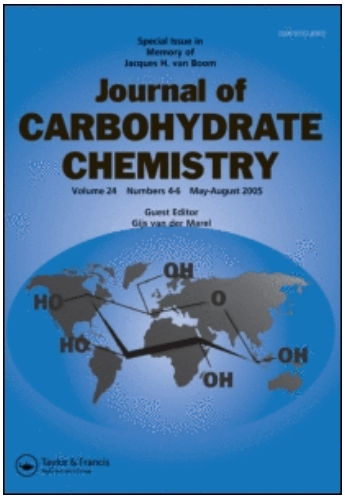

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β-DISACCHARIDES FOR MITHRAMYCIN ANALOG SYNTHESIS. TRIFLATE REARRANGEMENT IN DISACCHARIDE PREPARATION.[1]

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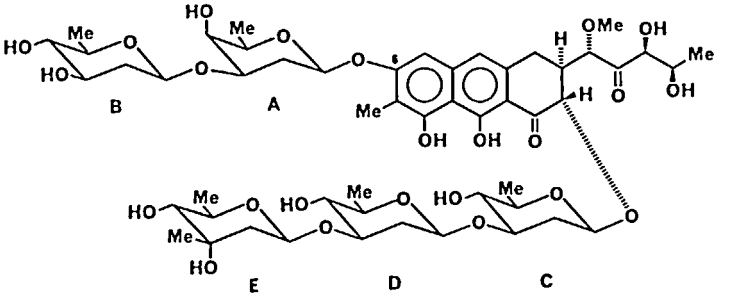
ABSTRACT

Three disaccharides (13, 16, and 20), compounds to be utilized in the preparation of analogs of the anticancer agent mithramycin (1), have been synthesized from appropriately protected 2,6-dideoxy sugars. In these syntheses triflate rearrangement was used to invert configuration at specific chiral centers. Silver-silicate controlled reaction generated the desired β-linkages between saccharide units. Silver-silicate also catalyzed β-glycoside formation when the glycosyl bromides derived from 13 and 20 each were coupled with *o*-methylphenol (a model aglycon).

INTRODUCTION

Mithramycin (1), chromomycin A_3 (2), and olivomycin A (3) are structurally related, antitumor agents which belong to the aureolic acid family of antibiotics.[2] These compounds bind to DNA in the presence of magnesium ions to inhibit selectively DNA-dependent RNA synthesis.[3] Since mithramycin (1) and chromomycin A_3 (2) differ only in carbohydrate structure yet do not exhibit the same biological activity,[2a] their ability to function as anticancer agents must depend, in part, upon the carbohydrate portions of these molecules. Additional support for the critical involvement of the carbohydrate residues in anticancer activity arises from the finding that partial hydrolytic removal of sugars from olivomycin A (3) yields compounds which bind weakly to DNA and are inactive.[2a,d] These observations not only underscore the importance of the



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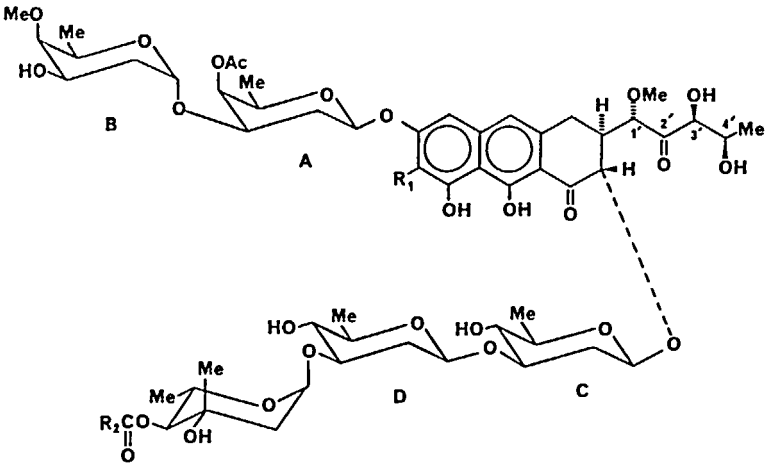
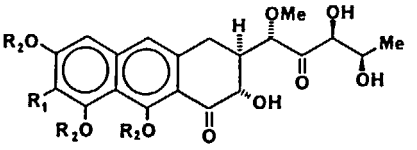


2 $R_1 = CH_3$, $R_2 = CH_3$

3 $R_1 = H$, $R_2 = i\text{-}Pr$



4 $R_1 = H$ $R_2 = H$

5 $R_1 = H$ $R_2 = Me$

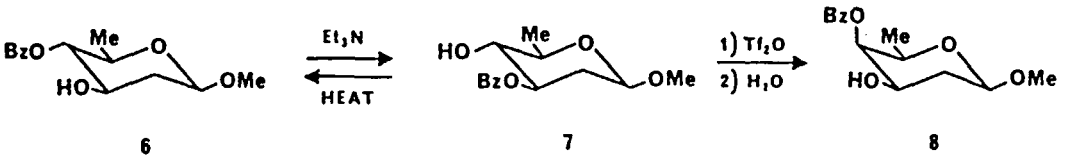
carbohydrate structure to the behavior of the aureolic acids but they also indicate that analogs with modified monosaccharide residues could have increased activity or reduced toxicity or both.

Several research teams have been interested in the synthesis of members of the aureolic acid family.[5-10] Much of this effort has been directed toward the formation of olivin (4) (the aglycon portion of 3). The Franck[5] and Weinreb[6] groups each have reported syntheses of tri-*O*-methylolivin (5) while Roush[7] and coworkers recently have synthesized olivin (4) itself. The Roush group also has been interested in the carbohydrate portions of 3 and has developed a method for forming the A-B ring system found in olivomycin A (3) from non-carbohydrate precursors.[8] Thiem has directed a series of studies initially concerned with structure elucidation in the aureolic acids and later with the development of reactions for preparation of the carbohydrate residues in these compounds (1-3).[11-14] This work has led to the synthesis of a portion of the trisaccharide found in chromomycin A_3,[14] a derivative of the mithramycin disaccharide,[12] and derivatives of the olivomycin A[15] and mithramycin[16] trisaccharides.

Our interest in mithramycin analog synthesis[17] originated with the observed dependence of aureolic acid activity on carbohydrate structure. In particular, we were attracted to the preparation of analogs in which epimerization had occurred at one or more of the hydroxyl bearing chiral centers in the sugar residues.[18] If such structural changes forced alteration in analog binding to DNA (when compared to the binding of mithramycin), a significantly different anticancer activity could result. In this paper a synthesis of the disaccharides to be used in analog preparation is described and a procedure is given for attaching them to a model aglycon.

RESULTS AND DISCUSSION

The first disaccharide to be prepared was one containing the A-B ring system found in mithramycin (1). This synthesis began with the conversion of methyl 4-*O*-benzoyl-2,6-dideoxy-*β*-D-*arabino*-hexopyranoside (6) into methyl 4-*O*-benzoyl-2,6-dideoxy-*β*-D-*lyxo*-hexopyranoside (8) (Scheme I), a process which was accomplished by migration of the benzoyl group from O-4 to O-3 (to give 7) followed by a rearrangement which in-

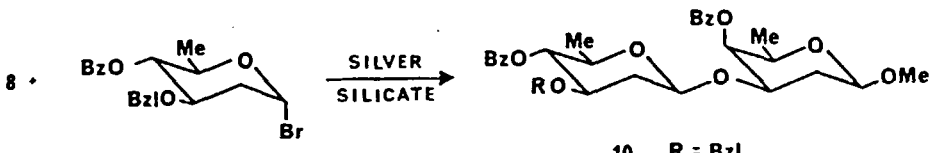


6 7 8

Scheme I

cluded an inversion of configuration at C-4 and a reverse migration of the benzoyl group.[19]

The glycosyl acceptor 8 was coupled with 4-*O*-benzoyl-3-*O*-benzyl-2,6-dideoxy-α-D-*arabino*-hexopyranosyl bromide (9), using the silver-silicate method developed by Paulsen,[20] to give the β-disaccharide 10 in 72% yield along with a 13% yield of the α-anomer 11 (β/α = 5.4/1). The selection of 9 as the glycosyl donor was guided by the work of Van Boeckel and Beetz[21] on glycoside formation catalyzed by insoluble silver salts. These workers found that an electron donating substituent at O-3 (e.g., benzyl) and an electron withdrawing one at O-4 (e.g., benzoyl) maximized β-glycoside formation.



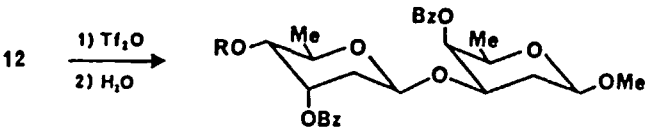
9

10 R = Bzl

12 R = H

The benzyl group in 10 was removed by photochemically initiated reaction with NBS and water in the presence of calcium carbonate[22] to generate the partially protected disaccharide 12, a compound which represented a synthetic branching point. Benzoylation of 12 produced the disaccharide 13 containing the mithramycin A-B ring system fully protected by groups which could be removed under mildly basic conditions. (These deprotection conditions are significant since the aureolic acids are hydrolyzed by weak acids[23] and decomposed by strong bases but are de-esterified under mildly basic conditions.[23-25]) The two electron-withdrawing benzoyl groups on ring B protected the inter-

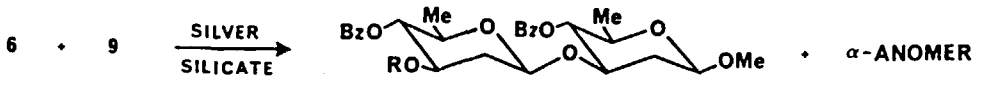
glycosidic linkage in 13 sufficiently from hydrolysis that the methoxy containing acetal was selectively hydrolyzed.



15 R = H

16 R = Bz

A second role for compound 12 arose from its conversion into the isomeric disaccharide 15 by reaction with triflic anhydride followed by treatment with water. This second triflate rearrangement, as with the first (7 --> 8), gave only a single product. Benzoylation of 15 produced the fully protected disaccharide 16 with configuration inverted at C-3 in ring B. Triflate rearrangement is a valuable tool for modifying configuration in oligosaccharides. Triflate formation and reaction occur under extremely mild conditions; thus, the process is effective when relatively unstable compounds are involved.



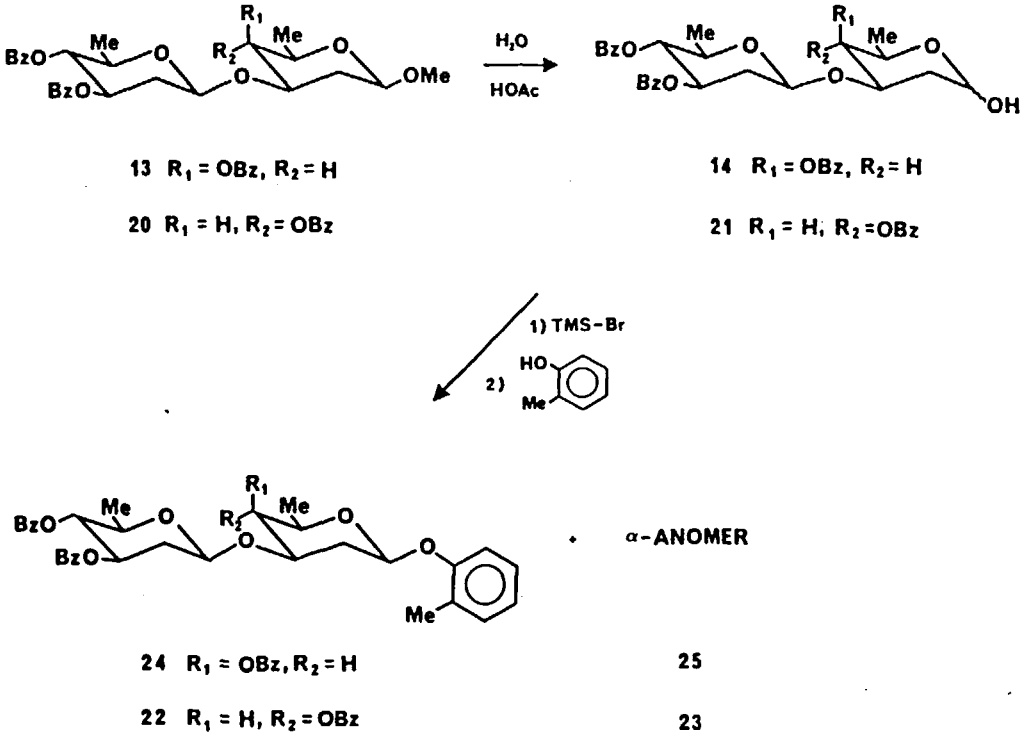
17 R = Bzl

19 R = H

24

In order to form a disaccharide in which one of the chiral centers in ring A had been inverted, the glycosyl bromide 9 was coupled with the acceptor 6 to give a 3.5/1 (β/α) mixture of the disaccharides 17 and 18. The 3'-O-benzyl group was removed to give 19, a compound which, like 12, can serve two purposes. First, benzoylation of 19 gave 20, a compound containing a suitably protected A-B ring system with inverted configuration at C-4 in ring A. Second, 19 is a glycosyl acceptor to be used in future trisaccharide synthesis since it has the substitution pattern and configuration of the C-D ring system in mithramycin (1) and contains an unprotected 3'-hydroxyl group.

Since the disaccharides synthesized ultimately will be coupled to one of the phenolic hydroxyl groups in the mithramycin aglycon, it was important to determine if reaction with this less nucleophilic (phenolic) type of hydroxyl group would occur to form β-glycosides selectively.[26b,c] Compound 20 was hydrolyzed in aqueous acetic acid to give 21. (The electron-withdrawing benzoyl groups in ring B again protected the interglycosidic linkage.) Compound 21 then was converted into the corresponding glycosyl bromide which reacted with o-methylphenol in the presence of silver silicate to give the β-glycoside 22 in 65% yield along with a 21% yield of the α-anomer 23 (β/α = 3/1). A similar set of reactions converted 13 into the glycosides 24 and 25.



13 R_1 = OBz, R_2 = H

20 R_1 = H, R_2 = OBz

14 R_1 = OBz, R_2 = H

21 R_1 = H, R_2 = OBz

24 R_1 = OBz, R_2 = H

22 R_1 = H, R_2 = OBz

25

23

Scheme II

This final coupling process demonstrated that reaction occurs without difficulty between the glycosyl bromides to be used in analog

synthesis and a model aglycon. Since compounds now have been produced which not only contain the A-B ring system in mithramycin (1) but also ring systems with configuration inverted at chiral centers in each monosaccharide residue, the necessary materials have been obtained and procedures established to complete the "disaccharide" phase of analog preparation. These procedures also provide the basic approach to be used in formation of modified trisaccharides.

EXPERIMENTAL

General Procedures. ^1H NMR and ^{13}C NMR spectra were determined using a Brucker AC300F spectrometer with $CDCl_3$ as the solvent. Chemical shifts are relative to tetramethylsilane (δ = 0.0). Column chromatography was conducted using a 2.5 x 15 cm column of Baker 240-400 mesh silica gel with hexane-ethyl acetate (3:1) as the developer. TLC was done using Whatman silica gel 60 A plates developed with hexane-ethyl acetate (3:1). Optical rotations were determined at 578 nm for solutions in ethyl acetate at 22 °C using a Perkin-Elmer model 241 spectrometer.

Methyl 3-*O*-Benzoyl-2,6-dideoxy-β-D-*arabino*-hexopyranoside (7). Methyl 4-*O*-benzoyl-2,6-dideoxy-β-D-*arabino*-hexopyranoside (6)[19] (5.38 g, 2.38 mmol) was dissolved in 22 mL of triethylamine and heated under reflux for two days. The solvent was distilled under reduced pressure and the residue chromatographed in the standard fashion to give 3.01 g (1.33 mmol) of unreacted 6 and 2.36 g (1.05 mmol) of compound 7: R_f = 0.65; [α] = - 51° (c = 1.06); ^{13}C NMR δ 17.81 (C_6), 36.43 (C_2), 56.48 (OMe), 72.05 (C_5), 74.45 (C_3), 74.60 (C_4), 100.16 (C_1), 128.35, 129.69, 133.21 (aromatic carbons), 166.63 (C=O); ^1H NMR δ 1.35 (H_6, $J_{5,6}$ = 5.2 Hz), 1.76 (H_{2a}, $J_{1,2a}$ = 9.6 Hz, $J_{2a,3}$ = 11.6 Hz, $J_{2a,2e}$ = 12.2 Hz), 2.37 (H_{2e}, $J_{1,2e}$ = 1.8 Hz, $J_{2e,3}$ = 5.2 Hz), 3.33-3.46 (H_4, H_5), 3.46 (OMe), 4.45 (H_1), 5.06 (H_3, $J_{3,4}$ = 8.5 Hz), 7.34-7.44, 7.92-8.02 (aromatic); Anal. Calcd for $C_{14}H_{18}O_5$: C, 63.14; H, 6.81. Found: C, 63.16; H, 6.71.

Methyl 4-*O*-Benzoyl-2,6-dideoxy-β-D-*lyxo*-hexopyranoside (8). Compound 7 (1.37 g, 6.05 mmol) and 3 mL of pyridine were dissolved in 30 mL of dichloromethane and cooled to -20 °C. Triflic anhydride (2.82 g, 10 mmol) in 10 mL of dichloromethane was added dropwise with stirring. The reaction mixture was removed from the cooling bath and allowed to

warm to room temperature over a period of 30 min. Water (1.3 mL) was added and the reaction mixture was stirred for 48 h at room temperature. The reaction mixture was passed through a 1 cm layer of silica gel and the solvent evaporated from the solution to give 1.26 g (5.57 mmol, 92%) of compound 8; mp = 142–143 °C; $[\alpha] = -3.5°$ (c = 0.34); R_f = 0.21; ^{13}C NMR δ 16.83 (C_6), 35.05 (C_2), 56.71 (OMe), 68.64, 69.60 (C_3, C_5), 72.41 (C_4), 101.28 (C_1), 128.47, 129.53, 130.05, 133.41 (aromatic carbons), 167.26 (C=O); ^{1}H NMR δ 1.28 (H_6, $J_{5,6}$ = 6.5 Hz), 1.73 (H_{2a}), 2.06 (H_{2a}), 3.55 (OMe), 3.70 (H_5, $J_{4,5}$ = 1.2 Hz), 4.02 (H_3, $J_{2a,3}$ = 11.8 Hz, $J_{2e,3}$ = 5.3 Hz, $J_{3,4}$ = 3.3 Hz), 4.42 (H_1, $J_{1,2a}$ = 9.5 Hz, $J_{1,2e}$ = 2.4 Hz), 5.25 (H_5), 7.26–7.54, 8.07–8.09 (aromatic). Anal. Calcd for $C_{14}H_{18}O_5$: C, 63.14; H, 6.81. Found: C, 62.96; H, 6.77.

Methyl 4-*O*-Benzoyl-3-*O*-(4-*O*-benzoyl-3-O-benzyl-2,6-dideoxy-β-D-*arabino*-hexopyranosyl)-2,6-dideoxy-β-D-*lyxo*-hexopyranoside (10) and Methyl 4-*O*-Benzoyl-3-*O*-(4-*O*-benzoyl-3-O-benzyl-2,6-dideoxy-α-D-*arabino*-hexopyranosyl)-2,6-dideoxy-β-D-*lyxo*-hexopyranoside (11). Compound 8 (1.00 g, 4.4 mmol) was dissolved in 25 mL of anhydrous toluene containing 1 g of 3A molecular sieves and allowed to stand overnight. To this solution was added 5 g of silver silicate and, with rapid stirring, 2.31 g (5.72 mmol) of the glycosyl bromide 9[17f]. After stirring for 30 min, the reaction mixture was filtered through a 2 cm layer of silica gel and the silica gel washed with 100 mL of 3:1 hexane-ethyl acetate. The solvent was distilled from the filtrate and combined washings to leave a residue which was chromatographed in the standard fashion to give 10 (1.87 g, 3.17 mmol, 72%) and 11 (0.34 g, 0.57 mmol, 13%) (β/α = 5.4/1). Compound 10: R_f = 0.30; mp = 127–128 °C; $[\alpha] = -6.6°$ (c = 1.41); ^{13}C NMR δ 16.80 (C_6), 17.64 ($C_{6'}$), 32.41 (C_2), 36.47 ($C_{2'}$), 56.40 (OMe), 69.91 (C_5), 70.33 (CH_2), 70.99 ($C_{5'}$), 72.71 (C_3), 75.35 ($C_{3'}$), 76.09 ($C_{4'}$), 97.01 ($C_{1'}$), 100.99 (C_1), 127.35, 128.12, 128.21, 129.64, 129.86, 130.26, 132.75, 133.01 (aromatic carbons), 165.48, 165.84 (C=O); ^{1}H NMR δ 1.22 ($H_{6'}$, $J_{5',6'}$ = 6.3 Hz), 1.26 (H_6, $J_{5,6}$ = 6.6 Hz), 1.66 (H_{2a}, $J_{2a',2e'}$ = 12.4 Hz, $J_{1,2a'}$ = 9.0 Hz, $J_{2a',3'}$ = 9.9 Hz), 1.96 (H_{2a}, $J_{2a,2e}$ = 11.8 Hz, $J_{1,2a}$ = 9.5 Hz, $J_{2a,3}$ = 12.0 Hz), 2.13 (H_{2e}, $J_{2e,3}$ = 4.0 Hz), 2.25 ($H_{2e'}$, $J_{2e',3}$ = 4.6 Hz), 3.47 ($H_{5'}$, $J_{4',5'}$ = 9.3 Hz), 3.55 (OMe), 3.61 ($H_{3'}$, $J_{3',4'}$ = 9.1 Hz), 3.72 (H_5, $J_{4',5'}$ = 9.3 Hz), 4.09 (H_3, $J_{3,4}$ = 3.0 Hz), 4.36, 4.54 (CH_2, J_{CH2} = 12.4 Hz), 4.45 (H_1), 4.63 ($H_{1'}$), 4.95 ($H_{4'}$), 5.41 (H_4), 7.08–7.18, 7.41–7.55, 7.98, 8.01, 8.11, 8.14 (aromatic protons). Anal. Calcd for $C_{34}H_{38}O_9$: C, 69.14; H, 6.48. Found: C, 68.91; H, 6.45. Compound 11: R_f = 0.53; $[\alpha]$ = –

14° (c = 0.34); ^{13}C NMR δ 16.80 ($C_{6'}$), 17.73 (C_6), 33.73 ($C_{2'}$), 35.06 (C_2), 56.71 (OMe), 66.83 ($C_{5'}$), 68.45 (C_4), 69.53 (C_5), 70.86 (CH_2), 71.36 (C_3), 73.39 ($C_{3'}$), 76.64 ($C_{4'}$), 95.24 ($C_{1'}$), 101.33 (C_1), 127.28, 127.46, 128.05, 128.32, 128.48, 129.78, 130.01, 133.01, 133.18 (aromatic carbons), 165.73, 166.47 (C=O); ^1H NMR δ 1.14 ($H_{6'}$, $J_{5',6'}$ = 6.0 Hz), 1.26 (H_6, $J_{5,6}$ = 6.2 Hz) 1.67 ($H_{2a'}$, $J_{1',2a'}$ = 3.6 Hz, $J_{2a',3'}$ = 11.0 Hz, $J_{2a',2e'}$ = 12.7 Hz), 1.80–1.95 (H_{2a}, H_{2e}), 2.03 ($H_{2e'}$, $J_{1',2e'}$ = 1.0 Hz, $J_{2e',3'}$ = 4.8 Hz), 3.43 (OMe), 3.58 (H_5, $J_{4,5}$ = 9.1 Hz), 3.59 ($H_{3'}$, $J_{3',4'}$ = 9.1 Hz), 3.68 ($H_{5'}$, $J_{4',5'}$ = 9.3 Hz), 3.83 (H_3, $J_{3,4}$ = 2.9 Hz), 4.01, 4.22 (CH_2, J_{CH2} = 11.6 Hz), 4.29 (H_1), 4.76 ($H_{4'}$), 5.01 ($H_{1'}$), 5.14 (H_4), 6.61-6.95, 7.12-7.30, 7.62-7.65, 7.83-7.86 (aromatic protons). Anal. Calcd for $C_{34}H_{36}O_9$: C, 69.14; H, 6.48. Found: C, 69.00; H, 6.40.

Methyl 4-*O*-Benzoyl-3-*O*-(4-*O*-benzoyl-2,6-dideoxy-β-D-*arabino*-hexopyranosyl)-2,6-dideoxy-β-D-*lyxo*-hexopyranoside (12). Compound 10 (1.00 g, 1.7 mmol) and *N*-bromosuccinimide (0.39 g, 2.82 mmol) were dissolved in 35 mL of carbon tetrachloride in which 5 mL of water and 0.51 g (5.1 mmol) of calcium carbonate were suspended by rapid stirring. The reaction mixture was purged with nitrogen for 1 h and the purge continued during 2 h of irradiation with a 375-W incandescent lamp. After irradiation, the solvent was removed under reduced pressure and the reaction mixture was immediately chromatographed in the standard fashion to give 0.75 g (1.5 mmol, 88%) of 12: R_f = 0.14; [α] = + 0.34 (c = 1.11); ^{13}C NMR δ 16.76 ($C_{6'}$), 17.75 (C_6), 33.61 (C_2), 37.83 ($C_{2'}$), 56.65 (OMe), 69.76 ($C_{5'}$), 70.03 (C_5), 70.11 ($C_{5'}$), 70.99 (C_4), 72.79 (C_3), 78.77 ($C_{4'}$) 96.89 ($C_{1'}$), 101.09 (C_1), 128.42, 129.78, 129.94, 133.17, 133.29 (aromatic carbons), 166.43, 166.74 (C=O); ^1H NMR δ 1.26 (H_6, $J_{5,6}$ = 6.4 Hz), 1.26 ($H_{6'}$, $J_{5',6'}$ = 6.2 Hz), 1.67 ($H_{2a'}$, $J_{1',2a'}$ = 9.9 Hz, $J_{2a',2e'}$ = $J_{2a',3'}$ = 11.5 Hz), 1.97 (H_{2a}, $J_{1,2a}$ = 9.7 Hz, $J_{2a,2e}$ = $J_{2a,3}$ = 12.0 Hz), 2.15 (H_{2e}, $J_{1,2e}$ = 2.0 Hz, $J_{2e,3}$ = 4.2 Hz), 2.19 ($H_{2e'}$, $J_{1',2e'}$ = 2.0 Hz, $J_{2e',3'}$ = 5.3 Hz), 3.56 ($H_{5'}$, $J_{4',5'}$ = 9.1 Hz), 3.56 (OMe), 3.73 (H_5, $J_{4,5}$ < 1 Hz), 3.82 ($H_{3'}$, $J_{3',4'}$ = 8.8 Hz), 4.09 (H_3, $J_{3,4}$ = 3.1 Hz), 4.46 (H_1), 4.67 ($H_{4'}$), 4.69 ($H_{1'}$), 5.42 (H_4), 7.39-7.62, 7.99-8.15 (aromatic protons). Anal. Calcd for $C_{27}H_{32}O_9$: C, 64.78; H, 6.45. Found: C, 64.77; H, 6.32.

Methyl 4-*O*-Benzoyl-3-*O*-(3,4-di-*O*-benzoyl-2,6-dideoxy-β-D-*arabino*-hexopyranosyl)-2,6-dideoxy-β-D-*lyxo*-hexopyranoside (13). Pyridine (0.79 g, 10 mmol) and benzoyl chloride (0.56 g, 4.0 mmol) were added to compound 12 (0.14 g, 0.28 mmol) in 10 mL of dichloromethane. After 14 h, 0.5 mL of water was added and the reaction mixture stirred for 30 min. The layers

were separated and the aqueous layer was washed with 10 mL of dichloromethane. The solvent was removed from the combined organic extracts under reduced pressure. Toluene (10 mL) was added and the solvent again removed under reduced pressure to give 0.17 g (0.28 mmol, 100%) of 13: R_f = 0.30; [α] = - 17° (c = 0.82); ^{13}C NMR δ 16.84 (C_6), 17.68 ($C_{6'}$), 32.39 (C_2), 36.66 ($C_{2'}$), 56.64 (OMe), 70.11 (C_5), 70.46 ($C_{5'}$), 70.89 (C_4), 71.42 ($C_{3'}$), 73.13 (C_3), 74.63 ($C_{4'}$). 96.75 ($C_{1'}$), 101.14 (C_1), 128.31, 129.66, 129.97, 130.17, 132.89, 133.12, (aromatic carbons), 165.70, (C=O); ^{1}H NMR δ 1.32 ($H_{6'}$, $J_{5',6'}$ = 6.2 Hz), 1.28 (H_6, $J_{6,5}$ = 6.4 Hz), 1.83 ($H_{2a'}$, $J_{1',2a'}$ = 9.7 Hz, $J_{2a',2e'}$ = 12.4 Hz, $J_{2a',3'}$ = 11.6 Hz), 2.01 (H_{2a}, $J_{1,2a}$ = 9.8 Hz, $J_{2a,2e}$ = 12.1 Hz, $J_{2a,3}$ = 12.1 Hz), 2.19 (H_{2e}, $J_{1,2e}$ = 1.9 Hz, $J_{2e,3}$ = 4.5 Hz), 2.43 ($H_{2e'}$, $J_{1',2e'}$ = 1.8 Hz, $J_{2e',3'}$ = 5.2 Hz), 3.57 (OMe), 3.71 ($H_{5'}$, $J_{4',5'}$ = 9.5 Hz), 3.74 (H_5, $J_{4,5}$ < 1 Hz), 4.14 (H_3, $J_{3,4}$ = 3.4 Hz), 4.48 (H_1), 4.87 ($H_{1'}$), 5.18 ($H_{4'}$, $J_{3',4'}$ = 9.5 Hz), 5.31 ($H_{3'}$), 5.47 (H_4), 7.14-7.58, 7.84-8.17 (aromatic protons). Anal. Calcd for $C_{34}H_{36}O_{10}$: C, 67.54; H, 6.00. Found: C, 67.24; H, 6.25.

4-*O*-Benzoyl-3-*O*-(3,4-di-*O*-benzoyl-2,6-dideoxy-β-D-*arabino*-hexopyranosyl)-2,6-dideoxy-D-*lyxo*-hexopyranose (14). Compound 13 (0.50 g, 0.82 mmol) was combined with 10 mL of acetic acid and 4 mL of water and heated at 100 °C for three h. The solvent was distilled under reduced pressure and the residue chromatographed in the standard fashion to give 0.39 g (0.66 mmol, 80%) of compound 14 (α/β = 3/1): R_f = 0.10; [α] = + 38° (c = 0.21); ^{13}C NMR (α-anomer) δ 17.05 (C_6), 17.68 ($C_{6'}$), 31.00 (C_2), 36.78 ($C_{2'}$), 65.84 (C_5), 70.26, 70.39 (C_4, $C_{5'}$), 71.60 ($C_{3'}$), 72.21 (C_3), 74.40 (C_4), 92.56 (C_1), 97.42 ($C_{1'}$), 128.35, 129.69, 129.87, 132.86, 133.14 (aromatic carbons), 166.13 (C=O).

Methyl 4-*O*-Benzoyl-3-*O*-(3-*O*-benzoyl-2,6-dideoxy-β-D-*ribo*-hexopyranosyl)-2,6-dideoxy-β-D-*lyxo*-hexopyranoside (15). Compound 12 (0.25 g, 0.50 mmol) was dissolved in 20 mL of dichloromethane. One mL of pyridine was added and the mixture was cooled to -20 °C. Triflic anhydride (0.28 g, 1.0 mmol) in 5 mL of dichloromethane was added dropwise to the stirred reaction mixture. After the solution had warmed to room temperature (1 h) and TLC indicated complete disappearance of starting material, 1.0 mL of water was added and the mixture stirred at room temperature for 24 h. The layers were separated and the aqueous layer was extracted with two mL of dichloromethane. The solvent was distilled from the combined organic extracts and the residue

chromatographed in the standard fashion to give 0.22 g (0.44 mmol, 88%) of compound 15: R_f = 0.20; [α] = + 84° (c = 1.98); ^{13}C NMR δ 16.67 (C_6), 17.96 ($C_{6'}$), 32.80 (C_2), 35.90 ($C_{2'}$), 55.53 (OMe), 70.00 (C_5), 70.43 ($C_{5'}$), 71.04, 71.43 ($C_{3'}$, C_4), 72.03 ($C_{4'}$), 72.51 (C_3), 96.27 ($C_{1'}$), 101.02 (C_1), 128.59, 129.68, 133.00, 133.12 (aromatic carbons), 166.00, 166.20 (C=O); ^{1}H NMR δ 1.24 (H_6, $J_{5,6}$ = 6.4 Hz), 1.31 ($H_{6'}$, $J_{5',6'}$ = 6.1 Hz), 1.75 ($H_{2a'}$, $J_{1',2a'}$ = 9.3 Hz, $J_{2a',3'}$ = 2.7 Hz), 1.92 (H_{2a}, $J_{1,2a}$ = 9.5 Hz, $J_{2a,3}$ = 12.1 Hz), 2.04 ($H_{2e'}$), 2.13 (H_{2e}, $J_{1,2e}$ < 1 Hz, $J_{2e,3}$ = 3.8 Hz), 3.42 ($H_{4'}$, $J_{3',4'}$ = 2.8 Hz, $J_{4',5'}$ = 9.4 Hz), 3.52 (OMe), 3.70 (H_5, $J_{4,5}$ <1 Hz), 3.82 ($H_{5'}$, $J_{4',5'}$ = 9.4 Hz), 4.08 (H_3, $J_{3,4}$ = 3.8 Hz), 4.43 (H_1), 4.96 ($H_{1'}$), 5.38-5.45 (H_4, $H_{3'}$), 7.36-7.58, 7.95-8.10 (aromatic protons). Anal. Calcd for $C_{27}H_{32}O_9$: C, 64.79; H, 6.45. Found: C, 65.01; H, 6.44.

Methyl 4-*O*-Benzoyl-3-*O*-(3,4-di-*O*-benzoyl-2,6-dideoxy-β-D-*ribo*-hexopyranosyl)-2,6-dideoxy-β-D-*lyxo*-hexopyranoside (16). Pyridine (0.79 g, 10 mmol) and benzoyl chloride (0.56 g, 4.0 mmol) were added to compound 15 (0.28 g, 0.55 mmol) in 10 mL of dichloromethane. After 14 h, 0.5 ml of water was added and the reaction mixture stirred for 30 min. The layers were separated and the aqueous layer was washed with 10 mL of dichloromethane. The solvent was removed from the combined organic extracts under reduced pressure. Toluene (10 mL) was added and the solvent again removed under reduced pressure to give 0.34 g (0.54 mmol, 100%) of 16: R_f = 0.30; [α] = 84° (c = 1.98); ^{13}C NMR δ 16.90 (C_6), 18.00 ($C_{6'}$), 32.53 (C_2), 35.89 ($C_{2'}$), 56.53 (OMe), 68.28 ($C_{3'}$), 68.57 ($C_{5'}$), 69.98 (C_5), 71.15 (C_4), 72.96 ($C_{4'}$), 73.22 (C_3). 95.89 ($C_{1'}$), 101.06 (C_1), 128.31, 129.66, 129.97, 130.17, 132.89, 133.12, (aromatic carbons), 165.70, (C=O); ^{1}H NMR δ 1.32 ($H_{6'}$, $J_{5',6'}$ = 6.2 Hz), 1.28 (H_6, $J_{6,5}$ = 6.3 Hz), 1.98 ($H_{2a'}$, $J_{1',2a'}$ = 9.3 Hz, $J_{2a',2e'}$ = 12.4 Hz, $J_{2a',3'}$ = 3.0 Hz), 2.05 (H_{2a}, $J_{1,2a}$ = 9.7 Hz, $J_{2a,2e}$ = 12.1 Hz, $J_{2a,3}$ = 11.4 Hz), 2.19 (H_{2e}, $J_{1,2e}$ = <1 Hz, $J_{2e,3}$ = 5.4 Hz), 2.24 ($H_{2e'}$, $J_{1',2e'}$ = 2.0 Hz, $J_{2e',3'}$ = 3.0 Hz), 3.54 (OMe), 3.77 (H_5, $J_{4,5}$ = <1 Hz), 4.31 ($H_{5'}$, $J_{4',5'}$ = 9.5 Hz), 4.22 (H_3, $J_{3,4}$ = 2.6 Hz), 4.51 (H_1), 5.21 ($H_{1'}$), 4.94 ($H_{4'}$, $J_{3',4'}$ = 2.8 Hz), 5.78 ($H_{3'}$), 5.53 (H_4), 7.23-8.13 (aromatic protons). Anal. Calcd for $C_{34}H_{36}O_{10}$: C, 67.54; H, 6.00. Found: C, 67.14; H, 6.11.

Methyl 4-*O*-Benzoyl-3-*O*-(4-*O*-benzoyl-3-O-benzyl-2,6-dideoxy-β-D-*arabino*-hexopyranosyl)-2,6-dideoxy-β-D-*arabino*-hexopyranoside (17) and Methyl 4-*O*-Benzoyl-3-*O*-(4-*O*-benzoyl-3-O-benzyl-2,6-dideoxy-α-D-*arabino*-hexopyranosyl)-2,6-dideoxy-β-D-*arabino*-hexopyranoside (18). Compound 6 (1.04 g, 4.6 mmol) was dissolved in 25 mL of anhydrous

toluene containing 1 g of 3A molecular sieves and allowed to stand overnight. To this rapidly stirred solution was added 5 g of silver silicate followed by 2.23 g (5.5 mmol) of compound 9. After stirring for 30 min, the reaction mixture was filtered through a 2 cm layer of silica gel and the silica gel washed with 100 mL of 3:1 hexane–ethyl acetate. The solvent was distilled from the filtrate and combined washings to leave a residue which was chromatographed in the standard fashion to give 17 (1.79 g, 3.04 mmol, 66%) and 18 (0.51 g, 0.87 mmol, 19%) (β/α = 3.5/1). Compound 17: R_f = 0.49; [α] = - 109° 9c = 0.282); ^{13}C NMR δ 17.56 ($C_{6'}$), 17.85 (C_6), 36.50 ($C_{2'}$), 36.83 (C_2), 56.63 (OMe), 70.23 ($C_{5'}$), 70.34, 70.34 (C_5, CH_2), 73.70 (C_3), 75.28 ($C_{3'}$), 75.34 (C_4), 76.07 ($C_{4'}$), 96.58 ($C_{1'}$), 100.60 (C_1), 127.49, 128.25, 128.31, 128.39, 129.84, 129.73, 130.00, 133.06, 133.09 (aromatic carbons), 165.72, 165.99 (C=O); ^{1}H NMR δ 1.04 ($H_{6'}$, $J_{5',6'}$ = 6.2 Hz), 1.31 (H_6, $J_{5,6}$ = 6.2 Hz), 1.63 ($H_{2a'}$, $J_{1',2a'}$ = 9.9 Hz, $J_{2a',3'}$ = 12.2 Hz, $J_{2a',2e'}$ = 12.2 Hz), 1.75 (H_{2a}, $J_{1,2a}$ = 9.6 Hz, $J_{2a,3}$ = 11.9 Hz, $J_{2a,2e}$ = 12.3 Hz), 2.23 ($H_{2e'}$, $J_{1',2e'}$ = 1.8 Hz, $J_{2e',3'}$ = 5.2 Hz), 3.38 ($H_{5'}$, $J_{4',5'}$ = 9.3 Hz) 3.53 (OMe), 3.60 ($H_{3'}$, $J_{3',4'}$ = 9.3 Hz), 3.60 (H_5, $J_{4,5}$ = 9.4 Hz), 4.10 (H_3, $J_{3,4}$ = 9.3 Hz), 4.33, 4.52 (CH_2, J_{CH2} = 12.4 Hz), 4.46 (H_1), 4.59 ($H_{1'}$), 4.83 ($H_{4'}$), 4.92 (H_4), 7.07–7.21, 7.40–7.62, 7.94–8.12 (aromatic protons). Anal. Calcd for $C_{34}H_{38}O_9$: C, 69.14; H, 6.48. Found: C, 69.01; H, 6.45. Compound 18: R_f = 0.53; [α] = - 36° (c = 5.06); ^{13}C NMR δ 17.57 ($C_{6'}$), 17.72 ($C_{6'}$), 35.72 ($C_{2'}$), 38.56 (C_2), 56.63 (OMe), 66.65 ($C_{5'}$), 70.19 (C_5), 71.38 ($C_{3'}$), 73.76 (CH_2), 76.77, 76.77, 75.76 (C_3, C_4, $C_{4'}$), 99.43 ($C_{1'}$), 100.60 (C_1), 127.34, 127.48, 128.12, 128.37, 128.63, 129.54, 129.75, 133.04, 133.38 (aromatic carbons), 165.65, 165.76 (C=O); ^{1}H NMR δ 1.17 ($H_{6'}$, $J_{5',6'}$ = 6.3 Hz), 1.30 (H_6, $J_{5',6'}$= 6.2 Hz), 1.55 ($H_{2a'}$, $J_{1',2a'}$ = 11.9 Hz, $J_{2a',2e'}$ = 12.4 Hz, $J_{2a',3'}$ = 3.7 Hz), 1.85 (H_{2a}, $J_{1,2a}$ = 12.2 Hz, $J_{2a,2e}$ = 12.2 Hz, $J_{2a,3}$ = 9.8 Hz), 2.00 ($H_{2e'}$, $J_{2e',3'}$ = 5.5 Hz), 2.32 (H_{2e}, $J_{2e,3}$ = 5.4 Hz, $J_{1,2e}$ = 2.1 Hz), 3.53 (OMe), 3.56 (H_5), 3.86–3.97 (H_3, $H_{3'}$, $H_{5'}$), 4.34, 4.48 (CH_2, J_{CH2} = 11.9 Hz), 4.49 (H_1), 4.94 ($H_{4'}$, $J_{4',5'}$ = $J_{3',4'}$ = 9.5 Hz), 4.98 (H_4, $J_{4,5}$ = $J_{3,4}$ = 9.5 Hz), 7.10–7.61, 7.99–8.06 (aromatic). Anal. Calcd for Anal. Calcd for $C_{34}H_{38}O_9$: C, 69.14; H, 6.48. Found: C, 69.00; H, 6.30.

Methyl 4-*O*-Benzoyl-3-*O*-(4-*O*-benzoyl-2,6-dideoxy-*β*-D-*arabino*-hexopyranosyl)-2,6-dideoxy-*β*-D-*arabino*-hexopyranoside (19). Compound 17 (1.25 g, 2.1 mmol) and *N*-bromosuccinimide (0.49 g, 2.8 mmol) were dissolved in 35 mL of carbon tetrachloride in which 5 mL of water and 0.84 g (8.4 mmol) of calcium carbonate were suspended by rapid stirring.

The reaction mixture was purged with nitrogen for 1 h and the purge continued during 2 h of irradiation with a 375-W incandescent lamp. After irradiation, the solvent was removed under reduced pressure and the reaction mixture was immediately chromatographed in the standard fashion to give 0.89 g (1.8 mmol, 85%) of 19: R_f = 0.10; [α] = - 53° (c = 0.76); ^{13}C NMR δ 17.61 (C_6), 17.85 ($C_{6'}$), 36.73 (C_2), 39.62 ($C_{2'}$), 56.59 (OMe), 69.89 ($C_{5'}$), 69.94 (C_5), 70.32 ($C_{3'}$), 74.29 (C_3), 75.32 (C_4), 78.89 ($C_{4'}$), 96.05 ($C_{1'}$), 100.56 (C_1), 128.26, 128.46, 129.58, 129.77, 129.84, 132.98, 133.39 (aromatic carbons), 165.98, 166.95 (C=O). Compound 19 had a ^{1}H NMR spectrum which matched that reported for this compound.[15]

Methyl 4-*O*-Benzoyl-3-*O*-(3,4-di-*O*-benzoyl-2,6-dideoxy-β-D-*arabino*-hexopyranosyl)-2,6-dideoxy-β-D-*arabino*-hexopyranoside (20). Pyridine (0.79 g, 10 mmol) and benzoyl chloride (0.56 g, 4.0 mmol) were added to compound 19 (0.36 g, 0.72 mmol) in 10 mL of dichloromethane. After 14 h, 0.5 mL of water was added and the reaction mixture stirred for 30 min. The layers were separated and the aqueous layer was washed with 10 mL of dichloromethane. The solvent was removed from the combined organic extracts under reduced pressure. Toluene (10 mL) was added and the solvent again removed under reduced pressure to give 0.43 g (0.72 mmol, 100%) of 20: R_f = 0.37; [α] = - 61° (c = 2.11); ^{13}C NMR δ 17.50 (C_6), 17.89 ($C_{6'}$), 36.98, 36.98 (C_2, $C_{2'}$), 56.49 (OMe), 70.23 ($C_{5'}$), 70.38 (C_5), 71.49 ($C_{3'}$), 74.62 ($C_{4'}$), 74.75 (C_3), 75.69 (C_4). 96.72 ($C_{1'}$), 100.59 (C_1), 126.05, 128.34, 128.96, 129.60, 129.95, 130.52, 132.99, 134.60, 142.23, 144.42 (aromatic carbons), 165.78, 165.85 (C=O); ^{1}H NMR δ 1.05 ($H_{6'}$, $J_{5',6'}$ = 6.1 Hz), 1.31 (H_6, $J_{5,6}$ = 6.1 Hz), 1.77 (H_{2a}, $J_{1,2a}$ = 9.7 Hz, $J_{2a,2e}$ = 12.1 Hz, $J_{2a,3}$ = 11.9 Hz), 1.79 ($H_{2a'}$, $J_{1',2a'}$ = 10.1 Hz, $J_{2a',2e'}$ = 12.1 Hz, $J_{2a',3'}$ = 11.6 Hz), 2.37 (H_{2e}, $J_{1,2e}$ = 1.6 Hz, $J_{2e,3}$ = 5.5 Hz), 2.42 ($H_{2e'}$, $J_{1',2e'}$ = 1.8 Hz, $J_{2e',3'}$ = 5.0 Hz), 3.55 ($H_{5'}$, $J_{4',5'}$ = 9.5 Hz), 3.55 (OMe), 3.59 (H_5, $J_{4,5}$ = 9.4 Hz), 4.13 (H_3, $J_{3,4}$ = 9.2 Hz), 4.48 (H_1), 4.78 ($H_{1'}$), 4.95 (H_4), 5.02 ($H_{4'}$, $J_{3',4'}$ = 9.5 Hz), 5.29 ($H_{3'}$), 7.27–7.56, 7.86–7.92, 8.08, 8.10 (aromatic protons). Anal. Calcd for $C_{34}H_{36}O_{10}$: C, 67.54; H, 6.00. Found: C, 67.68; H, 6.25.

4-*O*-Benzoyl-3-*O*-(3,4-di-*O*-benzoyl-2,6-dideoxy-β-D-*arabino*-hexopyranosyl)-2,6-dideoxy-D-*arabino*-hexopyranose (21). Compound 20 (0.43 g, 0.71 mmol) was combined with 10 mL of acetic acid and 4 mL of water and heated at 100 °C for three h. The solvent was distilled under reduced pressure and the residue chromatographed in the standard

fashion to give 0.30 g (0.51 mmol, 72%) of compound 21 [mixture of anomers (α/β = 4/1)]: R_f = 0.15; [α] = - 71° (c =0.068); ^{13}C NMR (α anomer) 17.46 (C_6), 17.68 ($C_{6'}$), 36.16 (C_2), 37.04 (C_2), 66.37 ($C_{5'}$), 70.23 ($C_{5'}$), 71.83 ($C_{3'}$), 72.88 (C_3), 74.60 ($C_{4'}$), 76.07 (C_4), 91.84 (C_1), 97.20 ($C_{1'}$), 128.35, 129.69, 129.95, 132.93, 133.13 (aromatic carbons), 165.82, 165.92, 166.01 (C=O).

o-Methylphenyl 4-*O*-Benzoyl-3-*O*-(3,4-di-*O*-benzoyl-2,6-dideoxy-β-D-*arabino*- hexopyranosyl)-2,6-dideoxy-β-D-*arabino*-hexopyranoside (22) and o-Methylphenyl 4-*O*-Benzoyl-3-*O*-(3,4-di-*O*-benzoyl-2,6-dideoxy-β-D-*arabino*-hexopyranosyl)-2,6-dideoxy-α-D-*arabino*-hexopyranoside (23). Trimethylsilyl bromide (0.11 g, 0.74 mmol) was added dropwise to compound 21 (0.22 g, 0.37 mmol) dissolved in 10 mL of benzene. After stirring for 5 min, the solvent was removed under reduced pressure to give the glycosyl bromide which was immediately dissolved in 5 mL of toluene and the solution added in a dropwise manner to a solution of 0.10 g (0.92 mmol) of o-methylphenol in 10 mL of toluene in which 0.5 g of silver silicate had been suspended by rapid stirring. After 30 min, the mixture was filtered through a 2 cm layer of silica gel. The silica gel was washed with 100 mL of 10/1 toluene-ethyl acetate and the solvent was removed from the combined filtrate and washings under reduced pressure. The residue was chromatographed in the standard fashion using 50/1 toluene-ethyl acetate to give compounds 22 and 23. Compound 22: 0.17 g (0.24 mmol, 64%); R_f = 0.48 (50/1 toluene-ethyl acetate); [α] = - 96° (c = 0.084); ^{13}C NMR δ 16.27 (Ar$\underline{C}H_3$), 17.54 ($C_{6'}$), 18.06 (C_6), 36.97, 36.97 (C_2, $C_{2'}$), 70.36 ($C_{5'}$), 70.68 (C_5), 71.43 ($C_{3'}$), 74.55 ($C_{4'}$), 74.55 (C_4), 75.33 (C_3), 96.79 ($C_{1'}$), 97.90 (C_1), 114.89, 122.46, 126.86, 128.34, 129.67, 129.91, 130.94, 133.12 (aromatic carbons), 165.77, 165.82 (C=O); ^{1}H NMR δ 1.05 ($H_{6'}$, $J_{5',6'}$ = 6.1 Hz), 1.35 (H_6, $J_{5,6}$ = 6.2 Hz), 1.82 ($H_{2a'}$, $J_{1',2a'}$ = 9.6 Hz, $J_{2a',3a'}$ = 12.6 Hz), 2.14 (H_{2a}, $J_{1,2a}$ = 9.9 Hz, $J_{2a,3}$ = 11.8 Hz), 2.28 (ArCH_3), 2.45 ($H_{2e'}$, $J_{1',2e'}$ = 1.8 Hz, $J_{2e',3'}$ = 5.2 Hz), 2.56 (H_{2e}, $J_{1,2e}$ = 1.9 Hz, $J_{2e,3}$ = 5.2 Hz), 3.57 ($H_{5'}$, $J_{3',4'}$ = $J_{4',5'}$ = 9.5 Hz), 3.76 (H_5, $J_{3,4}$ = $J_{4,5}$ = 9.2 Hz), 4.21 (H_3), 4.82 ($H_{1'}$), 5.03 ($H_{4'}$, $J_{3',4'}$ = 9.5 Hz), 5.04 (H_4), 5.19 (H_1), 5.29 ($H_{3'}$), 6.93-7.55, 7.86-7.92, 8.08-8.11). Anal. Calcd for $C_{40}H_{40}O_{10}$: C, 70.57; H, 5.92. Found: C, 70.45; H, 5.90. Compound 23: 0.05 g (0.08 mmol, 21 %); R_f = 0.40 (50/1 toluene-ethyl acetate); [α] = - 3.8° (c = 0.35); ^{13}C NMR δ 16.28 (Ar$\underline{C}H_3$), 17.49 ($C_{6'}$), 17.84 (C_6), 36.38, (C_2), 37.08 ($C_{2'}$), 67.23 (C_5), 70.38 ($C_{5'}$), 71.57 ($C_{3'}$), 73.35 (C_3), 74.33 ($C_{4'}$), 75.74 (C_4), 95.96 (C_1), 97.40 ($C_{1'}$), 114.66, 122.06,

127.04, 128.34, 129.68, 130.53, 132.97, 133.12 (aromatic carbons), 165.87 (C=O); ^{1}H NMR δ 1.02 ($H_{6'}$, $J_{5',6'}$ = 6.2 Hz), 1.22 (H_6, $J_{5,6}$ = 6.3 Hz), 1.83 ($H_{2a'}$, $J_{1',2a'}$ = 9.8 Hz, $J_{2a',2e'}$ = $J_{2a',3'}$ = 12.0 Hz), 2.03 (H_{2a}, $J_{1,2a}$ = 3.4 Hz, $J_{2a,2e}$ = $J_{2a,3}$ = 12.3 Hz), 2.33 ($ArCH_3$), 2.47 ($H_{2e'}$, $J_{1',2e'}$ = 1.4 Hz, $J_{2e',3'}$ = 4.6 Hz), 2.50 (H_{2e}, $J_{1,2e}$ = 1.0 Hz, $J_{2e,3}$ = 4.5 Hz), 3.58 ($H_{5'}$, $J_{4',5'}$ = 9.4 Hz), 4.08 (H_5, $J_{4,5}$ = 9.4 Hz), 4.52 (H_3, $J_{3,4}$ = 9.4 Hz), 4.84 ($H_{1'}$), 5.04 ($H_{4'}$), 5.07 (H_4), 5.29 ($H_{3'}$, $J_{3',4'}$ = 9.4 Hz), 5.66 (H_1), 7.16-8.20 (aromatic). Anal. Calcd for $C_{40}H_{40}O_{10}$: C, 70.57; H, 5.92. Found: C, 70.95; H, 5.88.

o-Methylphenyl 4-*O*-Benzoyl-3-*O*-(3,4-di-*O*-benzoyl-2,6-dideoxy-β-D-*arabino*-hexopyranosyl)-2,6-dideoxy-β-D-*lyxo*-hexopyranoside (24) and o-Methylphenyl 4-*O*-Benzoyl-3-*O*-(3,4-di-*O*-benzoyl-2,6-dideoxy-β-D-*arabino*-hexopyranosyl)-2,6-dideoxy-α-D-*lyxo*-hexopyranoside (25). Trimethylsilyl bromide (0.11 g, .74 mmol) was added dropwise to compound 14 (0.20 g, 0.34 mmol) dissolved in 10 mL of benzene. After stirring for 5 min, the solvent was removed under reduced pressure to give the glycosyl bromide which was immediately dissolved in 5 mL of toluene and the solution added in a dropwise manner to a solution of 0.10 g (0.92 mmol) of o-methylphenol in 10 mL of toluene in which 0.5 g of silver silicate had been suspended by rapid stirring. After 30 min, the mixture was filtered through a 2 cm layer of silica gel. The silica gel was washed with 100 mL of 10/1 toluene--ethyl acetate and the solvent was removed from the combined filtrate and washings under reduced pressure. The residue was chromatographed in the standard fashion using 50/1 toluene--ethyl acetate to give compounds 24 and 25. Compound 24: 0.16 g (0.23 mmol, 64 %); R_f = 0.38 (50/1 toluene-ethyl acetate); [α] = - 13° 9 c = 0.23); ^{13}C NMR: δ 16.33 ($ArCH_3$), 1697 (C_6), 17.67 ($C_{6'}$), 32.40 (C_2), 36.63 ($C_{2'}$), 70.34, 70.47, 70.60 (C_4, C_5, $C_{5'}$), 71.38 ($C_{3'}$), 72.88 C_3), 74.28 ($C_{4'}$), 96.76 ($C_{1'}$), 98.38 (C_1), 114.58, 122.25, 126,80, 127.68, 128.32, 129.46, 129.98, 132.95 (aromatic carbons), 165.68, 166.10 (C=O); ^{1}H NMR: δ 1.30 ($H_{6'}$, $J_{5',6'}$ = 6.4 Hz), 1.32 (H_6, $J_{5,6}$ = 6.6 Hz), 1.83 ($H_{2a'}$, $J_{1',2a'}$ = 9.9 Hz, $J_{2a',2e'}$ = 11.7 Hz, $J_{2a',3'}$ = 11.4 Hz), 2.32-2.39 (H_{2a}, H_{2e}), 3.68 ($H_{5'}$, $J_{4',5'}$ = 9.2 Hz), 3.90 ($H_{4,5}$ <1 Hz), 4.21 (H_3, $J_{3,4}$ = 3.2 Hz), 4.87 ($H_{1'}$), 5.16 (H_1, $J_{1,2e}$ = 5.0 Hz, $J_{1,2a}$ = 10 Hz), 5.17 ($H_{4'}$, $J_{3',4'}$ = 9.7 Hz, 5.29 ($H_{3'}$), 5.51 (H_4), 6.90-7.62, 7.83-8.16 (aromatic protons). Anal. Calcd for $C_{40}H_{40}O_{10}$: C, 70.57; H, 5.92. Found: C, 70.99; H, 5.80. Compound 25 (0.05 g 0.08 mmol, 21 %); R_f = 0.45 (50/1 toluene-ethyl acetate); [α] = - 39° (c - 0.19); ^{13}C NMR: δ

16.26 (Ar$\underline{C}H_3$), 16.96 (C_6), 17.66 ($C_{6'}$), 31.23 (C_2), 36.75 ($C_{2'}$), 66.66 (C_5), 70.49 ($C_{5'}$), 70.84 (C_3), 71.55 ($C_{3'}$), 71.85 (C_4), 74.33 ($C_{4'}$), 96.21 (C_1), 97.42 ($C_{1'}$), 114.14, 121.76, 126.99, 127.05, 128.35, 129.66, 129.85, 130.36, 132.89, 133.18 (aromatic carbons), 165.88 (C=O); ^1H NMR: δ 1.17 (H_6, $J_{5,6}$ = 6.1 Hz), 1.31 ($H_{6'}$, $J_{5',6'}$ = 5.7 Hz), 1.85 ($H_{2a'}$, $J_{1',2a'}$ = 9.3 Hz, $J_{2a',2e'}$ = $J_{2e',3'}$ = 11.7 Hz), 2.25-2.41 (H_{2a}, H_{2e}), 2.29 ($ArCH_3$), 2.49 ($H_{2e'}$, $J_{1',2e'}$ = 0.9 Hz, $J_{2e',3'}$ = 5.0 Hz), 3.75 ($H_{5'}$, $J_{4',5'}$ = 9.2 Hz), 4.24 (H_5), 4.62 (H_3, $J_{3,4}$ = $J_{2e,3}$ = 4.0 Hz, $J_{2a,3}$ = 11.0), 4.91 ($H_{1'}$), 5.18 ($H_{4'}$, $J_{3',4'}$ = 9.2 Hz), 5.31 ($H_{3'}$), 5.60 (H_4), 5.81 (H_1), 7.16-7.59, 7.87, 7.91, 7.93, 7.96, 8.10, 8.13 (aromatic protons). Anal. Calcd for $C_{40}H_{40}O_{10}$: C, 70.57; H, 5.92. Found: C, 70.45; H, 5.48.

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