable starting material for KDO α-glycoside syntheses.

1. Introduction. – The 3-deoxy-D-*manno*-2-octulosonic acid (KDO) is an integral constituent of the lipopolysaccharide of *Gram*-negative bacteria [1] [2]. Several syntheses of this compound have been described using either D-mannose or D-arabinose derivatives and C_2- or C_3-building blocks, respectively, as starting materials [3–9]. Biosynthetic studies have shown D-arabinose 5-phosphate and phosphoenol pyruvate to be the precursors [1]. In analogy to the biosynthesis, we searched for pyruvate-equivalent C_3-synthons corresponding to intermediate **1A** which provide, in a diastereoselective reaction with *O*-protected D-arabinose, KDO derivatives. We found that functionally substituted acrylates furnish, *via* β-*C*-lithiation, such synthetic equivalents quite readily [10]. *E.g.*, the dilithiated species **2A** and **3A** obtained *via* direct lithiation of the corresponding H-systems provided, *via* D-*manno* selective reactions with di-*O*-isopropylidene-D-arabinose, a straightforward entry into KDO [3] [9]. Correspondingly, in a D-*gluco*-selective reaction from the *C*-lithiated species **4A**, preferentially 3-deoxy-D-*gluco*-2-octulosonic acid was obtained [8]. The PhS group in **3A** and the β-carboxylate group in **4A** constitute H-atom equivalents which promote the β-*C*-lithiation, the nucleophilic reactivity, and the diastereoselectivity in this reaction. Starting from the dilithiated species **3A**, we synthesized a methylamide derivative of KDO which proved valuable in the synthesis of the naturally occurring KDO α-glycosides [11]. Therefore, we are reporting the investigations for the synthesis of this compound in full detail[3]).

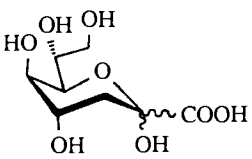
[1]) Part 35: [9].

[2]) Taken in part from the Ph. D. thesis of *A. E.* [13] and *R. B.* [12].

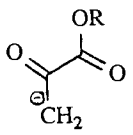
[3]) For a preliminary publication of part of this work, see [3].



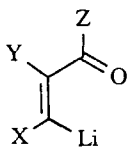
3-Deoxy-D-*manno*-2-octulosonic acid (KDO)



3-Deoxy-D-*gluco*-2-octulosonic acid



1A

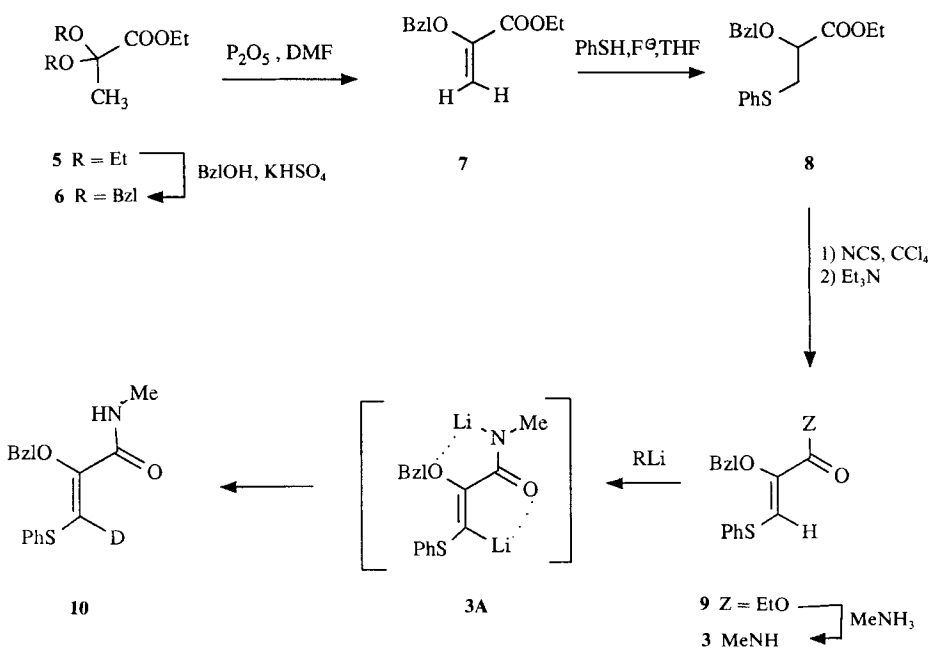


2A X = H, Y = RO, Z = RN(Li)
3A X = PhS, Y = RO, Z = RN(Li)
4A X = COOR, Y = R_2N, Z = RO

2. Direct Lithiation of α-(Benzyloxy)-*N*-methyl-β-(phenylthio)acrylamide. – From the investigation of α-alkoxy-substituted acrylates in direct β-*C*-lithiations, it was concluded [3] [10] [12–14] that a β-thio substituent and a monosubstituted amide group support direct β-*C*-lithiation strongly. In this way, dilithiated species of type **3A** were generated which exhibited excellent nucleophilic properties in reactions with aldehydes as electrophiles. In a simple cyclization, the hydroxyalkyl-substituted products provided α-alkoxy-substituted butenolides quite readily [3] [10] [14]. However, α-alkoxy ether cleavage in the butenolide system requires acidic conditions which will decompose acid-labile side chains, *e.g.*, as observed for KDO and derivatives [12] [13]. Therefore, we decided to introduce the hydrogenolytically removable α-benzyloxy group leading to compound **3** as an ideal starting material for the KDO synthesis *(Scheme 1)*.

For the synthesis of amide **3**, the commercially available pyruvate diethyl acetal (**5**) was transformed into the corresponding dibenzyl acetal **6** *via* acid-catalyzed transacetalisation. Elimination of benzyl alkohol by treatment with P_2O_5 provided the α-(benzyloxy)-

Scheme 1

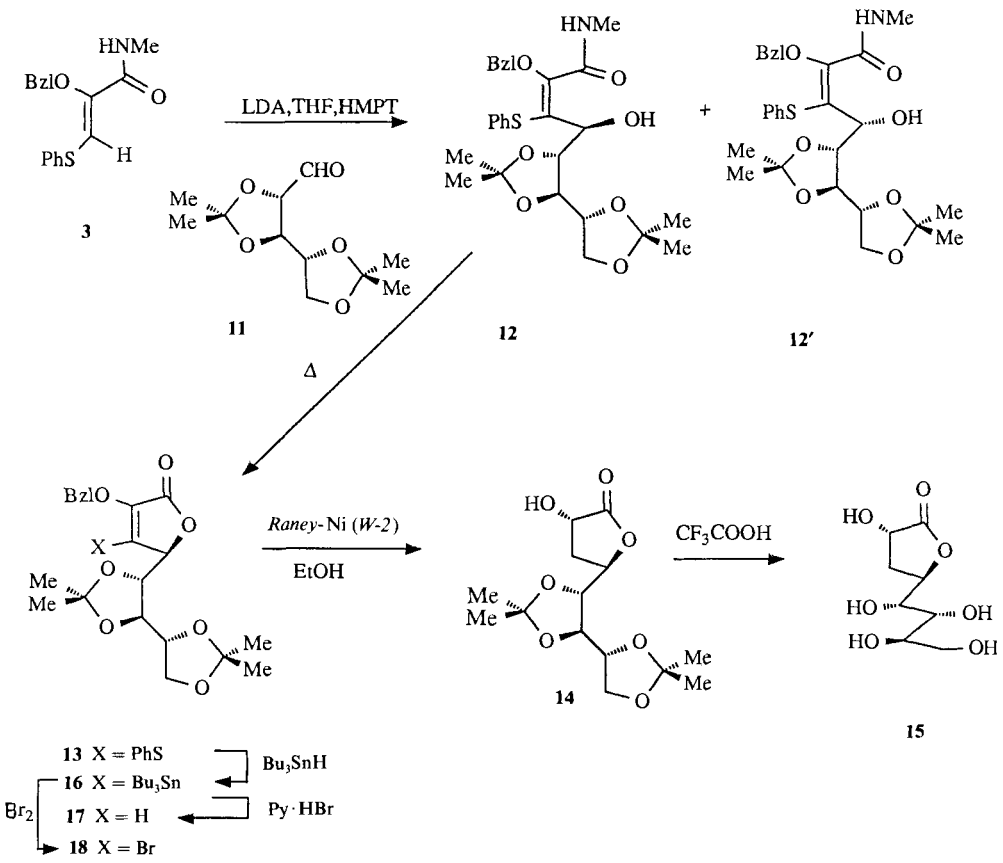


acrylate **7** in very good yield. Subsequent thiophenol addition under fluoride catalysis led to propionate derivative **8**. Chlorination with *N*-chlorosuccinimide (NCS) and treatment with Et_3N as base afforded the acrylate **9** ((*Z*)-isomer $\geq 95\%$). This compound furnished, with $MeNH_2$, the desired starting material **3** in good overall yield independently of the scale. The structural assignment is based on comparisons of the ^{1}H-NMR shift of H–C(3) with that of related (*Z*)- and (*E*)-configurated compounds [9] [12].

The advantage of amide **3** in direct lithiations, *e.g.* as compared with ester **9** or the corresponding acid, was clearly demonstrated by the ease of this reaction [12]. With 2 equiv. of lithium diisopropylamide (LDA) as base, the dilithiated species **3A** was generated practically quantitatively as evidenced by quenching the reaction mixture with MeOD and subsequent aqueous workup. Side-product formation did not occur; the only isolated product was the *β-C*-deuterated compound **10**. The assignment of (*Z*)-configuration is based on the fact that inversion of configuration is not observed in related α-thio-substituted vinyllithium species [10] [15] [16].

3. Synthesis of KDO. – The convenient synthesis of acrylamide **3**, its quantitative *β-C*-lithiation generating intermediate **3A**, and the high-yielding formation of the deute-

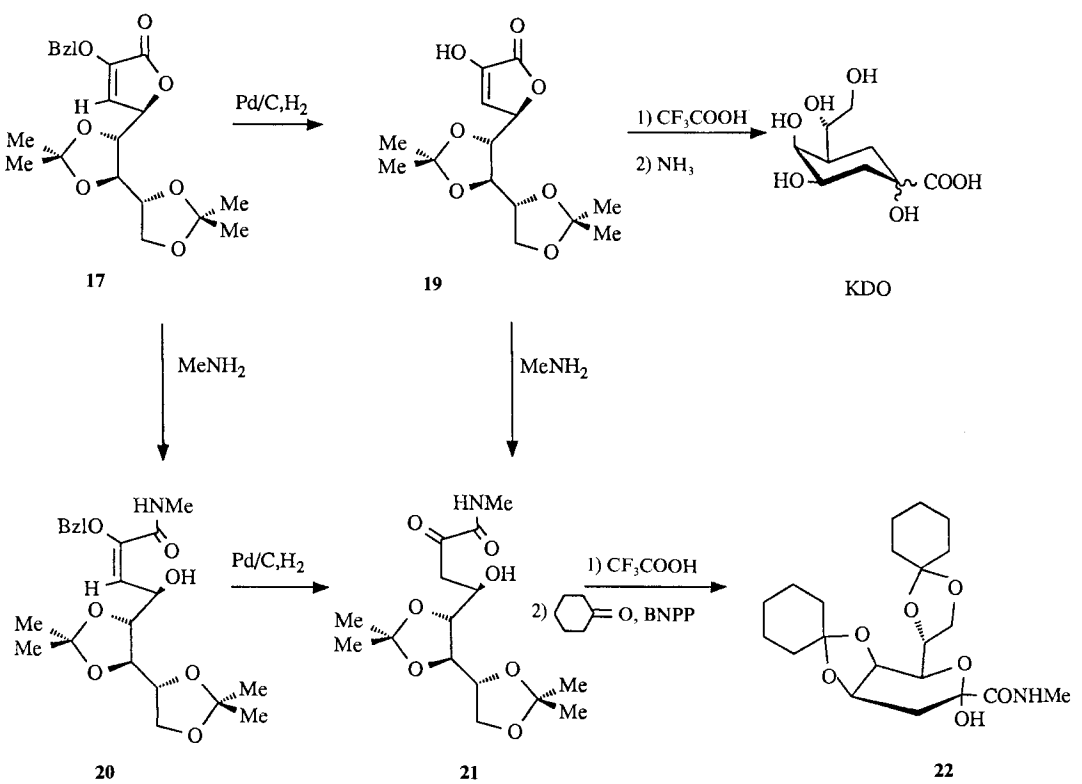
Scheme 2



rated derivative **10** were excellent prerequisites for successful reactions with aldehydes as electrophiles. For the synthesis of KDO, 2,3:4,5-di-*O*-isopropylidene-D-arabinose (**11**) [17] was used *(Scheme 2)*. With **3A**, generated from **3** by LDA at −80° in tetrahydrofuran (THF), the desired D-*manno*-isomer **12** was formed preferentially (D-*manno*-isomer **12**/D-*gluco*-isomer **12′** 8:1; 75% yield); the structures were assigned by transformation into KDO and its D-*gluco*-isomer, respectively [12]. The D-*manno*-isomer **12** crystallized from the reaction mixture in 60% yield thus obviating chromatographic separations. Addition of small amounts of hexamethylphosphorous triamide (HMPT) to the reaction mixture led almost completely to the desired **12** (**12**/**12′** ⩾ 15:1; 85% yield), directly obtained in 75% yield as crystalline material. The diastereofacial selection can be explained in terms of the *Felkin* model [3] [18]. Steric and stereoelectronic effects favour *Re* attack of intermediate **3A** on the *M*-conformer of arabinose derivative **11** [3].

Compound **12** having the required KDO configuration was first transformed into the butenolide **13** by simple heating in high-boiling petroleum ether *(Scheme 2)*. Investigations of the selective PhS-group removal with *Raney*-Ni and of the simultaneous debenzylation to yield directly KDO derivative **19** (see below, *Scheme 3*) gave varying results, depending on the activity of the *Raney*-Ni. However, controlled formation of **19** was difficult to accomplish. Also controlled removal of only the PhS group gave mainly

Scheme 3



modest results. However, complete reduction of **13** with *Raney*-Ni was easily possible; it provided diastereoselectively the α-hydroxybutyrolactone **14**. The structure of **14** was assigned after acid-catalyzed removal of the isopropylidene groups affording the known 3-deoxy-D-*glycero*-D-*galacto*-octonolactone **15** [19]. Therefore, the required PhS/H exchange in **13** was investigated with Bu_3SnH. However, unexpectedly, the PhS group was replaced by the Bu_3Sn group affording compound **16** which turned out to be an interesting intermediate for further reactions with electrophiles. Thus, treatment of **16** with Br_2 gave the bromo derivative **18** in almost quantitative yield. HBr turned out to be too strong an electrophile for controlled Bu_3Sn/H exchange. Therefore, we used pyridinium bromide suggested also by *Pallenberg* and *White* for such reactions [20] to synthesize compound **17** in high yield.

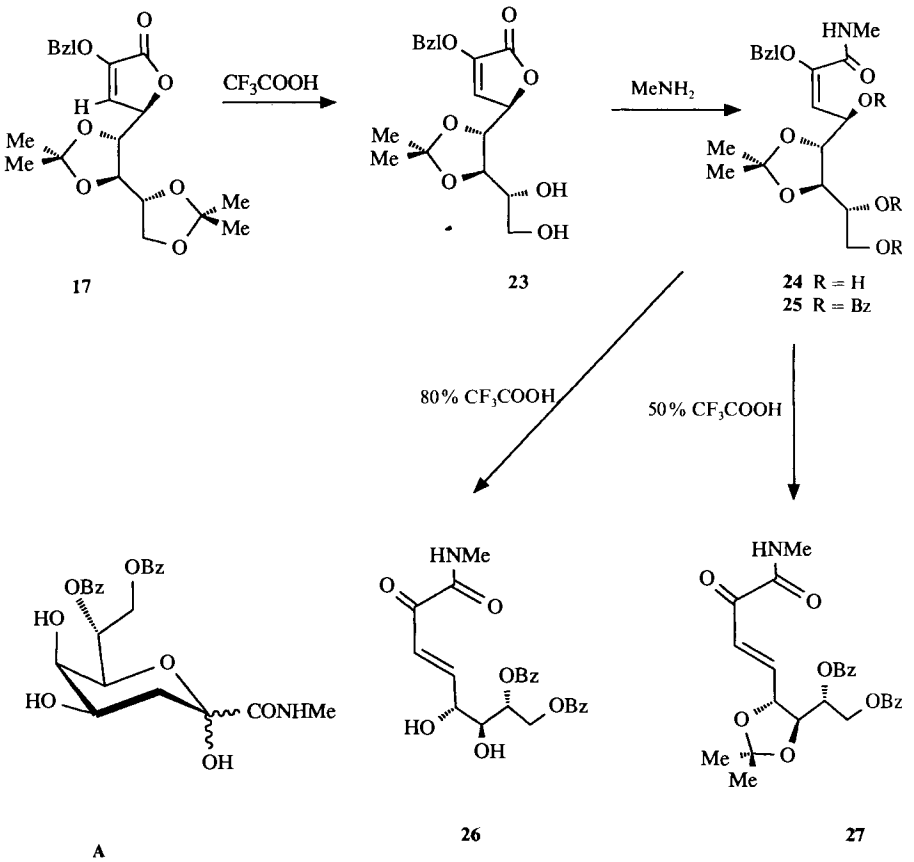
Hydrogenolytic debenzylation of **17** afforded cleanly the known KDO derivative **19** [4a] which was found to exist mainly in the enol form according to the ^{1}H-NMR data (enol/ketone 9:1; *Scheme 3*). Following a known procedure [4a] [6a], deprotection of **19** with CF_3COOH and subsequent treatment with NH_3 provided the pyranose-ammonium salt of KDO in high yield, thus concluding an efficient KDO synthesis.

4. Synthesis of KDO Derivatives. – For the investigation of glycoside-bond formation, 4,5,7,8-*O*-protected pyranose derivatives of KDO are required. Thus far, these investigations were mainly carried out with *O*-acyl protected compounds. However, acetal formation suggested by the pyranose structure of KDO might lead to compounds with different reactivity. For this aim, butenolide **17** was first treated with $MeNH_2$ providing the amide **20** in high yield *(Scheme 3)*. However, hydrogenolytic debenzylation of this open-chain compound to yield **21** proved to be less successful than the corresponding transformation of butenolide **17** to the debenzylated butenolide **19**. Therefore, **19** was treated with $MeNH_2$, affording the desired intermediate **21** in high overall yield. CF_3COOH-catalyzed removal of the isopropylidene groups and subsequent acetalisation with cyclohexanone in the presence of bis(*p*-nitrophenyl) hydrogen phosphate (BNPP) furnished the 4,5:7,8-di-*O*-cyclohexylidene-KDO derivative **22** in 84% yield. According to the ^{1}H-NMR data, **22** prefers a boat conformation [11] as recently also found for a 4,5:7,8-di-*O*-isopropylidene-KDO derivative [21]. Compound **22** proved to be very valuable in α-specific glycoside bond formations *via* the anomeric-*O*-alkylation procedure as demonstrated recently by us [11] [22].

The direct synthesis of *O*-acylated and partially *O*-acylated KDO derivatives from butenolide **17**, *e.g.* of compound **A** *(Scheme 4)*, turned out to be more difficult. Partial removal of the isopropylidene groups of **17** with CF_3COOH gave cleanly the mono-isopropylidene derivative **23** which furnished, with $MeNH_2$, the corresponding amide **24** *(Scheme 4)*. The (*E*)-configuration was assigned on the basis of ^{1}H-NMR comparisons with related compounds obtained *via* a different route [9] [23]. Subsequent *O*-benzoylation provided compound **25**. However, direct acid-catalyzed ring closure without prior hydrogenolytic removal of the *O*-benzyl group resulted in the elimination products **26** and **27** depending on the concentration of CF_3COOH.

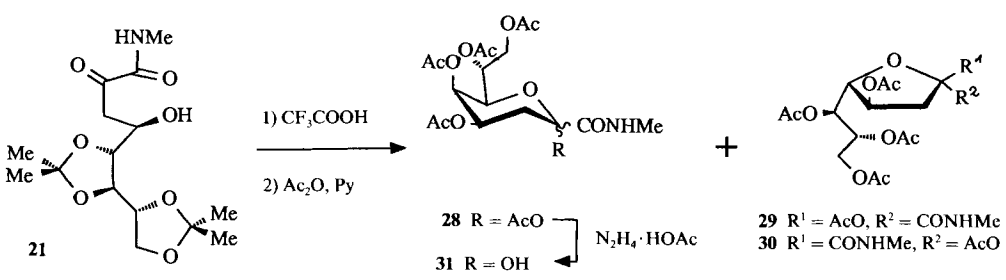
However, when the *O*-debenzylated compound **21** was used as starting material for *O*-acylated KDO derivatives, acid-catalyzed removal of the isopropylidene groups and subsequent *O*-acetylation afforded the pyranose **28** which was accompanied by the α- and β-furanoses **29** and **30**, respectively. The structures of these compounds were as-

Scheme 4



signed by their ^{1}H-NMR data and by comparison with structurally similar compounds [1] [6c] [24]. Yet, the anomeric configurations of **28** and **31** are not unambiguous on this basis. According to the chemical-shift differences $\Delta\delta(H_{eq}-C(3)/H_{ax}-C(3))$, the configurations could be β for **28** and α for **31**. Selective anomeric *O*-deacylation of **28** was possible with hydrazine acetate providing compound **31**.

Scheme 5



We gratefully acknowledge the financial support of this work by the *Deutsche Forschungsgemeinschaft* and the *Fonds der Chemischen Industrie*. We thank the *BASF AG* for providing D-arabinose.

Experimental Part

General. Solvents were purified in the usual way. All substances were purified by MPLC for elemental analyses. Column chromatography: *Merck* silica gel *60* (mesh size 0.063–0.200). Medium-pressure liquid chromatography (MPLC): *Merck* silica gel *LiChroprep Si 60* (mesh size 0.063–0.0125). TLC: *Merck* plates, silica gel *60* F_{254}, layer thickness 0.2 mm; detection by UV light or treatment with a 15% H_2SO_4 soln., followed by heating at 120°. M.p. (uncorrected): metal bloc. Optical rotations: *Perkin-Elmer-241/MS* polarimeter, 1-dm cell. ^{1}H-NMR spectra: *Bruker WP80* (80 MHz), *Bruker WM250 Cryospec* (250 MHz), *Jeol JNM-GX400* (400 MHz); chemical shifts in ppm downfield from tetramethylsilane (TMS) as internal standard, coupling constants *J* in Hz.

*(Z)-2-(Benzyloxy)-*N*-methyl-3-(phenylthio)acrylamide* (**3**) *and Ethyl (Z)-2-(Benzyloxy)-3-(phenylthio)-acrylate* (**9**). To an ice-cooled soln. of **8** (36 g, 0.114 mol) in abs. CCl_4 (200 ml), *N*-chlorosuccinimide (16.7 g, 0.125 mol) was added. The suspension was stirred for 6–10 h at r.t. The precipitate was filtered off and the soln. evaporated. The oily residue was dissolved in dry $CHCl_3$ (100 ml), Et_3N (19.2 ml, 0.137 mol) added, and the mixture refluxed for 1 h. The cooled soln. was diluted with H_2O (200 ml), acidified to pH 1 with conc. HCl soln. under ice-cooling and extracted with $CHCl_3$ (3 × 100 ml). The extract was washed with sat. aq. $NaHCO_3$ soln. (100 ml), dried ($MgSO_4$), and evaporated. The dark oil was filtered over silica gel (petroleum ether/AcOEt 9:1, R_f 0.53). The slightly yellow oil **9** 5.6M $MeNH_2$/MeOH (150 ml) was stirred for 15 h at r.t. The solvent was evaporated and the residue filtered over silica gel (petroleum ether/AcOEt 1:1, R_f 0.47). Recrystallization from AcOEt/petroleum ether gave 24.7 g (73%) of **3** as colourless crystals. M.p. 53–54°. ^{1}H-NMR (80 MHz, $CDCl_3$): 7.60–7.20 (*m*, 10 arom. H); 7.22 (*s*, H–C(3)); 6.40 (br. *s*, MeN*H*); 5.00 (*s*, PhCH_2O); 2.78 (*d*, *Me*NH). Anal. calc. for $C_{17}H_{17}NO_2S$ (299.4): C 68.21, H 5.72, N 4.68; found: C 68.42, H 5.66, N 4.64.

Ethyl 2,2-Bis(benzyloxy)propionate (**6**). To a soln. of **5** (200 g, 1.05 mol) in dry benzyl alcohol (560 g, 5.18 mmol), $KHCO_3$ (3.5 g, 25.7 mmol) was added. The mixture was heated (bath temp. 100°) while passing a strong N_2 stream through the soln. After 8–10 h, EtOH (80 g) was distilled off. The mixture was cooled to r.t., diluted with 500 ml Et_2O, and filtered (petroleum ether/AcOEt 9:1, R_f 0.48) over a short silica-gel column. Evaporation followed by distillation of the crude product afforded 280 g (85%) of **6** as colourless oil. B.p. 135–140°/0.01 Torr. ^{1}H-NMR (80 MHz, $CDCl_3$): 7.50–7.25 (*m*, 10 arom. H); 4.65 (*s*, PhCH_2O); 4.25 (*q*, CH_3CH_2O); 1.70 (*s*, Me); 1.30 (*t*, CH_3CH_2O).

Ethyl 2-(Benzyloxy)acrylate (**7**). To a soln. of **6** (280 g, 0.89 mol) in dry DMF (700 ml), P_2O_5 (6.8 g, 0.48 mol) was added under strong stirring. The mixture was heated for 1 h at 100°, cooled to r.t., poured onto sat. aq. $NaHCO_3$ soln. (1500 ml), and extracted with Et_2O (4 × 200 ml). The combined org. layers were washed with H_2O (300 ml), dried ($MgSO_4$), and evaporated. Distillation gave 157 g (86%) of **7** as colourless oil. B.p. 85–87°/0.01 Torr. TLC (petroleum ether/AcOEt 9:1): R_f 0.40. ^{1}H-NMR (80 MHz, $CDCl_3$): 7.40 (*m*, 5 arom. H); 5.35 (*d*, *J* = 2.0, H–C(3)); 4.85 (*s*, PhCH_2O); 4.62 (*d*, *J* = 2.0, H′–C(3)); 4.23 (*q*, CH_3CH_2O); 1.32 (*t*, CH_3CH_2O). Anal. calc. for $C_{12}H_{14}O_3$ (206.2): C 69.90, H 6.84; found: C 69.68, H 6.92.

Ethyl 2-(Benzyloxy)-3-(phenylthio)propionate (**8**). To a soln. of **7** (140 g, 0.68 mol) and thiophenol (82.2 g, 0.75 mol) in abs. THF (500 ml), 1M Bu_4NH/THF (10 ml) was added under N_2. The mixture was refluxed for 24 h, 1M Bu_4NF/THF (5 ml) added, and the mixture refluxed for additional 12 h. The cold soln. was diluted with Et_2O (200 ml), washed with 1M $NaHCO_3$ (2 × 150 ml) and H_2O (100 ml), dried ($MgSO_4$), and evaporated. Distillation afforded 159 g (74%) of **8** as colourless oil and 20 g (14%) of **7**. B.p. 170–175°/0.01 Torr. TLC (petroleum ether/AcOEt 9:1): R_f 0.38. ^{1}H-NMR (80 MHz, $CDCl_3$): 7.50–7.20 (*m*, 10 arom. H); 4.72 (*d*, *J* = 12, PhCH_2O); 4.48 (*d*, PhCH_2O); 4.18 (*q*, CH_3CH_2O); 4.08 (*dd*, H–C(2)); 3.30 (*dd*, 2 H–C(3)); 1.25 (*t*, CH_3CH_2O).

*(Z)-2-(Benzyloxy)-*N*-methyl-3-(phenylthio)(3-^{2}H)acrylamide* (**10**). LDA (7.36 mmol) in hexane/THF was slowly and dropwise added to a soln. of **3** (1.0 g, 3.34 mmol) in dry THF (30 ml) at –80°. After 1 h at –80°, MeOD (0.5 ml) was added and stirring continued for 30 min. Then, the mixture was warmed up to 0°, poured onto sat. aq. NH_4Cl soln. (100 ml), extracted with Et_2O (3 × 50 ml), dried ($MgSO_4$), and evaporated. The residue was treated with AcOEt (*ca.* 1 ml), and addition of petroleum ether gave 900 mg (90%) of **10** (deuteration 95%).

*2,3:4,5-Di-*O*-isopropylidene-*D*-arabinose* (**11**) was prepared according to [17] and freshly distilled (bulb to bulb) before each reaction. B.p. 80–90°/0.04 Torr (oven temp.).

*(2Z)-2-*O*-Benzyl-3-deoxy-5,6:7,8-di-*O*-isopropylidene-*N*-methyl-3-(phenylthio)-*D*-manno-oct-2-enonamide* (**12**) *and (2Z)-2-*O*-Benzyl-3-deoxy-5,6:7,8-di-*O*-isopropylidene-*N*-methyl-3-(phenylthio)-*D*-gluco-oct-2-enonamide* (**12′**). a) *Without HMPT:* LDA (55.2 mmol) in hexane/THF was slowly and dropwise added to a soln. of **3**

(7.5 g, 25.05 mmol) in dry THF (180 ml) at −80°. After 30 min, fine colourless crystals precipitated, and the mixture was stirred for additional 60 min. Then, **11** (6.91 g, 30.0 mmol) was added and stirring continued for 2 h at −80°. The soln. was warmed up to −20° and poured onto ice/H_2O after 5 h. The mixture was acidified to pH 1 with conc. HCl soln., extracted with Et_2O (3 × 300 ml), the extract washed with sat. aq. $NaHCO_3$ soln., dried ($MgSO_4$), and evaporated, and the residue dissolved in AcOEt (20 ml) and treated slowly with petroleum ether: 5.3 g (60%) of **12** as colourless crystals (overall yield 75%).

b) *With HMPT:* As in *Exper. a*, with LDA (29.4 mmol) and **3** (4.0 g, 13.36 mmol) in dry THF (120 ml). To the colourless suspension of the dianion, HMPT (7.0 ml, 40.2 mmol) was added. The precipitate dissolved completely, and after 1 h, **11** (3.68 g, 16.03 mmol) was added. After reaction and workup as in *Exper. a*, 5.3 g (75%) of **12** as colourless crystals were obtained (overall yield 85%). M.p. 113–113.5° TLC (petroleum ether/AcOEt 6:4): R_f 0.37. $[\alpha]_{578}^{21} = +197$ ($c = 1$, $CHCl_3$). ^{1}H-NMR (250 MHz, $CDCl_3$): 7.46–7.41 (*m*, 2 arom. H); 7.32–7.18 (*m*, 8 arom. H); 6.78 (*d*, $J = 4.88$, MeN*H*); 5.57 (*d*, $J = 7.32$, OH); 4.83 (*s*, PhCH_2O); 4.51 (*dd*, $J(4,5) = 8.54$, H–C(4)); 4.23–4.08 (*m*, H–C(5), H–C(6), H–C(7)); 4.02–3.94 (*m*, 2 H–C(8)); 2.82 (*d*, *Me*NH); 1.43, 1.36, 1.35, 1.34 (4*s*, 4 Me). Anal. calc. for $C_{28}H_{35}NO_7S$ (529.6): C 63.50, H 6.66, N 2.65; found: C 63.42, H 6.59, N 2.67.

Isomer **12′** was only isolated as crude product.

*2-*O*-Benzyl-3-deoxy-5,6:7,8-di-*O*-isopropylidene-3-(phenylthio)-*D*-*manno*-oct-2-enono-1,4-lactone* (**13**). A suspension of **12** (8.8 g, 16.6 mmol) in AcOEt (10 ml) and petroleum ether (100–140°; 100 ml) was heated under reflux for 6 h. The soln. was evaporated and chromatographed (petroleum ether/AcOEt 8:2, R_f 0.51) to give 8.1 g (91%) of **13** as colourless oil. $[\alpha]_{578}^{21} = +278.5$ ($c = 1$, $CHCl_3$). ^{1}H-NMR (250 MHz, $CDCl_3$): 7.37–7.27 (*m*, 10 arom. H); 5.37 (*s*, PhCH_2O); 4.99 (*d*, $J(4,5) = 2.75$, H–C(4)); 4.26 (*dd*, $J(5,6) = 6.1$, H–C(5)); 4.09 (*dd*, $J(6,7) = 7.93$, H–C(6)); 4.01 (*m*, H–C(7)); 3.91–3.82 (*m*, 2 H–C(8)); 1.36, 1.35, 1.34, 1.33 (4*s*, 4 Me). Anal. calc. for $C_{27}H_{30}O_7S$ (498.5): C 65.05, H 6.07; found: C 64.86, H 6.17.

*3-Deoxy-5,6:7,8-di-*O*-isopropylidene-*D*-glycero-*D*-talo-octono-1,4-lactone* (**14**). To a soln. of **13** (4.1 g, 8.22 mmol) in dry EtOH (100 ml) freshly prepared *Raney*-Ni *W-2* (*ca.* 10–15 g) was added. The reaction was followed by TLC (petroleum ether/AcOEt 1:1, R_f 0.37). After 2 h, the *Raney*-Ni was filtered off and washed with EtOH and acetone. The combined org. layers were evaporated and filtered over silica gel. Recrystallization from Et_2O/petroleum ether gave 2.14 g (86%) of **14**. $[\alpha]_{578}^{21} = +17.9$ ($c = 1$, $CHCl_3$). ^{1}H-NMR (250 MHz, $CDCl_3$): 4.75 (*ddd*, $J(4,5) = 2.75$, $J(3',4) = 8.55$, H–C(4)); 4.51 (*ddd*, $J = 5.49$, $J(2,3') = J(2,3) = 8.55$, H–C(2)); 4.31 (*dd*, $J(5,6) = 7.93$, H–C(5)); 4.19–4.05 (*m*, H–C(7), H–C(8)); 3.97 (*dd*, $J(6,7) = 4.58$, H–C(6)); 3.61 (*dd*, $J(7,8') = J(8,8') = 7.90$, H′–C(8)); 3.25 (*d*, OH); 2.58 (*ddd*, $J(3,3') = 13.2$, H–C(3)); 2.35 (*ddd*, H′–C(3)); 1.43, 1.40, 1.39, 1.35 (4*s*, 4 Me). Anal. calc. for $C_{14}H_{22}O_7$ (302.3): C 55.63, H 7.34; found: C 55.86, H 7.25.

*3-Deoxy-*D*-glycero-*D*-talo-octono-1,4-lactone* (**15**). A mixture of **14** (500 mg, 1.65 mmol) and 10% aq. CF_3COOH soln. (20 ml) was stirred for 15 h at r.t. The soln. was diluted with toluene (20 ml), evaporated, and again co-evaporated with toluene (20 ml). The colourless crystalline residue was treated with EtOH/Et_2O to give 350 mg (95%) of colourless crystals. M.p. 174–175° ([19]: 174.5–175.5°). $[\alpha]_{589}^{21} = -8.9$ ($c = 1$, H_2O; [19]: $[\alpha]_{589}^{21} = -9.6$ ($c = 1.7$, H_2O)).

*2-*O*-Benzyl-3-deoxy-5,6:7,8-di-*O*-isopropylidene-3-(tributylstannyl)-*D*-manno-oct-2-enono-1,4-lactone* (**16**). To a soln. of **13** (6.6 g, 13.24 mmol) and Bu_3SnH (11.56 g, 39.72 mmol) in dry benzene (100 ml), 2,2′-azo-bis[isobutyronitrile] (AIBN; 100 mg) was added. After heating for 8 h under reflux, the mixture was poured onto aq. sat. $NaHCO_3$ soln. (100 ml), extracted with Et_2O (3 × 100 ml), dried ($MgSO_4$), and evaporated. The residue was purified by chromatography on silica gel (petroleum ether/AcOEt 9:1, R_f 0.33) giving 7.05 g (78%) of colourless oil. $[\alpha]_{578}^{21} = +13.3$ ($c = 1$, $CHCl_3$). ^{1}H-NMR (250 MHz, $CDCl_3$): 7.39–7.29 (*m*, 5 arom. H); 5.36 (*d*, $J = 11.3$, 1 H, PhCH_2O); 5.26 (*d*, 1 H, PhCH_2O); 4.86 (*d*, $J(4,5) = 7.6$, H–C(4)); 4.30–4.20 (*m*, H–C(6), H–C(7)); 4.06–3.92 (*m*, 2 H–C(8)); 3.45 (*dd*, $J(5,6) = 6.4$, H–C(5)); 1.45, 1.44, 1.38, 1.36 (4*s*, 4 Me). Anal. calc. for $C_{33}H_{52}O_7Sn$ (679.4): C 58.34, H 7.72; found: C 58.18, H 7.58.

*2-*O*-Benzyl-3-deoxy-5,6:7,8-di-*O*-isopropylidene-*D*-manno-oct-2-enono-1,4-lactone* (**17**). To a soln. of **16** (7.89 g, 11.61 mmol) in dry toluene (100 ml), pyridinium hydrobromide (9.2 g, 58 mmol) was added. The mixture was heated under reflux for 24 h, filtered, and evaporated. The residue was chromatographed (petroleum ether/AcOEt 7:3, R_f 0.41): 4.26 g (94%) of colourless crystals. M.p. 102–103°. $[\alpha]_{578}^{21} = +26.7$ ($c = 1$, $CHCl_3$). ^{1}H-NMR (250 MHz, $CDCl_3$): 7.41–7.34 (*m*, 5 arom. H); 6.14 (*d*, $J(3,4) = 2.14$, H–C(3)); 5.03–5.00 (*m*, PhCH_2O, H–C(4)); 4.12–4.05 (*m*, H–C(5), H–C(6), H–C(7)); 3.98–3.85 (*m*, 2 H–C(8)); 1.41, 1.38, 1.34, 1.33 (4*s*, 4 Me). Anal. calc. for $C_{21}H_{26}O_7$ (390.4): C 64.61, H 6.71; found: C 64.74 H 6.85.

*2-*O*-Benzyl-3-bromo-3-deoxy-5,6:7,8-di-*O*-isopropylidene-*D*-manno-oct-2-enono-1,4-lactone* (**18**). To an ice-cooled soln. of **16** (2.27 g, 3.34 mmol) in dry CH_2Cl_2 (30 ml), a soln. of Br_2 (530 mg, 3.34 mmol) in CH_2Cl_2 (5 ml) was added dropwise. After the reaction was completed (light red soln.), the mixture was poured onto aq. sat. $NaHCO_3$ soln. (50 ml), extracted with $CHCl_3$ (3 × 30 ml), dried ($MgSO_4$), and evaporated. For purification, the

residue was chromatographed on silica gel (petroleum ether/AcOEt 85:15, R_f 0.40). Addition of petroleum ether to the colourless oil afforded 1.46 g (93%) of **18** as colourless crystals. M.p. 52–53°. $[\alpha]_{578}^{21} = +2.3$ ($c = 1$, $CHCl_3$). ^{1}H-NMR (250 MHz, $CDCl_3$): 7.44–7.33 (*m*, 5 arom. H); 5.47 (*s*, PhCH_2O); 5.13 (*d*, *J*(4,5) = 2.44, H–C(4)); 4.38 (*dd*, *J*(5,6) = 6.41, H–C(5)); 4.12 (*dd*, *J*(6,7) = 7.93, H–C(6)); 4.04–3.88 (*m*, H–C(7), 2 H–C(8)); 1.40, 1.37, 1.36, 1.32 (4*s*, 4 Me). Anal. calc. for $C_{21}H_{25}BrO_7$ (469.3): C 53.75, H 5.37, Br 17.03; found: C 53.87, H 5.35, Br 17.10.

3-Deoxy-5,6:7,8-di-O-*isopropylidene*-D-manno-*oct-2-enono-1,4-lactone* (**19**). A suspension of **17** (3.6 g, 9.22 mmol) and 10% Pd/C (500 mg) in abs. AcOEt (50 ml) was stirred under H_2 for 2 h (TLC monitoring (petroleum ether/AcOEt 7:3), R_f 0.20). Filtration, evaporation, and recrystallization from AcOEt/petroleum ether gave 2.65 g (95%) of **19** as colourless crystals. Physical properties: in accordance with [4a]. Enol/keto form *ca.* 9:1. ^{1}H-NMR (250 MHz, $CDCl_3/C_6D_6$ 4:1): 6.09 (*d*, *J*(3,4) = 1.83, H–C(3)); 6.06 (*s*, 0.9 H, OH); 4.99 (*dd*, *J*(4,5) = 4.58, 0.9 H, H–C(4)); 4.11 (*dd*, *J*(5,6) = 6.41, H–C(5)); 4.07–3.88 (*m*, H–C(6), H–C(7), 1 H–C(8)); 3.77–3.71 (*m*, 1 H–C(8)); 2.72 (*dd*, *J*(3,4) = 3.36, *J*(3,3′) = 18.9, 0.1 H, H–C(3)); 2.46 (*dd*, *J*(3′,4) = 8.24, H′–C(3)); 1.37, 1.35, 1.34, 1.29 (4*s*, 4 Me).

*(2E)-2-*O-*Benzyl-3-deoxy-5,6:7,8-di*-O-*isopropylidene*-N-*methyl*-D-manno-*oct-2-enonamide* (**20**). A soln. of **17** (1.0 g, 2.56 mmol) in 5.6M $MeNH_2$/MeOH was stirred for 2 h at r.t. Evaporation and chromatography (petroleum ether/AcOEt 7:3, R_f 0.32) afforded 990 mg (92%) of **20** as colourless oil. ^{1}H-NMR (250 MHz, $CDCl_3$): 7.42–7.30 (*m*, 5 arom. H); 6.82 (*d*, *J* = 4.57, MeN*H*); 5.54 (*d*, *J*(3,4) = 6.7, H–C(3)); 4.94 (*dd*, *J*(4,5) = 5.49, H–C(4)); 4.86 (br. *s*, OH); 4.84 (*d*, *J* = 10.98, 1 H, PhCH_2O); 4.76 (*d*, *J* = 10.98, 1 H, PhCH_2O); 4.23–3.84 (*m*, H–C(5), H–C(6), H–C(7), 2 H–C(8)); 2.84 (*d*, *Me*NH); 1.40, 1.38, 1.33 (3*s*, 4 Me). Anal. calc. for $C_{22}H_{31}NO_7$ (421.5): C 62.69, H 7.41, N 3.32; found: C 62.56, H 7.54, N 3.48.

3-Deoxy-5,6:7,8-di-O-*isopropylidene*-N-*methyl*-D-manno-*2-octulosonamide* (**21**). a) *From* **20**: A suspension of **20** (210 mg, 0.5 mmol) and 10% Pd/C (*ca.* 50 mg) in abs. AcOEt (15 ml) was stirred under H_2 for 2 h. The mixture was filtered and the residue evaporated. Chromatography (petroleum ether/AcOEt 4:6, R_f 0.42) gave 80 mg (48%) of **21**.

b) *From* **17** via **19**: A suspension of **17** (5 g, 12.8 mmol) and 10% Pd/C (1 g) in dry AcOEt (40 ml) was stirred under H_2 for 1 h. The mixture was filtered, the filtrate evaporated, and the residue chromatographed over silica gel (AcOEt). After evaporation, a soln. of the residue in 5.6M $MeNH_2$/EtOH (100 ml) was stirred for 12 h at r.t., evaporated again, and chromatographed (petroleum ether/AcOEt 6:4, R_f 0.42) giving 3.5 g (83%) of **21**. $[\alpha]_{578}^{21} = +10.5$ ($c = 1$, $CHCl_3$). ^{1}H-NMR (250 MHz, $CDCl_3$): 6.95 (br. *s*, MeN*H*); 4.27–3.70 (*m*, 7 H); 3.30 (*dd*, *J*(3,3′) = 16.7, *J*(3′,4) = 3.96, H′–C(3)); 3.14 (*dd*, *J*(3,4) = 8.24, H–C(3)); 2.89 (*d*, *J* = 5.18, *Me*NH); 1.44, 1.34 (2*s*, 4 Me). Anal. calc. for $C_{15}H_{25}NO_7$ (331.4): C 54.37, H 7.60, N 4.23; found: C 54.18, H 7.66, N 4.05.

4,5:7,8-Di-O-*cyclohexylidene-3-deoxy*-N-*methyl*-α-D-manno-*2-octulopyranosonamide* (**22**). To a soln. of **21** (2.73 g, 6.5 mmol) in CH_2Cl_2 (30 ml), 10% aq. CF_3COOH soln. (15 ml) was added. After stirring for 6 h at r.t., the mixture was evaporated and the residue coevaporated 3 times with toluene (20 ml). The residue was chromatographed ($CHCl_3/CH_3OH$ 6:4, R_f 0.41). To the colourless product in freshly distilled cyclohexanone (50 ml), 1-(trimethylsiloxy)cyclohexene (1.4 ml, 7.15 mmol) and BNPP (550 mg, 1.6 mmol) were added. After 72 h at r.t., again 1-(trimethylsilyloxy)cyclohexene (1.4 ml, 7.15 mmol) and BNPP (550 mg, 1.6 mmol) were added. After additional 24 h, the mixture was evaporated, the residue filtered over silica gel (petroleum ether/AcOEt 1:3, R_f 0.47), and the crude product chromatographed (petroleum ether/AcOEt 1:2): 2.24 g (84%) of **22**. $[\alpha]_{578}^{21} = -8.3$ ($c = 1.5$, $CHCl_3$). ^{1}H-NMR (250 MHz, $CDCl_3$): 8.01 (br. *s*, MeN*H*); 4.56 (*ddd*, *J*(4,5) = 7.62, H–C(4)); 4.40 (*dd*, *J*(5,6) = 1.83, H–C(5)); 4.23 (*ddd*, *J*(6,7) = 8.53, *J*(7,8) = 2.74, *J*(7,8′) = 4.57, H–C(7)); 4.04–3.91 (*m*, H–C(8), H′–C(8)); 3.61 (*dd*, H–C(6)); 2.84 (*d*, *J* = 4.57, *Me*NH); 2.48 (*dd*, *J*(3eq,3ax) = 16.78, *J*(3eq,4) = 2.44, H_{eq}–C(3)); 2.40 (br. *s*, OH); 2.03 (*dd*, *J*(3ax,4) = 3.05, H_{ax}–C(3)); 1.73–1.23 (*m*, 2 C_6H_{10}). Anal. calc. for $C_{21}H_{33}NO_7 \cdot 0.5\ H_2O$ (420.5): C 59.98, H 8.15, N 3.33; found: C 60.16, H 8.05, N 2.94.

2-O-*Benzyl-3-deoxy-5,6*-O-*isopropylidene*-D-manno-*oct-2-enono-1,4-lactone* (**23**). To a soln. of **17** (2.0 g, 5.12 mmol) in acetone (60 ml), 50% aq. CF_3COOH (37 ml) was added. After 1 h, the mixture was poured onto aq. sat. $NaHCO_3$ soln., extracted with $CHCl_3$, dried ($MgSO_4$), and evaporated. Chromatography (petroleum ether/AcOEt 1:2, R_f 0.35) gave 1.4 g (78%) of **23**. $[\alpha]_{589}^{21} = +19.4$ ($c = 3$, $CHCl_3$). ^{1}H-NMR (80 MHz, $CDCl_3$): 7.40–7.33 (*m*, 5 arom. H); 6.21 (*d*, *J*(3,4) = 2.13, H–C(3)); 5.03 (*s*, PhCH_2O); 4.97 (*dd*, *J*(4,5) = 5.79, H–C(4)); 4.05–3.94 (*m*, H–C(5), H–C(6)); 3.80–3.67 (*m*, H–C(7), 2 H–C(8)); 2.17 (br. *s*, 2 OH); 1.39, 1.36 (2*s*, 2 Me). Anal. calc. for $C_{18}H_{22}O_7$ (350.4): C 61.71, H 6.33; found: C 61.47, H 6.37.

*(2E)-2-*O-*Benzyl-3-deoxy-5,6-*O-*isopropylidene*-N-*methyl*-D-manno-*oct-2-enonamide* (**24**). A soln. of **23** (720 mg, 2.05 mmol) in 5.6M $MeNH_2$/EtOH (40 ml) was stirred for 5 h at r.t. Evaporation (bath temp. < 30°) and silica-gel chromatography (AcOEt/acetone 6:4, R_f 0.47) afforded 695 mg (89%) of colourless crystals. M.p. 94°. $[\alpha]_{578}^{21} = +52.4$ ($c = 1$, $CHCl_3$). ^{1}H-NMR (250 MHz, $CDCl_3$): 7.44–7.33 (*m*, 5 arom. H); 6.86 (*d*, *J* = 5.18, MeN*H*); 6.45 (br. *s*, OH); 5.60 (*d*, *J*(3,4) = 5.18, H–C(3)); 4.81 (*dd*, PhCH_2O); 4.68–4.60 (*m*, H–C(4), OH); 4.02–3.72 (*m*,

H–C(5), H–C(6), H–C(7), 2 H–C(8)); 2.87 (*d*, *Me*NH); 2.69 (br. *s*, OH); 1.42, 1.38 (*s*, 2 Me). Anal. calc. for $C_{19}H_{27}NO_7$ (381.4): C 59.83, H 7.14, N 3.67; found: C 59.34, H 7.15, N 3.63.

*(2E)-4,7,8-Tri-*O*-benzoyl-2-*O*-benzyl-3-deoxy-5,6-*O*-isopropylidene-*N*-methyl-*D*-manno-oct-2-enonamide* (**25**). To a soln. of **24** (425 mg, 1.12 mmol) in pyridine (20 ml), benzoyl chloride (0.78 ml, 6.7 mmol) was added under ice-cooling, After 24 h at r.t., the mixture was poured onto H_2O, extracted with Et_2O, and dried ($MgSO_4$). Evaporation followed by silica-gel chromatography (petroleum ether/AcOEt 6:4, R_f 0.46) gave 520 mg (71%) of **25** as a foam. $[\alpha]_{578}^{21} = +56.2$ ($c = 1$, $CHCl_3$). ^{1}H-NMR (250 MHz, $CDCl_3$): 8.11–7.31 (*m*, 20 arom. H); 6.99 (*dd*, $J(3,4) = 8.79$, $J(4,5) = 2.68$, H–C(4)); 6.66 (br. *s*, MeN*H*); 5.72 (*ddd*, H–C(7)); 5.24 (*d*, H–C(3)); 4.89 (*dd*, $J(7,8') = 3.18$, $J(8,8') = 11.97$, H–C(8′)); 4.82 (*d*, $J = 10.98$, 1 H, PhCH_2O); 4.74 (*d*, $J = 10.98$, 1 H, PhCH_2O); 4.70–4.65 (*m*, H–C(8), H–C(5)); 4.60 (*dd*, $J(6,5) = 7.33$, $J(6,7) = 5.13$, H–C(6)); 2.83 (*d*, $J = 4.88$, MeNH); 1.43, 1.39 (*s*, 2 Me). Anal. calc. for $C_{40}H_{39}NO_{10} \cdot H_2O$ (711.8): C 67.50, H 5.81, N 1.96; found: C 67.53, H 6.03, N 1.72.

*(3E)-7,8-Di-*O*-benzoyl-3,4-dideoxy-*N*-methyl-*D*-arabino-oct-3-en-2-ulosonamide* (**26**). To a soln. of **25** (510 mg, 0.735 mmol) in CH_2Cl_2 (5 ml), 80% aq. CF_3COOH (5 ml) was added. After 5 h at r.t., the mixture was concentrated and filtered over silica gel (petroleum ether/AcOEt 1:2, R_f 0.40). Recrystallization gave 140 mg (44%) of **26** as colourless crystals. M.p. 142–143°. $[\alpha]_{589}^{21} = +17.5$ ($c = 1$, CH_3OH). ^{1}H-NMR (80 MHz, $CDCl_3/CD_3OD$): 8.03–7.21 (*m*, 10 arom. H, MeN*H*, H–C(3), H–C(4)); 5.54 (*ddd*, $J(6,7) = 8.84$, $J(7,8') = 2.44$, H–C(7)); 4.88 (*dd*, $J(8,8') = 12.5$, H–C(8′)); 4.71 (*dd*, H–C(8)); 4.48 (br. *s*, H–C(5)); 4.04 (*dd*, $J(5,6) = 1.83$, H–C(6)); 2.88 (*d*, $J = 5.18$, *Me*NH). Anal. calc. for $C_{23}H_{23}NO_8$ (441.4): C 62.58, H 5.25, N 3.17; found: C 62.46, H 5.34, N 2.94.

*(3E)-7,8-Di-*O*-benzoyl-3,4-dideoxy-5,6-*O*-isopropylidene-*N*-methyl-*D*-arabino-oct-3-en-2-ulosonamide* (**27**). To a soln. of **25** (760 mg, 1.09 mmol) in CH_2Cl_2 (5 ml), 50% aq. CF_3COOH (5 ml) was added. After 4 h at r.t., the mixture was poured onto sat. aq. $NaHCO_3$ soln., extracted with $CHCl_3$, and dried ($MgSO_4$). Evaporation and chromatography (petroleum ether/AcOEt 1:1, R_f 0.60) and recrystallization from Et_2O/petroleum ether afforded 460 mg (88%) of **27** as colourless crystals. $[\alpha]_{578}^{21} = +21.3$ ($c = 1.6$, $CHCl_3$). ^{1}H-NMR (250 MHz, $CDCl_3$): 8.02–7.26 (*m*, 10 arom. H, H–C(3)); 7.18 (*dd*, $J(3,4) = 14.86$ $J(4,5) = 4.88$, H–C(4)); 6.94 (*d*, $J = 4.88$, MeN*H*); 5.63 (*ddd*, $J(7,8) = 6.1$ $J(7,8') = 3.05$, $J(6,7) = 7.62$, H–C(7)); 4.81 (*dd*, $J(8,8') = 12.2$, H–C(8′)); 4.71 (*dd*, $J(5,6) = 7.62$, H–C(5)); 4.56 (*dd*, H–C(8)); 4.21 (*dd*, H–C(6)); 2.85 (*d*, *Me*NH); 1.48, 1.47 (2*s*, 2 Me). Anal. calc. for $C_{26}H_{27}NO_8$ (481.5): C 64.86, H 5.65, N 2.91; found: C 64.59, H 5.64, N 2.79.

*2,4,5,7,8-Penta-*O*-acetyl-3-deoxy-*N*-methyl-*D*-manno-2-octulopyranosonamide* (**28**), *2,4,5,7,8-Penta-*O*-acetyl-3-deoxy-*N*-methyl-β-*D*-manno-2-octulofuranosonamide* (**29**), *and 2,4,5,7,8-Penta-*O*-acetyl-3-deoxy-*N*-methyl-α-*D*-manno-2-octulofuranosonamide* (**30**). To a soln. of **21** (830 mg, 2.51 mmol) in CH_2Cl_2 (20 ml), 10% aq. CF_3COOH (15 ml) was added. After 12 h at r.t., the mixture was concentrated and coevaporated 3 times with toluene. To the colourless oil in abs. pyridine, freshly distilled Ac_2O (10 ml) was added under ice-cooling, and the mixture was stirred for 12 h at r.t. Evaporation and coevaporation with toluene followed by chromatography (AcOEt) afforded 500 mg (44%) of **28**, 250 mg (22%) of **29**, and 140 mg (12%) of **30**.

28: TLC (AcOEt): R_f 0.57. $[\alpha]_{578}^{21} = +117.8$ ($c = 3$, $CHCl_3$). ^{1}H-NMR (400 MHz, $CDCl_3$): 6.65 (*d*, $J = 4.88$, MeN*H*); 5.40 (br. *s*, H–C(5)); 5.34 (*ddd*, $J(4,5) = 3.05$, $J(3ax,4) = 12.32$, $J(3eq,4) = 4.88$, H–C(4)); 5.19 (*ddd*, $J(7,8') = 4.39$, $J(6,7) = 9.89$, H–C(7)); 4.48 (*dd*, $J(8,8') = 12.33$, H–C(8′)); 4.13 (*dd*, $J(5,6) = 1.22$, H–C(6)); 4.03 (*dd*, H–C(8)); 2.88 (*d*, *Me*NH); 2.34 (*dd*, $J(3ax,3eq) = 12.82$, H_{eq}–C(3)); 2.12, 2.10, 2.05, 2.01, 1.99 (4*s*, 5 Ac); 1.94 (*dd*, H_{ax}–C(3)). Anal. calc. for $C_{19}H_{27}NO_{12}$ (461.4): C 49.46, H 5.90, N 3.04; found: C 49.22, H 5.75, N 3.25.

29: TLC (AcOEt): R_f 0.50. $[\alpha]_{578}^{21} = -60.8$ ($c = 2.5$, $CHCl_3$). ^{1}H-NMR (400 MHz, $CDCl_3$): 6.86 (*d*, $J = 4.63$, MeN*H*); 5.32 (*dd*, $J(6,7) = 4.64$, $J(5,6) = 4.15$, H–C(6)); 5.26 (*ddd*, $J(7,8) = 5.74$, $J(7,8') = 3.3$, H–C(7)); 5.07 (*ddd*, $J(3,4) = 1.95$, $J(3',4) = 7.32$, $J(4,5) = 2.81$, H–C(4)); 4.52 (*dd*, H–C(5)); 4.34 (*dd*, $J(8,8') = 12.21$, H–C(8′)); 4.26 (*dd*, H–C(8)); 2.86 (*d*, *Me*NH); 2.56 (*dd*, $J(3,3') = 15.01$, H–C(3)); 2.37 (*dd*, H′–C(3)); 2.12, 2.11, 2.10, 2.09 (4*s*, 5 Ac). Anal. calc. for $C_{19}H_{27}NO_{12}$ (461.4): C 49.46, H 5.90, N 3.04; found: C 49.68, H 5.94, N 2.92.

30: TLC (AcOEt): R_f 0.48. $[\alpha]_{578}^{21} = +95.1$ ($c = 1.2$, $CHCl_3$). ^{1}H-NMR (250 MHz, $CDCl_3$): 6.84 (*d*, $J = 4.88$, MeN*H*); 5.31–5.22 (*m*, H–C(6), H–C(4), H–C(7)); 4.44 (*dd*, $J(8,8') = 12.5$, $J(7,8') = 2.74$, H′–C(8)); 4.37 (*dd*, $J(5,6) = 4.88$, H–C(5)); 4.14 (*dd*, $J(7,8) = 6.4$, H–C(8)); 2.91 (*dd*, $J(3,4) = 7.0$, H–C(3)); 2.86 (*d*, *Me*NH); 2.30 (*dd*, $J(3',4) = 5.7$, $J(3,3') = 14.2$, H′–C(3)); 2.11–2.06 (*m*, 5 Ac). Anal. calc. for $C_{19}H_{27}NO_{12}$ (461.4): C 49.46, H 5.90, N 3.04; found: C 49.36, H 6.00, N 3.17.

*4,5,7,8-Tetra-*O*-acetyl-3-deoxy-*N*-methyl-*D*-manno-2-octulopyranosonamide* (**31**). To a soln. of **28** (100 mg, 0.22 mmol) in abs. DMF (1 ml) was added hydrazine acetate (22 mg, 0.3 mmol). After heating to 50° for 30 min, the mixture was diluted with AcOEt and washed with sat. aq. NaCl soln. The org. layer was dried (drierite). Evaporation and chromatography (AcOEt, R_f 0.44) afforded 30 mg (32%) of **31**. ^{1}H-NMR (250 MHz, $CDCl_3$): 6.44 (*d*, $J = 4.88$, MeN*H*); 5.41 (*ddd*, $J(4,5) < 1$, $J(3ax,4) = 13.3$, $J(3eq,4) = 4.27$, $J(4,5) = 3.05$, H–C(4)); 4.40 (br. *s*, H–C(5)); 4.16 (*ddd*, $J(7,8') = 2.13$, $J(7,8) = 5.18$, H–C(7)); 4.53 (br. *s*, OH); 4.40 (*dd*, $J(8,8') = 12.2$, H–C(8′)); 4.34 (*dd*, $J(5,6) = 0.91$, $J(6,7) = 9.76$, H–C(6)); 4.16 (*dd*, H–C(8)); 2.91 (*d*, *Me*NH); 2.12–1.93 (*m*, 4

Ac, H–C(3ax), H–C(3eq)). Anal. calc. for $C_{17}H_{25}NO_{11} \cdot H_2O$ (428.4): C 47.66, H 6.12, N 3.27; found: C 47.74, H 6.19, N 3.27.

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