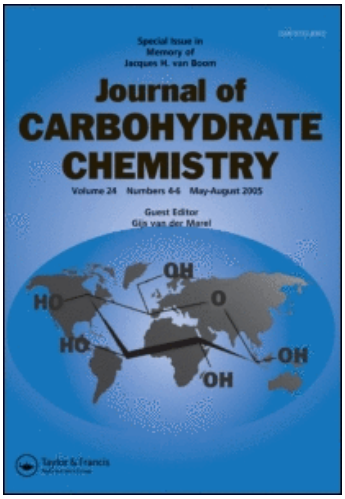

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Iodoacetoxylation Reaction: A Convenient Route to α-Glycosides in the 2-Iodo and 2-Deoxy Series

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IODOACETOXYLATION REACTION: A CONVENIENT ROUTE TO α-GLYCOSIDES IN THE 2-IODO AND 2-DEOXY SERIES

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ABSTRACT

Iodoacetoxylation of 3,4,6-tri-*O*-acetyl-1,5-anhydro-2-deoxy-D-*arabino*-hex-1-enitol (tri-*O*-acetyl-D-glucal) (**1**) and 3,4-di-*O*-acetyl-1,5-anhydro-2,6-dideoxy-L-*arabino*-hex-1-enitol (di-*O*-acetyl-L-rhamnal) (**3**) gave the α-1,2-*trans*-1-*O*-acetyl-2-deoxy-2-iodo adducts with high stereoselectivities and good yields, in accordance with the results reported on 3,6-di-*O*-acetyl-4-*O*-(2,3,4,6-tetra-*O*-acetyl-β-D-galactopyranosyl)-1,5-anhydro-2-deoxy-D-*arabino*-hex-1-enitol (hexa-*O*-acetyl lactal) (**2**). The α-1,2-*trans* adducts were reacted with an excess of alcohol in the presence of trimethylsilyl trifluoromethanesulfonate affording the corresponding α-1,2-*trans*-2-deoxy-2-iodo-glycopyranosides in good yields. The octyl 2-deoxy-2-iodo-α-D-glycosides **10** and **11** prepared in two steps from the glycals **1** and **2** were deiodinated and deacetylated, giving **28** and **29**, and the physicochemical-properties (cmc) of **29** are reported.

INTRODUCTION

Glycosides of 2-deoxy sugars constitute part of numerous biologically active natural products such as antibiotics[1-4] (e.g. olivomycin, aclacinomycin, marcellomycin, etc.) or cardiac glycosides[2,5] (digoxin, digitoxin, etc...) and their syntheses are therefore of interest. 2-Deoxy-2-halogeno sugars are very important intermediates for the synthesis of 2-deoxy glycosides[6-8] or *C*-2 isotopically labelled glycosides.[9,10] Furthermore, 2-deoxy-2-halogeno substituted anthracycline glycosides have shown antitumor activity.[1,11,12] The obtention in good yield of anomerically homogeneous α- or β-glycosides is governed by the substituent at *C*-2 that may direct the aglycon group to the α-

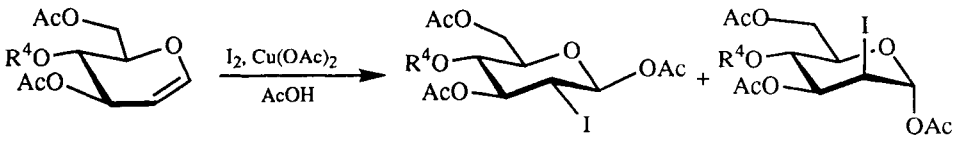
or β-anomeric position. 2-Deoxy-2-halogeno glycosides are generally prepared from glycals *via* halogenation[13-18] or alkoxyhalogenation, using either *N*-bromo-, *N*-iodo-succinimide[7,19,20] or iodine collidine perchlorate[21] as electrophilic source in the presence of an alcohol. Most of these methods are very stereoselective in favor of the α-1,2-*trans* diaxial adduct; however, the separation of the 1,2-*trans* adducts is often difficult or even impossible. This prompted us to report our results involving a two step iodoalkoxylation reaction which allows the stereospecific formation of the α-1,2-*trans* adduct.

RESULTS AND DISCUSSION

Cohalogenation in organic synthesis has been recently reviewed.[22] Thus *trans*-iodoacetoxylation can be achieved using either iodine and a metal acetate in acetic acid or *N*-iodosuccinimide, most often in acetic acid. Applications of these reactions to carbohydrate chemistry were recently reported in the literature. Thus, 1,2,3,4-tetra-*O*-acetyl-2-deoxy-2-iodo-α-D-mannopyranose (**5**) was obtained in 50% yield from 3,4,6-tri-*O*-acetyl-D-glucal (**1**) and iodine in *tert*-butyl alcohol in the presence of an acetate buffer.[23] Roush et al.[24] prepared 1-*O*-acetyl-2,6-dideoxy-2-iodo-4-*O*-isobutyryl-3-*C*-methyl-α-L-mannopyranose *via* a highly stereoselective addition of *N*-iodosuccinimide and acetic acid to a glycal precursor in acetonitrile at low temperature. The iodoacetoxylation reaction (*N*-iodosuccinimide/AcOH/60 °C) has also been applied to a 2,3-unsaturated derivative of KDO affording the α-2,3-*trans*-diaxial iodo adduct as the major compound.[25]

Recently, we have published a three step synthesis of β-glycosides of *N*-acetyllactosamine from peracetylated lactal **2** *via* an iodoacetoxylation reaction.[26] Thus, the iodoacetoxylation reaction [I_2/Cu(OAc)$_2$/AcOH/80 °C] applied to hexa-*O*-acetyl lactal **2** was regio- and stereospecific leading to the α-1,2-*trans*-1-*O*-acetyl-2-deoxy-2-iodo adduct **6** in high yield and without purification by column chromatography.

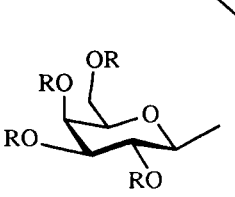
Since then, we have performed the same reaction on 3,4,6-tri-*O*-acetyl-D-glucal (**1**) and 3,4-di-*O*-acetyl-L-rhamnal (**3**). A high stereoselectivity was observed in favor of the α-1,2-*trans*-diaxial adducts **5** and **8** (**4**:**5** and **7**:**8** = 1:11 and 1:4 respectively). Evidence for α-1,2-*trans*-diaxial configuration of the compounds **5**, **6**, **8** was obtained by ^{1}H and ^{13}C NMR ($\delta_{H\text{-}1}$ 6.34-6.40 ppm, $\delta_{H\text{-}2}$ 4.52-4.54 ppm, $J_{1,2}$ 1.0-2.3 Hz, $J_{2,3}$ 4.2-4.5 Hz, $\delta_{C\text{-}1}$ 94.49-94.75 ppm, $\delta_{C\text{-}2}$ 27.36-28.03 ppm); the β-1,2-*trans*-diequatorial configuration of compounds **4** and **7** was also ascertained by ^{1}H and ^{13}C NMR ($\delta_{H\text{-}1}$ 5.85-5.88 ppm, $\delta_{H\text{-}2}$ 3.96-3.99 ppm, $J_{1,2}$ 9.5-9.6 Hz, $J_{2,3}$ 11.1 Hz, $\delta_{C\text{-}1}$ 93.66-93.86 ppm, $\delta_{C\text{-}2}$ 25.84-26.47 ppm). The products **4**, **5**, **7**, **8** could be separated by column chromatography and the major isomers were recovered in good yields (81% for **5** and 72% for **8**).



1 R^4 = Ac
2 R^4 = **2a**

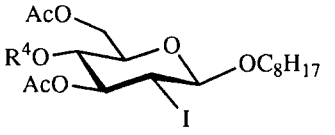
4 R^4 = Ac

5 R^4 = Ac
6 R^4 = **2a**



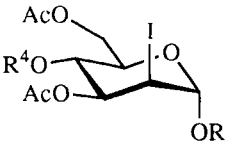
2a R = Ac
2b R = H

ROH, TMSOTf
CH_2Cl_2

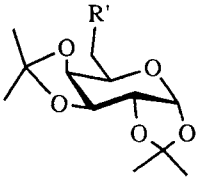


14 R^4 = Ac
15 R^4 = **2a**

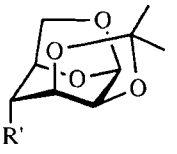
ROH, TMSOTf
CH_2Cl_2



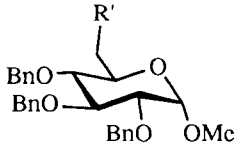
9 R = Me, R^4 = Ac
10 R = *n*-C_8H_{17}, R^4 = Ac
11 R = *n*-C_8H_{17}, R^4 = **2a**
12 R = *n*-$C_{10}H_{21}$, R^4 = **2a**
13 R = *n*-$C_{12}H_{25}$, R^4 = **2a**
19 R = **16a**, R^4 = Ac
20 R = **17a**, R^4 = Ac
21 R = **18a**, R^4 = Ac
22 R = **16a**, R^4 = **2a**
23 R = **17a**, R^4 = **2a**
24 R = **18a**, R^4 = **2a**



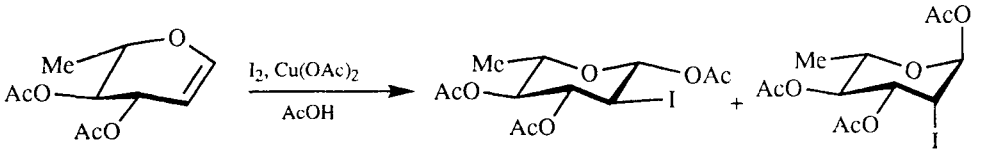
16 R' = OH
16a R' = –



18 R' = OH
18a R' = –



17 R' = OH
17a R' = –



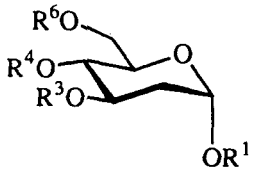
3 **7** **8**

Compounds **5** and **6** were tested as glycosyl donors in glycosylation reactions with simple linear alcohols. Thus, glycosylation of methanol with the donor **5** promoted by trimethylsilyl trifluoromethanesulfonate (0.27 equiv) in methylene chloride (rt, 4Å molecular sieves) was very fast and gave the methyl 3,4,6-tri-*O*-acetyl-2-deoxy-2-iodo-α-D-mannopyranoside (**9**) in 90% yield. An iodonium intermediate can be postulated to explain the attack of the alcohol on the α-face, at the anomeric position. Glycosylation of linear fatty alcohol ($C_nH_{2n+1}OH$, n = 8,10,12) under similar conditions were unsuccessful, probably due to their lower reactivity; nevertheless, their silylated analogs could afford the expected glycosides **10-13** in good yields (73-80%). In order to compare this method with that previously reported (using *N*-iodosuccinimide and the alcohol in methylene chloride), the glycals **1** and **2** were reacted with an excess of *n*-octanol and *N*-iodosuccinimide at room temperature. A mixture of the 1,2-*trans* 2-deoxy-2-iodo adducts **10** and **14** (8:1) was obtained from **1**, together with the starting material (12%). Compound **10** and **14** could be isolated in a pure form in 65 and 8% yield respectively. Addition of *n*-octanol onto lactal **2** under the same conditions was complete and more stereoselective (9:1), but it was impossible to isolate the pure isomers **11** and **15** from the crude mixture.

Glycosylations of donors **5** and **6** with monosaccharide acceptors **16-18** were also tested in order to obtain di- and trisaccharides. These reactions were performed at lower temperature (-15 °C) in methylene chloride in the presence of a slight excess of acceptor (1.25-1.40 equiv) and a stoichiometric amount of trimethylsilyl trifluoromethane-sulfonate. Good yields were obtained from the donors **5** and **6** (73-80% and 65-79% respectively). For comparison, the reaction of peracetylated glucal **1** with 1,2:3,4-bis-*O*-(1-methylethylidene)-α-D-galactopyranose (**16**) and *N*-iodosuccinimide in methylene chloride afforded compound **19** in 62% yield[19] (**19** was obtained in 72% yield from the iodoacetate **5** and the alcohol **16** with our method). In our hand, reaction of peracetylated lactal **2** with NIS and the same alcohol **16** afforded the trisaccharide **22** in 60% yield (79% following the iodoacetoxylation method). As for the iodoacetate adducts, the structure of the glycosides were confirmed by ^1H and ^{13}C NMR.

Compound **9-11** were deiodinated by tributyltin hydride in benzene at 60 °C, affording the per-*O*-acetylated methyl 2-deoxy-α-D-*arabino*-hexopyranoside **25**[27] (77%), octyl 2-deoxy-α-D-*arabino*-hexopyranoside **26** (84%) and octyl 2-deoxy-4-*O*-β-D-galactopyranosyl-α-D-*arabino*-hexopyranoside **27** (91%), respectively. Product **26** and **27** were deacetylated by Zemplén procedure, and water solubility of the corresponding deprotected sugars **28** and **29** was examined in order to determine their physicochemical properties and to compare them with literature data.[28] Octyl 2-deoxy-α-D-*arabino*-hexopyranoside (**28**) was insoluble in water, contrary to octyl 2-deoxy-4-*O*-β-D-

galactopyranosyl-α-D-*arabino*-hexopyranoside (**29**). In this later case, we were able to determine the Krafft boundary temperature, the critical micellar concentration (cmc), the



25 R^1 = Me, R^3 = R^4 = R^6 = Ac
26 R^1 = n-C_8H_{17}, R^3 = R^4 = R^6 = Ac
27 R^1 = n-C_8H_{17}, R^3 = R^6 = Ac, R^4 = **2a**
28 R^1 = n-C_8H_{17}, R^3 = R^4 = R^6 = H
29 R^1 = n-C_8H_{17}, R^3 = R^6 = H, R^4 = **2b**

interfacial area per molecule at the air-water interface and surface tension at the cmc. Krafft temperature (36 °C) was determined by slow heating of aqueous mixtures containing 0.01 M, 0.1 M and 1 M of compound **29**. The surface tension (γ) measurements were carried out by the ring method of Lecomte du Nouÿ[29] and corrected according to Harkins and Jordan.[30] Measurements were performed above the Krafft temperature (at 40 °C) and the cmc was determined at the break of the slope in the γ versus log[C] plots, as usual. The interfacial area per molecule (a_o) was calculated for concentrations just below the cmc according to the Gibbs law. The experimental values thus determined, were respectively 6 mM for the cmc, 36.2 $mN.m^{-1}$ for γ at the interface and 65 $Å^2$ for a_o. The cmc value was very close to that found at 60 °C for octyl α-D-mannopyranoside.[28]

CONCLUSION

In conclusion, the use of 2-iodo sugars with an anomeric acetyl group in α-1,2-*trans* configuration complements the previous methods for the synthesis of 2-iodo and 2-deoxy glycosides. This methodology simplifies the separation of the intermediate adducts and can afford derivatives useful for biochemical applications such as labeled oligosaccharides (^2H, ^3H, ^{125}I or ^{131}I) or nonionic surfactants.

EXPERIMENTAL

General methods. Pyridine was dried by boiling with calcium hydride prior to distillation. Dichloromethane was washed twice with water, dried with calcium chloride

and distilled from phosphorous pentoxide. Methanol was refluxed with sodium methylate before distillation. Pyridine and dichloromethane were stored over 4 Å molecular sieves and methanol over 3 Å molecular sieves. Melting points were determined on a Büchi apparatus and were uncorrected. TLC analyses were performed on aluminium sheets coated with silica gel 60 F 254 Merck. Compounds were visualized by spraying the TLC plates with dilute 15 % aqueous sulfuric acid, followed by charring at 150 °C for a few minutes. Column chromatographies were performed on silica-gel Geduran Si 60 Merck. Optical rotations were recorded on a Perkin Elmer 241 polarimeter in a 1 dm cell at 21 °C. ^1H and ^{13}C NMR spectra were recorded with Bruker AC-200 or AM-300 spectrometers operating at 200 or 300 MHz and 50 or 75.5 MHz respectively with tetramethylsilane as internal standard. Elemental analyses were carried out by the "Laboratoire Central d'Analyses du CNRS" (Vernaison, France).

1,3,4,6-Tetra-*O*-acetyl-2-deoxy-2-iodo-β-D-glucopyranose (4) and 1,3,4,6-tetra-*O*-acetyl-2-deoxy-2-iodo-α-D-mannopyranose (5). 3,4,6-Tri-*O*-acetyl-D-glucal (**1**) (5.0 g, 18.36 mmol), $Cu(OAc)_2.6H_2O$ (4.03 g, 20.20 mmol, 1.10 equiv) and iodine (5.65 g, 22.26 mmol, 1.22 equiv) were successively added to AcOH (110 mL) and the mixture was stirred for 6 h at 80 °C under argon, then cooled to room temperature and concentrated to dryness. Ether (200 mL) was added to the residue and the organic layer was washed with saturated aq $NaHCO_3$ until neutral, then with aq $Na_2S_2O_3$, then with water. The organic layer was dried (Na_2SO_4) and concentrated. The ^1H NMR spectrum of the crude reaction mixture showed the presence of two compounds in a 1:11 ratio. Purification by column chromatography (EtOAc/petroleum ether 1:2 v/v) afforded the pure products **4** and **5** in 7 and 81% yields respectively.

Compound **4** : 0.59 g; colorless solid; mp 110 °C (hexane); R_f 0.57 (EtOAc/petroleum ether 1:2 v/v); $[\alpha]_D$ + 65.6° (*c* 1.0, $CHCl_3$); ^1H NMR ($CDCl_3$) δ 2.02, 2.07, 2.08, 2.10 (4 s, 12 H, 4 CH_3CO), 3.88 (ddd, 1 H, $J_{4,5}$ = 10.0 Hz, $J_{5,6a}$ = 4.5 Hz, $J_{5,6b}$ = 2.1 Hz, H-5), 3.99 (dd, 1 H, $J_{1,2}$ = 9.6 Hz, $J_{2,3}$ = 11.1 Hz, H-2), 4.10 (dd, 1 H, $J_{6a,6b}$ = 12.5 Hz, H-6b), 4.33 (dd, 1 H, H-6a), 5.02 (dd, 1 H, $J_{3,4}$ = 9.1 Hz, H-4), 5.35 (dd, 1 H, H-3), 5.88 (d, 1 H, H-1); ^{13}C NMR ($CDCl_3$) δ 20.54, 20.67, 20.67, 20.67 (4 C, 4 CH_3CO), 25.84 (C-2), 61.46 (C-6), 68.50 (C-4), 72.89 (C-3), 75.14 (C-5), 93.86 (C-1), 168.43, 169.37, 169.42, 170.43 (4 C, 4 CH_3CO).

Anal. Calcd for $C_{14}H_{19}IO_9$ (458.19): C, 36.69; H, 4.18; I, 27.70. Found: C, 36.95; H, 4.20; I, 27.37.

Compound **5** : 6.81 g; syrup; R_f 0.45 (EtOAc/petroleum ether 1:2 v/v); $[\alpha]_D$ + 14.2° (*c* 1.0, $CHCl_3$) [lit[23] $[\alpha]_D$ + 13.0° (*c* 1.0, $CHCl_3$)]; ^1H NMR ($CDCl_3$) δ 2.07, 2.11, 2.12, 2.17 (4 s, 12 H, 4 CH_3CO), 4.12 (ddd, 1 H, $J_{4,5}$ = 9.6 Hz, $J_{5,6a}$ = 4.6 Hz, $J_{5,6b}$ = 2.3

Hz, H-5), 4.15 (dd, 1 H, $J_{6a,6b}$ = 12.4 Hz, H-6b), 4.24 (dd, 1 H, H-6a), 4.53 (dd, 1 H, $J_{1,2}$ = 1.5 Hz, $J_{2,3}$ = 4.4 Hz, H-2), 4.59 (dd, 1 H, $J_{3,4}$ = 9.2 Hz, H-3), 5.46 (dd, 1 H, H-4), 6.40 (d, 1 H, H-1); ^{13}C NMR ($CDCl_3$) δ 20.59, 20.68, 20.80, 20.87 (4 C, 4 CH_3CO), 27.30 (C-2), 61.82 (C-6), 67.03 (C-4), 68.60 (C-3), 71.39 (C-5), 94.65 (C-1), 168.10, 169.25, 169.80, 170.55 (4 C, 4 CH_3CO).

1,3,4-Tri-*O*-acetyl-2,6-dideoxy-2-iodo-β-L-glucopyranose (7) and 1,3,4-tri-*O*-acetyl-2,6-dideoxy-2-iodo-α-L-mannopyranose (8). Prepared as described for **4** and **5** from **1**, starting from 3,4-di-*O*-acetyl-L-rhamnal (**3**) (1.02 g, 4.72 mmol), $Cu(OAc)_2.6H_2O$ (1.04 g, 5.20 mmol, 1.10 equiv) and iodine (1.46 g, 5.75 mmol, 1.22 equiv) in AcOH (30 mL). The ^{1}H NMR spectrum of the crude reaction mixture showed the presence of the two compounds **7** and **8** in a 1:4 ratio. Purification by column chromatography (EtOAc/petroleum ether 2:5 v/v) afforded the pure products **7** and **8** in 18 and 72% yields respectively.

Compound **7** : 0.34 g; colorless solid; mp 100-101 °C (hexane); R_f 0.50 (EtOAc /petroleum ether 1:3 v/v); $[\alpha]_D$ - 83.5° (*c* 1.0, $CHCl_3$); ^{1}H NMR ($CDCl_3$) δ 1.24 (d, 3 H, J_{5,CH_3} = 6.2 Hz, C*H*$_3$), 2.04, 2.10, 2.16 (3 s, 9 H, 3 C*H*$_3$CO), 3.76 (dq, 1 H, $J_{4,5}$ = 9.7 Hz, H-5), 3.96 (dd, 1 H, $J_{1,2}$ = 9.5 Hz, $J_{2,3}$ = 11.1 Hz, H-2), 4.74 (dd, 1 H, $J_{3,4}$ = 9.1 Hz, H-4), 5.30 (dd, 1 H, H-3), 5.85 (d, 1 H, H-1); ^{13}C NMR ($CDCl_3$) δ 17.12 (C-6), 20.52, 20.58, 20.61 (3 C, 3 *C*H_3CO), 26.47 (C-2), 70.99 (C-4), 73.65 (C-3), 75.06 (C-5), 93.66 (C-1), 168.42, 169.28, 169.53 (3 C, 3 CH_3*C*O).

Anal. Calcd for $C_{12}H_{17}IO_7$ (400.16): C, 36.02; H, 4.28; I, 31.71. Found: C, 36.06; H, 4.26; I, 31.59.

Compound **8** : 1.36 g; syrup; R_f 0.38 (EtOAc/petroleum ether 1:3 v/v); $[\alpha]_D$ - 16.9° (*c* 1.0, $CHCl_3$); ^{1}H NMR ($CDCl_3$) δ 1.25 (d, 3 H, J_{5,CH_3} = 6.3 Hz, C*H*$_3$), 2.08, 2.11, 2.15 (3 s, 9 H, 3 C*H*$_3$CO), 4.03 (dq, 1 H, $J_{4,5}$ = 9.6 Hz, H-5), 4.52 (dd, 1 H, $J_{2,3}$ = 4.5 Hz, $J_{3,4}$ = 9.1 Hz, H-3), 4.54 (dd, 1 H, $J_{1,2}$ = 1.0 Hz, H-2), 5.20 (dd, 1 H, H-4), 6.34 (d, 1 H, H-1); ^{13}C NMR ($CDCl_3$) δ 17.53 (C-6), 20.65, 20.81, 20.88 (3 C, 3 *C*H_3CO), 28.03 (C-2), 68.70 (C-4), 69.42 (C-5), 71.98 (C-3), 94.75 (C-1), 168.31, 169.47, 169.87 (3 C, 3 CH_3*C*O).

Anal. Calcd for $C_{12}H_{17}IO_7$ (400.16): C, 36.02; H, 4.28; I, 31.71. Found: C, 35.52; H, 4.24; I, 31.13.

Methyl 3,4,6-Tri-*O*-acetyl-2-deoxy-2-iodo-α-D-mannopyranoside (9). A solution of 1,3,4,6-tetra-*O*-acetyl-2-deoxy-2-iodo-α-D-mannopyranose (**5**) (0.573 g, 1.25 mmol) and methanol (76 μL, 1.87 mmol, 1.50 equiv) in dry CH_2Cl_2 (10 mL) was treated for one hour under argon by trimethylsilyl trifluoromethanesulfonate (79 μL, 0.40 mmol, 0.27 equiv) in the presence of activated 4Å molecular sieves. After filtration and

dilution with CH_2Cl_2, the organic phase was washed with aq $NaHCO_3$, dried and concentrated; the residue was purified by column chromatography using EtOAc/ petroleum ether (2:5 v/v) as the eluent. Yield 90%; syrup; R_f 0.45 (EtOAc/petroleum ether 1:2 v/v); $[\alpha]_D$ + 5.5° (*c* 1.0, $CHCl_3$); ^1H NMR ($CDCl_3$) δ 2.05, 2.08, 2.12 (3 s, 9 H, 3 C*H*$_3$CO), 3.40 (s, 3 H, C*H*$_3$O), 4.00 (ddd, 1 H, $J_{4,5}$ = 9.9 Hz, $J_{5,6a}$ = 4.8 Hz, $J_{5,6b}$ = 2.6 Hz, H-5), 4.15 (dd, 1 H, $J_{6a,6b}$ = 12.2 Hz, H-6b), 4.24 (dd, 1 H, H-6a), 4.53 (dd, 1 H, $J_{1,2}$ = 0.8 Hz, $J_{2,3}$ = 4.3 Hz, H-2), 4.63 (dd, 1 H, $J_{3,4}$ = 9.4 Hz, H-3), 5.09 (d, 1 H, H-1), 5.37 (dd, 1 H, H-4); ^{13}C NMR ($CDCl_3$) δ 20.51, 20.60, 20.79 (3 C, 3 *C*H$_3$CO), 29.19 (C-2), 55.27 (*C*H$_3$O), 62.10 (C-6), 67.36 (C-4), 68.85, 68.87 (2 C, C-3,5), 102.13 (C-1), 168.30, 169.61, 170.46 (3 C, 3 CH$_3$*C*O).

Octyl 3,4,6-Tri-*O*-acetyl-2-deoxy-2-iodo-α-D-mannopyranoside (10). Obtained as described for **9**, from **5** (1.83 g, 4.00 mmol) and *n*-octyl trimethylsilyl ether (1.21 g, 6.00 mmol, 1.50 equiv) in dry CH_2Cl_2 (15 mL) in the presence of trimethylsilyl triflate (506 μL, 2.80 mmol, 0.7 equiv). Stirring was maintained overnight, before treatment. The crude product was purified by column chromatography using EtOAc/petroleum ether (1:4 v/v) as the eluent, affording 1.56 g of pure product **10**. Yield 74%; syrup; R_f 0.53 (EtOAc/petroleum ether 1:3, v/v); $[\alpha]_D$ + 17.1° (*c* 1.0, $CHCl_3$); ^1H NMR ($CDCl_3$) δ 0.88 (t, 3 H, octyl C*H*$_3$), 1.30 (m, 10 H, 5 octyl C*H*$_2$), 1.61 (m, 2 H, 1 octyl C*H*$_2$), 2.06, 2.06, 2.12 (3 s, 9 H, 3 C*H*$_3$CO), 3.45 (ddd, 1 H, CH$_A$*H*$_B$O), 3.66 (ddd, 1 H, C*H*$_A$H$_B$O), 4.02 (ddd, 1 H, $J_{4,5}$ = 9.9 Hz, $J_{5,6a}$ = 4.8 Hz, $J_{5,6b}$ = 2.5 Hz, H-5), 4.14 (dd, 1 H, $J_{6a,6b}$ = 12.2 Hz, H-6b), 4.24 (dd, 1 H, H-6a), 4.53 (dd, 1 H, $J_{1,2}$ = 0.6 Hz, $J_{2,3}$ = 4.3 Hz, H-2), 4.65 (dd, 1 H, $J_{3,4}$ = 9.4 Hz, H-3), 5.17 (d, 1 H, H-1), 5.37 (dd, 1 H, H-4); ^{13}C NMR ($CDCl_3$) δ 13.90 (octyl *C*H$_3$), 20.44, 20.52, 20.74 (3 C, 3 *C*H$_3$CO), 22.43, 25.88, 28.98, 29.08, 29.14 (5 octyl *C*H$_2$), 29.68 (C-2), 31.58 (1 octyl *C*H$_2$), 62.10 (C-6), 68.48 (O*C*H$_2$), 67.43 (C-4), 68.89, 68.93 (C-3,5), 101.07 (C-1), 169.22, 169.52, 170.33 (3 C, 3 CH$_3$*C*O).

Anal. Calcd for $C_{20}H_{33}IO_8$ (528.36): C, 45.46; H, 6.29; I, 24.01. Found: C, 45.49; H, 6.30; I, 24.88.

Octyl 3,6-Di-*O*-acetyl-4-*O*-(2,3,4,6-tetra-*O*-acetyl-β-D-galactopyranosyl)-2-deoxy-2-iodo-α-D-mannopyranoside (11). Obtained as described for **10**, from **6** (2.24 g, 3.0 mmol) and *n*-octyl trimethylsilyl ether (0.910 g, 4.50 mmol, 1.50 equiv) in dry CH_2Cl_2 (10 mL) in the presence of trimethylsilyl triflate (380 μL, 2.10 mmol, 0.70 equiv). The crude product was purified by column chromatography using EtOAc/petroleum ether (1:2 then 1:1 v/v) as the eluent, affording 1.79 g of pure product **11**. Yield 73%; solid, mp 100-101 °C (hexane); R_f 0.32 (EtOAc/petroleum ether 1:2 v/v); $[\alpha]_D$ + 23.8° (*c* 1.0, $CHCl_3$); ^1H NMR ($CDCl_3$) δ 0.89 (t, 3 H, octyl C*H*$_3$), 1.29 (m, 10

H, 5 octyl CH_2), 1.59 (m, 2 H, 1 octyl CH_2), 1.98, 2.05, 2.08, 2.14, 2.14, 2.16 (6 s, 18 H, 6 CH_3CO), 3.42 (ddd, 1 H, CH_AH_BO), 3.64 (ddd, 1 H, CH_AH_BO), 3.90-3.96 (m, 2 H, H-5,5'), 3.98 (dd, 1 H, $J_{3,4}$ = 7.2 Hz, $J_{4,5}$ = 9.4 Hz, H-4), 4.08 (dd, 1 H, $J_{5',6'b}$ = 6.8 Hz $J_{6'a,6'b}$ = 11.0 Hz, H-6'b), 4.13 (m, 1 H, H-6b), 4.18 (dd, 1 H, $J_{5',6'a}$ = 7.0 Hz, H-6'a), 4.44 (dd, 1 H, $J_{5,6a}$ = 1.0 Hz, $J_{6a,6b}$ = 10.8 Hz, H-6a), 4.51 (dd, 1 H, $J_{1,2}$ = 1.0 Hz, $J_{2,3}$ = 4.1 Hz, H-2), 4.57 (d, 1 H, $J_{1',2'}$ = 7.8 Hz, H-1'), 4.72 (dd, 1 H, $J_{3,4}$ = 7.2 Hz, H-3), 5.00 (dd, 1 H, $J_{2',3'}$ = 10.4 Hz, $J_{3',4'}$ = 3.1 Hz, H-3'), 5.10 (d, 1 H, H-1), 5.17 (dd, 1 H, H-2'), 5.37 (dd, 1 H, $J_{4',5'}$ = 0.6 Hz, H-4'); ^{13}C NMR ($CDCl_3$) δ 14.03 (octyl CH_3), 20.45, 20.55, 20.55, 20.64, 20.79, 21.02 (6 C, 6 CH_3CO), 22.55, 25.95, 28.96, 29.11, 29.22 (5 octyl CH_2), 30.30 (C-2), 31.72 (1 octyl CH_2), 61.18 (C-6'), 62.21 (C-6), 66.80 (C-4'), 68.66 (OCH_2), 69.16 (C-2'), 69.36 (C-5), 69.79 (C-3), 70.58 (C-5'), 70.95 (C-3'), 75.97 (C-4), 101.05 (C-1), 101.29 (C-1'), 169.20, 169.31, 169.95, 170.06, 170.33, 170.38 (6 C, 6 CH_3CO).

Anal. Calcd for $C_{32}H_{49}IO_{16}$ (816.62): C, 47.06; H, 6.05; I, 15.04. Found: C, 47.13; H, 6.05; I, 14.76.

Decyl 3,6-Di-*O*-acetyl-4-*O*-(2,3,4,6-tetra-*O*-acetyl-β-D-galactopyranosyl)-2-deoxy-2-iodo-α-D-mannopyranoside (12). Obtained as described for **10**, from **6** (1.12 g, 1.50 mmol) and *n*-decyl trimethylsilyl ether (0.518 g, 2.25 mmol, 1.50 equiv) in dry CH_2Cl_2 (8 mL) in the presence of trimethylsilyl triflate (190 μL, 1.05 mmol, 0.70 equiv). The crude product was purified by column chromatography using EtOAc/petroleum ether (1:2 then 1:1 v/v) as the eluent, affording 0.975 g of pure product **12**. Yield 77%; solid, mp 77-78 °C (hexane); R_f 0.83 (EtOAc/petroleum ether 1:1 v/v); $[\alpha]_D$ + 23.0° (*c* 1.0, $CHCl_3$).

Anal. Calcd for $C_{34}H_{53}IO_{16}$ (844.66): C, 48.34; H, 6.32; I, 15.02. Found: C, 48.17; H, 6.12; I, 15.20.

Dodecyl 3,6-Di-*O*-acetyl-4-*O*-(2,3,4,6-tetra-*O*-acetyl-β-D-galactopyranosyl)-2-deoxy-2-iodo-α-D-mannopyranoside (13). Obtained as described for **10**, from **6** (1.49 g, 2.00 mmol) and *n*-dodecyl trimethylsilyl ether (0.904 g, 3.50 mmol, 1.75 equiv) in dry CH_2Cl_2 (10 mL) in the presence of trimethylsilyl triflate (253 μL, 1.40 mmol, 0.70 equiv). The crude product was purified by column chromatography using EtOAc/petroleum ether (1:2 then 1:1 v/v) as the eluent, affording 1.40 g of pure product **13**. Yield 80%; solid, mp 78-79 °C (hexane); R_f 0.60 (EtOAc/petroleum ether 4:5 v/v); $[\alpha]_D$ + 26.9° (*c* 1.0, $CHCl_3$).

Anal. Calcd for $C_{36}H_{57}IO_{16}$ (872.72): C, 49.54; H, 6.58; I, 14.54. Found: C, 49.46; H, 6.50; I, 15.14.

Octyl 3,4,6-Tri-*O*-acetyl-2-deoxy-2-iodo-β-D-glucopyranoside (14). 3,4,6-Tri-*O*-acetyl-D-glucal (**1**) (0.136 mg, 0.50 mmol) was dissolved in dry acetonitrile (2 mL) and *n*-octanol (118 μL, 0.75 mmol, 1.50 equiv) was added, followed by *N*-iodosuccinimide (0.169 g, 0.75 mmol, 1.50 equiv). The mixture was stirred overnight in the dark, then concentrated and diluted with CH_2Cl_2 (30 mL), washed with 10% aq $Na_2S_2O_3$ and then with water and dried (Na_2SO_4). The ^1H NMR spectrum of the crude product showed the presence of the α-D-*manno* and the β-D-*gluco* adducts in an 8:1 ratio together with starting material (~12%). The crude mixture was purified by column chromatography (EtOAc/petroleum ether 2:5 v/v) affording the pure compounds **10** and **14**. Compound **10** (0.172 g, 65%) was identical with the sample described preceedingly; compound **14** (0.021 g, 8%) was a syrup; R_f 0.43 (EtOAc/petroleum ether 1:3 v/v); $[\alpha]_D$ + 41.7 ° (*c* 1.0, $CHCl_3$); ^1H NMR ($CDCl_3$) δ 0.88 (t, 3 H, octyl CH_3), 1.27 (m, 10 H, 5 octyl CH_2), 1.62 (m, 2 H, 1 octyl CH_2), 2.01, 2.08, 2.09 (3 s, 9 H, 3 CH_3CO), 3.54 (ddd, 1 H, CH_AH_BO), 3.73 (ddd, 1 H, $J_{4,5}$ = 9.9 Hz, $J_{5,6a}$ = 4.7 Hz, $J_{5,6b}$ = 2.3 Hz, H-5), 3.88 (ddd, 1 H, CH_AH_BO), 3.89 (dd, 1 H, $J_{1,2}$ = 9.0 Hz, $J_{2,3}$ = 11.1 Hz, H-2), 4.12 (dd, 1 H, $J_{6a,6b}$ = 12.3 Hz, H-6b), 4.30 (dd, 1 H, H-6a), 4.60 (d, 1 H, H-1), 4.96 (dd, 1 H, $J_{3,4}$ = 9.1 Hz, H-4), 5.30 (dd, 1 H, H-3); ^{13}C NMR ($CDCl_3$) δ 13.92 (octyl CH_3), 20.41, 20.53, 20.59 (3 C, 3 CH_3CO), 22.46, 25.71 (2 octyl CH_2), 28.38 (C-2), 29.13, 29.18, 29.18, 31.70 (4 octyl CH_2), 61.86 (C-6), 69.15 (C-4), 70.64 (OCH_2), 71.81 (C-5), 75.48 (C-3), 102.89 (C-1), 169.31, 169.49, 170.41 (3 C, 3 CH_3CO).

Anal. Calcd for $C_{20}H_{33}IO_8$ (528.36): C, 45.46; H, 6.29; I, 24.01. Found: C, 45.46; H, 6.30; I, 23.96.

Octyl 3,6-Di-*O*-acetyl-4-*O*-(2,3,4,6-tetra-*O*-acetyl-β-D-galactopyranosyl)-2-deoxy-2-iodo-β-D-glucopyranoside (15). Obtained as described for **10** and **14**, from peracetylated lactal **2** (0.230 g, 0.5 mmol), *n*-octanol (118 μL, 0.75 mmol, 1.50 equiv) and *N*-iodosuccinimide (0.169 g, 0.75 mmol, 1.50 equiv) in dry acetonitrile (2 mL). The ^{13}C NMR spectrum of the crude product showed the presence of two products, i.e., the α-D-*manno* adduct **11** and the β-D-*gluco* adduct **15** ($\delta_{C\text{-}1}$ 103.03, $\delta_{C\text{-}1'}$ 101.02) in quantitative yield (9:1 ratio). However, their separation by column chromatography was unsuccessful.

6-*O*-(3,4,6-Tri-*O*-acetyl-2-deoxy-2-iodo-α-D-mannopyranosyl)-1,2:3,4-bis-*O*-(1-methylethylidene)-α-D-galactopyranose (19). A solution of 1,3,4,6-tetra-*O*-acetyl-2-deoxy-2-iodo-α-D-mannopyranose (**5**) (0.165 g, 0.36 mmol) and 1,2:3,4-bis-*O*-(1-methylethylidene)-α-D-galactopyranose (**16**) (0.117 g, 0.45 mmol, 1.25 equiv) in dry CH_2Cl_2 (3 mL) containing activated 4Å molecular sieves was cooled to -15 °C under argon and TMSOTf (68 μL, 0.376 mmol, 1.05 equiv) was added. Stirring was

maintained for 16 h at - 15 °C and after addition CH_2Cl_2 (30 mL), the the organic layer was washed with aq $NaHCO_3$, then with water, dried (Na_2SO_4) and concentrated. Purification of the residue by column chromatography, using EtOAc/petroleum ether 1:1 (v/v) as the eluent afforded the pure product **19** (0.171 g) as an amorphous solid. Yield 72%; R_f 0.66 (EtOAc/petroleum ether 1:1 v/v); $[\alpha]_D$ - 18.0° (*c* 1.0, $CHCl_3$) [lit[19] - 16.4 (*c* 1.0, $CHCl_3$)]; ^1H NMR ($CDCl_3$) δ 1.34, 1.34, 1.43, 1.54 (4 s, 12 H, 4 CH_3C), 2.05, 2.08, 2.12 (3 s, 9 H, 3 CH_3CO), 3.71 (dd, 1 H, $J_{5,6b}$ = 6.4 Hz, $J_{6a,6b}$ = 10.3 Hz, H-6b), 3.80 (dd, 1 H, $J_{5,6a}$ = 6.3 Hz, H-6a), 3.96 (ddd, 1 H, $J_{4,5}$ = 1.5 Hz, H-5), 4.10-4.20 (m, 3 H, H-5',6'a,6'b), 4.23 (dd, 1 H, $J_{3,4}$ = 8.0 Hz, H-4), 4.32 (dd, 1 H, $J_{1,2}$ = 5.0 Hz, $J_{2,3}$ = 2.5 Hz, H-2), 4.57 (dd, 1 H, $J_{1',2'}$ = 1.1 Hz, $J_{2',3'}$ = 4.3 Hz, H-2'), 4.60-4.67 (m, 2 H, H-3,3'), 5.24 (d, 1 H, H-1'), 5.38 (dd, 1 H, $J_{3',4'}$ = 9.1 Hz, $J_{4',5'}$ = 9.5 Hz, H-4'), 5.51 (d, 1 H, H-1); ^{13}C NMR ($CDCl_3$) δ 20.61, 20.71, 20.89 (3 C, 3 CH_3CO), 24.48, 24.89, 25.92, 26.06, (4 C, 4 CH_3C), 29.51 (C-2'), 62.06 (C-6'), 66.11 (C-4), 66.98 (C-6), 67.36 (C-4'), 69.03, 69.15 (2 C, C-3',5'), 70.46, 70.57, 70.85 (3 C, C-2,3,5), 96.20 (C-1), 101.21 (C-1'), 108.60, 109.36 (2 C, 2 $C(CH_3)_2$), 169.38, 169.69, 170.57 (3 C, 3 CH_3CO).

Methyl 6-*O*-(3,4,6-Tri-*O*-acetyl-2-deoxy-2-iodo-α-D-mannopyranosyl)-2,3,4-tri-*O*-benzyl-α-D-glucopyranoside (20). Obtained as described for **19**, from **5** (0.185 g, 0.40 mmol) and methyl 2,3,4-tri-*O*-benzyl-α-D-glucopyranoside (**17**) (0.260 g, 0.56 mmol, 1.40 equiv) in dry CH_2Cl_2 in the presence of TMSOTf (75 μL, 0.418 mmol, 1.05 equiv). After conventional treatment, the residue was acetylated overnight in a 2:1 (v/v) mixture of Ac_2O and pyridine (5 mL) before to be purified by column chromatography [eluent: EtOAc/petroleum ether 4:5 (v/v)]. Product **20** (0.350 g) was recovered as a syrup. Yield 73%; R_f 0.54 (EtOAc/petroleum ether 1:1 v/v); $[\alpha]_D$ + 38.9° (*c* 1.0, $CHCl_3$); ^1H NMR ($CDCl_3$) δ 2.02, 2.05, 2.08 (3 s, 9 H, 3 CH_3CO), 3.38 (s, 3H, CH_3O), 3.43-4.05 (m, 9 H, H-2,3,4,5,6a,6b,5',6'a,6'b), 4.50-4.60 (m, 3 H, H-1,2',CHPh), 4.62 (dd, 1 H, $J_{2',3'}$ = 4.1 Hz, $J_{3',4'}$ = 8.7 Hz, H-3'), 4.70-5.02 (m, 5H, 2.5 CH_2Ph), 5.22 (bs, 1 H, H-1'), 5.35 (d, 1 H, $J_{4',5'}$ = 9.5 Hz, H-4'), 7.25-7.32 (m, 15 H, 3 C_6H_5); ^{13}C NMR ($CDCl_3$) δ 20.70, 20.78, 21.01 (3 C, 3 CH_3CO), 29.36 (C-2'), 55.29 (CH_3O), 62.06 (C-6'), 66.80 (C-6), 67.46 (C-4'), 67.36 (C-4'), 69.04 (C-5'), 69.26 (C-3'), 69.75 (C-5), 73.44, 74.95, 75.85 (3 C, 3 CH_2Ph), 77.64 (C-4), 80.14 (C-2), 82.18 (C-3), 98.03 (C-1), 101.47 (C-1'), 127.50-128.56, 138.16, 138.29, 138.66 (18 C, 3 C_6H_5), 169.42, 169.76, 170.60 (3 C, 3 CH_3CO).

Anal. Calcd for $C_{40}H_{47}IO_{13}$ 0.5 H_2O (871.68): C, 55.11; H, 5.55; I, 14.55. Found: C, 55.10; H, 5.53; I, 14.25.

4-*O*-(3,4,6-Tri-*O*-acetyl-2-deoxy-2-iodo-α-D-mannopyranosyl)-1,6-anhydro-2,3-*O*-(1-methylethylidene)-β-D-manopyranose (21). Obtained as described for **19**, from **5** (0.135 g, 0.295 mmol) and 1,6-anhydro-2,3-*O*-(1-methylethylidene)-β-D-mannopyranose (**18**) (0.080 g, 0.395 mmol, 1.34 equiv). The residue was purified by column chromatography, using EtOAc/petroleum ether 3:2 (v/v) as the eluent. Product **21** (0.141 g) was recovered as a solid. Yield 80%; mp 167-168 °C; R_f 0.71 (EtOAc/petroleum ether 1:1 v/v); $[\alpha]_D$ - 16.3° (*c* 1.0, $CHCl_3$); ^1H NMR ($CDCl_3$) δ 1.33, 1.53 (2 s, 6 H, 2 CH_3C), 2.07, 2.09, 2.10 (3 s, 9 H, 3 CH_3CO), 3.73 (dd, 1 H, $J_{5,6b}$ = 6.3 Hz, $J_{6a,6b}$ = 7.3 Hz, H-6b), 3.91 (m, 1 H, H-4), 3.96 (dd, 1 H, $J_{5,6a}$ = 1.5 Hz, H-6a), 4.09 (dd, 1 H, $J_{1,2}$ = 2.9 Hz, $J_{2,3}$ = 6.5 Hz, H-3), 4.16 (d, 1 H, $J_{5',6'b}$ = 5.5 Hz, J6'a,6'b = 12.5 Hz, H-6'b), 4.18-4.22 (m, 2 H, H-3,6'a), 4.27 (dd, 1 H, $J_{4',5'}$ = 9.9 Hz, $J_{5',6'a}$ = 2.6 Hz, H-5'), 4.59 (dd, 1 H, $J_{1',2'}$ = 1.5 Hz, $J_{2',3'}$ = 4.4 Hz, H-2'), 4.65 (dd, 1 H, $J_{3',4'}$ = 8.2 Hz, H-3'), 4.79 (ddd, 1 H, $J_{4,5}$ = 1.0 Hz, H-5), 5.34 (dd, 1 H, H-4'), 5.35 (d, 1 H, H-1), 5.40 (d, 1 H, H-1'); ^{13}C NMR ($CDCl_3$) δ 20.76, 20.79, 21.04 (3 C, 3 CH_3CO), 26.02, (2 C, 2 CH_3C), 29.41 (C-2'), 62.42 (C-6'), 64.43 (C-6), 67.63 (C-4'), 69.03 (C-5'), 69.92 (C-3'), 72.12 (C-2), 73.73 (C-3), 74.35 (C-5), 77.83 (C-4), 99.36 (C-1), 102.53 (C-1'), 110.17 ($C(CH_3)_2$), 169.61, 169.87, 170.57 (3 C, 3 CH_3CO).

Anal. Calcd for $C_{21}H_{29}IO_{12}$ (600.34): C, 42.01; H, 4.87; I, 21.14. Found: C, 42.23; H, 4.83; I, 20.93.

6-*O*-[3,6-Di-*O*-acetyl-4-*O*-(2,3,4,6-tetra-*O*-acetyl-β-D-galactopyranosyl)-2-deoxy-2-iodo-α-D-mannopyranosyl]-1,2:3,4-bis-*O*-(1-methylethylidene)-α-D-galactopyranose (22). Obtained as described for **20**, from the disaccharidic donor **6** (0.187 g, 0.25 mmol) and 1,2:3,4-bis-*O*-(1-methylethylidene)-α-D-galactopyranose (**16**) (0.091 g, 0.35 mmol, 1.40 equiv). The acetylated residue was purified by column chromatography, using EtOAc/petroleum ether 3:2 (v/v) as the eluent. Product **22** (0.187 g) was recovered as an amorphous solid. Yield 79%; R_f 0.72 (EtOAc/petroleum ether 3:2 v/v); $[\alpha]_D$ - 5.0° (*c* 1.0, $CHCl_3$); ^1H NMR ($CDCl_3$) δ 1.33, 1.34, 1.42, 1.55 (4 s, 12 H, 4 CH_3C), 1.97, 2.07, 2.08, 2.12, 2.14, 2.16 (6 s, 18 H, 6 CH_3CO), 3.70 (dd, 1 H, $J_{5,6b}$ = 6.6 Hz, $J_{6a,6b}$ = 10.3 Hz, H-6b), 3.77 (dd, 1 H, $J_{5,6a}$ = 6.0 Hz, H-6a), 3.90-4.20 (m, 7 H, H-5,4',5',6'b,5",6"a,6"b), 4.24 (dd, 1 H, $J_{3,4}$ = 7.7 Hz, $J_{4,5}$ = 1.8 Hz, H-4), 4.31 (dd, 1 H, $J_{1,2}$ = 4.9 Hz, $J_{2,3}$ = 2.4 Hz, H-2), 4.43 (dd, 1 H, $J_{5',6'a}$ = 1.4 Hz, $J_{6'a,6'b}$ = 11.8 Hz, H-6'a), 4.54 (dd, 1 H, $J_{1',2'}$ = 1.7 Hz, $J_{2',3'}$ = 4.2 Hz, H-2'), 4.57 (d, 1 H, $J_{1",2"}$ = 7.8 Hz, H-1"), 4.62 (dd, 1 H, H-3), 4.67 (dd, 1 H, $J_{3',4'}$ = 7.6 Hz, H-3'), 4.99 (dd, 1 H, $J_{2",3"}$ = 10.5 Hz, $J_{3",4"}$ = 3.3 Hz, H-3"), 5.15 (dd, 1 H, H-2"), 5.17 (d, 1 H, H-1'), 5.37 (dd, 1 H, $J_{4",5"}$ = 0.8 Hz, H-4"), 5.48 (d, 1 H, H-

1); ^{13}C NMR ($CDCl_3$) δ 20.46, 20.54, 20.58, 20.67, 20.86, 21.02 (6 C, 6 CH_3CO), 24.41, 24.82, 25.90, 26.03, (4 C, 4 CH_3C), 30.06 (C-2'), 61.18 (C-6"), 62.09 (C-6'), 66.33, 66.81 (C-4,4"), 67.25 (C-6), 69.05, 69.46, 69.50, 70.54, 70.54, 70.54, 70.82, 71.02 (8 C, C-2,3,5,3',5',2",3",5"), 75.68 (C-4'), 96.16 (C-1), 101.13, 101.17 (C-1',1"), 108.82, 109.33 (2 C, 2 $C(CH_3)_2$), 169.14, 169.48, 169.97, 170.09, 170.35, 170.50 (6 C, 6 CH_3CO).

Anal. Calcd for $C_{36}H_{51}IO_{21}$ (946.67): C, 45.67; H, 5.43; I, 13.40. Found: C, 45.36; H, 5.48; I, 13.27.

Methyl 6-*O*-[3,6-Di-*O*-acetyl-4-*O*-(2,3,4,6-tetra-*O*-acetyl-β-D-galactopyranosyl)-2-deoxy-2-iodo-α-D-mannopyranosyl)-2,3,4-tri-*O*-benzyl-α-D-glucopyranoside (23). Obtained as described for **20**, from the disaccharidic donor **6** (0.187 g, 0.25 mmol) and methyl 2,3,4-tri-*O*-benzyl-α-D-glucopyranoside (**18**) (0.162 g, 1.40 equiv). The acetylated residue was purified by column chromatography, using EtOAc/petroleum ether 4:5 (v/v) as the eluent. Product **23** (0.193 g) was recovered as an amorphous solid. Yield 65%; R_f 0.50 (EtOAc/petroleum ether 1:1 v/v); $[\alpha]_D$ + 36.9° (*c* 1.0, $CHCl_3$); ^1H NMR ($CDCl_3$) δ 1.33, 1.34, 1.42, 1.55 (4 s, 12 H, 4 CH_3C), 1.98, 2.01, 2.07, 2.08, 2.13, 2.15 (6 s, 18 H, 6 CH_3CO), 3.37 (s, 1 H, CH_3O), 3.43-4.16 (m, 7 H, H-5,4',5',6'b,5",6"a,6"b), 4.39 (dd, 1 H, $J_{5',6'a}$ = 1.0 Hz, $J_{6'a,6'b}$ = 11.5 Hz, H-6'a), 4.50 (dd, 1 H, $J_{1',2'}$ = 1.9 Hz, $J_{2',3'}$ = 4.2 Hz, H-2'), 4.57 (d, 1 H, $J_{1",2"}$ = 7.8 Hz, H-1"), 4.58 (dd, 1 H, $J_{3',4'}$ = 8.0 Hz, H-3'), 4.59 (d, 1 H, $J_{1,2}$ = 3.5 Hz, H-1), 4.60-4.95 (m, 6 H, 3 CH_2Ph), 4.98 (dd, 1 H, $J_{2",3"}$ = 10.4 Hz, $J_{3",4"}$ = 3.4 Hz, H-3"), 5.15 (dd, 1 H, H-2"), 5.17 (d, 1 H, H-1'), 5.36 (dd, 1 H, $J_{4",5"}$ = 0.8 Hz, H-4"); ^{13}C NMR ($CDCl_3$) δ 20.58, 20.63, 20.68, 20.77, 20.90, 21.10 (6 C, 6 CH_3CO), 29.69 (C-2'), 55.29 (CH_3O), 61.19 (C-6"), 62.08 (C-6'), 66.46 (C-6), 66.85 (C-4"), 69.21, 69.58, 69.76, 70.00, 70.64, 71.04 (6 C, C-5,3',5',2",3",5"), 73.33, 75.02, 75.82 (3 C, 3 CH_2Ph), 75.92 (C-4'), 77.61 (C-4), 79.97 (C-2), 82.15 (C-3), 97.84 (C-1), 101.12, 101.45 (C-1',1"), 127.56-128.51, 138.14, 138.66, 138.66 (18 C, 3 C_6H_5), 169.19, 169.44, 170.04, 170.09, 170.18, 170.48 (6 C, 6 CH_3CO).

Anal. Calcd for $C_{52}H_{63}IO_{21}$, 2 H_2O (1186.96): C, 52.61; H, 5.69; I, 10.69. Found: C, 52.51; H, 5.47; I, 10.57.

4-*O*-[3,6-Di-*O*-acetyl-4-*O*-(2,3,4,6-tetra-*O*-acetyl-β-D-galactopyranosyl)-2-deoxy-2-iodo-α-D-mannopyranosyl)-1,6-anhydro-2,3-*O*-(1-methylethylidene)-β-D-mannopyranose (24). Obtained as described for **19**, from **6** (0.187 g, 0.25 mmol) and 1,6-anhydro-2,3-*O*-(1-methylethylidene)-β-D-mannopyranose (**18**) (0.071 g, 0.35 mmol, 1.40 equiv). The residue was purified by column chromatography, using EtOAc/CH_2Cl_2/petroleum ether 4:8:1 (v/v/v) as the eluent. Compound **24** (0.162 g)

was recovered as an amorphous solid. Yield 70%, R_f 0.53 (EtOAc/CH_2Cl_2/petroleum ether 4:8:1 v/v/v); $[\alpha]_D$ + 4.5° (*c* 1.0, $CHCl_3$); ^1H NMR ($CDCl_3$) δ 1.33, 1.53 (2 s, 6 H, 2 C*H*$_3$C), 1.98, 2.07, 2.07, 2.11, 2.16, 2.17 (6 s, 18 H, 6 C*H*$_3$CO), 3.37 (dd, 1 H, $J_{5,6b}$ = 6.3 Hz, $J_{6a,6b}$ = 7.3 Hz, H-6b), 3.88 (m, 1 H, H-4), 3.93-3.98 (m, 2 H, H-5",6a), 4.05-4.20 (m, 7 H, H-2,3,4',5',6'b,6"a,6"b), 4.46 (dd, 1 H, $J_{5',6'a}$ = 1.0 Hz, $J_{6'a,6'b}$ = 10.5 Hz, H-6'a), 4.55 (dd, 1 H, $J_{1',2'}$ = 2.8 Hz, $J_{2',3'}$ = 4.0 Hz, H-2'), 4.63 (d, 1 H, $J_{1",2"}$ = 7.8 Hz, H-1"), 4.75 (m, 1 H, H-5), 4.83 (dd, 1 H, $J_{3',4'}$ = 7.0 Hz, H-3'), 5.00 (dd, 1 H, $J_{2",3"}$ = 10.4 Hz, $J_{3",4"}$ = 3.3 Hz, H-3"), 5.17 (dd, 1 H, H-2"), 5.35 (m, 2 H, H-1,1'), 5.38 (dd, 1 H, $J_{4",5"}$ = 0.8 Hz, H-4"); ^{13}C NMR ($CDCl_3$) δ 20.40, 20.51, 20.51, 20.61, 20.66, 20.91 (6 C, 6 *C*H$_3$CO), 25.80, 25.83 (2 C, (*C*H$_3$)$_2$C), 28.70 (C-2'), 55.29 (*C*H$_3$O), 61.12 (C-6"), 62.18 (C-6'), 64.24 (C-6), 66.77 (C-4"), 69.04 (C-2"), 69.69 (C-5'), 70.09 (C-3'), 70.66 (C-5"), 70.85 (C-3"), 71.91 (C-2), 73.67, 73.99 (2 C, C-3,5), 76.18 (C-4'), 77.23 (C-4), 99.08 (C-1), 101.36 (C-1"), 102.27 (C-1'), 109.86 (*C*(CH$_3$)$_2$), 169.18, 169.30, 169.90, 170.00, 170.17, 170.27 (6 C, 6 CH$_3$*C*O).

Anal. Calcd for $C_{33}H_{45}IO_{20}$, 2 H_2O (924.62): C, 42.86; H, 5.34; I, 13.72. Found: C, 42.99; H, 5.02; I, 13.37.

Methyl 3,4,6-Tri-*O*-acetyl-2-deoxy-α-D-*arabino*-hexopyranoside (25) A solution of methyl 3,4,6-tri-*O*-acetyl-2-deoxy-2-iodo-α-D-mannopyranoside (**9**) (0.140 g, 0.32 mmol) in dry benzene (1.5 mL) was stirred with tributyltin hydride (130 μL, 0.49 mmol, 1.53 equiv) and AIBN (5 mg) at 60 °C under argon. The reaction was complete after 1 h. After concentration, addition of pentane (5-10 mL), extraction of the glycoside with acetonitrile (3x5-10 mL) and concentration again, the residue was treated for 5 min with a solution of $NaBH_4$ (0.019 g, 0.50 mmol, 1.57 equiv) in ethanol (5 mL). After evaporation of ethanol, the residue was dissolved in CH_2Cl_2 (15 mL), the organic phase washed with water (2x5 mL), dried (Na_2SO_4) and concentrated. The residue was purified by column chromatography using EtOAc/petroleum ether (1:1 v/v) as the eluent, affording 0.096 g of the pure product **25** as a syrup. Yield 77%; R_f 0.62 (EtOAc/petroleum ether 1:1 v/v); $[\alpha]_D$ + 121.3° (*c* 1.0, $CHCl_3$) [lit.[27] $[\alpha]_D$ + 108° (*c* 2.3, $CHCl_3$)]; ^1H NMR ($CDCl_3$) δ 1.82 (ddd, 1 H, $J_{1,2a}$ = 3.6 Hz, $J_{2a,2e}$ = 12.9 Hz, $J_{2a,3}$ = 11.6 Hz, H-2a), 2.01, 2.04, 2.10 (3 s, 9 H, 3 C*H*$_3$CO), 2.25 (ddd, 1 H, $J_{1,2e}$ = 1.1 Hz, $J_{2e,3}$ = 5.4 Hz, H-2e), 3.40 (s, 3 H, C*H*$_3$O), 3.95 (ddd, 1 H, $J_{4,5}$ = 9.9 Hz, $J_{5,6a}$ = 4.7 Hz, $J_{5,6b}$ = 2.2 Hz, H-5), 4.07 (dd, 1 H, $J_{6a,6b}$ = 12.2 Hz, H-6b), 4.32 (dd, 1 H, H-6a), 4.85 (dd, 1 H, H-1), 5.01 (dd, 1 H, $J_{3,4}$ = 9.5 Hz, H-4), 5.09 (d, 1 H, H-1), 5.21 (dd, 1 H, H-3); ^{13}C NMR ($CDCl_3$) δ 20.67, 20.67, 20.78 (3 C, 3 *C*H$_3$CO), 34.88 (C-2), 54.82 (*C*H$_3$O), 62.37 (C-6), 67.69 (C-4), 69.00, 69.29 (2 C, C-3,5), 97.99 (C-1), 169.83, 170.08, 170.65 (3 C, 3 CH$_3$*C*O).

Octyl 3,4,6-Tri-*O*-acetyl-2-deoxy-α-D-*arabino*-hexopyranoside (26). Obtained as described for **25**, from compound **10** (1.42 g, 2.69 mmol) which was treated for 2 h in dry benzene (5 mL) with tributyltin hydride (1.070 mL, 4.03 mmol, 1.50 equiv) and AIBN (10 mg) at 60 °C under argon.. The crude product was purified by column chromatography using EtOAc/petroleum ether (1:9 v/v then 1:3 v/v) as the eluent, affording 0.910 g of pure product **26**. Yield 84%; syrup; R_f 0.60 (EtOAc/petroleum ether 1:3 v/v); $[\alpha]_D$ + 88.2° (*c* 1.0, $CHCl_3$); ^1H NMR ($CDCl_3$) δ 0.88 (t, 3 H, octyl C*H*$_3$), 1.30 (10 H, 5 octyl C*H*$_2$), 1.58 (m, 2 H, octyl C*H*$_2$), 1.81 (ddd, 1 H, $J_{1,2a}$ = 3.7 Hz, $J_{2a,2e}$ = 12.8 Hz, $J_{2a,3}$ = 11.7 Hz, H-2a), 2.01, 2.04, 2.09 (3 s, 9 H, 3 C*H*$_3$CO), 2.23 (ddd, 1 H, $J_{1,2e}$ < 0.5 Hz, $J_{2e,3}$ = 5.4 Hz, H-2e), 3.37 (ddd, 1 H, OCH$_A$*H*$_B$), 3.62 (ddd, 1 H, OC*H*$_A$H$_B$), 3.96 (ddd, 1 H, $J_{4,5}$ = 9.9 Hz, $J_{5,6a}$ = 4.6 Hz, $J_{5,6b}$ = 2.2 Hz, H-5), 4.05 (dd, 1 H, $J_{6a,6b}$ = 12.2 Hz, H-6b), 4.31 (dd, 1 H, H-6a), 4.99 (dd, 1 H, H-1), 4.99 (dd, 1 H, $J_{3,4}$ = 9.4 Hz, H-4), 5.33 (ddd, 1 H, H-3); ^{13}C NMR ($CDCl_3$) δ 13.91 (octyl *C*H$_3$), 20.53, 20.53, 20.76 (3 C, 3 *C*H$_3$CO), 22.47, 26.06, 29.05, 29.19, 29.24 (5 octyl *C*H$_2$), 34.96 (C-2), 62.30 (C-6), 67.68 (C-4), 69.03, 69.40 (2 C, C-3,5), 67.62 (OC*H*$_2$), 96.74 (C-1), 169.70, 169.94, 170.49 (3 C, 3 CH$_3$*C*O).

Anal. Calcd for $C_{20}H_{33}O_8$ (402.472): C, 59.68; H, 8.52. Found: C, 59.97; H, 8.44.

Octyl 3,6-Di-*O*-acetyl-4-*O*-(2,3,4,6-tetra-*O*-acetyl-β-D-galactopyranosyl)-2-deoxy-α-D-*arabino*-hexopyranoside (27). Obtained as described for **9**, from compound **11** (1.75 g, 2.34 mmol) which was treated for 3 h in dry benzene (7 mL) with tributyltin hydride (0.932 mL, 3.51 mmol, 1.50 equiv) and AIBN (10 mg) at 60 °C under argon. The crude product was purified by column chromatography using EtOAc/petroleum ether (1:9 v/v then 1:1 v/v) as the eluent, affording 1.35 g of pure product **27**. Yield 91%; liquid; R_f 0.57 (EtOAc/petroleum ether 1:1 v/v); $[\alpha]_D$ + 51.4° (*c* 1.0, $CHCl_3$); ^1H NMR ($CDCl_3$) δ 0.88 (t, 3 H, octyl C*H*$_3$), 1.35 (10 H, 5 octyl C*H*$_2$), 1.60 (m, 2 H, octyl C*H*$_2$), 1.82 (ddd, 1 H, $J_{1,2a}$ = 3.7 Hz, $J_{2a,2e}$ = 12.9 Hz, $J_{2a,3}$ = 11.6 Hz, H-2a), 1.97, 2.05, 2.06, 2.06, 2.11, 2.16 (6 s, 18 H, 6 C*H*$_3$CO), 2.24 (ddd, 1 H, $J_{1,2e}$ = 0.8 Hz, $J_{2e,3}$ = 5.4 Hz, H-2e), 3.33 (ddd, 1 H, OCH$_A$*H*$_B$), 3.59 (ddd, 1 H, OC*H*$_A$H$_B$), 3.66 (dd, 1 H, $J_{3,4}$ = 8.7 Hz, $J_{4,5}$ = 9.3 Hz, H-4), 3.84-3.90 (m, 2 H, H-5,5'), 4.07 (dd, 1 H, $J_{5',6'b}$ = 7.2 Hz, $J_{6'a,6'b}$ = 11.0 Hz, H-6'b), 4.15 (dd, 1 H, $J_{5,6b}$ = 4.9 Hz, $J_{6a,6b}$ = 11.8 Hz, H-6b), 4.18 (dd, 1 H, $J_{5',6'a}$ = 6.4 Hz, H-6'a), 4.31 (dd, 1 H, $J_{5,6a}$ = 1.9 Hz, H-6a), 4.57 (d, 1 H, $J_{1',2'}$ = 7.8 Hz, H-1'), 4.86 (dd, 1 H, H-1), 4.97 (dd, 1 H, $J_{2',3'}$ = 10.4 Hz, $J_{3',4'}$ = 3.3 Hz, H-3'), 5.16 (dd, 1 H, H-2'), 5.31 (ddd, 1 H, H-3), 5.35 (dd, 1 H, $J_{4',5'}$ = 0.5 Hz, H-4'); ^{13}C NMR ($CDCl_3$) δ 14.05 (octyl *C*H$_3$), 20.48, 20.59, 20.59, 20.59, 20.83, 21.15 (6 C, 6 *C*H$_3$CO), 22.60, 26.14, 29.18, 29.33,

31.79 (5 octyl CH_2), 34.85 (C-2), 60.14 (C-6'), 62.84 (C-6), 66.74 (C-4'), 67.22 (OCH_2), 68.20 (C-2'), 69.26 (C-5), 69.82 (C-3), 70.51 (C-5'), 71.07 (C-3'), 77.52 (C-4), 96.72 (C-1), 101.12 (C-1'), 169.17, 169.54, 170.06, 170.15, 170.30, 170.47 (6 C, 6 CH_3CO).

Anal. Calcd for $C_{32}H_{50}O_{14}$ (690.72): C, 55.64; H, 7.30. Found: C, 55.84; H, 7.37.

Octyl 2-Deoxy-α-D-*arabino*-hexopyranoside (28). A suspension of compound **26** (1.51 g, 3.75 mmol) in MeOH (50 mL) was treated with a catalytic amount of MeONa. Dissolution of the product occurred after few minutes and stirring was maintained overnight. The solution was neutralized with Amberlite IR 120 (H^+) resin, then concentrated. The crystalline residue was recrystallized from water affording **28** as a solid (0.985 g). Yield 95%; mp 108 °C (H_2O); $[\alpha]_D$ + 93.1° (*c* 1.1, $CHCl_3$/ EtOH 1:1 v/v); ^1H NMR (C_5D_5N) δ 0.90 (t, 3 H, octyl CH_3), 1.33 (m, 10 H, 5 octyl CH_2), 1.66 (m, 2 H, octyl CH_2), 2.16 (ddd, 1 H, $J_{1,2a}$ = 3.6 Hz, $J_{2a,2e}$ = 12.9 Hz, $J_{2a,3}$ = 11.6 Hz, H-2a), 2.60 (ddd, 1 H, $J_{1,2e}$ = 0.8 Hz, $J_{2e,3}$ = 5.1 Hz, H-2e), 3.50 (ddd, 1 H, OCH_AH_B), 3.97 (ddd, 1 H, OCH_AH_B), 4.16 (dd, 1 H, $J_{3,4}$ = 8.4 Hz, $J_{4,5}$ = 9.6 Hz, H-4), 4.33 (ddd, 1 H, $J_{5,6a}$ = 2.4 Hz, $J_{5,6b}$ = 5.2 Hz, H-5), 4.47 (dd, 1 H, $J_{6a,6b}$ = 11.5 Hz, H-6b), 4.62 (dd, 1 H, H-6a), 4.72 (ddd, 1 H, H-3), 5.23 (dd, 1 H, H-1).

Anal. Calcd for $C_{14}H_{28}O_5$ (276.36): C, 60.84; H, 10.20. Found: C, 61.02; H, 10.24.

Octyl 2-Deoxy-4-*O*-β-D-galactopyranosyl-α-D-*arabino*-hexopyranoside (29). Prepared as described for compound **28**, from **27** (1.35 g, 1.95 mmol). The product was crystallized from ethanol. Yield 94%; mp 143 °C (EtOH); $[\alpha]_D$ + 67.9° (*c* 0.7, H_2O); ^1H NMR (C_5D_5N) δ 0.90 (t, 3 H, octyl CH_3), 1.25 (m, 10 H, 5 octyl CH_2), 1.61 (m, 2 H, octyl CH_2), 2.00 (ddd, 1 H, $J_{1,2a}$ = 3.6 Hz, $J_{2a,2e}$ = 12.9 Hz, $J_{2a,3}$ = 11.4 Hz, H-2a), 2.54 (ddd, 1 H, $J_{1,2e}$ < 0.5 Hz, $J_{2e,3}$ = 5.2 Hz, H-2e), 3.43 (ddd, 1 H, OCH_AH_B), 3.81 (ddd, 1 H, OCH_AH_B), 4.15-4.64 (m, 11 H, H-3,4,5,6a,6b,2',3', 4',5',6'a,6'b), 5.12 (bd, 1 H, H-1), 5.15 (d, 1 H, $J_{1',2'}$ = 8.0 Hz, H-1').

Anal. Calcd for $C_{20}H_{38}O_{10}$ 0.5 H_2O (439.51): C, 53.67; H, 8.78. Found: C, 53.80; H, 8.71.

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