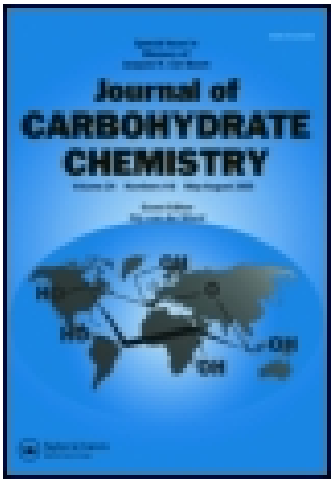


Journal of Carbohydrate Chemistry
Publication details, including instructions for authors and subscription information:
http://www.tandfonline.com/loi/lcar20

Preparation of Disaccharide Haptens Corresponding to Salmonella Serogroups B and D

Korien Zegelaar-Jaarsveld [a] , Simon C. van der Plas [a] , Gijs A. van der Marel [a] & Jacques H. van Boom [a]
[a] Leiden Institute of Chemistry, Gorlaeus Laboratoria, Leiden University , P.O. Box 9502, 2300 RA, Leiden, The Netherlands
Published online: 22 Aug 2006.

To cite this article: Korien Zegelaar-Jaarsveld , Simon C. van der Plas , Gijs A. van der Marel & Jacques H. van Boom (1996) Preparation of Disaccharide Haptens Corresponding to Salmonella Serogroups B and D, Journal of Carbohydrate Chemistry, 15:6, 665-689, DOI: 10.1080/07328309608005684

To link to this article: http://dx.doi.org/10.1080/07328309608005684

J. CARBOHYDRATE CHEMISTRY, 15(6), 665-689 (1996)

PREPARATION OF DISACCHARIDE HAPTENS CORRESPONDING TO *SALMONELLA* SEROGROUPS B AND D

Korien Zegelaar-Jaarsveld, Simon C. van der Plas, Gijs A. van der Marel, and Jacques H. van Boom*

Leiden Institute of Chemistry, Gorlaeus Laboratoria, Leiden University, P.O. Box 9502, 2300 RA Leiden, The Netherlands

Received December 18, 1995 - Final Form April 5, 1996

ABSTRACT

The properly protected ethyl 1-thio-abequopyranoside **11** and ethyl 1-thio-tyvelopyranoside **26** were prepared by a sequence of reactions, the key step of which was the regioselective hydride-mediated ring-opening of the cyclic sulfate function in compounds **8** and **18**. Iodonium ion-assisted glycosylation of allyl mannopyranoside **30** with the individual ethyl 3,6-dideoxy-1-thio-D-hexopyranoside donors **11** and **26** furnished, after deprotection, the respective allyl 3-*O*-(α-D-abequopyranosyl)-α-D-mannopyranoside **1** and allyl 3-*O*-(α-D-tyvelopyranosyl)-α-D-mannopyranoside **2**.

INTRODUCTION

It is well documented that the antigenic determinant of *Salmonella* resides in the lipopolysaccharide (LPS) of the outer membrane.[1] The LPS is composed of three structural entities of which lipid A and the core oligosaccharide are common to all serotypes, whereas the third unit, an O-specific polysaccharide (OSP), bears the antigenic

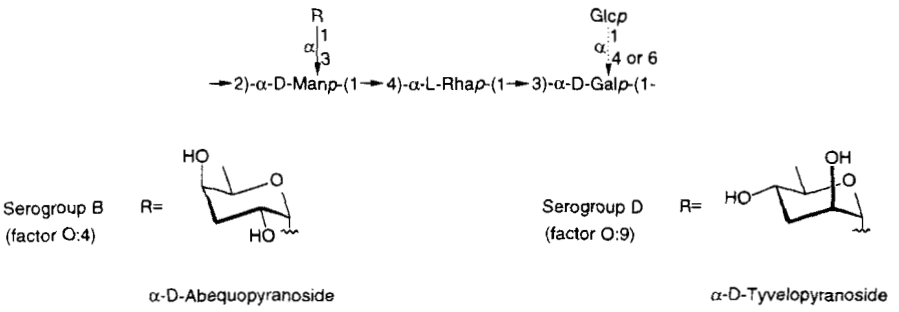


Figure 1

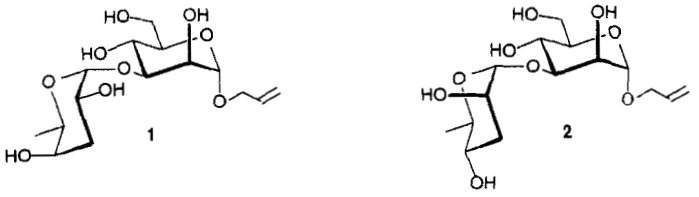


Figure 2

determinant.[2] The OSP of *Salmonella* serogroups B and D (factor O:4 and O:9, respectively) are defined by a repeating tetrasaccharide (see Figure 1) in which position 3 of the mannopyranoside residue is α-linked to 3,6-dideoxy-D-*xylo*-hexopyranoside (D-abequopyranoside) in serogroup B (factor O:4)[3] and to 3,6-dideoxy-D-*arabino*-hexopyranoside (D-tyvelopyranoside) in serogroup D (factor O:9).[4]

As part of an ongoing programme to develop serodiagnostics for salmonellosis, we here describe an alternative synthetic route[5,6] to allyl 3-*O*-(α-D-abequopyranosyl)-α-D-mannopyranoside **1** and allyl 3-*O*-(α-D-tyvelopyranosyl)-α-D-mannopyranoside **2** (Figure 2) using cyclic sulfate intermediates. The presence of the allyl group in disaccharides **1** and **2** enables the production of artificial high-molecular weight antigens by radical induced copolymerisation with acrylamide.[7]

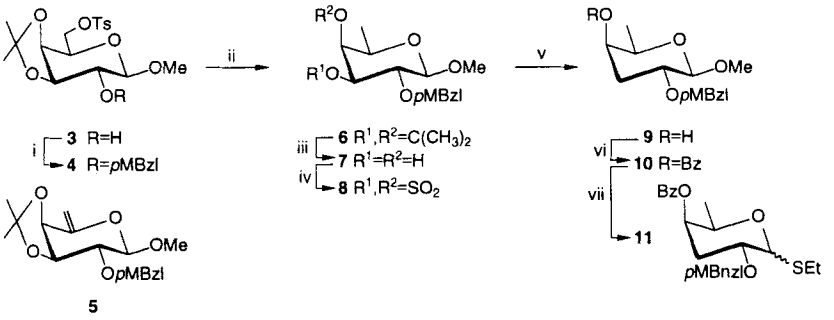
RESULTS AND DISCUSSION

In the last thirty years several approaches towards the preparation of methyl D-abequo- and D-tyvelopyranoside have been reported.[8-11] In principle, 3,6-dideoxy-hexopyranosides can be prepared by reductive and oxidative ring-opening of an epoxide

and a benzylidene acetal, respectively. For instance, methyl α-D-tyvelopyranoside is accessible by $LiAlH_4$ reduction of methyl 2,3-anhydro-4,6-*O*-benzylidene-α-D-mannopyranoside,[12] followed by oxidative ring-opening of the benzylidene acetal with *N*-bromosuccinimide (NBS, Hanessian-Plessas conditions)[13] and subsequently catalytic hydrogenation of the resulting 6-bromo derivative.[8] In a typical example, methyl 4-*O*-benzoyl-α-D-abequopyranoside was prepared by treatment of methyl 3,4-*O*-benzylidene-6-deoxy-α-D-galactopyranoside under Hanessian-Plessas conditions followed by reduction.[10] In addition, methyl α-D-abequopyranoside could be obtained by reduction of methyl 3,4-anhydro-6-*O*-tosyl-α-D-galactopyranoside with either $LiAlH_4$ or lithium triethylborohydride.[11]

Earlier studies from this laboratory[14] revealed that cyclic sulfate functions in carbohydrates can be opened regioselectively by carbon and nitrogen nucleophiles.

We here report the synthesis of the shelf-stable ethyl 3,6-dideoxy-1-thio-α(β)-D-hexopyranosides **11** and **26** via regioselective hydride-mediated ring-opening[15] of a 3,4- and a 2,3-cyclic sulfate function in compounds **8** and **18**, respectively.



Reagents and conditions: i) *p*MBzlCl, NaH, *n*-Bu_4NI, DMF, 2.5 h, 88%. ii) $LiAlH_4$, THF, 22 h, 82%. iii) 50% HOAc, 60 °C, 1 h, 89%. iv) $SOCl_2$, pyridine, EtOAc, 0 °C, 30 min; $RuCl_3$, $NaIO_4$, dichloromethane, CH_3CN, H_2O, 30 min, 95%. v) Bu_4NBH_4, THF, reflux, 30 min; H_2SO_4, H_2O, THF, 2 × 30 min, 60%. vi) BzCl, pyridine, 1.5 h, 87%. vii) $EtSSiMe_3$, ZnI_2, *n*-Bu_4NI, 1,2-dichloroethane, 60 °C, 9 min, 82% (α:β=3:1).

Scheme 1

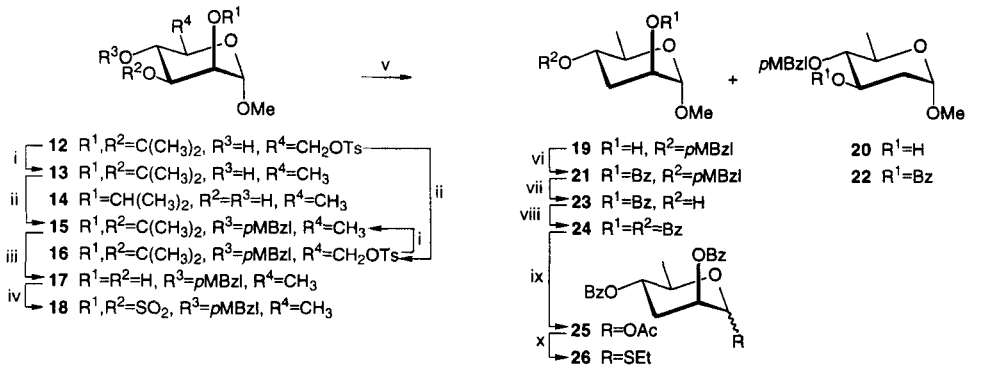
The synthetic route to ethyl 1-thio-D-abequopyranoside **11** is depicted in Scheme 1 and commences with deoxygenation of methyl 3,4-*O*-isopropylidene-6-*O*-tosyl-β-D-galactopyranoside[16] (**3**). To this end, the *p*-methoxybenzyl (*p*MBzl) was introduced at HO-2 to give **4**. Analysis of the crude mixture revealed, apart from the expected compound **4**, the presence of the elimination product **5**. The formation of the latter could

be suppressed by addition of a catalytic amount of tetrabutylammonium iodide to give **4** in 88% yield. Reduction of **4** with $LiAlH_4$ in tetrahydrofuran proceeded sluggishly to furnish derivative **6**. Deacetonation of **6** with acetic acid-water proceeded without concomitant removal of the acid-sensitive *p*-methoxybenzyl group and led to the isolation of **7** in an excellent yield.

Treatment of *cis*-diol **7** with thionyl chloride gave a mixture of diastereomeric cyclic sulfites, which were subsequently oxidised with sodium periodate in the presence of a catalytic amount of ruthenium trichloride to give cyclic sulfate **8**.[17] Reductive ring-opening of **8** with tetrabutylammonium borohydride[18] gave exclusively the 3-deoxy derivative **9**. Benzoylation of **9** provided fully protected methylglycoside **10**, which was converted into the ethyl 1-thio-glycoside **11** according to the procedure of Hanessian et al.[19] Thus, reaction of compound **10** with (ethylthio)trimethylsilane in the presence of zinc iodide and tetrabutylammonium iodide in 1,2-dichloroethane at 60 °C gave, after separation by column chromatography, the individual anomers of **11** in an overall yield of 26% based on **3**.

The same sequence of reactions, as described above for the conversion of **3** into **11**, was performed starting from the corresponding α-anomer of **3**. Unfortunately, conversion of methyl α-glycoside **10** into ethyl 1-thio-glycoside **11** by the Hanessian procedure resulted in an intractable mixture of products.

A similar synthetic route was adopted for the preparation of ethyl 1-thio-D-tyvelopyranoside **26** (see Scheme 2). Deoxygenation of methyl 2,3-*O*-isopropylidene-6-*O*-tosyl-α-D-mannopyranoside[20] (**12**) with $LiAlH_4$ gave, apart from the expected and known[20] product **13**, the 2-*O*-isopropyl derivative **14**.[21] Benzylation of compound **13** with *p*-methoxybenzyl chloride and sodium hydride gave the fully protected derivative **15**. In this respect it is of interest to note that **15** was obtained in a higher yield by *p*-methoxybenzylation of compound **12** (to give **16**) followed by reduction. Deacetonation of **15** gave the *cis*-diol **17**, which was converted into tyvelopyranoside **21** under similar conditions as mentioned above for the transformation of **7** into **10**. However, in this particular case, reduction of the readily accessible cyclic sulfate function in **18** with tetrabutylammonium borohydride yielded the desired 3-deoxy compound **19** together with its 2-deoxy isomer **20** as an inseparable mixture in a ratio of 6:1. Benzoylation of both regioisomers followed by separation of the individual isomers by silica gel column chromatography gave homogeneous D-tyvelopyranoside **21**. Conversion of methyl α-D-tyvelopyranoside **21** into the corresponding ethyl 1-thio-glycoside donor **26** by the procedure of Hanessian was abortive. However, the anomeric ethylthio group could be introduced as follows. Oxidative removal of the *p*-methoxybenzyl group in **21** with

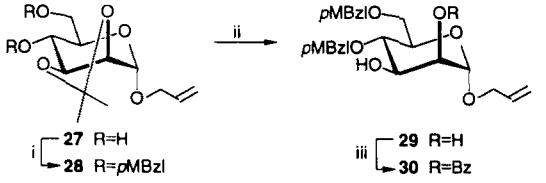


Reagents and conditions: i) $LiAlH_4$, Et_2O, 2 h, **13** 54% and **14** 14%, **15** 75%. ii) *p*MBzlCl, NaH, DMF, 2 h, **15** 93%, **16** 90%. iii) 50% HOAc, 60 °C, 1 h, 80%. iv) $SOCl_2$, pyridine, EtOAc, 0 °C, 30 min; $RuCl_3$, $NaIO_4$, dichloromethane, CH_3CN, H_2O, 30 min, 86%. v) Bu_4NBH_4, THF, reflux, 2 h; H_2SO_4, H_2O, THF, 2 × 1 h, 86%. vi) BzCl, pyridine, 2.5 h, 92%. vii) DDQ, dichloromethane-water, 2 h, 93%. viii) BzCl, pyridine, 1 h, 95%. ix) Ac_2O, H_2SO_4, 0 °C, 45 min; NaOAc, 1 h, 84%. x) EtSH, $SnCl_4$, dichloromethane, 2 h, 84% (α:β=10:1).

Scheme 2

2,3-dichloro-5,6-dicyano-1,4-benzoquinone[22] (DDQ) led to compound **23**,[23] which in turn was benzoylated to give dibenzoate **24**.[24] Acidolysis of **24** with acetic anhydride in the presence of sulfuric acid furnished the anomeric acetate **25**. Subsequent treatment of **25** with ethanethiol and catalytic tin tetrachloride yielded, after separation of the anomers by column chromatography, the ethyl 1-thio-α(β)-D-tyvelopyranosyl donor **26** in an overall yield of 20% based on **12**.[25]

Having donors **11** and **26** in hand, acceptor **30** was prepared by the following sequence of reactions (see Scheme 3). *p*-Methoxybenzylation of known[5b] allyl 2,3-*O*-isopropylidene-α-D-mannopyranoside **27** was followed by selective deblocking of the

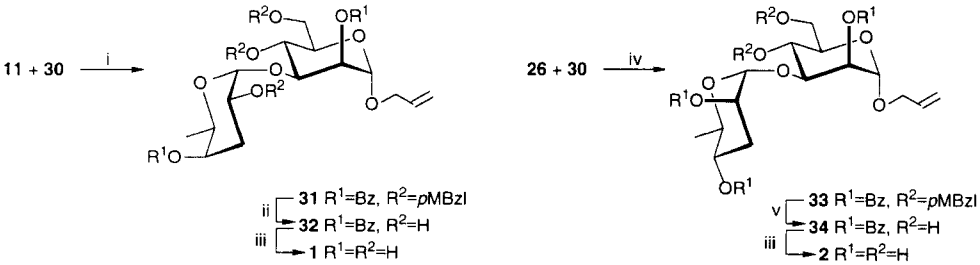


Reagents and conditions: i) *p*MBzlCl, NaH, DMF, 2 h, 86%. ii) 80% HOAc, 45 min, 82%. iii) $PhC(OCH_3)_3$, *p*TsOH, CH_3CN, 30 min; HOAc, 45 min, 83%.

Scheme 3

2,3-*O*-isopropylidene ketal in **28** to yield diol **29**. Conversion of **29** with trimethyl orthobenzoate in the presence of *p*-TsOH and subsequent hydrolysis of the resulting ortho-ester[26] gave allyl 2-*O*-benzoyl-4,6-di-*O*-(*p*-methoxybenzyl)-α-D-mannopyranoside (**30**).

The assembly of disaccharides **1** and **2** is illustrated in Scheme 4. Glycosylation of mannopyranoside acceptor **30** with ethyl 4-*O*-benzoyl-2-*O*-(*p*-methoxybenzyl)-1-thio-α-D-abequopyranoside **11** in the presence of *N*-iodosuccinimide (NIS) and a catalytic amount of triflic acid (TfOH)[27] gave an anomeric mixture of disaccharides **31** (α:β=4:1). On the other hand, glycosylation of **11** with **30** under the agency of the weaker thiophilic promoter iodonium di-*sym*-collidine triflate[28] (IDCT) led, after separation of the crude mixture (α:β=9:1) by column chromatography, to the isolation of the homogeneous α-D-linked disaccharide **31** and the β-D-linked analogue. Standard oxidative removal of the *p*-methoxybenzyl group in compound **31** with DDQ gave **32** in a moderate yield. However, mild acid hydrolysis of **31** gave compound **32** in a more satisfactory yield. Finally, Zemplén type debenzoylation of **32** afforded allyl 3-*O*-(α-D-abequopyranosyl)-α-D-mannopyranoside (**1**), the NMR data of which were in good accordance with those reported earlier.[5b]



Reagents and conditions: i) IDCT, Et_2O, 0 °C, 2 h, 87%. ii) HCl-MeOH (0.5 N), 60 °C, 45 min, 74%. iii) KO*t*-Bu, MeOH, 19 h, **1** 88%, **2** 84%. iv) NIS/TfOH(cat.), 1,2-dichloroethane-Et_2O, -30 °C, 15 min, 93%. v) HCl-MeOH-dioxane (0.5 M), 60 °C, 3 h, 88%.

Scheme 4

Stereoselective 1,2-*trans* glycosylation of mannopyranosyl acceptor **30** with ethyl 2,4-di-*O*-benzoyl-1-thio-α-D-tyvelopyranoside (**26**) under the agency of NIS/TfOH(cat.) at low temperature gave α-linked disaccharide **33**, as evidenced by ^{13}C NMR (96.5, 98.3, $^1J_{C,H}$ 171.4 Hz). Deblocking of compound **33** was effected by acid hydrolysis of the *p*-methoxybenzyl groups to give, after Zemplén type deacylation of **34**, the required disaccharide **2**. The spectral data of **2** were in accordance with those reported by Kochetkov et al.[6]

In summary, the preparation of 3,6-dideoxyglycosides by hydride-mediated ring-opening of cyclic sulfate functions is a promising alternative for the thus far devised methods for the synthesis of methyl abequo- and tyvelopyranoside donors. Moreover, ethyl 3,6-dideoxy-1-thio-D-glycoside donors **11** and **26** are efficient and stable building blocks for the assembly of abequo- and tyvelopyranoside containing oligosaccharides.

EXPERIMENTAL

General methods and materials: *N,N*-Dimethylformamide (DMF) was stirred with calcium hydride for 19 h, then distilled under reduced pressure and stored over molecular sieves 4 Å (Aldrich). Acetonitrile (p.a. Rathburne) was dried over molecular sieves 4 Å. Pyridine was refluxed for 18 h in the presence of calcium hydride, then distilled and stored over molecular sieves 4 Å. Ethyl acetate was refluxed in the presence of calcium hydride for 2 h, then distilled and stored over molecular sieves 4 Å. Tetrahydrofuran (THF, p.a. Merck) was dried over molecular sieves 4 Å before use. Toluene, dichloromethane and 1,2-dichloroethane were distilled from P_2O_5. Diethyl ether was distilled from $LiAlH_4$. Toluene and diethyl ether were stored over sodium wire, dichloromethane and 1,2-dichloroethane over molecular sieves 4 Å. Methanol was dried by refluxing with magnesium methoxide, distilled and stored over molecular sieves 3 Å. Solvents used for column chromatography were of technical grade and distilled before use. Petroleum ether used for elution of the columns was low-boiling (40-60 °C).

Reactions were performed under anhydrous conditions at room temperature unless stated otherwise. Solvents were evaporated under reduced pressure at 40 °C. TLC analyses were conducted on Schleicher & Schüll DC Fertigfolien (F 1500 LS 254). Compounds were visualised by UV light and by charring with H_2SO_4-ethanol (1/4, v/v). Column chromatography was performed on column of silica gel (Baker, 0.063-0.200 nm).

Optical rotations were measured with a Propol polarimeter for solutions in chloroform (p.a. Baker) unless stated otherwise (20 °C). ^1H and ^{13}C NMR spectra were recorded with a JEOL JNM-FX-200 (at 200 and 50.1 MHz, respectively), a Bruker WM-300 spectrometer equipped with an Aspect 2000 computer (^1H, 300 MHz) and a Bruker 600 DMX (600 MHz). Chemical shifts are given in ppm (δ) relative to tetramethylsilane as an internal standard. Mass spectra of compounds dissolved in methanol-water (4/1, v/v) were recorded with a Finnigan MAT TSQ-70 equipped with a custom-made Electrospray Interface (ESI).

Methyl 3,4-*O*-Isopropylidene-2-*O*-(*p*-methoxybenzyl)-6-*O*-tosyl-β-D-galacto-pyranoside (4). To a solution of compound **3** (20.62 g, 50.5 mmol) in DMF (187 mL)

were added *p*-methoxybenzyl chloride (8.90 mL, 65.7 mmol) and tetrabutylammonium iodide (5.61 g, 15.2 mmol). The solution was cooled in an ice-bath and sodium hydride (60%, 2.22 g, 55.6 mmol) was added. Subsequently, the reaction mixture was stirred for 1 h at room temperature, then sodium hydride was added in portions of 0.05 equiv. (60%, 100 mg, 2.5 mmol) until all starting material was consumed. The reaction was quenched with methanol (10 mL) and the solvents were removed. The residue was taken up in diethyl ether (200 mL). The solution was washed with water (100 mL) and aq $NaHCO_3$ (10%, 100 mL), dried ($MgSO_4$), and filtered. The filtrate was concentrated and the oily residue was applied to a silica gel column. Elution of the column with 10→40% ethyl acetate in petroleum ether gave first the side-product methyl 6-deoxy-2,3-*O*-isopropylidene-4-*O*-(*p*-methoxybenzyl)-β-D-*arabino*-hex-5-enopyranoside (**5**, 1.72 g, 5.1 mmol). Further elution of the column yielded the required product **4** (23.13 g, 43.8 mmol). **4**: ^{1}H NMR ($CDCl_3$) δ 1.26, 1.28 (2s, 6H, $2CH_3$ Isopr), 2.45 (s, 3H, CH_3 Ts), 3.31 (dd, 1H, $J_{H,H}$ = 6.4 Hz, $J_{H,H}$ = 7.7 Hz, CH sugar ring), 3.50 (s, 3H, CH_3 1-*O*-Me), 3.79 (s, 3H, CH_3 OMe *p*MBzl), 3.95-4.30 (m, 6H, CH sugar ring), 4.69 (s, 2H, CH_2 *p*MBzl), 6.83-6.89 (m, 2H, H_{Ar} *p*MBzl), 7.25-7.36 (m, 4H, H_{Ar} arom), 7.78-7.82 (m, 2H, H_{Ar} Ts); $^{13}C\{^1H\}$ NMR ($CDCl_3$) δ 21.2 (CH_3 Ts), 25.8, 27.2 (CH_3 Isopr), 54.8, 56.3 ($2CH_3$ 1-*O*-Me, OMe *p*MBzl), 68.5 (C-6), 72.6 (CH_2 *p*MBzl), 70.1, 72.7, 78.4 (C-2, C-3, C-4, C-5), 103.2 (C-1), 109.7 (qC Isopr), 113.2 (CH *p*MBzl), 127.5, 129.4, 129.5 (C_{Ar}), 129.9 (qC_{Ar} *p*MBzl), 132.5, 144.6 (qC_{Ar} Ts), 158.8 (qC_{Ar} *p*MBzl). **5**: $[\alpha]_D$ -40.8° (*c* 1); ^{1}H NMR ($CDCl_3$): δ 1.36, 1.44 (2s, 6H, $2CH_3$ Isopr), 3.49 (s, 3H, CH_3 1-*O*-Me), 3.54 (t, 1H, $J_{2,1} \approx J_{2,3}$ = 5.6 Hz, H-2), 3.76 (s, 3H, CH_3 OMe *p*MBzl), 4.23 (dd, 1H, $J_{3,2}$ = 5.6 Hz, $J_{3,4}$ = 6.8 Hz, H-3), 4.63 (t, 1H, $^2J_{6,6} \approx {}^4J_{6,4}$ = -0.9 Hz, H-6), 4.64 (d, 1H, $J_{1,2}$ 5.6 = Hz, H-1), 4.65-4.67 (m, 1H, H-4), 4.67 (s, 2H, CH_2 *p*MBzl), 4.77 (t, 1H, $^2J_{6,6} \approx {}^4J_{6,4}$ = -0.9 Hz, H-6), 6.84-6.88 (m, 2H, H_{Ar} *p*MBzl), 7.27-7.30 (m, 2H, H_{Ar} *p*MBzl); $^{13}C\{^1H\}$ NMR ($CDCl_3$) δ 25.3, 26.6 ($2CH_3$ Isopr), 54.7, 55.6 ($2CH_3$ 1-*O*-Me, OMe *p*MBzl), 72.2 (CH_2 *p*MBzl), 72.1, 75.8, 76.5 (C-2, C-3, C-4), 97.2 (C-6), 101.7 (C-1), 109.9 (qC Isopr), 113.3, 129.2 (C_{Ar} *p*MBzl), 129.3 (qC_{Ar} *p*MBzl), 152.5 (C-5), 158.9 (qC_{Ar} *p*MBzl).

Methyl 3,4-*O*-Isopropylidene-2-*O*-(*p*-methoxybenzyl)-β-D-fucopyranoside (6). Galactopyranoside **4** (23.13 g, 43.8 mmol) was dried by evaporation with toluene and subsequently dissolved in THF (438 mL). $LiAlH_4$ (3.30 g, 87.0 mmol) was added and the mixture was heated under reflux. After 2 h, the reaction was cooled and a second portion of $LiAlH_4$ (1.65 g, 43.5 mmol) was added. The reaction mixture was heated under reflux for 20 h and subsequently recooled in an ice bath and diluted with diethyl ether (300 mL). Excess $LiAlH_4$ was destroyed carefully with oxalic acid (1M). The reaction mixture was filtered and the filtrate was washed with water (200 mL), dried ($MgSO_4$), and filtered. The

solvents were evaporated and the residue was purified by column chromatography. The column was eluted with a gradient of ethyl acetate in petroleum ether (10→80%) to give compound **6** (12.08 g, 35.7 mmol) and methyl 3,4-*O*-isopropylidene-2-*O*-(*p*-methoxybenzyl)-β-D-galactopyranoside (1.65 g, 4.4 mmol). **6**: ^{1}H NMR ($CDCl_3$) δ 1.39 (d, 3H, $J_{6,5}$ = 6.3 Hz, H-6), 1.33, 1.37 (2s, 6H, $2CH_3$ Isopr), 3.35 (t, 1H, $J_{2,1}\approx J_{2,3}$ = 7.2 Hz, H-2), 3.54 (s, 3H, CH_3 1-*O*-Me), 3.79 (s, 3H, CH_3 OMe *p*MBzl), 3.79-4.19 (m, 3H, H-3, H-4, H-5), 4.17 (d, 1H, $J_{1,2}$ = 8.0 Hz, H-1), 4.73 (s, 2H, CH_2 *p*MBzl), 6.85 (d, 2H, $J_{H,H}$ = 8.2 Hz, H_{Ar} *p*MBzl), 7.31 (d, 2H, $J_{H,H}$ = 8.4 Hz, CH *p*MBzl); $^{13}C\{^1H\}$ NMR ($CDCl_3$) δ 15.8 (C-6), 25.6, 27.2 (CH_3 Isopr), 54.3, 55.6 ($2CH_3$ 1-*O*-Me, OMe *p*MBzl), 72.2 (CH_2 *p*MBzl), 67.8, 75.7, 78.4, 78.6 (C-2, C-3, C-4, C-5), 103.0 (C-1), 108.5 (qC Isopr), 112.8, 128.9 (C_{Ar} *p*MBzl), 129.9, 158.4 (qC_{Ar} *p*MBn).

Anal. Calcd for $C_{18}H_{26}O_6$ (338.40): C, 63.89; H, 7.74. Found: C, 63.75; H, 7.67.

Side-product: $^{13}C\{^1H\}$ NMR ($CDCl_3$) δ 26.1, 27.4 ($2CH_3$ Isopr), 55.0, 56.6 ($2CH_3$ 1-*O*-Me, OMe *p*MBzl), 61.9 (C-6), 72.9 (CH_2 *p*MBzl), 72.9, 73.6, 78.8, 78.9 (C-2, C-3, C-4, C-5), 103.6 (C-1), 109.8 (qC Isopr), 113.4, 129.5 (C_{Ar} *p*MBzl), 130.1, 158.9 (qC_{Ar} *p*MBzl).

Methyl 2-*O*-(*p*-Methoxybenzyl)-β-D-fucopyranoside (7). Water (165 mL) was added to a solution of fucopyranoside **6** (2.08 g, 35.7 mmol) in acetic acid (165 mL). The solution was heated at 60 °C for 1 h and subsequently concentrated. The remaining solvents were removed by repeated evaporation with toluene. Purification of the residue by crystallisation (ethyl acetate and petroleum ether) gave diol **7** (9.46 g, 31.8 mmol). **7**: mp 86 °C; $[\alpha]_D$ +36.0° (*c* 1); ^{1}H NMR ($CDCl_3$, 300 MHz, HH-COSY) δ 1.32 (d, 3H, $J_{6,5}$ = 6.5 Hz, H-6), 2.65 (d, 1H, $J_{HO,H}$ =4.7 Hz, OH), 2.82 (d, 1H, $J_{HO,H}$ = 4.3 Hz, OH), 3.41 (dd, 1H, $J_{2,1}$ = 7.6 Hz, $J_{2,3}$ =9.5 Hz, H-2), 3.55 (s, 3H, CH_3 1-*O*-Me), 3.52-3.58 (m, 2H, H-4, H-5), 3.66 (dd, 1H, $J_{3,2}$ = 9.8 Hz, $J_{3,4}$ = 3.4 Hz, H-3), 3.79 (s, 3H, CH_3 OMe *p*MBzl), 4.22 (d, 1H, $J_{1,2}$ = 7.7 Hz, H-1), 4.71 (AB, 2H, CH_2 *p*MBzl), 6.84-6.89 (m, 2H, H_{Ar} *p*MBzl), 7.26-7.31 (m, 2H, H_{Ar} *p*MBzl); $^{13}C\{^1H\}$ NMR ($CDCl_3$) δ 15.9 (C-6), 54.6, 54.8 ($2CH_3$ 1-*O*-Me, OMe *p*MBzl), 73.8 (CH_2 *p*MBzl), 69.9, 71.0, 73.1, 78.5 (C-2, C-3, C-4, C-5), 104.3 (C-1), 113.4, 129.2 (C_{Ar} *p*MBn), 130.5, 158.8 (qC_{Ar} *p*MBzl).

Anal. Calcd for $C_{15}H_{22}O_6$ (298.32): C, 60.39; H, 7.43. Found: C, 60.47; H, 7.49.

Methyl 2-*O*-(*p*-Methoxybenzyl)-3,4-*O*-sulfonyl-β-D-fucopyranoside (8). To a solution of compound **7** (4.73 g, 15.9 mmol) in ethyl acetate (159 mL) was added pyridine (2.57 mL, 31.8 mmol). The solution was cooled to 0 °C and thionyl chloride (1.25 mL, 17.1 mmol) was added. After stirring for 30 min, the reaction mixture was diluted with ethyl acetate (150 mL), washed with water (200 mL), dried ($MgSO_4$), filtered, and concentrated.

The resulting diastereomeric cyclic sulfites containing carbohydrates were dissolved in a mixture of dichloromethane, acetonitrile and water (2/2/3, v/v/v, 108 mL). Sodium periodate (6.80 g, 31.8 mmol) and a catalytic amount of ruthenium trichloride were added. After stirring for 30 min, the sulfites were converted into a more polar material. The reaction mixture was diluted with dichloromethane (250 mL) and washed with brine (150 mL). The organic layer was dried ($MgSO_4$), filtered, and concentrated to yield crude cyclic sulfate. The residue was purified by column chromatography (20→40% ethyl acetate in petroleum ether) to give the compound **8** (5.44 g, 15.1 mmol). **8**: ^{1}H NMR ($CDCl_3$) δ 1.45 (d, 3H, $J_{6,5}$ = 6.6 Hz, H-6), 3.57 (s, 3H, CH_3 1-*O*-Me), 3.80 (s, 3H, CH_3 OMe *p*MBzl), 3.80-3.89 (m, 2H, H-2, H-5), 4.24 (d, 1H, $J_{1,2}$ = 7.9 Hz, H-1), 4.72 (AB, 2H, CH_2 *p*MBzl), 4.78-4.88 (m, 2H, H-3, H-4), 6.88 (d, 2H, H_{Ar} *p*MBzl, $J_{H,H}$ = 8.6 Hz), 7.28 (d, 2H, H_{Ar} *p*MBzl, $J_{H,H}$ = 8.6 Hz); ^{13}C{^{1}H} NMR ($CDCl_3$) δ 15.6 (C-6), 54.7, 56.5 ($2CH_3$ 1-*O*-Me, OMe *p*MBzl), 73.9 (CH_2 *p*MBzl), 67.2, 76.8, 82.4, 85.3 (C-2, C-3, C-4, C-5), 102.4 (C-1), 113.4, 129.4 (C_{Ar} *p*MBzl), 129.3, 159.1 (qC_{Ar} *p*MBzl).

Anal. Calcd for $C_{15}H_{20}O_8S$ (360.39): C, 49.99; H, 5.59. Found: C, 49.88; H, 5.67.

Methyl 3,6-Dideoxy-2-*O*-(*p*-methoxybenzyl)-β-D-*xylo*-hexopyranoside (9). Tetrabutylammonium borohydride (4.66 g, 18.1 mmol) was added to a solution of compound **8** (5.44 g, 15.1 mmol) in THF (150 mL). The solution was heated under reflux for 30 min and subsequently cooled in an ice-bath. A few drops of acetone were added to destroy the reducing agent. Sulfuric acid (0.80 mL, 15.1 mmol) and water (0.26 mL, 15.1 mmol) were added to the reaction mixture and stirring was continued for 30 min at room temperature. The solvent was evaporated and the residue was taken up in ethyl acetate (200 mL). The solution was washed with aq $NaHCO_3$ (100 mL), dried ($MgSO_4$), filtered, and concentrated.

The oily residue was dissolved in THF (150 mL), sulfuric acid (0.80 mL, 15.5 mmol) and water (0.26 mL, 15.1 mmol) were added. The reaction was stirred until no further conversion was observed by TLC-analysis (3 h). The reaction mixture was diluted with ethyl acetate (200 mL), washed with aq $NaHCO_3$ (100 mL), dried ($MgSO_4$), and filtered. The filtrate was concentrated and the crude product was purified by column chromatography. The column was eluted with ethyl acetate in petroleum ether (30→50%) to give 3,6-dideoxy-*xylo*-hexopranoside **9** (3.04 g, 10.8 mmol). **9**: ^{1}H NMR ($CDCl_3$) δ 1.26 (d, 3H, $J_{6,5}$ = 6.6 Hz, H-6), 1.59 (dt, 1H, $^2J_{3,3}\approx J_{3,2}$ = 12.7 Hz, $J_{3,4}$ = 3.0 Hz, H-3-ax), 2.28 (ddd, 1H, $^2J_{3,3}$ = -13.7 Hz, $J_{3,2}$ = 5.1 Hz, $J_{3,4}$ = 3.2 Hz, H-3-eq), 3.44-3.77 (m, 3H, H-2, H-4, H-5), 3.56 (s, 3H, CH_3 1-*O*-Me), 3.79 (s, 3H, CH_3 OMe *p*MBzl), 4.27 (d, 1H, $J_{1,2}$ = 7.7 Hz, H-1), 4.63 (AB, 2H, CH_2 *p*MBzl), 6.85 (m, 2H, $J_{H,H}$ = 8.6 Hz, H_{Ar} *p*MBzl), 7.26 (d, 2H, $J_{H,H}$ = 8.4 Hz, H_{Ar} *p*MBzl); ^{13}C{^{1}H} NMR ($CDCl_3$) δ 16.1 (C-6), 36.7 (C-3),

54.8, 55.9 ($2CH_3$ 1-*O*-Me, OMe *p*MBzl), 72.0 (CH_2 *p*MBzl), 68.4, 72.2, 73.1 (C-2, C-4, C-5), 105.9 (C-1), 113.3, 128.6 (C_{Ar} *p*MBzl), 130.5, 158.6 (qC_{Ar} *p*MBzl).

Anal Calcd for $C_{15}H_{20}O_5$ (282.34): C, 63.81; H, 7.85. Found: C, 63.73; H, 7.94.

Methyl 4-*O*-Benzoyl-3,6-dideoxy-2-*O*-(*p*-methoxybenzyl)-β-D-*xylo*-hexopyranoside (10). To a solution of compound **9** (3.04 g, 10.8 mmol) in pyridine (23 mL) was added benzoyl chloride (1.90 mL, 16.4 mmol). The reaction mixture was stirred at room temperature for 1.5 h, water (5 mL) was added and the solvents were evaporated. A solution of the residue in ethyl acetate (50 mL) was washed successively with water (30 mL) and aq $NaHCO_3$ (30 mL). The organic layer was dried ($MgSO_4$), filtered, and concentrated. The residue was applied to a silica gel column, which was eluted with 10→30% ethyl acetate in petroleum ether to yield product **10** (3.64 g, 9.4 mmol). **10**: $[\alpha]_D$ +31.6° (*c* 1); ^{1}H NMR ($CDCl_3$, 300 MHz, HH-COSY) δ 1.25 (d, 3H, $J_{6,5}$ = 6.5 Hz, H-6), 1.79 (ddd, 1H, $^2J_{3,3}$ = -14.3 Hz, $J_{3,2}$ = 11.7 Hz, $J_{3,4}$ = 3.2 Hz, H-3-ax), 2.35 (ddd, 1H, $^2J_{3,3}$ = -14.3 Hz, $J_{3,2}$ = 3.0 Hz, $J_{3,4}$ = 5.1 Hz, H-3-eq), 3.58 (ddd, 1H, $J_{2,1}$ = 7.3 Hz, $J_{2,3}$ = 4.7 Hz, $J_{2,3}$ = 11.9 Hz, H-2), 3.62 (s, 3H, CH_3 1-*O*-Me), 3.75 (s, 3H, CH_3 OMe *p*MBzl), 3.83 (dq, 1H, $J_{5,4}$ = 1.3 Hz, $J_{5,6}$ = 6.1 Hz, H-5), 4.36 (d, 1H, $J_{1,2}$ = 7.6 Hz, H-1), 4.50 (AB, 2H, CH_2 *p*MBzl), 5.16 (dd, 1H, $J_{4,3}$ = 3.1 Hz, $J_{4,3}$ = 4.3 Hz, H-4), 6.80-6.82 (m, 2H, H_{Ar} *p*MBzl), 7.22-7.25 (m, 2H, H_{Ar} *p*MBzl), 7.42-7.60 (m, 3H, H_{Ar} Bz), 8.05-8.08 (m, 2H, H_{Ar} Bz); $^{13}C\{^1H\}$ NMR ($CDCl_3$) δ 15.8 (C-6), 33.5 (C-3), 54.1, 55.5 ($2CH_3$ 1-*O*-Me, OMe *p*MBzl), 71.6 (CH_2 *p*MBzl), 70.5, 71.3, 71.8 (C-2, C-4, C-5), 105.4 (C-1), 112.8 (C_{Ar} *p*MBzl), 127.6, 128.6, 128.9 (C_{Ar}), 129.3, 129.9 (qC_{Ar}), 132.3 (C_{Ar} Bz), 158.4 (qC_{Ar} *p*MBzl), 164.9 (C=O Bz).

Anal. Calcd for $C_{22}H_{26}O_6$ (386.45): C, 68.38; H, 6.78. Found: C, 68.44; H, 6.69.

Ethyl 4-*O*-Benzoyl-3,6-dideoxy-2-*O*-(*p*-methoxybenzyl)-α-D-*xylo*-hexopyranoside (11-α) and **Ethyl 4-*O*-Benzoyl-3,6-dideoxy-2-*O*-(*p*-methoxybenzyl)-β-D-*xylo*-hexopyranoside (11-β)**. Zinc iodide (7.66 g, 24 mmol) was dried by heating at 60 °C under reduced pressure for 3 h, and subsequently cooled to room temperature. To the zinc iodide were added successively a solution of methyl 3,6-dideoxy-*xylo*-hexopyranoside **10** (3.09 g, 8.0 mmol) in 1,2-dichloroethane (32 mL), tetrabutylammonium iodide (3.55 g, 9.6 mmol), and (ethylthio)trimethylsilane (5.20 mL, 32.1 mmol). After stirring for 9 min at 60 °C, the reaction mixture was poured into aq $NaHCO_3$ (10%, 25 mL). The layers were separated and the organic phase was washed with water (20 mL), dried ($MgSO_4$), filtered, and concentrated. The crude product was purified by silica gel column chromatography. Elution with 0→20% ethyl acetate in petroleum ether gave the α-linked ethyl 1-thio-D-abequopyranoside **11-α** (2.13 g, 5.1 mmol) followed by the β-anomer **11-β** (632 mg, 1.5 mmol). **11-α**: $[\alpha]_D$ +191.5° (*c* 1); ^{1}H NMR ($CDCl_3$) δ 1.18 (d, 3H, $J_{6,5}$ = 6.4 Hz, H-6),

1.34 (t, 3H, $J_{H,H}$ = 7.4 Hz, CH_3 SEt), 1.96-2.16 (m, 2H, H-3), 2.62 (ABX, 2H, CH_2 SEt), 3.75 (s, 3H, CH_3 OMe *p*MBzl), 4.11 (dt, 1H, $J_{2,1}$ = 5.2 Hz, $J_{2,3}$≈$J_{2,3}$ = 11.6 Hz, H-2), 4.49 (q, 1H, $J_{5,6}$ = 6.2 Hz, H-5), 4.51 (AB, 2H, CH_2 *p*MBzl), 5.22 (br s, 1H, H-4), 5.52 (d, 1H, $J_{1,2}$ = 5.1 Hz, H-1), 6.77-6.80 (m, 2H, CH *p*MBzl), 7.22-7.26 (m, 2H, H_{Ar} *p*MBzl), 7.40-7.60 (m, 3H, H_{Ar} Bz), 8.01-8.05 (m, 2H, H_{Ar} Bz); $^{13}C\{^1H\}$ NMR ($CDCl_3$) δ 14.8 (CH_3 SEt), 16.1 (C-6), 23.3 (CH_2 SEt), 30.7 (C-3), 54.8 (CH_3 OMe *p*MBzl), 69.8 (CH_2 *p*MBzl), 64.8, 69.5, 71.3 (C-2, C-4, C-5), 83.8 (C-1), 113.4 (CH *p*MBzl), 128.1, 129.4 (C_{Ar}), 130.0 (qC_{Ar}), 132.8 (C_{Ar} Bz), 159.0 (qC_{Ar} *p*MBzl), 165.4 (C=O Bz).

Anal. Calcd for $C_{23}H_{28}O_5S$ (416.54): C, 66.33; H, 6.78. Found: C, 66.41; H, 6.65.

11-β: $[\alpha]_D$ +10.0° (*c* 1); ^1H NMR: ($CDCl_3$) δ 1.24 (d, 3H, $J_{6,5}$ = 6.4 Hz, H-6), 1.34 (t, 3H, $J_{H,H}$ = 7.5 Hz, CH_3 SEt), 1.79 (ddd, 1H, $^2J_{3,3}$ = -14.0 Hz, $J_{3,2}$ = 11.0 Hz, $J_{3,4}$ = 3.2 Hz, H-3-ax), 2.48 (dt, 1H, $^2J_{3,3}$ = -14.0 Hz, $J_{3,2}$≈$J_{3,4}$ = 3.8 Hz, H-3-eq), 2.78 (ABX, 2H, CH_2 SEt), 3.56-3.66 (m, 1H, H-2), 3.74 (s, 3H, CH_3 OMe *p*MBzl), 3.80 (q, 1H, $J_{5,6}$ = 6.4 Hz, H-5), 4.56 (AB, 2H, CH_2 *p*MBzl), 4.56 (d, 1H, $J_{1,2}$ = 7.9 Hz, H-1), 5.20 (br s, 1H, H-4), 6.76-6.80 (m, 2H, H_{Ar} *p*MBzl), 7.23-7.26 (m, 2H, H_{Ar} *p*MBzl), 7.41-7.63 (m, 3H, H_{Ar} Bz), 8.03-8.08 (m, 2H, H_{Ar} Bz); $^{13}C\{^1H\}$ NMR ($CDCl_3$) δ 14.7 (CH_3 SEt), 16.8 (C-6), 24.3 (CH_2 SEt), 35.4 (C-3), 55.0 (CH_3 OMe *p*MBzl), 71.8 (CH_2 *p*MBzl), 71.2, 71.8, 74.9 (C-2, C-4, C-5), 86.5 (C-1), 113.5 (C_{Ar} *p*MBzl), 128.2, 129.6 (C_{Ar}), 132.9 (C_{Ar} Bz), 159.1 (qC_{Ar} *p*MBzl), 165.6 (C=O Bz).

Anal. Calcd for $C_{23}H_{28}O_5S$ (416.54): C, 66.33; H, 6.78. Found: C, 66.25; H, 6.67.

Methyl 2,3-*O*-Isopropylidene-α-D-rhamnopyranoside (13). Known[20] D-mannopyranoside **12** (5.74 g, 14.8 mmol) was dried by repeated evaporation of toluene, and subsequently dissolved in freshly distilled diethyl ether (70 mL). The solution was cooled in an ice-bath and $LiAlH_4$ (841 mg, 22.2 mmol) was added. The ice-bath was removed and the reaction mixture was heated under reflux for 2 h. The reaction mixture was cooled and excess reagent was carefully destroyed with oxalic acid (1 M, 1.5 mL). The reaction mixture was filtered and filtrate was diluted with diethyl ether (15 mL). The organic layer was washed with water (10 mL) and aq $NaHCO_3$ (10%, 10 mL), dried ($MgSO_4$), filtered, and concentrated. The crude product was applied to a silica gel column, which was eluted with a gradient of diethyl ether in petroleum ether (20→40%) to furnish known[20] methyl 2,3-*O*-isopropylidene-α-D-rhamnopyranoside (**13**, 1.88 g, 8.6 mmol) and methyl 6-deoxy-2-*O*-isopropyl-α-D-mannopyranoside (**14**, 453 mg, 2.1 mmol).

The position of the isopropyl substituent in **14** was established through the corresponding dibenzoate, which was prepared as follows. A solution of compound (191 mg, 0.9 mmol) in pyridine (5.5 mL) was stirred in the presence of benzoyl chloride (0.31 mL, 2.7 mmol) for 2 h. The reaction was quenched with water (1 mL) and the solvents

were evaporated. The residue was redissolved in ethyl acetate (15 mL), washed with water (10 mL) and aq $NaHCO_3$ (10%, 10 mL). The organic layer was dried ($MgSO_4$), filtered, and concentrated. The crude product was purified by column chromatography (0→20% ethyl acetate in petroleum ether) to yield the benzoylated derivative of **14** (322 mg, 0.76 mmol). **14**: $[\alpha]_D$ +13.8° (*c* 1). ^1H NMR ($CDCl_3$) δ 1.19 (d, 6H, $J_{H,H}$ = 6.2 Hz, $2CH_3$ isopropyl), 1.31 (d, 3H, $J_{6,5}$ = 6.2 Hz, H-6), 2.54, 2.91 (2br s, 1H, OH), 3.35 (s, 3H, CH_3 1-*O*-Me), 3.34-3.78 (m, 7H, H-2, H-3, H-4, H-5, H-6, CH isopropyl), 4.64 (s, 1H, H-1); $^{13}C\{^1H\}$ NMR ($CDCl_3$) δ 17.3 (C-6), 21.8, 22.6 ($2CH_3$ isopropyl), 54.3 (CH_3 1-*O*-Me), 67.5, 71.0, 72.1, 73.2, 76.1 (C-2, C-3, C-4, C-5, CH isopropyl), 99.3 (C-1).

Anal. Calcd for $C_{10}H_{20}O_5$ (220.27): C, 54.53; H, 9.15. Found: C, 54.63; H, 9.08.

Benzoylated derivative of 14: ^1H NMR ($CDCl_3$) δ 1.14 (d, 6H, $J_{H,H}$ = 6.0 Hz, CH_3 isopropyl), 1.32 (d, 3H, $J_{6,5}$ = 6.2 Hz, H-6), 3.45 (s, 3H, CH_3 1-*O*-Me), 3.56-3.68 (m, 1H, CH isopropyl), 4.00 (dd, 1H, $J_{2,1}$ = 1.7 Hz, $J_{2,3}$ = 3.0 Hz, H-2), 4.06 (dq, 1H, $J_{5,4}$ = 9.6 Hz, $J_{5,6}$ = 6.4 Hz, H-5), 4.49 (d, 1H, $J_{1,2}$ = 1.7 Hz, H-1), 5.54 (dd, 1H, $J_{3,2}$ = 3.2 Hz, $J_{3,4}$ = 10.1 Hz, H-3), 5.61 (t, 1H, $J_{4,3} \approx J_{4,5}$ = 10.1 Hz, H-4), 7.31-7.49 (m, 6H, H_{Ar} Bz), 7.93-8.00 (m, 4H, H_{Ar} Bz); $^{13}C\{^1H\}$ NMR ($CDCl_3$) δ 17.3 (C-6), 22.2 ($2CH_3$ isopropyl), 54.6 (CH_3 1-*O*-Me), 66.3, 71.7, 72.1, 73.1, 74.3 (C-2, C-3, C-4, C-5, CH isopropyl), 100.2 (C-1), 128.0, 129.3, 132.8 (C_{Ar} Bz), 165.4, 165.6 (C=O Bz).

Methyl 2,3-*O*-Isopropylidene-4-*O*-(*p*-methoxybenzyl)-α-D-rhamnopyranoside (15). A, from 13: D-Rhamnopyranoside **13** (5.88 g, 27.0 mmol) was dissolved in DMF (100 mL) and cooled in an ice-bath. Sodium hydride (60%, 1.68 g, 42.0 mmol) and *p*-methoxybenzyl chloride (4.76 mL, 35.1 mmol) were added. After stirring for 2 h at room temperature, the reaction was quenched with methanol (0.5 mL) and concentrated. A solution of the residue in diethyl ether (200 mL) was washed with water (150 mL) and aq $NaHCO_3$ (10 %, 150 mL), dried ($MgSO_4$), filtered, and concentrated. The crude product was purified by silica gel chromatography (0→20% diethyl ether in petroleum ether) to yield compound **15** (8.47 g, 25.1 mmol).

B, from 16: Reduction of mannopyranoside **16** (14.4 g, 27.8 mmol) with lithium aluminium hydride (1.58 g, 42.9 mmol) was executed as described for the preparation of compound **13**. The residue was purified by column chromatography (0→20% diethyl ether in petroleum ether) to give compound **15** (6.74 g, 19.9 mmol). $[\alpha]_D$ +56.8° (*c* 1); ^1H NMR ($CDCl_3$) δ 1.26 (d, 3H, $J_{6,5}$ = 6.2 Hz, H-6), 1.37, 1.51 (2s, 6H, $2CH_3$ Isopr), 3.19 (dd, 1H, $J_{4,3}$ = 7.1 Hz, $J_{4,5}$ = 9.9 Hz, H-4), 3.35 (s, 3H, CH_3 1-*O*-Me), 3.64 (dq, 1H, $J_{5,4}$ = 9.8 Hz, $J_{5,6}$ = 6.2 Hz, H-5), 3.79 (s, 3H, CH_3 OMe *p*MBzl), 4.12 (d, 1H, $J_{2,3}$ = 5.9 Hz, H-2), 4.24 (t, 1H, $J_{3,2} \approx J_{3,4}$ = 6.4 Hz, H-3), 4.69 (AB, 2H, CH_2 *p*MBzl), 4.84 (s, 1H, H-1), 6.84-6.90 (m, 2H, H_{Ar} *p*MBzl), 7.26-7.30 (m, 2H, H_{Ar} *p*MBzl); $^{13}C\{^1H\}$ NMR

($CDCl_3$) δ 17.6 (C-6), 26.1, 27.8 ($2CH_3$ Isopr), 54.4, 54.9 ($2CH_3$ 1-*O*-Me, OMe *p*MBzl), 72.3 (CH_2 *p*MBzl), 64.2, 75.8, 78.5, 80.5 (C-2, C-3, C-4, C-5), 97.8 (C-1), 108.9 (qC Isopr), 113.4, 129.4 (C_{Ar} *p*MBzl), 130.3, 159.0 (qC_{Ar} *p*MBzl).

Anal. Calcd for $C_{18}H_{26}O_6$ (338.40): C, 63.89; H, 7.74. Found: C, 63.94; H, 7.66.

Methyl 2,3-*O*-Isopropylidene-4-*O*-(*p*-methoxybenzyl)-6-*O*-tosyl-α-D-manno-pyranoside (16). Treatment of compound **12** (9.96 g, 25.7 mmol) with sodium hydride (60%, 1.54 g, 38.6 mmol) and *p*-methoxybenzyl chloride (4.53 mL, 33.4 mmol) was performed as described for the synthesis of **15** (method A). The crude product was purified by column chromatography. Elution with ethyl acetate in petroleum ether (5→30%) gave mannopyranoside **16** (11.72 g, 23.1 mmol). $[\alpha]_D$ +32.4° (*c* 1); ^1H NMR ($CDCl_3$) δ 1.35, 1.49 (2s, 6H, $2CH_3$ Isopr), 2.44 (s, 3H, CH_3 Ts), 3.30 (s, 3H, CH_3 1-*O*-Me), 3.36 (dd, 1H, $J_{H,H}$ = 6.9 Hz, $J_{H,H}$ = 10.3 Hz, CH sugar ring), 3.72 (dd, 1H, $J_{H,H}$ = 5.8 Hz, $J_{H,H}$ = 9.9 Hz, CH sugar ring), 3.81 (s, 3H, CH_3 OMe *p*MBzl), 4.07-4.30 (m, 4H, CH sugar ring), 4.60 (AB, 2H, CH *p*MBzl), 4.82 (s, 1H, H-1), 6.83-6.88 (m, 2H, H_{Ar} *p*MBzl), 7.17-7.32 (m, 4H, H_{Ar}), 7.76-7.80 (m, 2H, H_{Ar} Ts); $^{13}C\{^1H\}$ NMR ($CDCl_3$) δ 21.2 (CH_3 Ts), 25.8, 27.6 (s, CH_3 Isopr), 54.5, 54.8 ($2CH_3$ 1-*O*-Me, OMe *p*MBzl), 69.0, 71.9 (C-6, CH_2 *p*MBzl), 66.3, 74.3, 75.2, 78.2 (C-2, C-3, C-4, C-5), 97.7 (C-1), 109.1 (qC Isopr), 113.4 (C_{Ar} *p*MBzl), 127.6, 129.3, 129.4 (C_{Ar}), 129.6, 132.6 (qC_{Ar}), 144.4 (qC_{Ar} Ts), 159.0 (qC_{Ar} *p*MBzl).

Methyl 4-*O*-(*p*-Methoxybenzyl)-α-D-rhamnopyranoside (17). Compound **15** (6.76 g, 20.0 mmol) was dissolved in acetic acid (60 mL) and water (60 mL) was added. The solution was stirred for 1 h at 60 °C, concentrated and the residue was dried by evaporation with toluene. Purification by silica gel chromatography (40→60% ethyl acetate in petroleum ether) gave diol **17** (4.00 g, 16.0 mmol). ^1H NMR ($CDCl_3$) δ 1.35 (d, 3H, $J_{6,5}$ = 6.2 Hz, H-6), 3.31 (t, 1H, $J_{4,3} \approx J_{4,5}$ = 9.0 Hz, H-4), 3.35 (s, 3H, CH_3 1-*O*-Me), 3.68 (dq, 1H, $J_{5,4}$ = 6.2 Hz, $J_{5,6}$ = 9.5 H, H-5z), 3.81 (s, 3H, CH_3 OMe *p*MBzl), 3.83-3.90 (m, 2H, H-2, H-3), 4.65 (s, 1H, H-1), 4.66 (AB, 2H, CH_2 *p*MBzl), 6.89 (d, 2H, $J_{H,H}$ = 8.2 Hz, H_{Ar} *p*MBzl), 7.28 (d, 2H, $J_{H,H}$ = 8.4 Hz, CH *p*MBzl); $^{13}C\{^1H\}$ NMR ($CDCl_3$) δ 17.8 (C-6), 54.5, 55.0 ($2CH_3$ 1-*O*-Me, OMe *p*MBzl), 74.4 (CH_2 *p*MBzl), 67.0, 71.0, 71.5, 81.0 (C-2, C-3, C-4, C-5), 100.6 (C-1), 113.6, 129.4 (C_{Ar} *p*MBzl), 130.5, 159.1 (qC_{Ar} *p*MBzl).

Anal. Calcd for $C_{15}H_{22}O_6$ (298.34): C, 60.39; H, 7.43. Found: C, 60.49; H, 7.41.

Methyl 4-*O*-(*p*-Methoxybenzyl)-2,3-*O*-sulfonyl-α-D-rhamnopyranoside (18). The vicinal diol **17** (4.00 g, 16.0 mmol) was treated with thionyl chloride (1.28 mL, 17.6 mmol) to give the cyclic sulfites, which were subsequently oxidised to the cyclic sulfate, according to the procedure to prepare compound **8**. The crude product was purified by

silica gel column chromatography. Elution of the column with 10→30% diethyl ether in petroleum ether furnished cyclic sulfate **18** (4.97 g, 13.8 mmol). ^{1}H NMR ($CDCl_3$) δ 1.28 (d, 3H, $J_{6,5}$ = 6.0 Hz, H-6), 3.38 (s, 3H, CH_3 1-*O*-Me), 3.60-3.70 (m, 2H, H-4, H-5), 3.81 (s, 3H, CH_3 OMe *p*MBzl), 4.67 (AB, 2H, CH_2 *p*MBzl), 4.79-5.01 (m, 3H, H-1, H-2, H-3), 6.89 (d, 2H, $J_{H,H}$ = 8.8 Hz, H_{Ar} *p*MBzl), 7.28 (d, 2H, $J_{H,H}$ = 7.9 Hz, CH *p*MBzl); ^{13}C{^{1}H} NMR ($CDCl_3$) δ 16.9 (C-6), 54.6, 54.7 ($2CH_3$ 1-*O*-Me, OMe *p*MBzl), 73.6 (CH_2 *p*MBzl), 64.1, 77.4, 79.7, 85.8 (C-2, C-3, C-4, C-5), 94.5 (C-1), 113.5, 129.6 (C_{Ar} *p*MBzl), 128.9, 159.2 (qC_{Ar} *p*MBzl).

Methyl 3,6-Dideoxy-4-*O*-(*p*-methoxybenzyl)-α-D-*arabino*-hexopyranoside (19) and **Methyl 2,6-Dideoxy-4-*O*-(*p*-methoxybenzyl)-α-D-*arabino*-hexopyranoside (20)**. Tetrabutylammonium borohydride (7.10 g, 27.6 mmol) was added to a solution of compound **18** (4.97 g, 13.8 mmol) in THF (135 mL). The solution was heated under reflux for 2 h, and cooled subsequently in an ice bath. The excess of reducing agent was destroyed with a few drops of acetone. Then sulfuric acid (0.74 mL, 13.8 mmol) and water (0.25 mL, 13.8 mmol) were added and the reaction was stirred at room temperature for 1 hr. The solvents were evaporated and the residue was taken up in ethyl acetate (100 mL). The organic solution was washed with aq $NaHCO_3$ (10%, 75 mL), dried ($MgSO_4$), filtered, and concentrated.

The acid-hydrolysis was repeated, thus the residue was redissolved in THF (135 mL) and stirred for 1 h in the presence of sulfuric acid (0.74 mL, 13.8 mmol) and water (0.25 mL, 13.8 mmol). The solution was diluted with ethyl acetate (75 mL), washed with aq $NaHCO_3$ (10%, 75 mL), dried ($MgSO_4$), filtered, and concentrated. Purification by silica gel chromatography using a gradient of ethyl acetate in petroleum ether (20→40%) gave an inseparable mixture of the isomeric 3- and 2-deoxy-glycosides **19** and **20**, respectively (3.35 g, 11.9 mmol) in the ratio of 6:1. **19**: ^{13}C{^{1}H} NMR ($CDCl_3$) δ 17.6 (C-6), 31.4 (C-3), 53.9, 54.5 ($2CH_3$ 1-*O*-Me, OMe *p*MBzl), 70.0 (CH_2 *p*MBzl), 67.4, 74.3 (C-2, C-4, C-5), 99.7 (C-1), 113.2, 128.7 (C_{Ar} *p*MBzl), 130.1 (qC_{Ar} *p*MBzl), 158.6 (qC_{Ar} *p*MBzl). **20**: ^{13}C{^{1}H} NMR ($CDCl_3$) δ 37.6 (C-2), 66.4, 68.2, 85.1 (C-3, C-4, C-5), 74.1 (CH_2 *p*MBzl).

Methyl 2-*O*-Benzoyl-3,6-dideoxy-4-*O*-(*p*-methoxybenzyl)-α-D-*arabino*-hexopyranoside (21) and **Methyl 3-*O*-Benzoyl-2,6-dideoxy-4-*O*-(*p*-methoxybenzyl)-α-D-*arabino*-hexopyranoside (22)**. Benzoyl chloride (2.10 mL, 17.9 mmol) was added to a solution of the aforementioned mixture of dideoxy isomers **19** and **20** (3.35 g, 11.9 mmol) in pyridine (75 mL). After stirring for 2.5 h, the reaction was quenched with water (10 mL) and the solvents were evaporated. The residue was taken up in ethyl acetate (50 mL) and the solution was washed with water (40 mL) and aq $NaHCO_3$ (10%, 40 mL), dried

($MgSO_4$), filtered, and concentrated. The two isomers were separated by silica gel chromatography. The column was eluted with a gradient of ethyl acetate in petroleum ether (0→10%) to give first the required 3,6-dideoxy compound **21** (3.51 g, 9.1 mmol). Further elution yielded the 2,6-dideoxy isomer **22** (687 mg, 1.8 mmol). **21**: ^{1}H NMR ($CDCl_3$, 300 MHz, HH-COSY) δ 1.33 (d, 3H, $J_{6,5}$ = 6.1 Hz, H-6), 1.97 (ddd, 1H, $^2J_{3,3}$ = -13.7 Hz, $J_{3,2}$ = 3.1 Hz, $J_{3,4}$ = 11.2 Hz, H-3-ax), 2.32 (dt, 1H, $^2J_{3,3}$ = -13.6 Hz, $J_{3,2}\approx J_{3,4}$ = 3.8 Hz, H-3-eq), 3.39 (s, 3H, CH_3 1-*O*-Me), 3.45 (ddd, 1H, $J_{4,3}$ = 4.4 Hz, $J_{4,3}$ = 11.3 Hz, $J_{4,5}$ = 9.4 Hz, H-4), 3.75 (s, 3H, CH_3 OMe *p*MBzl), 3.81 (dq, 1H, $J_{5,4}$ = 9.3 Hz, $J_{5,6}$ = 6.2 Hz, H-5), 4.74 (AB, 2H, CH_2 *p*MBzl), 4.65 (s, 1H, H-1), 5.15 (dt, 1H, $J_{2,3}$ = 3.1 Hz, $J_{2,3}$ = 4.5 Hz, H-2), 6.83 (d, 2H, $J_{H,H}$ = 8.6 Hz, H_{Ar} *p*MBzl), 7.23 (d, 2H, $J_{H,H}$ = 8.6 Hz, H_{Ar} *p*MBzl), 7.41-7.58 (m, 3H, H_{Ar} Bz), 8.00-8.10 (m, 2H, H_{Ar} Bz); $^{13}C\{^1H\}$ NMR ($CDCl_3$): δ 17.7 (C-6), 29.0 (C-3), 54.0, 54.5 ($2CH_3$ 1-*O*-Me, OMe *p*MBzl), 69.9 (CH_2 *p*MBzl), 67.5, 70.5, 73.6 (C-2, C-4, C-5), 96.8 (C-1), 113.2 (C_{Ar} *p*MBzl), 127.9, 129.0, 129.2 (C_{Ar}), 129.7, 129.8 (qC_{Ar}), 132.6 (C_{Ar} Bz), 158.8 (qC_{Ar} *p*MBzl), 164.8 (C=O Bz).

Anal. Calcd for $C_{22}H_{26}O_6$ (386.45): C, 68.38; H, 6.78. Found: C, 68.49; H, 6.73.

22: ^{1}H NMR ($CDCl_3$) δ 1.33 (d, 3H, $J_{6,5}$ = 6.4 Hz, H-6), 1.81 (ddd, 1H, $^2J_{2,2}$ = -12.7 Hz, $J_{2,1}$ = 3.7 Hz, $J_{2,3}$ = 11.2 Hz, H-2-ax), 2.38 (ddd, $J_{2,2}$ = 12.8 Hz, $J_{2,1}$ = 1.5 Hz, $J_{2,3}$ = 5.2 Hz, H-2-eq), 3.34 (s, 3H, CH_3 1-*O*-Me), 3.34 (t, 1H, $J_{4,3}\approx J_{4,5}$ = 9.2 Hz, H-4), 3.74 (s, 3H, CH_3 OMe *p*MBzl), 3.84 (dq, 1H, $J_{5,4}$ = 9.6 Hz, $J_{5,6}$ = 6.3 Hz, H-5), 4.62 (AB, 2H, CH_2 *p*MBzl), 4.77 (d, 1H, $J_{1,2}$ = 2.6 Hz, H-1), 5.55 (ddd, 1H, $J_{3,2}$ = 5.3 Hz, $J_{3,2}$ = 11.3 Hz, $J_{3,4}$ = 9.0 Hz, H-3), 6.73-6.79 (m, 2H, H_{Ar} *p*MBzl), 7.11-7.15 (m, 2H, H_{Ar} *p*MBzl), 7.40-7.61 (m, 3H, H_{Ar} Bz), 8.00-8.08 (m, 2H, H_{Ar} Bz); $^{13}C\{^1H\}$ NMR ($CDCl_3$) δ 18.2 (C-6), 35.4 (C-3), 54.5, 55.1 ($2CH_3$ 1-*O*-Me, OMe *p*MBzl), 74.3 (CH_2 *p*MBzl), 66.9, 72.3, 82.1 (C-3, C-4, C-5), 97.8 (C-1), 113.6 (C_{Ar} *p*MBzl), 128.3, 129.5 (C_{Ar}), 132.9 (C_{Ar} Bz), 159.1 (qC_{Ar} *p*MBzl), 165.5 (C=O Bz).

Methyl 2-*O*-Benzoyl-3,6-dideoxy-α-D-*arabino*-hexopyranoside (23).[23] A mixture of compound **21** (2.32 g, 6.0 mmol), dichloromethane (26.7 mL), water (3.3 mL), and DDQ (2.04 g, 9.0 mmol) was stirred for 2 h. The reaction mixture was filtered, diluted with dichloromethane (30 mL), and successively washed with water (30 mL) and aq $NaHCO_3$ (10%, 40 mL). The organic layer was dried ($MgSO_4$), filtered, and concentrated. Chromatography over silica gel with 20→30% ethyl acetate in petroleum ether gave compound **23** (1.50 g, 5.6 mmol). ^{1}H NMR ($CDCl_3$) δ 1.35 (d, 3H, $J_{6,5}$ = 6.0 Hz, H-6), 2.00 (ddd, 1H, $^2J_{3,3}$ = -13.8 Hz, $J_{3,2}$ = 3.0 Hz, $J_{3,4}$ = 10.9 Hz, H-3-ax), 2.23 (dt, 1H, $^2J_{3,3}$ = -13.8 Hz, $J_{3,2}\approx J_{3,4}$ = 3.0 Hz, H-3-eq), 3.42 (s, 3H, CH_3 1-*O*-Me), 3.67-3.71 (m, 2H, H-4, H-5), 4.66 (s, 1H, H-1), 5.16 (dt, 1H, $J_{2,1}$ = 1.4 Hz, $J_{2,3}\approx J_{2,3}$ = 3.1 Hz, H-2), 7.40-7.57 (m, 3H, H_{Ar} Bz), 8.02-8.07 (m, 2H, H_{Ar} Bz); $^{13}C\{^1H\}$ NMR ($CDCl_3$) δ 17.6

(C-6), 32.4 (C-3), 54.5 (CH_3 1-*O*-Me), 67.7, 69.1, 70.9 (C-2, C-4, C-5), 97.0 (C-1), 128.2, 129.4, 133.4 (C_{Ar} Bz), 165.6 (C=O Bz).

Methyl 2,4-Di-*O*-benzoyl-3,6-dideoxy-α-D-*arabino*-hexopyranoside (24).[24] Benzoylation of compound **23** (1.50 g, 5.6 mmol) in pyridine (35 mL) was executed as described for the preparation of **10**. The residue was purified by column chromatography (0→10% ethyl acetate in petroleum ether) to yield compound **24** (1.95 g, 5.3 mmol). ^{1}H NMR ($CDCl_3$) δ 1.31 (d, 3H, $J_{6,5}$ = 6.2 Hz, H-6), 2.19 (ddd, 1H, $^2J_{3,3}$ = -13.6 Hz, $J_{3,2}$ = 3.2 Hz, $J_{3,4}$ = 11.2 Hz, H-3-ax), 2.42 (dt, 1H, $^2J_{3,3}$ = -13.6 Hz, $J_{3,2}\approx J_{3,4}$ = 4.0 Hz, H-3-eq), 3.47 (s, 3H, CH_3 1-*O*-Me), 4.06 (dq, 1H, $J_{5,4}$ = 9.6 Hz, $J_{5,6}$ = 6.2 Hz, H-5), 4.74 (s, 1H, H-1), 5.18 (dd, 1H, $J_{4,3}$ = 4.7 Hz, $J_{4,3}$ = 11.3 Hz, H-4), 5.20-5.22 (m, 1H, H-2), 7.40-7.62 (m, 3H, H_{Ar} Bz), 7.99-8.13 (m, 2H, H_{Ar} Bz); ^{13}C{^{1}H} NMR ($CDCl_3$) δ 17.5 (C-6), 29.3 (C-3), 54.3 (CH_3 1-*O*-Me), 66.1, 70.0, 70.1 (C-2, C-4, C-5), 97.0 (C-1), 128.0, 129.1, 129.4, 132.7 (C_{Ar} Bz), 129.5, 129.6 (qC_{Ar} Bz), 164.9 (C=O Bz).

1-*O*-Acetyl 2,4-Di-*O*-benzoyl-3,6-dideoxy-α-D-*arabino*-hexopyranose (25). A solution of *arabino*-hexopyranoside **24** (1.95 g, 5.3 mmol) in acetic anhydride (30 mL) was cooled in an ice-bath. Sulfuric acid (1.22 mL, 22.9 mmol) was added and the solution was stirred for 45 min. The ice-bath was removed and sodium acetate (1.36 g, 16.5 mmol) was added. After stirring for 1 h, the reaction mixture was diluted with dichloromethane (25 mL), washed with water (20 mL), aq $NaHCO_3$ (20 mL) and water (15 mL), dried ($MgSO_4$), filtered, and concentrated. Purification was achieved by silica gel column chromatography. The column was eluted with 0→5% ethyl acetate in petroleum ether to furnish 1-*O*-acetate **25** (1.72 g, 4.5 mmol). ^{1}H NMR ($CDCl_3$) δ 1.33 (d, 1H, $J_{6,5}$ = 6.0 Hz, H-6), 2.14-2.58 (m, 2H, H-3), 2.19 (s, 3H, CH_3 Ac), 4.13 (dq, 1H, $J_{5,4}$ = 9.4 Hz, $J_{5,6}$ = 6.4 Hz, H-5), 5.15-5.28 (m, 2H, H-2, H-4), 6.15 (s, 1H, H-1), 7.42-7.64 (m, 6H, H_{Ar} Bz), 8.01-8.13 (m, 4H, H_{Ar} Bz); ^{13}C{^{1}H} NMR ($CDCl_3$) δ 17.3 (C-6), 20.1 (CH_3 Ac), 29.0 (C-3), 68.4, 68.8, 69.4 (C-2, C-4, C-5), 89.3 (C-1), 127.8, 128.9, 129.2, 132.6, 132.7 (C_{Ar} Bz), 164.5, 164.7 (C=O Bz), 167.8 (C=O Ac).

Ethyl 2,4-Di-*O*-benzoyl-3,6-dideoxy-1-thio-α-D-*arabino*-hexopyranoside (26-α) and **Ethyl 2,4-Di-*O*-benzoyl-3,6-dideoxy-1-thio-β-D-*arabino*-hexopyranoside (26-β).** Compound **25** (2.63 g, 6.6 mmol) was dried by evaporation with toluene and dissolved in dichloromethane (20 mL). Ethanethiol (0.50 mL, 6.9 mmol) and tin tetrachloride (77 μL, 0.7 mmol) were added at 0 °C. After stirring for 2 h at room temperature, the reaction mixture was washed twice with aq KF (1 M, 40 mL), dried ($MgSO_4$), filtered, and concentrated. The residue was purified by column chromatography (5→20% ethyl acetate in petroleum ether) to yield the α-glycoside **26-α** (2.06 g, 5.0 mmol) and the β-anomer **26-β** (246 mg, 0.6 mmol). **26-α**: $[\alpha]_D$ +70.4° (*c* 1); ^{1}H NMR ($CDCl_3$) δ 1.31 (d, 3H, $J_{6,5}$ =

6.2 Hz, H-6), 1.35 (t, 3H, $J_{H,H}$ = 7.4 Hz, CH_3 SEt), 2.17 (ddd, 1H, $^2J_{3,3}$ = -13.8 Hz, $J_{3,2}$ = 3.1 Hz, $J_{3,4}$ = 11.3 Hz, H-3-ax), 2.41-2.53 (m, 1H, H-3-eq), 2.71 (ABX, 2H, CH_2 SEt), 4.41 (dq, 1H, $J_{5,4}$ = 9.6 Hz, $J_{5,6}$ = 6.4 Hz, H-5), 5.23 (ddd, 1H, $J_{4,3}$ = 4.8 Hz, $J_{4,3}$ = 11.1 Hz, $J_{4,5}$ = 9.7 Hz, H-4), 5.35-5.36 (m, 1H, H-2), 5.36 (d, 1H, $J_{1,2}$ = 2.4 Hz, H-1), 7.35-7.64 (m, 6H, H_{Ar} Bz), 8.02-8.14 (m, 4H, H_{Ar} Bz); $^{13}C\{^1H\}$ NMR ($CDCl_3$) δ 15.0 (CH_3 SEt), 17.6 (C-6), 12.1 (CH_2 SEt), 30.5 (C-3), 67.0, 70.6, 72.0 (C-2, C-4, C-5), 82.0 (C-1, $^1J_{C,H}$ = 167.1 Hz), 128.2, 129.4, 129.6, 133.0 (C_{Ar} Bz), 165.3 (C=O Bz).

Anal. Calcd for $C_{22}H_{24}O_5S$ (400.50): C, 65.98; H, 6.04. Found: C, 66.07; H, 5.97.

26-β: $[\alpha]_D$ -52.8° (*c* 1); ^1H NMR ($CDCl_3$) δ 1.32 (t, 3H, $J_{H,H}$ = 7.5 Hz, CH_3 SEt), 1.40 (d, 3H, $J_{6,5}$ = 6.0 Hz, H-6), 1.99 (ddd, 1H, $^2J_{3,3}$ = -13.8 Hz, $J_{3,2}$ = 3.1 Hz, $J_{3,4}$ = 11.3 Hz, H-3-ax), 2.69 (ddd, 1H, $^2J_{3,3}$ = -13.8 Hz, $J_{3,2}$ = 3.1 Hz, $J_{3,4}$ = 4.7 Hz, H-3-eq), 2.78 (ABX, 2H, CH_2 SEt), 3.79 (dq, 1H, $J_{5,4}$ = 9.4 Hz, $J_{5,6}$ = 6.2 Hz, H-5), 4.88 (d, 1H, $J_{1,2}$ = 1.3 Hz, H-1), 5.13 (ddd, 1H, $J_{4,3}$ = 4.8 Hz, $J_{4,3}$ = 11.2 Hz, $J_{4,5}$ = 9.6 Hz, H-4), 5.48-5.51 (m, 1H, H-2), 7.40-7.63 (m, 6H, H_{Ar} Bz), 7.97-8.03 (m, 2H, H_{Ar} Bz), 8.12-8.18 (m, 2H, H_{Ar} Bz); $^{13}C\{^1H\}$ NMR ($CDCl_3$) δ 14.8 (CH_3 SEt), 18.1 (C-6), 25.3 (CH_2 SEt), 34.5 (C-3), 70.1, 71.5, 76.6 (C-2, C-4, C-5), 83.9 (C-1, $^1J_{C,H}$ = 152.4 Hz), 128.2, 129.3, 129.7, 133.0 (C_{Ar} Bz), 129.6 (qC_{Ar} Bz) 165.2, 165.4 (C=O Bz).

Anal. Calcd for $C_{22}H_{24}O_5S$ (400.50): C, 65.98; H, 6.04. Found: C, 65.91; H, 5.93.

Allyl 2,3-*O*-Isopropylidene-4,6-di-*O*-(*p*-methoxybenzyl)-α-D-mannopyranoside (28). Known[5b] mannopyranoside **27** (10.11 g, 38.9 mmol) was treated with sodium hydride (60%, 467 mg, 116.7 mmol) and *p*-methoxybenzyl chloride (13.18 mL, 97.3 mmol) as earlier described for the synthesis of **10**. Purification of the residue was effected by silica gel column chromatography (0→30% ethyl acetate in petroleum ether). Concentration of the appropriate fractions gave the fully protected mannopyranoside **28** (16.67 g, 33.4 mmol). $[\alpha]_D$ +40.0° (*c* 1); ^1H NMR ($CDCl_3$) δ 1.37, 1.51 (2s, 6H, $2CH_3$ Isopr), 3.78 (s, 6H, $2CH_3$ OMe *p*MBzl), 3.46-4.80 (m, 12H, H-2, H-3, H-4, H-5, H-6, CH_2 All, $2CH_2$ *p*MBzl), 5.09 (s, 1H, H-1), 5.18 (dd, 1H, $^2J_{H,H}$ = -1.4 Hz, $J_{H,H}$ = 11.7 Hz, CH_2 All), 5.31 (dd, 1H, $^2J_{H,H}$ = -1.6 Hz, $J_{H,H}$ = 17.2 Hz, CH_2 All), 5.89 (ddt, 1H, $J_{H,H}$ = 5.6 Hz, $J_{H,H}$ = 10.8 Hz, $J_{H,H}$ = 17.2 Hz, CH All), 6.81-6.90 (m, 2H, H_{Ar} *p*MBzl), 7.14-7.28 (m, 2H, H_{Ar} *p*MBzl); $^{13}C\{^1H\}$ NMR ($CDCl_3$) δ 25.7, 27.4 ($2CH_3$ Isopr), 54.3 ($2OCH_3$ *p*MBzl), 67.1, 68.3 (C-6, CH_2 All), 71.7, 72.3 ($2CH_2$ *p*MBzl), 67.9, 74.9, 75.3, 78.4 (C-2, C-3, C-4, C-5), 95.7 (C-1), 108.5 (qC Isopr), 113.0, 113.1 (C_{Ar} *p*MBzl), 116.8 (CH_2 All), 128.6, 128.9 (C_{Ar} *p*MBzl), 129.9 (qC_{Ar} *p*MBzl), 133.3 (CH All), 158.6 (qC_{Ar} *p*MBzl).

Anal. Calcd for $C_{28}H_{36}O_8$ (500.59): C, 67.18; H, 7.25. Found: C, 67.10; H, 7.32.

Allyl 4,6-Di-*O*-(*p*-methoxybenzyl)-α-D-mannopyranoside (29). Water (60 mL) was added to a solution of compound **28** (16.67 g, 33.4 mmol) in acetic acid (240 mL).

The resulting solution was heated at 60 °C for 45 min and subsequently concentrated. The remaining solvents were removed by repeated evaporation with toluene. The residue was crystallised from ethyl acetate and petroleum ether to yield mannopyranoside **29** (12.58 g, 27.4 mmol). mp 93-94 °C; ^{1}H NMR ($CDCl_3$) δ 3.61-4.19 (m, 6H, H-2, H-3, H-4, H-5, H-6), 3.78 (s, 6H, $2CH_3$ OMe *p*MBzl), 4.54, 4.55 (2AB, 4H, $2CH_2$ *p*MBn), 4.80 (s, 1H, H-1), 5.17 (ddd, 1H, $^2J_{H,H}$ = -1.8 Hz, $J_{H,H}$ = 10.4 Hz, $^4J_{H,H}$ = -0.7 Hz, CH_2 All), 5.26 (ddd, 1H, $^2J_{H,H}$ = -1.6 Hz, $J_{H,H}$ = 17.2 Hz, $^4J_{H,H}$ = -0.7 Hz, CH_2 All), 5.87 (dddd, 1H, $J_{H,H}$ = 5.0 Hz, $J_{H,H}$ = 5.9 Hz, $J_{H,H}$ = 11.2 Hz, $J_{H,H}$ = 17.1 Hz, CH All), 6.81-8.82 (m, 4H, H_{Ar} *p*MBzl), 7.11-7.16 (m, 2H, H_{Ar} *p*MBzl), 7.26-7.27 (m, 2H, H_{Ar} *p*MBzl); ^{13}C{^{1}H} NMR ($CDCl_3$) δ 55.1 ($2CH_3$ OMe *p*MBzl), 67.9, 68.3 (C-6, CH_2 All), 73.1, 74.3 ($2CH_2$ *p*MBzl), 70.7, 71.1, 71.9, 75.4 (C-2, C-3, C-4, C-5), 98.8 (C-1), 113.8 (C_{Ar} *p*MBzl), 117.3 (CH_2 All), 129.6, 129.7 (C_{Ar} *p*MBzl), 130.4 (qC_{Ar} *p*MBzl), 133.6 (CH All), 158.9 (qC_{Ar} *p*MBzl).

Anal. Calcd for $C_{25}H_{32}O_8$ (460.53): C, 65.10; H, 7.00. Found: C, 64.98; H, 7.06.

Allyl 2-*O*-Benzoyl-4,6-di-*O*-(*p*-methoxybenzyl)-α-D-mannopyranoside (30). Trimethyl orthobenzoate (4.71 mL, 27.4 mmol) and *p*-toluenesulfonic acid monohydrate (261 mg, 1.4 mmol) were added to a solution of mannopyranoside **29** (6.33 g, 13.7 mmol) in acetonitrile (125 mL). After stirring for 30 min, TLC-analysis of the reaction mixture showed complete conversion of compound **29**. Diluted acetic acid (80%, 140 mL) was added and the orthoester was hydrolysed in 45 min. The solvents were evaporated and the residue was dried by repeated evaporation with toluene. Purification by silica gel chromatography (10→30% ethyl acetate in petroleum ether) resulted in acceptor **30** (6.42 g, 11.4 mmol). $[\alpha]_D$ -12.6° (*c* 1); ^{1}H NMR ($CDCl_3$) δ 3.76, 3.80 (2s, 6H, $2CH_3$ OMe *p*MBzl), 3.70-4.28 (m, 7H, H-3, H-4, H-5, H-6, CH_2 All), 4.51, 4.69 (2AB, 4H, $2CH_2$ *p*MBzl), 5.01 (d, 1H, $J_{1,2}$ =1.7 Hz, H-1), 5.19 (dd, 1H, $^2J_{H,H}$ = -1.6 Hz, $J_{H,H}$ = 10.4 Hz, CH_2 All), 5.28 (dd, 1H, $^2J_{H,H}$ = -1.6 Hz, $J_{H,H}$ = 17.2 Hz, CH_2 All), 5.36 (dd, 1H, $J_{2,1}$ = 1.8 Hz, $J_{2,3}$ = 3.3 Hz, H-2), 5.78 (dddd, 1H, $J_{H,H}$ = 5.1 Hz, $J_{H,H}$ = 6.0 Hz, $J_{H,H}$ = 10.6 Hz, $J_{H,H}$ = 17.2 Hz, CH All), 6.79-6.90 (m, 4H, H_{Ar} *p*MBzl), 7.14-7.62 (m, 7H, C_{Ar}), 8.01-8.06 (m, 2H, H_{Ar} Bz); ^{13}C{^{1}H} NMR ($CDCl_3$) δ 54.9 ($2CH_3$ OMe *p*MBzl), 67.9, 68.4 (C-6, CH_2 All), 72.9, 74.2 (CH_2 *p*MBzl), 70.3, 71.2, 72.9, 75.0 (C-2, C-3, C-4, C-5), 96.4 (C-1), 113.6 (C_{Ar} *p*MBzl), 117.3 (CH_2 All), 128.1, 129.0, 129.5, 129.7 (C_{Ar}), 130.2 (qC_{Ar}), 132.9, 133.3 (C_{Ar} Bz, All), 159.1 (qC_{Ar} *p*MBzl), 165.9 (C=O Bz).

Anal. Calcd for $C_{32}H_{36}O_9$ (564.63): C, 68.07; H, 6.43. Found: C, 68.19; H, 6.34.

Allyl 2-*O*-Benzoyl-3-*O*-[4-*O*-benzoyl-3,6-dideoxy-2-*O*-(*p*-methoxybenzyl)-α-D-*xylo*-hexopyranosyl]-4,6-di-*O*-(*p*-methoxybenzyl)-α-D-mannopyranoside (31-α) and **Allyl 2-*O*-Benzoyl-3-*O*-[4-*O*-benzoyl-3,6-dideoxy-2-*O*-(*p*-methoxybenzyl)-β-D-*xylo*-hexopyranosyl]-4,6-di-*O*-(*p*-methoxybenzyl)-α-D-mannopyranoside (31-β).** Manno-

pyranoside acceptor **30** (2.71 g, 4.8 mmol) and ethyl 1-thio-α- or β-*xylo*-hexopyranoside donor **11-α** or **11-β** (2.04 g, 5.3 mmol) were dried by evaporation with toluene. The building blocks were dissolved in diethyl ether (64 mL) and stirred for 30 min in the presence of powdered molecular sieves (4 Å). The mixture was cooled in an ice-bath and IDCT (3.01 g, 5.8 mmol) was added. The temperature was slowly increased to room temperature during the next 2 h. Then, the reaction mixture was filtered and the filtrate was diluted with ethyl acetate (40 mL). The organic solution was washed with aq $Na_2S_2O_3$ (20%, 30 mL) and aq $NaHCO_3$ (10%, 20 mL), dried ($MgSO_4$), and filtered. The filtrate was concentrated and the residual oil was purified by silica gel column chromatography. Elution of the column with 10→30% ethyl acetate in petroleum ether afforded the α-linked disaccharide **31-α** (3.57 g, 3.95 mmol) followed by the β-linked anomer **31-β** (292 mg, 0.3 mmol). **31-α**: ^{1}H NMR ($CDCl_3$, 300 MHz, HH-COSY) δ 0.99 (d, 3H, $J_{6,5}$ = 6.6 Hz, H-6'), 2.05-2.11 (m, 2H, H-3'), 3.70 (s, 3H, CH_3 OMe *p*MBzl), 3.71-3.77 (m, 1H, $J_{6,5}$ = 2.2 Hz, H-6), 3.78, 3.81 (2s, 6H, $2CH_3$ OMe *p*MBn), 3.81-3.88 (m, 2H, H-6, H-2'), 3.87-3.91 (m, 1H, H-5), 4.03 (ddt, 1H, $^2J_{H,H}$ = -12.9 Hz, $J_{H,H}$ = 6.1 Hz, $^4J_{H,H}$ = -1.4 Hz, CH_2 All), 4.12 (dq, 1H, $J_{5,4}$ = 1.6 Hz, $J_{5,6}$ = 6.6 Hz, H-5'), 4.14 (t, 1H, $J_{4,3} \approx J_{4,5}$ = 9.6 Hz, H-4), 4.21 (ddt, 1H, $^2J_{H,H}$ = -12.9 Hz, $J_{H,H}$ = 5.2 Hz, $^4J_{H,H}$ = -1.5 Hz, CH_2 All), 4.36 (dd, 1H, $J_{3,2}$ = 3.3 Hz, $J_{3,4}$ = 9.3 Hz, H-3), 4.41, 4.48, 4.54 (3AB, 6H, $3CH_2$ *p*MBzl), 5.04 (d, 1H, $J_{1,2}$ = 2.0 Hz, H-1), 5.04-5.09 (m, 1H, $J_{4,5}$ = 1.5 Hz, H-4'), 5.18-5.19 (m, 1H, H-1'), 5.18-5.22 (m, 1H, $^2J_{H,H}$ = -1.5 Hz, CH_2 All), 5.30 (dd, 1H, $^2J_{H,H}$ = -1.6 Hz, $J_{H,H}$ = 17.2 Hz, CH_2 All), 5.46 (dd, 1H, $J_{2,1}$ = 2.0 Hz, $J_{2,3}$ = 3.1 Hz, H-2), 6.62-6.66 (m, 2H, H_{Ar} *p*MBzl), 6.74-6.79 (m, 2H, H_{Ar} *p*MBzl), 6.84-6.89 (m, 2H, H_{Ar} *p*MBzl), 7.03-7.13 (m, 4H, H_{Ar} *p*MBzl), 7.26-7.46 (m, 4H, H_{Ar} arom), 7.54-7.62 (m, 2H, H_{Ar} Bz), 7.96-7.99 (m, 2H, H_{Ar} Bz), 8.06-8.10 (m, 2H, H_{Ar} Bz); $^{13}C\{^1H\}$ NMR ($CDCl_3$) δ 16.0 (C-6'), 28.5 (C-3'), 55.0 (CH_3 OMe *p*MBzl), 68.2, 68.4 (C-6, CH_2 All), 70.1, 72.9, 74.4 ($3CH_2$ *p*MBzl), 65.8, 69.9, 71.6, 73.6, 74.4, 78.7 (CH sugar rings), 96.2, 99.3 (C-1, C-1', $^1J_{C,H}$ = 167.0, 171.4 Hz, respectively), 113.5 (CH *p*MBzl), 117.4 (CH_2 All), 128.2, 128.3, 129.1, 129.3, 129.5, 129.6 (C_{Ar}), 130.7 (qC_{Ar}), 132.9, 133.1. 133.4 (C_{Ar} Bz, All), 158.8, 159.0 (qC_{Ar} *p*MBzl), 165.7, 165.8 (C=O Bz).

Anal. Calcd for $C_{53}H_{58}O_{14}$ (919.05): C, 69.27; H, 6.36. Found: C, 69.21; H, 6.28.

31-β: ^{1}H NMR ($CDCl_3$, 300 MHz, HH-COSY) δ 1.24 (d, 3H, $J_{6,5}$ = 6.4 Hz, H-6'), 1.80 (ddd, 1H, $^2J_{3,3}$ = -14.2 Hz, $J_{3,2}$ = 11.8 Hz, $J_{3,4}$ = 3.03 Hz, H-3'-ax), 2.26 (ddd, 1H, $^2J_{3,3}$ = -14.2 Hz, $J_{3,2}$ = 4.9 Hz, $J_{3,4}$ = 3.1 Hz, H-3'-eq), 3.53 (ddd, 1H, $J_{2,1}$ = 7.4 Hz, $J_{2,3}$ = 5.0 Hz, $J_{2,3}$ = 11.7 Hz, H-2'), 3.63, 3.67 (2s, 6H, $2CH_3$ OMe *p*MBzl), 3.68-3.79 (m, 2H, H-6), 3.80 (s, 3H, CH_3 OMe *p*MBzl), 3.85-3.90 (m, 1H, H-5), 4.03 (ddt, 1H, $^2J_{H,H}$ = -13.3 Hz, $J_{H,H}$ = 6.5 Hz, $^4J_{H,H}$ = -1.6 Hz, CH_2 All), 4.18 (t, 1H, $J_{4,3} \approx J_{4,5}$ = 9.4 Hz, H-4), 4.17-

4.24 (m, 1H, CH_2 All), 4.33 (AB, 2H, CH_2 *p*MBzl), 4.54-4.61 (m, 1H, H-5'), 4.61 (AB, 2H, CH_2 *p*MBzl), 4.65 (dd, 1H, $J_{3,2}$ = 3.2 Hz, $J_{3,4}$ = 9.3 Hz, H-3), 4.69 (d, 1H, $J_{1,2}$ = 7.6 Hz, H-1'), 4.77 (AB, 2H, CH_2 *p*MBzl), 5.07 (d, 1H, $J_{1,2}$ = 1.9 Hz, H-1), 5.15 (br s, 1H, H-4'), 5.20 (ddd, 1H, $^2J_{H,H}$ = -1.3 Hz, $J_{H,H}$ = 10.4 Hz, CH_2 All), 5.29 (dd, 1H, $^2J_{H,H}$ = -1.6 Hz, $J_{H,H}$ = 17.7 Hz, CH_2 All), 5.58 (dd, 1H, $J_{2,1}$ = 2.1 Hz, $J_{2,3}$ = 3.1 Hz, H-2), 5.90 (dddd, 1H, $J_{H,H}$ = 5.3 Hz, $J_{H,H}$ = 6.1 Hz, $J_{H,H}$ = 10.6 Hz, $J_{H,H}$ = 17.0 Hz, CH All), 6.52-6.58 (m, 2H, H_{Ar} *p*MBzl), 6.69-6.92 (m, 4H, H_{Ar} *p*MBn), 7.24-7.58 (m, 12H, H_{Ar} arom), 7.95-7.99 (m, 2H, H_{Ar} Bz), 8.06-8.10 (m, 2H, H_{Ar} Bz); $^{13}C\{^1H\}$ NMR ($CDCl_3$) δ 16.3 (C-6'), 34.0 (C-3'), 54.7 ($3CH_3$ OMe *p*MBzl), 67.9, 68.3 (C-6, CH_2 All), 71.7, 72.7, 74.2 ($3CH_2$ *p*MBzl), 69.2, 71.0, 71.2, 72.0, 73.0, 73.5, 74.5 (CH sugar rings), 96.2 (C-1, $^1J_{C,H}$ = 172.9 Hz), 101.3 (C-1', $^1J_{C,H}$ = 158.3 Hz), 113.2, 113.3 (C_{Ar} *p*MBzl), 117.4 (CH_2 All), 128.0, 128.5, 128.9, 129.2, 129.5 (C_{Ar}), 130.2, 130.5 (qC_{Ar}), 132.7, 133.2 (C_{Ar} Bz, All), 158.8 (qC_{Ar} *p*MBzl), 165.3 (C=O Bz).

Allyl 2-*O*-Benzoyl-3-*O*-(4-*O*-benzoyl-3,6-dideoxy-α-D-*xylo*-hexopyranosyl)-α-D-mannopyranoside (32). A solution of disaccharide **31-α** (3.57 g, 3.9 mmol) in HCl-methanol (0.5 N, 35 mL) was stirred for 45 min at 60 °C, subsequently cooled, neutralised with ammonium hydroxide (25%), and concentrated. The residue was taken up in ethyl acetate (70 mL), and the solution was washed with water (50 mL), dried ($MgSO_4$), filtered, and concentrated. The product was purified by column chromatography. Elution with 30→60% ethyl acetate in petroleum ether yielded compound **32** (1.62 g, 2.9 mmol). $^{13}C\{^1H\}$ NMR ($CDCl_3$) δ 15.9 (C-6'), 31.2 (C-3'), 62.0 (C-6), 68.4 (CH_2 All), 64.4, 65.7, 66.9, 71.3, 72.2, 79.4 (CH sugar rings), 96.5, 101.1 (C-1, C-1', $^1J_{C,H}$ = 171.4, 167.1 Hz, respectively), 117.8 (CH_2 All), 128.3, 128.5, 129.5 (C_{Ar} Bz), 129.4, 129.7 (qC_{Ar} Bz), 133.0, 133.2, 133.4 (C_{Ar} Bz, All), 165.7 (C=O Bz).

Anal. Calcd for $C_{29}H_{34}O_{11}$ (558.59): C, 62.36; H, 6.14. Found: C, 62.45; H, 6.20.

Allyl 3-*O*-(3,6-Dideoxy-α-D-*xylo*-hexopyranosyl)-α-D-mannopyranoside (1).[5] Compound **32** (1.62 g, 2.9 mmol) was dissolved in methanol (15 mL) and potassium *tert*-butoxide (163 mg, 1.5 mmol) was added. After stirring for 19 h, the reaction mixture was neutralised, filtered, and methanol was evaporated. The oily residue was purified by silica gel chromatography. The column was eluted with 0→20% methanol in ethyl acetate to give disaccharide **1** (863 mg, 2.5 mmol). $[\alpha]_D$ +134.6° (*c* 1, MeOH); ^1H NMR (CD_3OD, 600 MHz, HH-COSY) δ 1.13 (d, 3H, $J_{6,5}$ = 6.6 Hz, H-6'), 1.91 (dddd, 1H, $^2J_{3,3}$ = -12.8 Hz, $J_{3,2}$ = 4.8 Hz, $J_{3,4}$ = 3.6 Hz, $^4J_{3,1}$ = -1.1 Hz, H-3'-eq), 2.03 (dt, 1H, $^2J_{3,3} \approx J_{3,2}$ = -12.6 Hz, $J_{3,4}$ = 2.9 Hz, H-3'-ax), 3.58 (ddd, 1H, $J_{5,4}$ = 9.2 Hz, $J_{5,6}$ = 2.4 Hz, $J_{5,6}$ = 5.7 Hz, H-5), 3.69-3.70 (m, 1H, H-4'), 3.72 (dd, 1H, $^2J_{6,6}$ = -11.8 Hz, $J_{6,5}$ = 5.7 Hz, H-6), 3.80 (dd, 1H, $J_{3,2}$ = 3.0 Hz, $J_{3,4}$ = 9.6 Hz, H-3), 3.82 (dd, 1H, $^2J_{6,6}$ = -12.5 Hz, $J_{6,5}$ = 2.9 Hz, H-6), 3.83

(t, 1H, $J_{4,3}\approx J_{4,5}$ = 9.7 Hz, H-4), 3.96 (dd, 1H, $J_{2,1}$ = 1.8 Hz, $J_{2,3}$ = 3.0 Hz, H-2), 3.96 (dddd, 1H, $J_{2,1}$ = 3.7 Hz, $J_{2,3}$ = 5.0 Hz, $J_{2,3}$ = 12.3 Hz, $^4J_{2,4}$ = -0.5 Hz, H-2'), 4.01 (ddt, 1H, $^2J_{H,H}$ = -13.0 Hz, $J_{H,H}$ = 6.0 Hz, $^4J_{H,H}$ = -1.4 Hz, CH_2 All), 4.11 (ddq, 1H, $J_{5,4}$ = 1.3 Hz, $J_{5,6}$ = 6.6 Hz, $^4J_{5,1}$ = -0.6 Hz, H-5'), 4.22 (ddt, 1H, $^2J_{H,H}$ = -13.1 Hz, $J_{H,H}$ = 5.1 Hz, $^4J_{H,H}$ = -1.6 Hz, CH_2 All), 4.78 (d, 1H, $J_{1,2}$ = 1.8 Hz, H-1), 5.00 (dt, 1H, $J_{1,2}$ = 3.9 Hz, $^4J_{1,3}\approx{}^4J_{1,5}$ = -0.7 Hz, H-1'), 5.17 (dq, 1H, $^2J_{H,H}\approx{}^4J_{H,H}$ = -1.5 Hz, $J_{H,H}$ = 10.5 Hz, CH_2 All), 5.30 (dq, 1H, $^2J_{H,H}\approx{}^4J_{H,H}$ = -1.5 Hz, $J_{H,H}$ = 17.2 Hz, CH_2 All), 5.94 (ddt, 1H, $J_{H,H}$ = 5.5 Hz, $J_{H,H}$ = 11.1 Hz, $J_{H,H}$ = 16.9 Hz, CH All); ^{13}C NMR (CD_3OD, 150 MHz, CH-COSY) δ 16.7 (C-6'), 35.7 (C-3'), 62.8 (C-6), 65.3 (C-2/C-2'), 67.6 (C-4), 67.8 (C-5'), 69.0 (CH_2 All), 70.0 (C-4'), 72.1 (C-2/C-2'), 74.8 (C-5), 81.1 (C-3), 100.7 (C-1), 102.3 (C-1'), 117.4 (CH_2 All), 135.4 (CH All); MS: $[M+H]^+$ for $C_{15}H_{26}O_9$: *m/z* 350.2.

Allyl 2-*O*-Benzoyl-3-*O*-[2-*O*-benzoyl-3,6-dideoxy-4-*O*-(*p*-methoxybenzyl)-α-D-*arabino*-hexopyranosyl]-4,6-di-*O*-(*p*-methoxybenzyl)-α-D-mannopyranoside (33). Mannopyranoside acceptor **30** (1.54 g, 2.8 mmol) and ethyl 1-thio-α- or β-*arabino*-hexopyranoside donor **26-α** or **26-β** (1.19 g, 3.0 mmol) were dried by evaporation of toluene and subsequently dissolved in a mixture of 1,2-dichloroethane-diethyl ether (1/1, v/v, 22 mL). The solution was stirred for 30 min in the presence of activated molecular sieves (4 Å). A suspension of NIS (697 mg, 3.1 mmol) and TfOH (36 μL, 41 μmol) in the same solvent mixture (22 mL) was added at -30 °C. After stirring for 15 min, pyridine (0.5 mL) was added and the resulting mixture was filtered. The filtrate was diluted with ethyl acetate (50 mL), washed with aq $Na_2S_2O_3$ (20%, 40 mL) and aq $NaHCO_3$ (10%, 30 mL), dried ($MgSO_4$), and filtered. The filtrate was concentrated and the crude product was purified by column chromatography. The column was eluted with 0→30% ethyl acetate in petroleum ether to furnish the α-linked disaccharide **33** (2.30 g, 2.6 mmol). $[\alpha]_D$ -31.2° (*c* 1); ^{1}H NMR ($CDCl_3$, 300 MHz, HH-COSY) δ 1.21 (d, 3H, $J_{6,5}$ = 6.2 Hz, H-6'), 2.05 (ddd, 1H, $^2J_{3,3}$ = -13.4 Hz, $J_{3,2}$ = 3.0 Hz, $J_{3,4}$ = 11.4 Hz, H-3'-ax), 2.35 (dt, 1H, $^2J_{3,3}$ = -13.4 Hz, $J_{3,2}\approx J_{3,4}$ = 3.7 Hz, H-3'-eq), 3.69 (s, 3H, CH_3 OMe *p*MBzl), 3.70-3.79 (m, 1H, H-6), 3.80 (s, 3H, CH_3 OMe *p*MBzl), 3.84-3.89 (m, 2H, H-5, H-6), 4.03 (ddt, 1H, $^2J_{H,H}$ = -12.9 Hz, $J_{H,H}$ = 6.1 Hz, $^4J_{H,H}$ = -1.4 Hz, CH_2 All), 4.08 (dq, 1H, $J_{5,4}$ = 9.8 Hz, $J_{5,6}$ = 6.3 Hz, H-5'), 4.17 (t, 1H, $J_{4,3}\approx J_{4,5}$ = 9.7 Hz, H-4), 4.20 (ddt, 1H, $^2J_{H,H}$ = -12.9 Hz, $J_{H,H}$ = 5.2 Hz, $^4J_{H,H}$ = -1.2 Hz, CH_2 All), 4.40 (dd, 1H, $J_{3,2}$ = 3.3 Hz, $J_{3,4}$ = 9.5 Hz, H-3), 4.59, 4.64 (2AB, 4H, $2CH_2$ *p*MBzl), 5.05 (dt, 1H, $J_{4,3}$ = 4.7 Hz, $J_{4,3}\approx J_{4,5}$ = 11.1 Hz, H-4'), 5.06 (d, 1H, $J_{1,2}$ = 1.8 Hz, H-1), 5.18 (br s, 1H, H-1'), 5.19 (dq, 1H, $^2J_{H,H}\approx{}^4J_{H,H}$ = -1.4 Hz, $J_{H,H}$ = 10.4 Hz, CH_2 All), 5.24-5.27 (m, 1H, H-2'), 5.29 (dq, 1H, $^2J_{H,H}\approx{}^4J_{H,H}$ = -1.6 Hz, $J_{H,H}$ = 17.2 Hz, CH_2 All), 5.47 (dd, 1H, $J_{2,1}$ = 1.9 Hz, $J_{2,3}$ = 3.3 Hz, H-2), 5.90 (ddt, 1H, $J_{H,H}$ = 5.4 Hz, $J_{H,H}$ = 10.8 Hz, $J_{H,H}$ = 17.1 Hz, CH All), 6.73-6.77 (m, 2H, H_{Ar} *p*MBzl), 6.85-6.90

(m, 2H, H_{Ar} *p*MBzl), 7.14-7.66 (m, 13H, H_{Ar}), 7.81-7.84 (m, 2H, H_{Ar} Bz), 8.06-8.10 (m, 2H, H_{Ar} Bz), 8.12-8.16 (m, 2H, H_{Ar} Bz); $^{13}C\{^1H\}$ NMR ($CDCl_3$) δ 17.7 (C-6'), 29.4 (C-3'), 55.0, 55.1 ($2CH_3$ OMe *p*MBzl), 68.2, 68.4 (C-6, CH_2 All), 73.1, 74.9 ($2CH_2$ *p*MBzl), 67.3, 70.2, 70.3, 71.7, 72.8, 74.5, 77.2 (CH sugar rings), 96.5, 98.3 (C-1, C-1', $^1J_{C,H}$ = 171.4, 171.4 Hz, respectively), 113.7 (C_{Ar} *p*MBzl), 117.5 (CH_2 All), 128.3, 128.4, 128.5, 129.2, 129.5, 129.8 (C_{Ar}), 130.0, 130.1, 130.3 (qC_{Ar}), 133.0, 133.2, 133.4 (C_{Ar} Bz, All), 165.3, 165.8 (C=O Bz).

Anal. Calcd for $C_{52}H_{54}O_{14}$ (905.02): C, 69.01; H, 6.01. Found; C ,68.90; H, 5.94.

Allyl 2-*O*-Benzoyl-3-*O*-(2-*O*-benzoyl-3,6-dideoxy-α-D-*arabino*-hexopyranosyl)-α-D-mannopyranoside (34). Dimer **33** (2.30 g, 2.6 mmol) was dissolved in dioxane (23 mL) and a solution of HCl-methanol (1 M, 23 mL) was added. The reaction mixture was stirred at 60 °C for 3 h, neutralised with ammonium hydroxide (25%), and concentrated. The residue was taken up in ethyl acetate (25 mL) and the resulting solution was washed twice with water (15 mL), dried ($MgSO_4$), filtered, and concentrated. The crude product was applied to a silica gel column, which was eluted with a gradient of 20 →50% ethyl acetate in petroleum ether. Concentration of the appropriate fractions gave compound **34** (1.48 g, 2.2 mmol). $[\alpha]_D$ -26.8° (*c* 1); $^{13}C\{^1H\}$ NMR ($CDCl_3$) δ 17.6 (C-6'), 29.3 (C-3'), 62.1, 68.2 (C-6, CH_2 All), 67.2, 70.1, 70.4, 72.2, 72.4, 77.4 (CH sugar rings), 96.6, 98.2 (C-1, C-1'), 117.6 (CH_2 All), 128.2, 128.3, 128.4, 129.4, 129.4, 129.7 (C_{Ar} Bz), 133.0, 133.2 (C_{Ar} Bz, All), 165.3, 165.9 (C=O Bz).

Anal. Calcd for $C_{34}H_{36}O_{11}$ (620.66): C, 65.80; H, 5.85. Found: C, 65.92; H, 5.99.

Allyl 3-*O*-(3,6-Dideoxy-α-D-*arabino*-hexopyranosyl)-α-D-mannopyranoside (2).[6] To a solution of compound **34** (1.48 g, 2.2 mmol) in methanol (15 mL) was added potassium *tert*-butoxide (126 mg, 1.1 mmol). After stirring for 19 h, the reaction mixture was neutralised with Dowex 50W×4 (H^+ form), filtered and concentrated. The crude product was purified by column chromatography. Elution of the column with 0→20% methanol in ethyl acetate yielded target disaccharide **2** (660 mg, 1.89 mmol). $[\alpha]_D$ +126.2° (*c* 1, MeOH); ^1H NMR (CD_3OD, 600 MHz, HH-COSY) δ 1.22 (d, 3H, $J_{6,5}$ = 6.3 Hz, H-6'), 1.88 (ddd, 1H, $^2J_{3,3}$ = -13.2 Hz, $J_{3,2}$ = 3.2 Hz, $J_{3,4}$ = 10.9 Hz, H-3'-ax), 1.91 (dddd, 1H, $^2J_{3,3}$ = -13.1 Hz, $J_{3,2}$ = 3.4 Hz, $J_{3,4}$ = 5.0 Hz, $^4J_{3,1}$ = -1.0 Hz, H-3'-eq), 3.53 (ddd, 1H, $J_{4,3}$ = 5.0 Hz, $J_{4,3}$ = 10.8 Hz, $J_{4,5}$ = 9.3 Hz, H-4'), 3.56 (ddd, 1H, $J_{5,4}$ = 9.8 Hz, $J_{5,6}$ = 2.4 Hz, $J_{5,6}$ = 5.7 Hz, H-5), 3.70 (dd, 1H, $^2J_{6,6}$ = -11.8 Hz, $J_{6,5}$ = 5.9 Hz, H-6), 3.73 (t, 1H, $J_{4,3} \approx J_{4,5}$ = 9.8 Hz, H-4), 3.76 (ddq, 1H, $J_{5,4}$ = 9.3 Hz, $J_{5,6}$ = 6.3 Hz, $^4J_{5,1}$ = -0.7 Hz, H-5'), 3.82 (dd, 1H, $^2J_{6,6}$ = -11.8 Hz, $J_{6,5}$ = 2.3 Hz, H-6), 3.83 (dd, 1H, $J_{3,2}$ = 3.3 Hz, $J_{3,4}$ = 9.6 Hz, H-3), 3.92 (dd, 1H, $J_{2,1}$ = 1.8 Hz, $J_{2,3}$ = 3.3 Hz, H-2), 3.95 (ddt, 1H, $J_{2,1}$ = 1.7 Hz, $J_{2,3} \approx J_{2,3}$ = 3.3 Hz, $^4J_{2,4}$ = -0.6 Hz, H-2'), 4.01 (ddt, 1H, $^2J_{H,H}$ = -13.1 Hz, $J_{H,H}$ = 6.0 Hz, $^4J_{H,H}$ =

-1.4 Hz, CH_2 All), 4.22 (ddt, 1H, $^2J_{H,H}$ = -13.1 Hz, $J_{H,H}$ = 5.1 Hz, $^4J_{H,H}$ = -1.6 Hz, CH_2 All), 4.77 (d, 1H, $J_{1,2}$ = 1.7 Hz, H-1), 4.84 (dt, 1H, $J_{1,2}$ = 1.8 Hz, $^4J_{1,3} \approx {}^4J_{1,5}$ = -0.8 Hz, H-1'), 5.17 (dq, 1H, $^2J_{H,H} \approx {}^4J_{H,H}$ = -1.5 Hz, $J_{H,H}$ = 10.4 Hz, CH_2 All), 5.30 (dq, 1H, $^2J_{H,H} \approx {}^4J_{H,H}$ = -1.7 Hz, $J_{H,H}$ = 17.2 Hz, CH_2 All), 5.94 (dddd, 1H, $J_{H,H}$ = 5.0 Hz, $J_{H,H}$ = 5.9 Hz, $J_{H,H}$ = 10.5 Hz, $J_{H,H}$ = 17.2 Hz, CH All); ^{13}C NMR (CD_3OD, 600 MHz, CH-COSY) δ 18.1 (C-6'), 35.8 (C-3'), 62.9 (C-6), 67.9 (C-4), 68.5 (C-4'), 68.9 (CH_2 All), 69.2 (C-2'), 71.3 (C-5'), 72.0 (C-2), 75.0 (C-5), 79.7 (C-3), 100.7 (C-1), 102.9 (C-1'), 117.3 (CH_2 All), 135.5 (CH All); MS: $[M+H]^+$ for $C_{15}H_{26}O_9$: *m/z* 350.2.

ACKNOWLEDGMENT

This research was supported by the Netherlands Organisation for Scientific Research (NWO).

REFERENCES AND NOTES

1. A.A. Lindberg, R. Wollins, G. Bruse, E. Ekwall, and S.B. Svenson, *Am. Chem. Soc., Symp. Ser.* **231**, 83 (1983).
2. K. Jann, and O. Westphal, in *The Antigens* Volume 5, Ed., M. Sela, Academic Press, New York, 1975, 1.
3. a) C.G. Hellerqvist, B. Lindberg, S. Svensson, T. Holme, and A.A. Lindberg, *Carbohydr. Res.*, **8**, 43 (1968). b) C.G. Hellerqvist, B. Lindberg, S. Svensson, T. Holme, and A.A. Lindberg, *Carbohydr. Res.*, **9**, 237 (1969).
4. C.G. Hellerqvist, O. Larm, B. Lindberg, T. Holme, and A.A. Lindberg, *Acta Chem. Scand.*, **23**, 1588 (1969).
5. a) N.K. Kochetkov, B.A. Dmitriev, A.Ya. Chernyak, and A.B. Levinsky, *Carbohydr. Res.*, **110**, C16 (1982). b) A. Ya. Cherniak, A.B. Levinsky, and N.K. Kochetkov, *Carbohydr. Res.*, **128**, 269 (1984).
6. A. Ya. Cherniak, A.B. Levinsky, and N.K. Kochetkov, *Bioorg. Khim.*, **14**, 1047 (1988).
7. V. Horejsi, P. Smolek, and J. Kocourek, *Biochem. Biophys. Acta,* **538**, 293 (1978).
8. G. Ekborg, P.J. Garegg, and B. Gotthamer, *Acta Chem. Scand.*, **B29**, 765 (1975).
9. H. Borén, P.J. Garegg, and N.-H. Wallin, *Acta Chem. Scand.*, **26**, 1082 (1972).
10. K. Eklind, P.J. Garegg, and B. Gotthamer, *Acta Chem. Scand.*, **B29**, 633 (1975).
11. a) G. Siewert, and O. Westphal, *Liebigs Ann. Chem.*, **720**, 171 (1968). b) H.H. Baer, and D.J. Astles, *Carbohydr. Res.*, **126**, 343 (1984).
12. D.A. Prins, *J. Am. Chem. Soc.*, **70**, 3955 (1948).
13. S. Hanessian, and N.R. Plessas, *J. Org. Chem.*, **34**, 1035 (1969).
14. a) P.A.M. van der Klein, G.J.P.H. Boons, G.H. Veeneman, G.A. van der Marel, and J.H.van Boom, *Tetrahedron Lett.*, **30**, 5477 (1989). b) P.A.M. van der Klein, G.J.P.H. Boons, G.H. Veeneman, G.A. van der Marel, and J.H. van Boom, *Synlett*, 311 (1990).

15. J.J.A. Beliën, G.A. van der Marel, and J.H. van Boom, to be published.
16. J.S. Brimacombe, and O.A. Ching, *J. Chem. Soc.*, C, 1642 (1968).
17. B.M. Kim, and K.B. Sharpless, *Tetrahedron Lett.*, **30**, 655 (1989).
18. K. Sato, T. Hoshi, and Y. Kajihara, *Chem. Lett.*, 1469 (1992).
19. a) S. Hanessian, and Y. Guindon, *Tetrahedron Lett.*, **21**, 2305 (1980). b) S. Hanessian, and Y. Guindon, *Carbohydr. Res.*, **86**, C3 (1980).
20. M.J. Eis, and B. Ganem, *Carbohydr. Res.*, **176**, 316 (1988).
21. Y.-H. Chen, T.-Y. Luh, G.-H. Lee, and S.-M. Peng, *J. Chem. Soc., Chem. Commun.*, 2369 (1994).
22. Y. Oikawa, T. Yoshioka, and O. Yonemitsu, *Tetrahedron Lett.*, **23**, 885 (1982).
23. The NMR spectroscopic data of **23** were in good accordance with those of its enantiomer. D.R. Bundle, and S. Josephson, *Can. J. Chem.*, **59**, 2686 (1978).
24. a) M. Haga, M. Chonan, and S. Tejima, *Carbohydr. Res.* **16**, 486 (1971). b) T. Iversen, and D.R. Bundle, *Carbohydr. Res.*, **103**, 29 (1982).
25. Upon completion of this paper, Bundle et al. described a similar reaction pathway to convert the anomeric methyl group into the corresponding thioethyl function. T.L. Lowary, E. Eichler, and D.R. Bundle, *J. Org. Chem.*, **60**, 7316 (1995).
26. J.F. King, and A.D. Albutt, *Can. J. Chem.*, **48**, 1754 (1970).
27. G.H. Veeneman, S.H. van Leeuwen, and J.H. van Boom, *Tetrahedron Lett.*, **31**, 1331 (1990).
28. G.H. Veeneman, S.H. van Leeuwen, H.M. Zuurmond, and J.H. van Boom, *J. Carbohydr. Chem.*, **9**, 783 (1990).