Glycosylation Reactions with Di-*O*-acetyl-2,6-dibromo-2,6-dideoxy-α-D-mannopyranosyl Bromide. A Simple Synthesis of Methyl 2,6-Dideoxy-D-*arabino*-hexopyranoside

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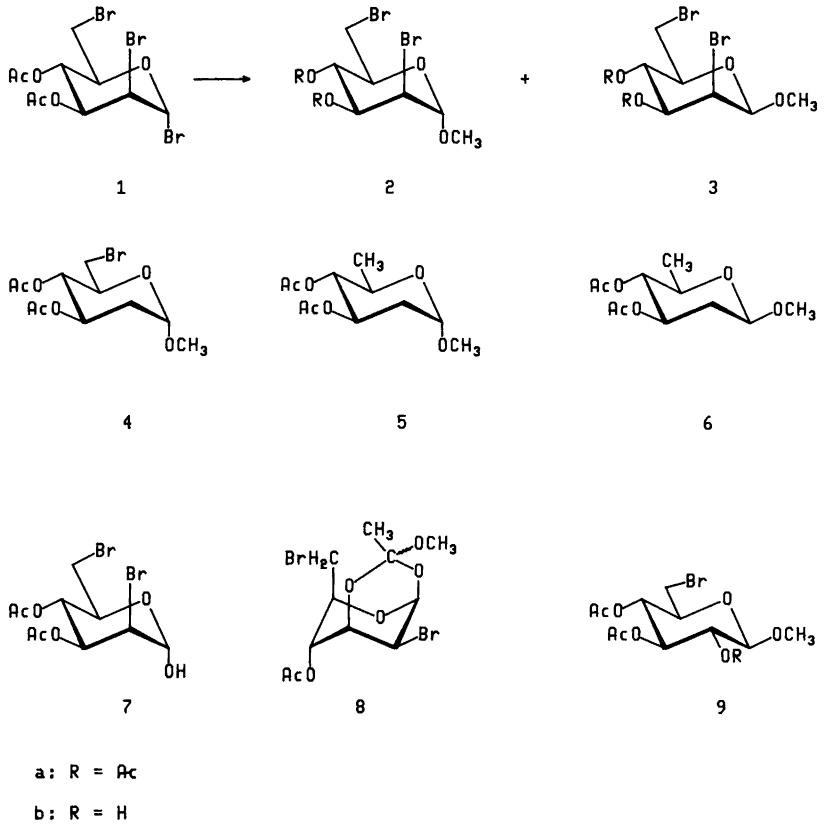
Glycosylation reactions using 3,4-di-*O*-acetyl-2,6-dibromo-2,6-dideoxy-α-D-mannopyranosyl bromide (**1**) have been investigated. Glycosylation with methanol and acid gives a high yield of the two anomeric glycosides, which can be isolated by fractional crystallization and further converted into the corresponding 2,6-dideoxyglycosides in good yield. In contrast, Koenig–Knorr glycosylation reaction conditions give only moderate yields of the methyl glycosides and the products are always contaminated with substantial amounts of by-products, including a 1,3-orthoester derivative. Glycosylation reactions of **1** promoted by halide ions or mercury(II) iodide give α-glycosides in good yield without the formation of by-products.

In previous papers on the synthetic applications of bromo lactones[1] we have described the facile synthesis[2] of 3,4-di-*O*-acetyl-2,6-dibromo-2,6-dideoxy-α-D-manno- and -α-D-glucopyranosyl bromides and their use as glycosyl donors in the synthesis of glycosides of dideoxyhexoses.[3,4] In this communication we report a simple and large-scale preparation of methyl 2,6-dideoxy-D-*arabino*-hexopyranosides starting from D-gluconolactone and using Fischer glycosylation reaction conditions. This method complements the synthesis of the corresponding L-isomer starting from L-rhamnal,[5] but is much more convenient than the photochemically induced deoxygenation described by Klausener *et al.*[6] We have, furthermore, studied the products formed when 3,4-di-*O*-acetyl-2,6-dibromo-2,6-dideoxy-α-D-mannopyranosyl bromide (**1**) is used in glycosylation reactions with silver carbonate (Koenig–Knorr), halide ion and mercury(II) iodide promoted reactions.

Results and discussion

Glycosylation of **1** with methanol and sulfuric acid gave, after neutralization and acetylation, a mixture of the two glycosides **2a** and **3a** from which first **3a** (12 %) and then **2a** (61 %) could be isolated by fractional crystallization directly from the crude reaction product. Alternatively, the mother liquor from the preparation of the glycosyl bromide (**1**) or the crude reaction mixture from the borohydride reduction of the 2,6-dibromomannolactone[2] could be treated similarly with methanol and acid. After work-up the reaction products were partitioned between water and diethyl ether; the methyl 2,6-dibromo-2,6-dideoxy-α-(and β)-D-mannopyranosides **2b** and **3b** being soluble in the organic phase while the impurities, including the dibromo alditol[2], went into the aqueous phase. Concentration of the organic phase left the mixture of the 2,6-dibromo glycosides (50 %) in an α/β ratio of about 8 as calculated from the ^{13}C NMR spectrum. Separation of the two anomers was accomplished by acetylation of the mixture and fractional crystallization of the



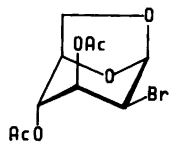
a: R = Ac

b: R = H

acetylated product as described above.

Catalytic hydrogenolysis of the glycosides **2a** and **3a** using Pd/C in ethyl acetate and triethylamine as the base, gave the 2,6-dideoxyhexoses **5** and **6** as syrups in 79 and 59 % yield, respectively. By reducing the reaction time the monobrominated product **4** could be isolated crystalline in 82 % yield. Hydrolysis of the glycosyl bromide (**1**) with water in acetone promoted by silver carbonate gave the crystalline hydroxy compound (**7**) in 55 % yield. However, prolonged reaction of compound **7** with methanol and silver carbonate led, unexpectedly, to the β-methyl glucoside (**9b**) in good yield. This product is most likely formed by generation of the 1,2-epoxide from **7** which subsequently reacts with methanol to form **9b** in analogy with the reaction described by Lemieux and Fraser–Reid.[11] Glycosylation of the bromide (**1**) under Koenig–Knorr reaction conditions gave a mixture of glycosides in which the expected products **2a** and **3a** amounted to only about 60 %, the remaining products being the 1-hydroxy compound (**7**) and a 1,3-orthoester (**8**). Owing to its instability, the latter product was characterized solely by its ^{1}H and ^{13}C NMR parameters, which were in good agreement with the proposed structure. Prolonged treatment of the glycosyl bromide (**1**) with methanol and silver carbonate gave the same amount of the glycosides **2a** and **3a** (about 60 %) but **7** was, in this cases converted into **9b** and only small amounts of the orthoester **8** being observed. In addition, a small amount (6 %) of the 2-bromo 1,6-anhydride **10** could be isolated.

These experiments clearly show that the best results for the preparation of the glycosides **2a** and **3a** are obtained using Fischer glycosylation reaction conditions and that silver-promoted reactions gives up to 40 % of by-products. However, it was possible to obtain the α-linked 8-ethoxycarbonyloctyl glycoside (**11**) in good yield (52 %) when the halide-catalyzed reaction condi-



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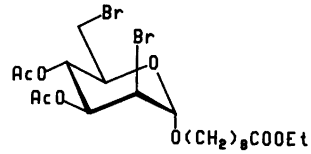

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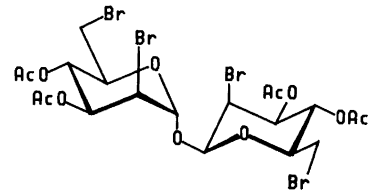

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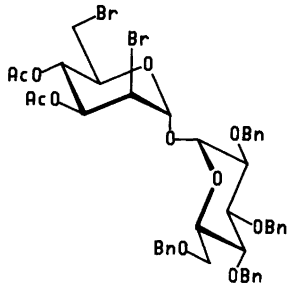

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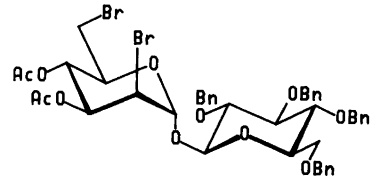

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tions proposed by Lemieux[7] were used. Glycosylation promoted by mercury(II) iodide[8] also gives α-glycosides in good yield as exemplified by the preparation of the α,β-trehalose derivative **12** which could be isolated crystalline in 57 % yield from **1** and **7**. In order to prove that the reaction conditions used above gave only the α-glycoside of the glycosylating reagent the reaction was also carried out using **1** with tetra-*O*-benzyl-D-glucopyranose as the aglycone. This gave a mixture of the two anomeric trehalose derivatives **13** and **14** in 22 and 24 % yield, respectively, but in both compounds the anomeric configuration of the 2,6-dibromo-2,6-dideoxymannose residue was α.

Experimental

Melting points are uncorrected. Optical rotations were measured on a Perkin Elmer 241 polarimeter. NMR spectra were obtained using Bruker WH-90, HX-270 or AM-500 NMR instruments. The spectra of protected compounds were measured in $CDCl_3$. Unprotected compounds were measured in D_2O relative to an internal reference: acetone (δ 2.22) for ^1H NMR spectra and dioxane (67.4 ppm) for ^{13}C NMR spectra. Microanalyses were performed by Novo Microanalytical Laboratory, Copenhagen, Denmark. TLC was performed on silica-gel coated plates (Merck F-254). Preparative TLC was performed on 20×40 cm plates coated with 1 mm thick silica gel.

*Methyl 3,4-di-*O*-acetyl-2,6-dibromo-2,6-dideoxy-α(β)-D-mannopyranoside* (**2a**)/(**3a**). The bromide (**1**)[2] (7.80 g) was dissolved in methanol (80 ml). Concentrated sulfuric acid (2 ml) was added, and the mixture was boiled for 48 h when the reaction mixture was cooled and neutralized with pyridine (10 ml) and concentrated to dryness. The residue was acetylated with acetic anhydride (15 ml) in pyridine (15 ml) at room temperature for 1 h and work up in the usual way gave a crude mixture of the glycosides (**2a**) and (**3a**). Crystallization from ethyl acetate–pentane gave 0.82 g (12 %) of **3a** m.p. 155–162 °C. Recrystallization from the same solvent gave an analytical specimen, m.p. 163–165 °C, $[\alpha]_D^{23}$ − 64.9° (*c* 2.1, chloroform). Anal $C_{11}H_{16}Br_2O_6$: C, H, Br. ^1H NMR (270 MHz): δ 4.44 (H-1), 4.56 (H-2), 4.96 (H-3), 5.27 (H-4), 3.70 (H-5), 3.47 (H-6), 3.49 (H-6'), 3.64 (OMe). $J_{1,2}$ 1.0, $J_{2,3}$ 4.0, $J_{3,3}$ 9.5, J_{45} 9.5, $J_{5,6}$ 5.0, $J_{5,6'}$ 6.0

Hz. ^{13}C NMR: 98.6 (C-1), 51.6 (C-2), 71.0, 68.5 (C-3, C-4), 74.3 (C-5), 30.5 (C-6), 57.0 (OMe) ppm. The glycoside (**2a**) was crystallized from the mother liquor material using diethyl ether–pentane to yield 4.22 g (61 %) m.p. 72–75 °C. Recrystallization of this from diethyl ether gave an analytical specimen m.p. 76.5–77 °C, $[\alpha]_D^{23}$ − 22.0° (*c* 2.2, chloroform). Anal. $C_{11}H_{16}Br_2O_6$: C, H, Br. ^1H NMR (270 MHz): δ 4.99 (H-1), 4.46 (H-2), 5.22 (H-3), 5.29 (H-4), 4.04 (H-5), 3.42 (H-6), 3.47 (H-6′), 3.50 (OMe). ^{13}C NMR: 100.6 ppm (C-1), 49.1 (C-2), 68.9 (C-3), 68.5 (C-4), 70.4 (C-5), 31.1 (C-6), 55.4 (OMe). Alternatively, the glycosidation solution could be neutralized with an ion-exchange resin [IR-4B(OH)] and evaporation of the solvent then gave a mixture of the unprotected glycosides **2b** and **3b**, in an α/β ration of 8. ^{13}C NMR of methyl 2,6-dibromo-2,6-dideoxy-α-D-mannopyranoside (**2b**) in D_2O: 101.8 ppm (C-1), 54.8 (C-2), 69.3, 70.1, 72.5 (C-3, C-4, C-5), 34.9 (C-6), 56.2 (OMe).

Methyl 2,6-dibromo-2,6-dideoxy-α-(β)-D-mannopyranoside (**2b**), (**3b**). 2,6-Dibromo-D-mannonolactone[2] (50.0 g) was dissolved in water (500 ml) and ethanol (250 ml) and cooled with stirring to about 0 °C. Ion-exchange resin IR 120 (H^+) (100 ml) was added followed by sodium borohydride (6 g) in small protions so that the pH was kept below 6. The reaction mixture was filtered and the ion-exchange resin washed with methanol. Concentration of the combined filtrate and washings gave 51 g of a crude product. This product was boiled in methanol (500 ml) containing H_2SO_4 (13 ml) for 48 h, then neutralized with pyridine and concentrated. The product was partitioned between diethyl ether (200 ml) and water (100 ml). The water phase was extracted once with diethyl ether and the combined organic phases were concentrated to give 26.5 g (50 %) of the title product as a syrup, which was shown by ^{13}C NMR spectroscopy to contain only the two glycosides in an α/β ratio of 8.

Methyl 3,4-di-O-acetyl-6-bromo-2,6-dideoxy-α-D-arabino-hexopyranoside (**4**). The glycoside **2a** (0.59 g) was dissolved in ethyl acetate (15 ml). Triethylamine (0.7 ml) and Pd/C (5 %; 200 mg) was added and the reaction mixture was subjected to hydrogenolysis at 50 atm for 72 h. The resulting mixture was filtered through charcoal and evaporated. The residue was dissolved in dichloromethane (25 ml), washed with 4 M hydrochloric acid and a saturated solution of sodium hydrogen carbonate, dried and concentrated to yield 0.39 g (82 %) of crystalline **4**, m.p. 90–99 °C. Recrystallization from diethyl ether–pentane gave a product with m.p. 97–103 °C, $[\alpha]_D^{23}$ − 116.7° (*c* 2.2, chloroform). Anal. $C_{11}H_{17}BrO_6$: C, H, Br. ^1H NMR (270 MHz): δ 4.77 (H-1), 1.72 (H-2a), 2.16 (H-2e), 5.21 (H-3), 4.81 (H-4), 3.88 (H-5), 3.41 (H-6), 3.45 (H-6′), 3.29 (OMe). $J_{1,2a}$ 4.0, $J_{1,2e}$ 2.0, $J_{2e,2a}$ 13.0, $J_{2a,3}$ 11.0, $J_{2e,3}$ 5.5 $J_{3,4}$ 9.5, $J_{4,5}$ 9.5, $J_{5,6}$ 2.5, $J_{5,6'}$ 6.0, $J_{6,6'}$ 11.0 Hz.

Methyl 3,4-di-O-acetyl-2,6-dideoxy-α(β)-D-arabino-hexopyranoside (**5**), (**6**). The glycoside (**2a**) (0.67 g) was hydrogenolysed as described above using a 1.46 atm hydrogen pressure for 96 h.

After work up, **5** was isolated as a syrup (0.32 g, 79 %). Purification of this by preparative TLC using ethyl acetate–pentane (1:1) as eluant gave pure **5**, $[\alpha]_D^{23}$ − 155.1° (*c* 1.6, chloroform) (lit.,[9] 156.1° for the L-enantiomer). ^1H NMR (270 MHz): δ 4.67 (H-1), 1.69 (H-2a), 2.16 (H-2e), 5.18 (H-3), 4.65 (H-4), 3.75 (H-5), 1.11 (H-6), 3.26 (OMe). $J_{1,2a}$ 3.0, $J_{1,2e}$ 1.0, $J_{2a,2e}$ 12.0, $J_{2a,3}$ 12.0, $J_{2e,3}$ 5.5, $J_{3,4}$ 9.5, $J_{4,5}$ 9.5, $J_{5,6}$ 6.5 Hz. ^{13}C NMR: 97.6 ppm (C-1), 35.1 (C-2), 65.3, 68.9 (C-3, C-4), 74.6 (C-5), 17.4 (C-6), 54.5 (OMe). The β-glycoside (**3a**) (0.5 g) was hydrogenolysed similarly to the 2,6-dideoxy compound (**6**), which was isolated in 59 % yield after purification by preparative TLC using ethyl acetate–pentane (1:2) as the eluant, $[\alpha]_D^{23}$ − 14.2° (*c* 1.1, chloroform), (lit.,[9] 13.1° for the L-enantiomer). ^1H NMR (270 MHz): δ 4.40 (H-1), 1.69 (H-2a), 2.30 (H-2e), 4.96 (H-3), 4.73 (H-4), 3.48 (H-5), 1.25 (H-6), 3.48 (OMe). $J_{1,2e}$ 2.0, $J_{1,2a}$ 10.0, $J_{2e,2a}$ 12.5, $J_{2e,3}$ 5.5, $J_{2a,3}$ 10.0, $J_{3,4}$ 9.0, $J_{4,5}$ 9.0, $J_{5,6}$ 6.5 Hz. ^{13}C NMR: 100.1 (C-1), 36.2 (C-2), 69.8, 70.5 (C-3, C-4), 74.1 (C-5), 17.4 (C-6), 56.4 (OMe) ppm.

3,4-Di-O-acetyl-2,6-dibromo-2,6-dideoxy-α-D-mannopyranose (**7**). The bromide (**1**) 2.0 g was dissolved in acetone (40 ml) containing water (4 ml), and silver carbonate (3 g) was added. The reaction mixture was stirred for 2 h at room temperature and the salts were removed by filtration through charcoal. A ^{13}C NMR spectrum of the product showed that the 1-hydroxy compound (**7**) was present in an α/β ratio of 85/15. Crystallization from diethyl ether–pentane afforded **7** in 55 % yield m.p. 150–158 °C. Two recrystalliza-

tions from the same solvent gave an analytical sample m.p. 162–164 °C, $[\alpha]_D^{23}$ − 3.3° (*c* 1.4, chloroform). Anal. $C_{10}H_{14}Br_2O_6$: C, H, Br. ^{1}H NMR (270 MHz): δ 5.51 (H-1), 4.46 (H-2), 5.31 (H-3), 5.35 (H-4), 4.28 (H-5), 3.3, 3,5 (H-6, H-6′), 3.18 (OH), $J_{1,2}$ 2.5, $J_{2,3}$ 3.5, $J_{3,4}$ 8.0, $J_{4,5}$ 8.0, $J_{5,6}$ 5.0, $J_{5,6}$, 8.0 Hz. ^{13}C NMR: 94.6 (C-1), 50.2 (C-2), 69.0 (C-3, C-4), 70.4 (C-5), 31.7 (C-6) ppm.

Reaction of **1** *with methanol and silver carbonate.* Treatment of **1** (13 g) in dry methanol (10 ml) and dry diethyl ether (10 ml) with silver carbonate (1.5 g) at room temperature, for 1 h, gave, after work up, a mixture of **2a, 3a, 7** and **8** in the ratio 37:28:24:11 as shown by ^{1}H and ^{13}C NMR spectroscopy. Separation of the products by preparative TLC using ethyl acetate–pentane as the eluant gave, as the fastest running fraction, 4-*O*-acetyl-2,6-dibromo-2,6-dideoxy-1,3-O-(1-methoxyethylidene)-β-D-mannopyranose (**8**) (85 mg, 8 %) as an unstable syrup which was characterized by its NMR parameters only. ^{1}H NMR (270 MHz): δ 5.42 (H-1), 4.26 (H-2), 4.01 (H-3), 5.61 (H-4), 3.83 (H-5), 3.40 (H-6), 3.48 (H-6′), 1.56 (Me), 3.35 (OMe), 2.10 (OAc), $J_{1,2}$ 2.0, $J_{1,3}$ 1.8, $J_{2,3}$ 2.0, $J_{3,4}$ 2.0, $J_{4,5}$ 9.0, $J_{5,6}$ 4.5, $J_{5,6}$, 9.0, $J_{6,6}$, 12.0 Hz. ^{13}C NMR: 92.1 (C-1), 37.8 (C-2), 72.5, 72.3 (C-3, C-4), 74.0 (C-5), 32.1 (C-6), 23.3 (CCH_3), 51.1 (OMe). 20.9 (OAc) ppm. The next fraction gave **2** (330 mg, 31 %), m.p. 71–74 °C and the last fraction gave **3a** and **7** as a 1:1 mixture (330 mg). Prolonged treatment of **1** (1.0 g, 168 h) undeer the same reaction conditions as described above gave, after work up, a mixture of **9b**, **2a** and **3a** in the ratio 30:45:25 together with small amounts of **8** and **10** as seen from ^{1}H and ^{14}C NMR spectra of the crude reaction mixture. Purification by preparative TLC using diethyl ether–pentane (3:1) as the eluant gave, as the fastest running fraction, **8** (21 mg, 2 %) followed by **2a** (106 mg, 12 %) m.p. 71–74 °C. The next fraction gave **3a** (36 mg, 4 %), m.p. 160–163 °C followed by a small amount (43 mg, 6 %) of 3,4-di-*O*-acetyl-1,6-anhydro-2-bromo-2-deoxy-β-D-mannopyranose (**10**) isolated as a syrup and characterized by its NMR parameters only. ^{1}H NMR (270 MHz): δ 5.49 (H-1), 4.23 (H-2), 5.22 (H-3), 4.78 (H-4), 4.64 (H-5), 4.27 (H-6), 3.84 (H-6′), 2.2 (2×OAc), $J_{1,2}$ 1.5, $J_{2,3}$ 6.0, $J_{3,4}$ 2.0, $J_{4,5}$ 2.0, $J_{5,6}$ 2.0, $J_{5,6'}$ 6.0, $J_{6,6'}$ 8.0 Hz. ^{13}C NMR:101.7 (C-1), 46.8 (C-2), 71.8, 68.5 (C-3, C-4), 73.3 (C-5), 65.3 (C-6), 20.8, 20.9 (OAc) ppm. The fourth fraction gave **9b** (74 mg, 10 %), which crystallized slowly from ethyl acetate, m.p. 100–106 °C. Two recrystallizations from the same solvent gave pure **9b**, m.p. 108–110 °C, $[\alpha]_D^{23}$ − 25.9° (*c* 1.0, chloroform), Anal $C_{11}H_{17}BrO_7$, C, H. ^{1}H NMR (270 MHz): δ 4.30 (H-1), 3.38 (H-2), 5.10 (H-3), 4.91 (H-4), 3.70 (H-5), 3.44 (H-6), 3.65 (H-6′), 2.52 (OH), 3.58 (OMe), 2.05, 2.07 (2×OAc), $J_{1,2}$ 8.0, $J_{2,3}$ 9.5, $J_{3,4}$ 9.5, $J_{4,5}$ 9.5, $J_{5,6}$ 2.5, $J_{5,6}$, 6.5, $J_{6,6}$, 11.0 Hz. ^{13}C NMR: 103.3 (C-1), 74.1 (C-2), 73.1, 72.1, 71.0 (C-3, C-4, C-5), 30.7 (C-6), 57.3 (OMe) ppm. This product was further characterized as its acetate after being acetylated with acetic anhydride in pyridine. The acetate **9a** was isolated by crystallization from ether, m.p. 108–111 °C. Two recrystallizations from ether gave m.p. 117–118 °C, $[\alpha]_D^{23}$ − 3.9 (*c* 0.6, chloroform), (lit.,[10] m.p. 126 °C).

*Methyl 3,4-di-*O*-acetyl-6-bromo-6-deoxy-β-*D*-glucopyranoside* (**9b**). Treatment of **7** (150 mg) with silver carbonate (300 mg) in methanol (2.5 ml) and diethyl ether (2.5 ml) for 72 h gave, after work up, a crude product, which contained mainly **9b** as seen from ^{1}H NMR spectrum. Crystallization of this from ether gave 43 mg (32 %) of *9b*, m.p. 85–93 °C. The product had the same ^{1}H and ^{13}C NMR data as the product described above.

*8-Ethoxycarbonyloctyl 3,4-di-*O*-acetyl-2,6-dibromo-2,6-dideoxy-α-*D*-mannopyranoside* (**11**). 8-Ethoxycarbonyloctan-1-ol (177 mg) was dissolved in dry dichloromethane (20 ml) and tetrabutylammonium bromide (250 mg) and molecular sieves (4 Å, 3 g) were added. A solution of **1** (0.4 g) in dry dichloromethane (5 ml) was added after 6 h at room temperature and the reaction mixture was left for a further 12 h at room temperature with stirring. After work up, the crude product contained only the α-anomer with no β-anomer being detected by NMR spectroscopy. Purification of the crude product by preparative TLC using ethyl acetate–pentane (1:3) as the eluant gave **11** (0.27 g, 52 %) as a syrup, $[\alpha]_D^{23}$ − 28.4° (*c.* 2.1, chloroform), Anal. $C_{20}H_{34}Br_2O_8$: C, H, Br. ^{1}H NMR (270 MHz): δ 5.05 (H-1), 4.37 (H-2), 5.20 (H-3), 5.27 (H-4), 4.01 (H-5), 3.41 (H-6), 3.48 (H-6′), $J_{1,2}$ 1.5, $J_{2,3}$ 3.5, $J_{3,4}$ 9.0, $J_{4,5}$ 9.0, $J_{5,6}$ 3.5, $J_{5,6}$, 6.0, $J_{6,6}$, 10.0 Hz.

(3,4-Di-O-acetyl-2,6-dibromo-2,6-dideoxy-α-D-mannopyranosyl)-3,4-di-O-acetyl-2,6-dibromo-2,6-dideoxy-β-D-mannopyranoside (**12**). The aglycone (**7**) (348 mg, 0.9 mmol) was dissolved in dry chloroform (5 ml), and mercury(II) iodide (600 mg) and molecular sieves 4 Å (5 g) were added. This mixture was kept at room temperature under nitrogen for 6 h. The bromide (**1**) (598 mg, 1.32 mmol) dissolved in dry chloroform (4 ml) was then added and the reaction mixture was left at room temperature for a further 4 days. The mixture was then filtered and the filter was washed with dichloromethane. The combined organic phases were washed with potassium iodide solution (2×15 ml) and saturated sodium hydrogen carbonate solution (2×15 ml), dried ($MgSO_4$), and concentrated, to yield 755 mg of crude semicrystalline product. Crystallization of this from ethanol water gave **12** (3.86 mg, 57 %) m.p. 198–202 °C. Two recrystallizations from ethyl acetate gave m.p. 206–207 °C, $[\alpha]_D^{23}$ − 5.4° (*c* 1.0, chloroform). Anal. $C_{20}H_{26}Br_4O_{11}$: C, H, Br. ^{1}H NMR (270 Mz): δ 5.39 (H-1), 4.56 (H-2), 4.93 (H-3), 5.33 (H-4), 4.37 (H-5), 3.64 (H-6), 3.45 (H-6_1), 4.84 (H-1′), 4.50 (H-2′), 5.26 (H-3′), 5.47 (H-4′), 3.74 (H-5′), 3.52 (H-6′), 3.42 (H-6_1′), $J_{1,2}$ 1.4, $J_{2,3}$ 4.5, $J_{3,4}$ 9.5, $J_{4,5}$ 9.5, $J_{5,6}$ 3.0, $J_{5,6}$, 2.5, $J_{6,6}$, 11.5, $J_{1',2}$, 1.5, $J_{2',3}$, 4.0, $J_{3',3}$, 10.0, $J_{4',5}$, 10.0, $J_{5',6}$, 3.0, $J_{5',6_1}$, 3.0, $J_{6',6_1}$, 13.0 Hz. ^{13}C NMR: 100.0 (C-1), 96.5 (C-1′), 48.2 (C-2), 51.4 (C-2′), 67.7, 67.7, 68.5, 70.1, 70.5 (C-3, C-4, C-5, C-3′, C-4′), 74.2 (C-5′), 30.4 (C-6), 31.7 (C-6′) ppm, $^1J_{CH_1}$ 176, $^1J_{CH_1'}$ 158 Hz.

[2,3,4,6-Tetra-O-*benzyl-α(β)-D-glucopyranosyl]-3,4-di-O-acetyl-2,6-dibromo-2,6-dideoxy-α-D-mannopyranoside* (**13**) and (**14**). Tetra-*O*-benzyl-α-D-glucopyranose (501 mg, 0.93 mmol) was glycosylated in chloroform under mercury(II) iodide catalysis with the glycosyl bromide (**1**) (630 mg, 1.5 mmol) as described above. After work up 985 mg crude product was isolated and shown by ^{13}C NMR spectroscopy to contain two disaccharides (**13**) and (**14**) together with **12** in a ratio of 2:2:1. The products were separated by preparative TLC using diethyl ether–pentane (1:1) as the eluant. The first fraction gave **13** (185 mg, 22 %), $[\alpha]_D^{23}$ − 72.5° (*c* 1.2, chloroform), the product was further purified by chromatography using ethyl acetate–pentane (1:3) as the eluant and gave **13** as a syrup with $[\alpha]_D^{23}$ − 80.9° (*c* 2.5, chloroform), Anal. $C_{44}H_{48}Br_2O_{11}$: C, H, Br. ^{1}H NMR (270 MHz): δ 5.38 (H-1), 5.35 (H-1′), 4.44 (H-2), 5.26 (H-3, H-4), 4.21 (H-5), 3.24 (H-6), 3.18 (H-6_1), $J_{1,2}$ 2.0, $J_{2,3}$ 4.0, $J_{5,6}$ 6.5, $J_{5,6_1}$ 3.0, $J_{6,6}$, 10.0, $J_{1',2'}$, 4.0 Hz. ^{13}C NMR: 95.2 (C-1), 93.0 (C-1′), 49.0 (C-2), 31.6 (C-6), 81.5, 80.8, 79.0, 77.4, 75.6, 75.1, 73.5, 71.5, 70.1, 60.9, 68.5, 68.1 ppm (C-3 to C-5 and C-2′ to C-6′ and 4×benzylic-H), $^1J_{CH_1}$ 176, $^1J_{C'H_1'}$ 170 Hz. The next fraction gave **14** (204 mg, 24 %) as a syrup, $[\alpha]_D^{23}$ − 27.8° (*c* 1.7, chloroform). Anal $C_{44}H_{48}Br_2O_{11}$: C, H, Br. ^{1}H NMR (270 MHz): δ 5.27 (H-1), 4.19 (H-2), 5.24 (H-3), 5.36 (H-4), 4.36 (H-5), 3.26 (H-6), 3.39 (H-6_1), $J_{1,2}$ 2.0, $J_{2,3}$ 4.0, $J_{3,4}$ 10.0, $J_{4,5}$ 10.0, $J_{5,6}$ 5.5, $J_{5,6_1}$ 3.0 Hz. ^{13}C NMR: 101.2 (C-1), 102,6 (C-1′), 48.6 (C-2), 31.5 (C-6), 82.0, 81.5, 77.3, 75.6, 75.2, 75.0, 73.3, 70.2, 68.9, 68.3 (C-3 to C-5 and C-2′ to C-6′ and 4×benzylic-H). Finally, the last fraction gave 89 mg of impure **12** as confirmed by its ^{1}H NMR spectrum.

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