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Convenient approach to higher carbon sugars. First synthesis of the free C12-sugar: D-*erythro*-L-*manno*-D-*manno*-dodecose

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Abstract

The model synthesis of a C12-aldose was initiated from the easily available dimethyl(benzyl 2,3,4-tri-*O*-benzyl-α-D-*manno*-heptopyranos-6-ulos-7-yl)phosphonate and 2,3:4,5-di-*O*-isopropylidene-D-arabinose. © 2003 Published by Elsevier Science Ltd.

Monosaccharides, containing more than 10 carbon atoms in the chain can be divided into three main classes: C-disaccharides (e.g., **1**[1]) higher aldoses (e.g., **2**[2]) and higher dialdoses (e.g., **3**[3]). Examples of these three classes are shown in Fig. 1.

Higher carbon sugars are interesting molecules, although very few of them can be found in nature. They can be used as non-metabolized analogues of di- and oligosaccharides, are interesting targets for developing new synthetic methodologies and studying the conformational features. The synthesis of compounds of type **1** and **3** is now well explored (especially well documented are the syntheses of *C*-glycosides[4]) and such derivatives may be prepared without special problems using different synthetic methods.[5] In principle, they can be prepared by total synthesis,[6] by iterative elongation of simple monosaccharides (pentoses, or hexoses) with a C_1-,[7] or C_2-units.[8] The best and most economic way, however, consists of coupling of two suitable activated monosaccharide subunits.[9]

Very little is known about higher aldoses. Only limited examples of such derivatives are reported in the literature[10–14] (very few in a free form), despite the fact that such complex molecules might be interesting targets for studying the conformational mobility of polyhydroxylated compounds. In this paper the synthesis of the free C12-sugar: D-*erythro*-L-*manno*-D-*manno*-dodecose will be presented.

In the past several years we elaborated a convenient methodology for the preparation of higher dialdoses by coupling of two suitably activated simple sugar subunits.[15] Especially useful was the reaction of sugar phosphoranes **4**[16] or better phosphonates **5**[14,17] with sugar aldehydes providing a higher enone **6**, finally converted into the desired dialdose (Fig. 2).

The key-step in the functionalization of a three-carbon atom bridge (connecting the sugar portions of **6**) is

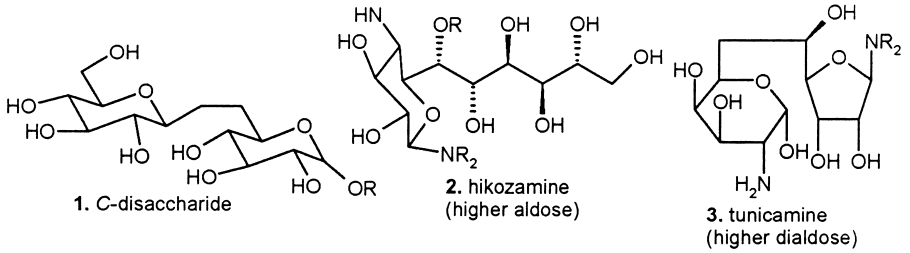

Fig. 1. The examples of different types of higher carbon sugars.

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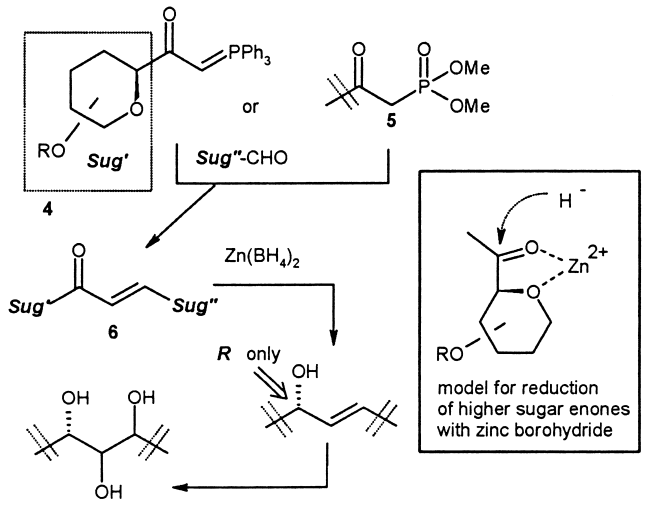


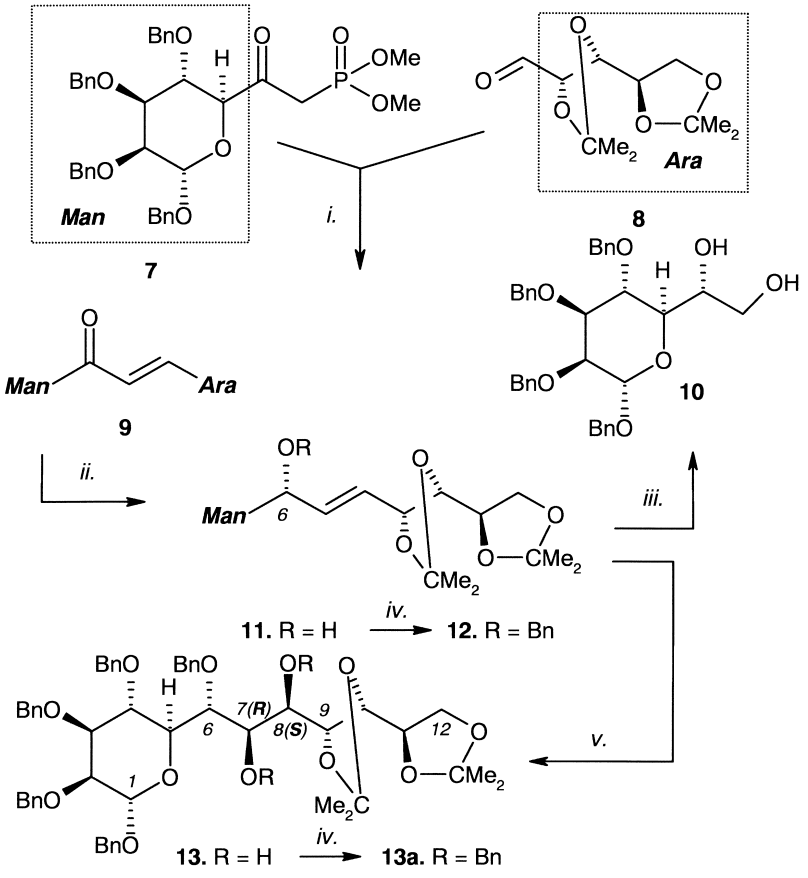
Fig. 2. The synthesis of higher dialdoses from simple sugar sub-units: phosphoranes (**4**) or phosphonates (**5**) and aldehydes.

a stereoselective reduction of the carbonyl group with zinc borohydride. This reaction performed for the D-sugars affords exclusively the allylic alcohols with the *R*-configuration at the newly created stereogenic center (see model in Fig. 2).[18]

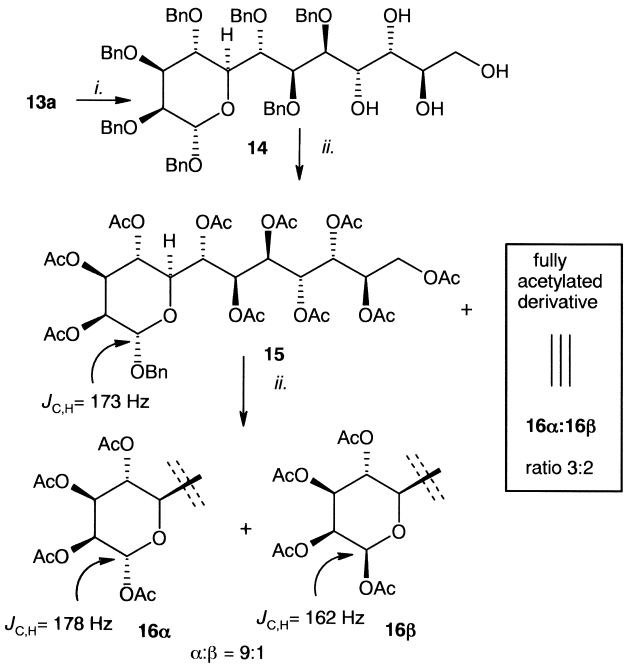
Slight modifications of the starting sugar sub-units should allow preparing a higher sugar aldose, which might be converted into a free saccharide by removal of suitable blocking groups. Therefore, one sub-unit should have the anomeric position blocked with the group easily removable under neutral conditions and the other one could be the simple aldose preferable in an open-chain form.

The model synthesis of a C12-aldose was initiated from the easily available dimethyl(benzyl 2,3,4-tri-*O*-benzyl-α-D-*manno*-heptopyranos-6-ulos-7-yl)phosphonate[17] (**7**) and 2,3:4,5-di-*O*-isopropylidene-D-arabinose (**8**) and is presented in Scheme 1.

Reaction of both partners **7** and **8** under mild phase transfer conditions K_2CO_3, 18-crown-6, toluene, room temperature)[13] afforded the *trans*-higher sugar enone **9** in 74% yield. Reduction of the carbonyl group with zinc borohydride gave, as expected[18], the *R*-alcohol **11**; its configuration was verified by chemical degradation to known[19] benzyl 2,3,4-tri-*O*-benzyl-D-*glycero*-α-D-*manno*-heptoside (**10**; Scheme 1 and Section 2). The next step required osmylation of the double bond what would provide the triol with the (7*R*,8*S*) configuration at the newly created chiral centers as predicted by the



Scheme 1. (i) K_2CO_3, 18-crown-6, toluene, rt, 74%; (ii) $Zn(BH_4)_2$, ether, 0 °C, 94%; (iii) from **11**, O_3, then $NaBH_4$; (iv) 85%; BnBr, NaH, DMF, rt; (v) OsO_4, NMO, THF, water.



Scheme 2. (i) THF, H_2O, 10% H_2SO_4, reflux, 20 h H_2/Pd then Ac_2O/Py.

Kishi's rule.[20] Confirmation of the configuration at these two centers in the triol would be rather difficult (unless the X-ray assignment is possible). However, since the absolute configuration of the sugar *threo*-diols can be easily assigned by the CD spectroscopy,[17,21,22] we decided to protect the free hydroxy group in **11** as benzyl ether prior to oxidation. Osmylation[23] of such protected olefin **12** afforded the diol **13**; the positive Cotton effect in the CD spectrum of the complex of **13** with dimolybdenum tetraacetate [λ: 362 ($\Delta\varepsilon'$ −0.35), 306.5 ($\Delta\varepsilon'$ +0.76) nm] pointed unequivocally at the (7*R*,8*S*) configuration of the newly created stereogenic centers.

To finish the synthesis of the free C12-aldose, the hydroxy groups in **13** were protected as benzyl ethers (→**13a**), the isopropylidene groups were removed by hydrolysis, and the resulting tetraol **14** was subjected to hydrogenolysis.

The product was acetylated and further isolated as diastereoisomeric mixture of acetates by column chromatography. The first product was identified as the benzyl glycoside of the deca-acetate **15**, the second—as a 3:2 mixture of two undeca-acetates (Scheme 2). Fortunately, isolation of the benzyl glycoside **15** provided a unique possibility of obtaining fully acetylated sugar with the known size of the ring, the pyranose **16**. Thus, removal of the benzyl protecting group with H_2/Pd followed by acetylation afforded the pyranose **16a** contaminated with the small amounts of other isomer (assigned as the β-anomer, **16**β; see below). This is consistent with the literature data, which report on formation of up to 30% of the β-pyranose during acetylation of mannose[24] and *manno*-heptoses.[25] The α-configuration at the C-1 was proved by the $J_{C\text{-}1-H\text{-}1}$ coupling constant[26] which was found to be 178 Hz.

The mixture of two fully acetylated dodecoses was separated by the HPLC chromatography and the individuals were identified as the α and β pyranoses **16**α and **16**β on the basis of their NMR data. The ^1H and ^{13}C NMR spectra of the main isomer were identical with the corresponding data of **16**α obtained from **15**. In the ^1H NMR spectrum of the minor isomer the highest up-field signal at δ was assigned to the H-5 proton (COSY), thus proving the pyranose structure of the product. Further proof of the β-pyranose structure came from the undecoupled ^{13}C NMR spectrum in which the coupling constant $J_{C\text{-}1-H\text{-}1}$ 162 Hz was observed. This compound was also identical with the minor isomer present as contamination of **16**α obtained from the benzyl glycoside **15**. No formation of furanoses was detected what is consistent with the literature data; such peracetylated *manno*-furanoses are obtained using special condition.[27]

1. Conclusion

The synthesis of unprotected dodecose was accomplished in a few steps from simple monosaccharide sub-units. The structure of the free sugar as well as its peracetate is similar to the structure of the parent hexoses (or heptoses). The statement of Angyal: "*Extension of the side-chain, on going from hexoses to heptoses, does not introduce any new steric interaction into the pyranose or the furanose ring*"[28] is also found for compounds extended by six carbon atoms.

2. Experimental

Optical rotations were measured with a JASCO DIP 360 automatic polarimeter at 20 ± 2 °C. NMR spectra were recorded with Varian Gemini AC-200 (200 MHz) or Bruker AM-500 (500 MHz) specrometers in $CDCl_3$ solns with Me_4Si as an internal standard unless otherwise stated. ^1H and ^{13}C signal of aromatic groups occurred at the expected chemical shifts were omitted in the description of spectra. ^{13}C NMR spectra were recorded in the DEPT 135 mode. The proton and carbon resonances in **17** and **18** were assigned by the COSY and HETCOR correlations. Mass spectra (LSIMS, positive mode) were recorded on an AMD-604 mass spectrometer. HPLC was carried out on a Shimadzu instrument: central unit C-R4A, pump unit LC-8A, RI detector Shimadzu RiD-6a on a column Macherey-Nagel AG, Nucleosil 100, 7 μ. CD spectrum of **13** was measured with JASCO 715 CD spectrometer

for soln in Me_2SO to which the complex $Mo_2(OAc)_4$ was added (molar ratio 1.25:1). TLC was performed on Silica Gel HF-254 ready plates and column chromatography on Silica Gel 230–400 or 70–230 mesh (E. Merck).

2.1. Benzyl 2,3,4-tri-*O*-benzyl-7(*E*)-dideoxy 7(*E*)-eno-9,10:11,12-di-*O*-isopropylidene-6-oxo-D-*arabino*-α-D-*manno*-dodeca-1,5 pyranoside (9)

To a soln of dimethyl(benzyl 2,3,4-tri-*O*-benzyl-α-D-*manno*-heptopyranos-6-ulos-7-yl)phosphonate[17] (**7**; 4.5 g, 6.7 mmol) and 2,3:4,5-di-*O*-isopropylidene-D-arabinose (**8**; 1.8 g, 7.8 mmol) in dry $C_6H_5CH_3$ (100 mL), solid potassium carbonate (3 g) was added followed by 18-crown-6 (50 mg) and the mixture was stirred for 24 h at room temperature (rt). After this time TLC (1:1 C_6H_{14}–EtOAc) showed disappearance of both starting materials and formation of a new, less polar product that was visible in the UV light. Water (80 mL) and ether (80 mL) were added, the organic phase was separated, washed with water, dried and concentrated, and the residue was chromatographed with C_6H_{14}–EtOAc (3:1 → 2:1) to afford enone **9** (3.8 g, 4.97 mmol, 74%) as an oil. $[\alpha]_D$ +23.3° (*c* 1.0, $CHCl_3$); ^{1}H NMR (200 MHz) inter alia δ: 7.05 (dd, 1 H, $J_{7,8}$ 4.6, $J_{8,9}$ 15.7 Hz, H-8), 6.80 (dd, 1 H, $J_{7,9}$ 1.2 Hz, H-7), 5.00 (d, 1 H, $J_{1,2}$ 2.2 Hz, H-1), 1.41, 1.36 (×2); ^{13}C NMR δ: 194.8 (C=O), 144.2 (C-8), 126.1 (C-7), 110.1, 109.7 (2× CMe_2), 97.6 (C-1), 81.1, 79.1 (×2), 76.8, 75.7, 75.5, 74.8 (CH_2Ph), 74.5, 72.7 (CH_2Ph), 72.3 (CH_2Ph), 69.5 (CH_2Ph), 67.3 (C-12), 26.9, 26.7 (×2), 25.2 (2× CMe_2). Anal. Calcd for $C_{46}H_{52}O_{10}\cdot 0.5H_2O$: C, 71.39; H, 6.90. Found: C, 71.74; H, 6.62.

2.2. Benzyl 2,3,4-tri-*O*-benzyl-7,8-dideoxy 7(*E*)-eno-9,10:11,12-di-*O*-isopropylidene-D-*gluco*-α-D-*manno*-dodeca-1,5 pyranoside (11)

Enone **9** (3.6 g, 4.69 mmol) was dissolved in dry ether (50 mL) and cooled to 0 °C. Zinc borohydride (10 mL of a approx 0.5 M soln in ether) was added and the mixture was stirred for 30 min at 0 °C. The excess of borohydride was decomposed by careful addition of water (5 mL), the mixture was partitioned between ether (50 mL) and brine (50 mL), the organic layer was separated washed with diluted H_2SO_4, brine (to neutrality) dried concentrated, and the residue was chromatographed with C_6H_{14}–EtOAc (2:1 → 1:1) to afford alcohol **11** (3.4 g, 4.43 mmol, 94%) as an oil. $[\alpha]_D$ +38.1° (*c* 1.1, $CHC1_3$); ^{1}H NMR (200 MHz) inter alia δ: 6.05 and 5.85 (dd, 1 H, *J* 6.2, $J_{8,9}$ 16.2 Hz, dd, 1 H, *J* 5.9 Hz, H-7,8),4.92 (d, 1 H, $J_{1,2}$ 1.8 Hz, H-1), 1.37, (×3), 1.28 (2× CMe_2); ^{13}C NMR δ: 194.8 (C=O), 131.1, 130.0 (C-7,8), 109.5, 109.2 (2× CMe_2), 97.1 (C-1), 81.0, 80.2, 79.6, 76.6, 76.0, 74.6 (CH_2Ph), 73.9, 72.1 (CH_2Ph), 71.9 (CH_2Ph), 69.1 (CH_2Ph), 66.8 (C 12), 27.0, 26.9, 26.6, 25.2 (2× CMe_2). Anal. Calcd for $C_{46}H_{54}O_{10}\cdot 0.5H_2O$: C, 71.20; H, 7.15. Found: C, 71.20; H, 7.04.

2.3. Determination of the configuration at the C-6 center in 11

Through a cooled to −78 °C soln of the alcohol **11** (100 mg, 0.13 mmol) in CH_2Cl_2 (10 mL) and MeOH (5 mL) ozone was bubbled until the blue color persisted (approx 15 min). Excess of ozone was removed by bubbling of a stream of oxygen through the solution for 5 min. Sodium borohydride (20 mg) was added, the mixture was stirred 1 h at rt and the desired heptoside **10** (50 mg) was isolated by column chromatography (C_6H_{14}–EtOAc 3:1 → 2:1). It was identical in all respect with the synthetic material prepared independently.[19]

2.4. Benzyl 2,3,4,6-tetra-*O*-benzyl-7,8-dideoxy 7(*E*)-eno-9,10:11,12-di-*O*-isopropylidene-D-*gluco*-α-D-*manno*-dodeca-1,5-pyranoside (12)

To a soln of alcohol **11** (3.25 g, 4.24 mmol) in DMF (20 mL), sodium hydride (50% dispersion in mineral oil; 300 mg) was added carefully and the mixture was stirred for 15 min at rt. Benzyl bromide (0.6 mL, 5.0 mmol) was added dropwise during 5 min and the mixture was stirred for another 30 min. Excess of hydride was decomposed by careful addition of water, the mixture was partitioned between ether (50 mL) and brine (30 mL), the organic phase was separated, washed with water (20 mL), dried, concentrated, and the residue was chromatographed with C_6H_{14}–EtOAc (3:1 → 2:1) to afford **12** (3.1 g, 3.62 mmol, 85%) as an oil. This product was used directly for the next step.

2.5. Benzyl 2,3,4,6-tetra-*O*-benzyl-9,10:11,12-di-*O*-isopropylidene-D-*erythro*-L-*manno*-α-D-*manno*-dodeca-1,5-pyranoside (13)

To a soln of **12** (3.0 g, 3.5 mmol) in THF (20 mL), *tert*-butyl alcohol (1.5 mL) and water (1.0 mL), *N*-methylmorpholine *N*-oxide (580 mg, 4.3 mmol) was added followed by osmium tetraoxide (0.8 mL of a approx 2% soln in $C_6H_5CH_3$). The mixture was stirred for 24 h (TLC monitoring in C_6H_{14}–EtOAc 2:1), then diluted with MeOH (30 mL), and aq 40% sodium hydrogensulphite was added. The mixture was stirred for 30 min, filtered through Celite, concentrated, and partitioned between water (50 mL) and ether (50 mL). Organic phase was separated, dried, concentrated, and the residue was chromatographed with C_6H_{14}–EtOAc (2:1 → 1:1) to afford **13** (2.4 g, 2.69 mmol, 77%) as the only product as an oil. ^{13}C NMR δ: 109.9, 109.4 (2× CMe_2), 97.0 (C-1), 80.7, 80.6, 79.6, 78.2, 76.5, 75.4,

75.0 (CH_2Ph), 74.8, 73.0 (CH_2Ph), 72.8 (CH_2Ph), 72.6, 71.2, 70.0, 68.8 (CH_2Ph), 67.4 (C-12), 27.1 ($\times 2$), 26.4, 25.2 ($2 \times CMe_2$). CD [λ ($\Delta\varepsilon'$)]: 362 (-0.35), 306.5 ($+0.76$) nm.

2.6. Benzyl 2,3,4,6,7,8-hexa-*O*-benzyl-9,10:11,12-di-*O*-isopropylidene-D-*erythro*-L-*manno*-α-D-*manno*-dodeca-1,5-pyranoside (13a)

This product was obtained (analogously to **12**) from **13** in 75% yield $[\alpha]_D$ $+21.3°$ (*c* 1.3, $CHCl_3$); ^{13}C NMR δ: 109.7, 109.4 ($2 \times CMe_2$), 96.9 (C 1), 80.9, 80.3, 79.6, 78.9, 78.5, 76.7, 76.0, 75.3, 74.9, 74.5 (CH_2Ph), 74.1 (CH_2Ph), 74.0 (CH_2Ph), 72.9 (CH_2Ph), 72.4 (CH_2Ph), 72.1 (CH_2Ph), 71.4, 68.5 (CH_2Ph), 65.1 (C-12), 27.5, 27.4, 26.3, 25.3 ($2 \times CMe_2$). Anal. Calcd for $C_{67}H_{74}O_{12}$: C, 75.11; H, 6.96. Found: C, 75.06; H, 7.00.

2.7. Benzyl-2,3,4,6,7,8-hexa-*O*-benzyl-D-*erythro*-L-*manno*-α-D-*manno*-dodeca-1,5-pyranoside (14)

To a soln of **13a** (2.0 g, 1.87 mmol) in THF (20 mL) and water (3 mL) a 10% soln of H_2SO_4 (1 mL) was added and the mixture was kept at rt overnight. Small amount of the mixture was worked-up as usual (approx 1 mL) and the product was analyzed by ^{13}C NMR spectroscopy. Only one isopropylidene group was seen what suggested partial hydrolysis of the C11–C12 isopropylidene grouping. ^{13}C NMR δ: 109.3 (CMe_2), 96.9 (C-1), 80.9, 80.7, 80.0, 79.1, 78.2, 77.7, 75.2, 74.8, 74.5 (CH_2Ph), 74.2 (CH_2Ph), 72.9 ($2 \times CH_2Ph$), 72.3 (CH_2Ph), 72.0 (CH_2Ph), 71.3, 68.6 (CH_2Ph), 63.5 (C-12), 26.9, 26.7 (CMe_2). The rest of the mixture was boiled under reflux for 20 h and after cooling to rt partitioned between EtOAc (50 mL) and brine (20 mL). The organic layer was separated washed with water to neutrality, dried, concentrated and the residue was chromatographed with C_6H_{14}–EtOAc (1:1 → 1:3) to afford **15** (1.57 g, 1.59 mmol, 85%) as a foam. ^{13}C NMR δ: 109.7, 109.4 ($2 \times CMe_2$), 97.0 (C-1), 80.8, 79.0, 78.5, 77.5, 75.2, 75.1, 74.5 (CH_2Ph), 74.0 ($2 \times CH_2Ph$), 73.1, 72.9 (CH_2Ph), 72.6 (CH_2Ph), 72.1 (CH_2Ph), 71.5, 70.1, 69.9, 68.5, (CH_2Ph), 63.7 (C-12). Anal. Calcd for $C_{61}H_{66}O_{12}\cdot 2.5H_2O$: C, 70.70; H, 6.91. Found: C, 70.76; H, 7.20.

2.8. Hydrogenolysis of the protected pyranose 14

A soln of the tetraol **14** (990 mg, 1.0 mmol) in MeOH (10 mL) and EtOAc (10 mL) was hydrogenated over 10% Pd/C (20 mg) for 24 h. The solution was filtered, through Celite, concentrated and the residue dissolved in Py (15 mL) to which Ac_2O (10 mL) was added followed by catalytic amount of DMAP (20 mg). The mixture was kept at rt overnight, concd and the residue was chromatographed with C_6H_{14}–EtOAc (2:1) to afford benzyl glycoside **15** (230 mg, 0.26 mmol, 26%) and fully acetylated derivative **16** (450 mg, 0.55 mmol, 55%) as a 3:2 mixture of α and β pyranoses as judged from the integration of the ^1H NMR resonances at δ ($CHCl_3$): 6.05 (d, 1 H, $J_{1,2}$ 2.6 Hz, H-1α) and 5.95 (d, 1 H, $J_{1,2}$ 2.0 Hz, H-1α). The α or β configuration of these derivatives was proved by the coupling constant $J_{C\text{-}1-H\text{-}1}$ which was assigned as 178 and 162 Hz, respectively.

The mixture of α and β pyranoses (**16**) was separated by HPLC. The 2D spectra allow to assign precisely the pyranose structure for both isomers (see below). Benzyl glycoside **15** was hydrogenated over Pd/C and then acetylated to give predominantly α pyranose **16**α contaminated with small amounts of the β-pyranose (ratio **16**α:**16**β = 10:1).

2.9. Benzyl 1,2,3,4,6,7,8,9,10,11,12-deca-*O*-acetyl-D-*erythro*-L-*manno*-α-D-*manno*-dodeca-1,5-pyranoside (15)

$[\alpha]_D$ $+35.6°$ (*c* 1.0, $CHCl_3$); ^1H NMR (500 MHz, COSY, $CDCl_3$) δ: 7.30 (m, 5 H, CH_2Ph), 5.50 (dd, 1 H, $J_{7,8}$ 9.2, $J_{8,9}$ 2.1 Hz, H-8), 5.41 (dd, 1 H, $J_{6,7}$ 2.0 Hz, H-7), 5.36 (dd, 1 H, $J_{9,10}$ 6.7 Hz, H-9), 5.31 (dd, 1 H, $J_{2,3}$ 3.02, $J_{3,4}$ 9.4 Hz, H-3), 5.29–5.27 (m, 2 H, H-6,10), 5.21 (dd, 1 H, $J_{1,2}$ 2.0 Hz, H-2), 5.20 (dd, 1 H, $J_{5,6}$ 9.6 Hz, H-4), 5.01 (ddd, 1 H, $J_{10,12}$ ~ 6, $J_{10,12'}$ 3.0, $J_{10,12''}$ 5.4 Hz, H-11), 4.79 and 4.55 (AB of CH_2Ph), 4.23 (dd, 1 H, $J_{12',12''}$ 12.4 Hz, H-12′), 4.15 (dd, 1 H, $J_{5,6}$ 4.2 Hz, H-5), 4.02 (dd, H-12″), 2.12, 2.09, 2.07, 2.06, 2.05, 2.042, 2.038, 2.02, 2.00, 197 (30 H, $10 \times OAc$); ^{13}C NMR (125 MHz, $CDCl_3$, HETCOR) δ: 170.5, 169.91, 169.87, 169.79, 169.73, 169.6, 169.50, 169.48, 169.28, 169.24 ($10 \times CH_3CO$), 136.2 (quat. CH_2Ph), 128.6 ($\times 2$), 128.2, 127.7 ($\times 2$), 96.1 (C-1), 69.9 (C 10), 69.7 (C-5), 69.5 (C-2), 69.4 (C-3), 69.3 (CH_2Ph), 68.5 (C-11), 67.7 (C-6), 67.6 (C-9), 67.5 (C-8), 67.3 (C-4), 67.2 (C-7), 61.9 (C-12), 20.9, 20.78 ($\times 3$), 20.75, 20.71, 20.68, 20.64 ($\times 3$). ^{13}C NMR (125 MHz, $CDCl_3$, undecoupled): $J_{C\text{-}1-H\text{-}1}$ 174.3 Hz. HR MS (LSIMS) *m*/*z* Calcd for $C_{39}H_{50}O_{22}Na$: 893.2681. Found: 893.2660.

2.10. 1,2,3,4,6,7,8,9,10,11,12-Undeca-*O*-acetyl-D-*erythro*-L-*manno*-α-D-*manno*-dodeca-1,5-pyranose (16α)[†]

^1H NMR (500 MHz, $CDCl_3$, COSY) δ: 6.03 (d, 1 H, $J_{1,2}$ 2.7 Hz, H-1), 5.43 (dd, 1 H, *J* 1.9 and 9.5 Hz, H-9), 5.40 (dd, 1 H, $J_{5,6}$ 6.2, $J_{6,7}$ 5.8 Hz, H-6), 5.30 (2 H, H-8,10), 5.29 (dd, 1 H, $J_{2,3}$ 3.4, $J_{3,4}$ 9.7 Hz, H-3), 5.19 (3 H, H-2,4,7), 4.99 (ddd, 1 H, $J_{10,11}$ 8.3, $J_{11,12'}$ 2.9, $J_{11,12''}$ 5.3 Hz, H-11), 4.21 (dd, 1 H, $J_{12',12''}$ 12.5 Hz, H-12′), 4.19 (dd, 1 H, $J_{4,5}$ 9.2 Hz, H-5), 4.02 (dd, 1 H, H-12″); ^1H NMR (500 MHz, C_6D_6, COSY) δ: 6.41(?) (d, 1 H, $J_{1,2}$ 2.8 Hz, H-1), 6.01 (dd, 1 H, $J_{5,6}$ 6.0, $J_{6,7}$ 5.7

[†] Compound **16**α was contaminated with ca. 5% of the isomer **16**β and vice versa.

Hz, H-6), 5.99 (dd, 1 H, $J_{8,9}$ 9.8, $J_{9,10}$ 1.9 Hz, H-9), 5.88 (dd, 1 H, $J_{7,8}$ 1.7 Hz, H-8), 5.82 (dd, 1 H, H-7), 5.79 (dd, 1 H, $J_{2,3}$ 2.9, $J_{3,4}$ 8.6 Hz, H-3), 5.78 (dd, 1 H, $J_{10,11}$ 8.4 Hz, H-10), 5.74 (dd, 1 H, $J_{4,5}$ 8.6 Hz, H-4), 5.57 (dd, 1 H, H-2), 5.40 (ddd, 1 H, $J_{11,12'}$ 2.9, $J_{11,12''}$ 5.2 Hz, H-11), 4.66 (dd, 1 H, H-5), 4.55 (dd, 1 H, $J_{12',12''}$ 12.5 Hz, H-12′), 4.26 (dd, 1 H, H-12″); ^{13}C NMR (125 MHz, $CDCl_3$, HETCOR) δ: 170.5, 170.0, 169.9 (× 2), 169.83, 169.81, 169.7, 169.5, 169.2, 169.0, 168.3 (11 × CH_3CO), 89.9 (C-1), 70.8 (C 5), 70.5 (C-6), 69.4, 68.4 (C-11), 68.5 (C-11), 68.0, 67.4, 67.1, 67.3, 66.9, 66.7 (C-9), 61.8 (C 12), 21.0, 20.9, 20.79, 20.78, 20.75 (× 2), 20.7, 20.64 (× 2), 20.58). ^{13}C NMR (125 MHz, $CDCl_3$, undecoupled): $J_{C\text{-}1-H\text{-}1}$ 178 Hz. HR MS (LSIMS) m/z Calcd for $C_{34}H_{46}O_{23}Na$: 845.2322. Found: 845.2354.

2.11. 1,2,3,4,6,7,8,9,10,11,12-Undeca-*O*-acetyl-D-*erythro*-L-*manno*-β-D-*manno*-dodeca-1,5-pyranose (16β)

^{1}H NMR (500 MHz, COSY, C_6D_6) δ: 6.06 (dd, 1 H, $J_{5,6}$ 7.0, $J_{6,7}$ 5.5 Hz, H 6), 5.98–5.93 (m, 3 H, $J_{1,2}$ 2.3 Hz, H 1, H 8,9), 5.77 (dd, 1 H, $J_{9,10}$ 1.7, $J_{10,11}$ 8.7 Hz, H 10), 5.64–5.61 (m, 2 H, H 2.7), 5.58 (t, $J_{3,4} = J_{4,5}$ 7.6 Hz, H 4), 5.43 (ddd, $J_{11,12'}$ 3.0, $J_{11,12''}$ 5.5 Hz, H 11), 5.33 (dd, 1 H, $J_{2,3}$ 3.2 Hz, H 3), 4.55 (dd, 1 H, $J_{12',12''}$ 12.5 Hz, H 12′), 4.38 (t, 1 H, H 6), 4.22 (dd, 1 H, H 12″), 2.09, 2.06, 2.03, 1.98, 1.95, 1.93, 1.92, 1.91, 1.88, 1.83, 1.78 (30 H, 11 × O*Ac*). ^{13}C NMR (125 MHz, $CDCl_3$, undecoupled): $J_{C\text{-}1-H\text{-}1}$ 162 Hz. HR MS (LSIMS) m/z Calcd for $C_{34}H_{46}O_{23}Na$: 845.2322. Found: 845.2343.

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