mannofuranose[10] were commercial products (Sigma). All sonicated reactions were performed by using a ELMA TRANSONIC-460/H Model ultrasonic cleaner with the reaction vessel completely submerged.

General Procedure for Reaction of Indolylmagnesium Bromides 1 with Furanoses 2 and 3. Synthesis of 3-(Alditol-1-yl)indole Derivatives 4 and 5. To a solution of EtMgBr (6 mmol) in diethyl ether (20 mL) a solution of the appropriate indole (6 mmol) in diethyl ether was added with stirring under nitrogen at room temperature. The ether was removed under vacuum, and then anhydrous methylene chloride (50 mL) was added. The reaction vessel was placed in a sonication bath, and a solution of furanose 2 and 3 (1 mmol) in CH_2Cl_2 (20 mL) was added. After being stirred for 48 h at room temperature, the mixture was quenched with saturated aqueous ammonium chloride solution and extracted with diethyl ether (3 × 30 mL). The combined extracts were dried and concentrated under reduced pressure, and the products were purified by chromatography on silica gel using a hexane/acetone (75:25) mixture. The following compounds were obtained.

3-(2,3,5-Tri-*O*-benzyl-D-*manno*-pentitol-1-yl)indole (4a): colorless oil; $[\alpha]^{21}_D$ = +20.0° (*c* 0.1, $CHCl_3$); ^1H NMR (200 MHz, CD_3OD) δ 7.53 (1 H, d, $J_{6,7}$ = 7.59 Hz, H-7), 7.29 (1 H, d, $J_{4,5}$ = 8.18 Hz, H-4), 7.25–6.85 (17 H, m, CH_2Ph, H-5, and H-6), 5.25 (1 H, d, $J_{1',2'}$ = 6.66 Hz, H-1'), 4.61, 4.37, 4.30 (each 2 H, m, CH_2Ph), 4.23 (1 H, dd, $J_{1',2'}$ = 6.66, $J_{2',3'}$ = 3.50 Hz, H-2'), 3.98 (1 H, m, H-4'), 3.60 (1 H, dd, $J_{2',3'}$ = 3.50, $J_{3',4'}$ = 6.42 Hz, H-3'), 3.58 (1/2 AB quartet, $J_{4',5'a}$ = 6.72, $J_{5'a,5'b}$ = 9.75 Hz, H-5'a), 3.46 (1 H, 1/2 AB quartet, $J_{4',5'b}$ = 5.55, $J_{5',5'}$ = 9.75, H-5'b). Anal. Calcd for $C_{34}H_{35}O_5N$: C, 75.95; H, 6.56; N, 2.61. Found: C, 75.70; H, 6.39; N, 2.57.

3-(2,3,5-Tri-*O*-benzyl-D-*arabino*-pentitol-1-yl)-7-azaindole (4b): colorless oil; $[\alpha]^{21}_D$ = +16.8° (*c* 0.33, $CHCl_3$); ^1H NMR (100 MHz, $CDCl_3$) δ 10.02 (1 H, bs, NH), 8.20 (1 H, dd, $J_{5,6}$ = 4.96, $J_{6,4}$ = 1.15 Hz, H-6), 7.86 (1 H, dd, $J_{4,5}$ = 7.88, $J_{5,6}$ = 4.69 Hz, H-4), 7.70–7.05 (15 H, m, CH_2Ph), 6.95 (1 H, dd, $J_{4,5}$ = 7.88, $J_{5,6}$ = 4.96 Hz, H-5), 6.86 (1 H, s, H-2), 5.25 (1 H, d, $J_{1',2'}$ = 5.85 Hz, H-1'), 4.95–4.40 (6 H, m, CH_2Ph), 4.20 (2 H, m, H-3' and H-4'), 3.75 (3 H, m, H-2' and H-5'), 3.35 (2 H, bs, OH). Anal. Calcd for $C_{33}H_{34}O_5N_2$: C, 73.58; H, 6.36; N, 5.20. Found: C, 73.46; H, 6.33; N, 5.24.

3-(2,3:5,6-Di-*O*-isopropylidene-D-*glycerol*-D-*talo*-hexitol-1-yl)indole (5): pale yellow oil; $[\alpha]^{21}_D$ = +15.5° (*c* 0.2, $CHCl_3$); ^1H NMR (200 MHz, $CDCl_3$) δ 8.33 (1 H, s, NH), 7.68 (1 H, d, $J_{6,7}$ = 7.59 Hz, H-7), 7.45–7.05 (3 H, m, H-6, H-5, H-4), 7.02 (1 H, s, H-2), 5.43 (1 H, d, $J_{1',2'}$ = 7.00 Hz, H-1'), 4.71 (1 H, t, $J_{3',4'}$ = $J_{4',5'}$ = 6.71 Hz, H-4'), 4.37 (1 H, d, $J_{3',4'}$ = 6.71 Hz, H-3'), 4.06 (3 H, m, H-5' and H-6'), 4.00 (1 H, dd, $J_{1',2'}$ = 7.00, $J_{2',3'}$ = 6.71 Hz, H-2'), 3.45, 3.23 (each 1 H, 2 bs, OH), 1.48, 1.35, 1.32, 1.28 (each 3 H, 4 s, CH_3). Anal. Calcd for $C_{20}H_{27}O_6N$: C, 63.60; H, 7.21; N, 3.71. Found: C, 63.71, H, 7.18; N, 3.68.

General Cyclization Procedure. Synthesis of (*C*-Glycofuranosyl)indole Derivatives 7–10. To a solution of the appropriate alditol (1 mmol) in CH_2Cl_2 (5 mL) was added 200 μL of a 1.75 M solution of HCl in CH_2Cl_2 at room temperature. After 30 min, the reaction was quenched with saturated aqueous $NaHCO_3$ solution and extracted with CH_2Cl_2. After removal of the solvent, the anomeric furanosides were separated by silica gel chromatography using petroleum ether/acetone (5:1) or CH_2Cl_2 eluants. The following compounds were obtained.

3-(2,3,5-Tri-*O*-benzyl-α-D-arabinofuranosyl)indole (7a): colorless oil; $[\alpha]^{21}_D$ = −27.0° (*c* 0.5, $CHCl_3$); ^1H NMR (270 MHz, CD_3OD) δ 7.67 (1 H, d, $J_{7,6}$ = 7.02 Hz, H-7), 7.38 (1 H, d, $J_{4,5}$ = 7.83 Hz, H-4), 7.35–7.15 (16 H, m, CH_2Ar and H-2), 7.12 (1 H, dd, $J_{5,6}$ = 7.56 Hz, $J_{4,5}$ = 7.83 Hz, H-5), 6.99 (1 H, t, $J_{5,6}$ = $J_{6,7}$ = 7.83 Hz, H-6), 5.23 (1 H, d, $J_{1',2'}$ = 6.73 Hz, H-1') 4.58 (4 H, m, CH_2Ar), 4.50 (1 H, dd, $J_{1',2'}$ = 6.73, $J_{2',3'}$ = 4.05 Hz, H-2'), 4.40 (2 H, m, CH_2Ar), 4.28 (1 H, dd, $J_{3',4'}$ = 4.86, $J_{4',5'}$ = 5.40 Hz, H-4'), 4.21 (1 H, t, $J_{2',3'}$ = $J_{3',4'}$ = 4.86 Hz, H-3'), 3.67 (2 H, m, H-5'); ^{13}C NMR (25.4 MHz, CD_3OD), DEPT sequence, CH_2 δ 71.17, 72.68, 72.94, 74.27, CH δ 80.19, 82.37, 86.22, 89.04, 112.48, 120.15, 120.40, 122.74, 124.62, Cq δ 112.16, 138.45, 139.32. Anal. Calcd for $C_{34}H_{33}O_4N$: C, 78.59; H, 6.40; N, 2.70. Found: C, 78.61; H, 6.38; N, 2.72.

3-(2,3,5-Tri-*O*-benzyl-β-D-arabinofuranosyl)indole (8a): colorless oil; $[\alpha]^{23}_D$ = +14.2° (*c* 0.1, $CHCl_3$); ^1H NMR (270 MHz, CD_3OD) δ 7.62 (1 H, d, $J_{7,6}$ = 7.56 Hz, H-7), 7.34 (1 H, d, $J_{4,5}$ = 8.37 Hz, H-4), 7.32–7.15 (16 H, m, CH_2Ph and H-2), 7.14 (1 H, m, H-5), 6.97 (1 H, t, J = 7.02, H-6), 5.36 (1 H, d, $J_{1',2'}$ = 3.78 Hz, H-1') 4.56 (4 H, m, CH_2Ph), 4.52 (2 H, m, CH_2Ph), 4.12 (1 H, m, H-4'), 4.06 (2 H, m, H-2' and H-3'), 3.72 (1 H, 33, $J_{4',5'a}$ = 6.48, $J_{5'a,5'b}$ = 10.77 Hz, H-5'a), 3.65 (1 H, dd, $J_{4',5'b}$ = 5.86, $J_{5'a,5'b}$ = 10.77 Hz, H-5'b); ^{13}C NMR (25.4 MHz, CD_3OD) DEPT sequence, CH_2 δ 71.59, 72.57, 72.90, 74.32, CH δ 79.42, 83.16, 85.15, 86.22, 114.69, 120.75, 122.39, 125.48, Cq 111.22, 139.14, 139.48. Anal. Calcd for $C_{34}H_{33}O_4N$: C, 78.59; H, 6.40; N, 2.70. Found: C, 78.49; H, 6.43; N, 2.63.

3-(2,3,5-Tri-*O*-benzyl-α-D-arabinofuranosyl)-7-azaindole (7b): colorless oil; $[\alpha]^{23}_D$ = +60.3° (*c* 0.1, MeOH); ^1H NMR (200 MHz, CD_3OD) δ 8.07 (1 H, dd, $J_{5,6}$ = 7.90, $J_{4,6}$ = 1.46 Hz, H-6), 7.7–6.7 (18 H, m, CH_2Ph and 3 H arom), 5.18 (1 H, d, $J_{1',2'}$ = 5.84 Hz, H-1'), 4.63 (4 H, m, CH_2Ph), 4.54 (1 H, dd, $J_{1',2'}$ = 5.84, $J_{2',3'}$ = 3.63 Hz, H-2'), 4.35 (3 H, m, CH_2Ph), 4.23 (1 H, dd, $J_{2',3'}$ = 3.63, $J_{3',4'}$ = 6.72 Hz, H-3'), 3.67 (2 H, m, H-5'). Anal. Calcd for $C_{33}H_{32}O_4N_2$: C, 76.13; H, 6.20; N, 5.38. Found: C, 76.16; H, 6.16; N, 5.41.

3-(2,3,5-Tri-*O*-benzyl-β-D-arabinofuranosyl)-7-azaindole (8b): colorless oil; $[\alpha]^{23}_D$ = +32.0° (*c* 0.1, MeOH); ^1H NMR (200 MHz, CD_3OD) δ 7.97 (1 H, dd, $J_{5,6}$ = 7.90, $J_{4,6}$ = 1.32 Hz, H-6), 7.5–6.5 (18 H, m, CH_2Ph and 3 H arom), 5.31 (1 H, d, $J_{1',2'}$ = 3.21 Hz, H-1'), 4.44 (4 H, m, CH_2Ph), 4.28 (2 H, m, CH_2Ph), 4.22 (1 H, m, H-4'), 4.15 (2 H, m, H-2' and H-3'), 3.62 (2 H, m, H-5'). Anal. Calcd for $C_{33}H_{32}O_4N_2$: C, 76.13; H, 6.20; N, 5.38. Found: C, 76.17; H, 6.26; N, 5.42.

3-(2,3:5,6-Di-*O*-isopropylidene-α-D-mannofuranosyl)indole (9): colorless oil; $[\alpha]^{21}_D$ = +69.2° (*c* 0.2, MeOH); ^1H NMR (200 MHz, $CDCl_3$) δ 8.31 (1 H, bs, NH), 7.78 (1 H, d, $J_{6,7}$ = 7.88 Hz, H-7), 7.36 (1 H, d, $J_{4,5}$ = 7.88, H-4), 7.17 (2 H, m, H-5 and H-6), 7.04 (1 H, bs, H-2), 5.48 (1 H, d, $J_{1',2'}$ = 0.77 Hz, H-1'), 5.14 (1 H, dd, $J_{1',2'}$ = 0.77 Hz, $J_{2',3'}$ = 6.13 Hz, H-2'), 4.81 (1 H, dd, $J_{2',3'}$ = 6.13 Hz, $J_{3',4'}$ = 3.79 Hz, H-3'), 4.49 (1 H ddd, $J_{4',5'}$ = 6.13, $J_{5',6'a}$ = 4.96 Hz, $J_{5',6'b}$ = 8.46 Hz, H-5'), 4.11 (2 H, 2 AB quartets, $J_{6'a,6'b}$ = 9.63, $J_{5',6'a}$ = 4.96, $J_{5',6'b}$ = 8.46 Hz, H-6'), 3.86 (1 H, dd, $J_{3',4'}$ = 3.79, $J_{4',5'}$ = 6.13 Hz, H-4'); ^{13}C NMR (25.4 MHz, $CDCl_3$), DEPT sequence, CH_3 δ 24.80, 25.23, 26.23, 26.96, CH_2 67.19, CH δ 73.52, 80.76, 80.67, 81.21, 85.33 (5CH), 111.32, 119.72, 120.09, 121.23, 122.70, Cq 112.71, 113.75. Anal. Calcd for $C_{20}H_{25}O_5N$: C, 66.83; H, 7.01; N, 3.90. Found: C, 66.78; H, 7.09; N, 3.86.

3-(2,3:5,6-Di-*O*-isopropylidene-β-D-mannofuranosyl)indole (10): colorless oil; $[\alpha]^{21}_D$ = +46.4° (*c* 0.2, $CHCl_3$); ^1H NMR (200 MHz, $CDCl_3$) δ 8.16 (1 H, bs, NH), 7.66 (1 H, d, $J_{6,7}$ = 7.29 Hz, H-7), 7.45–7.00 (4 H, m, H-2, H-4, H-5, and H-6), 5.00–4.85 (3 H, H-1', H-2' and H-4'), 4.53 (1 H, m, H-5'), 4.14 (1 H, m, H-6'), 3.68 (1 H, dd, J = 3.21, J = 4.96 Hz, H-3'), 1.53, 1.48, 1.40, 1.34 (each 3 H, 4 s, CH_3); ^{13}C NMR (25.4 MHz, $CDCl_3$), DEPT sequence, CH_3 δ 24.40, 24.82, 25.37, 25.88, CH_2 67.29, CH 73.33, 77.90, 80.69, 81.54, 82.33, 111.22, 119.48, 119.80, 122.22, 124.27, Cq 109.21, 112.36, 135.90. Anal. Calcd for $C_{20}H_{25}NO_5$: C, 66.83; H, 7.01; N, 3.90. Found: C, 66.75; H, 6.98; N, 3.94.

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Synthesis of 2-Deoxy Sugars from Glycals†

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2-Deoxy sugars are present in numerous biologically active natural products such as compactin, olivimycin, mithramycin, daunomycin, calicheamicin, etc. The chemical synthesis of these natural products requires the ready

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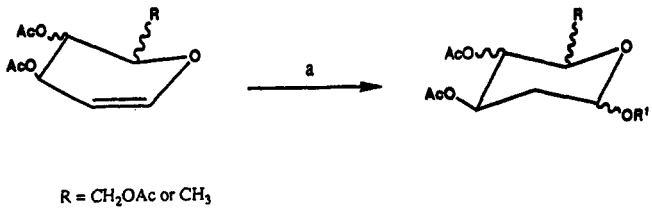

R = CH_2OAc or CH_3

Figure 1. a = AG 50W X2 (H^+, 100–200 mesh), LiBr, CH_3CN, R^1OH [R^1 = H, CH_3, $CH_2CH{=}CH_2$, $(CH_2)_5COOCH_3$, $(CH_2)_3CH{=}CH_2$, 1,2:3,4-di-*O*-isopropylidene-D-galactopyranose, or CH_3CH_2SH.

availability of various 2-deoxy sugars in large quantitites.[1-5] To this end, numerous reports have appeared for the preparation of 2-deoxy sugars in a multistep sequence. For example, derivatives of 2-deoxypyranoses and pyranosides have been obtained from glycals by hydration or hydroalkoxylation catalyzed by methanolic hydrogen halide,[6-8] methanesulfonic acid,[9] or enzymes;[10] by alkoxymercuration followed by borohydride reduction;[11,12] by treatment with hydrogen halides in acetic acid;[13,14] by halohydration or -alkoxylation followed by dehalogenation;[15-17] and by the addition of phosphorodithioate.[18] Also, 2-deoxy sugars have been prepared by Barton and Mccombie's deoxygenation procedure,[19-21] lithium aluminum hydride reduction of ketene dithioacetals,[22] and by trialkyltin hydride reduction of acylglycopyranosyl halides.[23] Of these, the acid-catalyzed addition of water or alcohol to acetylated glycals appears to be the most direct method for the synthesis of 2-deoxyhexopyranoses or pyranosides. Yet, to date the generality of this method to prepare 2-deoxy sugars has remained unattractive, as the protected glycals often give rearranged products under acidic condition.[8,9] (During the preparation of this manuscript, Bolitt et al. reported the preparation of 2-deoxyglucopyranosides by the triphenylphosphine hydrobromide catalyzed addition of alcohol to glucal triacetate. Bolitt, V.; Mioskowski, C.; Lee, S. G.; Falck, J. R. *J. Org. Chem.* **1990**, *55*, 5812–5813.) We report now a successful general procedure to prepare a number of 2-deoxy sugars, their α-glycosides, and a thio glycoside by the hydration or hydroalkoxylation of acetylated glycals catalyzed by specially treated sulfonic acid resin and in the presence of a soluble halide ion. We also include in the examples, the preparation of a "disarmed" 4-pentenyl 2-deoxy glycoside, as it has been shown to be a useful glycosylating agent to construct 2-deoxy disaccharides.[24] We have examined as substraes 3,4,6-tri-*O*-acetyl-D-glucal and -D-galactal, 3,4-di-*O*-acetyl-L-fucal and -L-rhamnal, and D-lactal hexaacetate. In all these cases, the addition of water or alcohol to glycals proceeded rapidly to give 2-deoxyhexopyranoses or hexopyranosides in high yield. The process can be scaled up for the large-scale preparation of these compounds. Figure 1 shows the general protocol used to prepare 2-deoxy sugars.

Hadfield and Sartorelli earlier reported[8] that a mixture glucal tribenzoate and AG 50W-X8 cation exchange resin when refluxed in methanol for 20 h gave anomeric mixture of methyl 2-deoxy-3,4,6-tri-*O*-benzoyl-D-*arabino*-hexopyranoside in 38% yield. About 19% of the starting material was recovered. Galactal tribenzoate under these conditions gave only 13% of the desired products along with significant amounts of Ferrier rearranged product.[9] As a result, this direct method for making 2-deoxy glycosides has remained synthetically unattractive. We envisioned that by lowering the polarity of the reaction solvent and by the removal of the resin bound excess water molecule we might generate a "nonhydrated" proton source that would preferentially protonate the C-2 carbon of the glycal to give the deoxy glycoside. Such a nonhydrated proton would have lesser tendency to protonate the C-3 acetoxy oxygen that normally leads to the rearranged products.

The commercial cation exchange resins contain up to 80% by weight of water. When the resin was treated with water-miscible aprotic solvents such as acetonitrile, most of the bound water molecules were removed. In the initial hydration experiments with glycals, this newly dehydrated resin in acetonitrile did not catalyze the addition of alcohols to the double bond. Surprisingly, rearranged products also did not form to significant extent. On the other hand, when lithium bromide was added to the reaction, the addition of alcohols to the glycals took place rapidly to produce the deoxy glycosides in high yield.

To carry out the reaction effectively, the sulfonic acid resin had to be thoroughly washed with water-miscible aprotic solvents (see Experimental Section). We find it convenient to dehydrate the resin with anhydrous acetonitrile by washing the commercial resin 10–15 times with equal volume of anhydrous acetonitrile. Other water-miscible solvents such as acetone, tetrahydrofuran, and dimethylformamide were also equally effective in dehydrating the acid catalyst. This dehydration of the commercial cation exchange resin (H^+ form) causes it to shrink considerably, probably as a result of the removal of the sulfonic acid bound water molecules.

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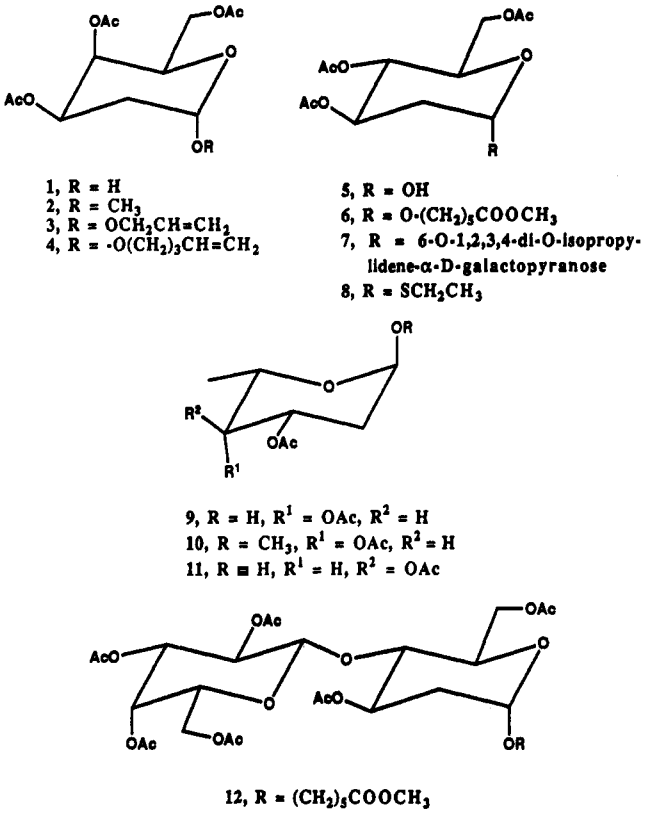

Figure 2. 2-Deoxyglycosides synthesized.

We find that the reaction is successful only in the presence of soluble chloride or bromide ions. Lithium bromide is the best catalyst among the number of bromides and chlorides we have examined (for example, sodium bromide, potassium bromide, tetra-*n*-butylammonium chloride, and tetraethylammonium chloride). Both lithium chloride and iodide *were not able* to catalyze the reaction of alcohols with glycals. (The failure of lithium chloride to catalyze the reaction may be due to its lack of solubility in acetonitrile. The iodides on the other hand, may not be able to either generate traces of HI needed for the reaction or the HI produced may be weakly acidic and may not be able to protonate the C-2 position of the glycals.) The reaction proceeds very effectively in acetonitrile and is slower in other solvents in the following order: acetone > tetrahydrofuran > nitromethane > chloroform. (In chloroform, soluble tetraethylammonium bromide instead of insoluble lithium bromide had to be used for successful reaction.) Surprisingly, in solvents such as dimethylformamide and dimethyl sulfoxide, there was no reaction even after 3 days. (The reaction appears to proceed best in solvents that least solvate the cation. Thus, the lithium ions in DMF and DMSO may be extensively solvated and may not effectively exchange with the proton of the sulfonic acid resin in order to generate the traces of HBr needed for the reaction. However, the choice of the solvent is limited due to the fact that the lithium bromide should also be soluble.)

To prepare methyl, allyl, 5-(methoxycarbonyl)pentyl, and 4-pentenyl 2-deoxyhexopyranosides, the acetonitrile-treated sulfonic acid resin was first dried under vacuum for 24 h over phosphorus pentoxide. This was used subsequently in the reaction with glycals and few equivalents of alcohols in the presence of 3- or 4-Å molecular sieves. α-Glycosides were predominantly formed over β, with the least reactive alcohols favoring the formation of α-glycosides. Figure 2 summarizes the list of 2-deoxy glycosides that we have made. We have confirmed the structure of these products by ^{1}H NMR analysis and by comparison with published reports.[16,29-31] Besides the coupling contants between anomeric and C-2 hydrogens, the chemical shifts of H-3 and H-5 of the 2-deoxypyranose residues were very useful to establish anomeric configurations. For example, in all the glycosides we have prepared, these two hydrogens (H-3 and H-5) are deshielded in α-anomers by greater than 0.25 ppm as compared to the corresponding β-anomers and thus serve as reporter groups for unambiguous structural assignments.

It is to be noted that the procedure described above is useful also to convert the disaccharide glycal, namely, the lactal hexaacetate to its 2-deoxy derivative **12**. In addition, reaction of a monosaccharide alcohol, such as 1,2:3,4-di-*O*-isopropylidenegalactopyranose with glucal triacetate allows one to prepare disaccharide such as **7**, even though the yield is low.

Use of thiols with tri-*O*-acetyl-D-glucal under anhydrous conditions does not give the thio glycoside. Addition of a catalytic amount of water is necessary to obtain an anomeric mixture of thio glycosides. Instead of D-glucal, the 2-deoxyhexopyranoses can be used directly with the acid resin and lithium bromide hydrate to obtain an anomeric mixture of thio glycosides **8**. Traces of water in this reaction may be necessary to generate hydrogen bromide needed to catalyze the addition of thiols to glycals.

The most commonly used procedure for the preparation of 2-deoxyhexoses employs *N*-bromo(iodo)succinimide in aqueous medium to get a 2-halogen-substituted 2-deoxyhexopyranose.[16] Conversion of this to the natural 2-deoxy sugars requires anomeric hydroxyl protection, hydrogenolysis of the halogen atom, and the removal of the anomeric protecting group. We have shown that the sulfonic acid resin–bromide combination methodology is a better way to prepare in a single step several biologically important 2-deoxyhexoses. Also, a variety of alcohols containing olefinic groups (that are incompatible in *N*-halosuccinimide method) or glycals containing azido (key intermediates in the preparation of amino-2-deoxy glycosides) groups can be employed. The resin can be regenerated and can be used again in the reaction. In most cases, the purification of the product involves simple filtration on a column of silica gel or crystallization as shown in the case of 2-deoxy-3,4,6-tri-*O*-acetyl-*arabino*-hexopyranose (**5**). The fact that many sugar glycals undergo hydration or hydroalkoxylation illustrates the generality and the advantage of this methodology over the recently described triphenylphosphine hydrobromide mediated reactions.

Experimental Section

General Details. Analytical grade cation exchange resin AG 50W X2 (H^+ form, 100–200 mesh) was purchased from Bio-Rad Laboratories (Richmond, CA). All solvents were purified according to standard procedures.[25] 3,4,6-Tri-*O*-acetyl-D-galactal, 3,4-di-*O*-acetyl-L-fucal and -L-rhamnal, and D-lactal hexacetate were prepared according to the published procedures.[26-28] All other reagents were purchased from Aldrich Chemical Co. Thin-layer chromatography was performed on precoated plates of silica gel 60 F_{254} (EM Science), and the spots were visualized with a spray containing 5% sulfuric acid in ethanol followed by heating. Column chromatography was performed on silica gel 60 (230–400 mesh, EM Science). Unless specified, ^{1}H NMR spectra of all compounds were recorded in $CDCl_3$ at 500 MHz (GE Omega-500),

(29) Korytnyk, W.; Sufrin, J. R.; Bernacki, R. J. *Carbohydr. Res.* **1982**, *103*, 170–175.
(30) Overend, W. G.; Shafizadeh, F.; Stacey, M. *J. Chem. Soc.* **1951**, 992–993.
(31) Michalska, M.; Borowiecka, J.; Lipka, P.; Rokita-Trygubiwicz, T. *J. Chem. Soc., Perkin Trans. 1* **1989**, 1619–1622.

and the chemical shifts are expressed relative to tetramethylsilane.

Preparation of the Acid Resin. The commercial Ag 50W-X2 (H^+ form, 50.0 g, Bio-Rad, 100–200 mesh, moisture content 72–84%) resin was washed with water (3 × 100 mL) until the filtrate was colorless and then with reagent grade acetonitrile (10 × 70 mL). It was then dried over phosphorus pentoxide in a desiccator under vacuum (0.01 mmHg) for 24 h to give the dry resin (10.0 g).

2-Deoxy-3,4,6-tri-*O*-acetyl-D-*lyxo*-hexopyranose (2-Deoxy-3,4,6-tri-*O*-acetyl-D-galactopyranose, 1). To a solution 3,4,6-tri-*O*-acetyl-D-galactal (5.0 g) and lithium bromide hydrate (5.0 g) in acetonitrile (150 mL) were added AG 50W-X2 resin (3.0 g) and water (6 mL), and the mixture was stirred at room temperature for 15 min. The solution was filtered, neutralized with triethylamine, and evaporated to dryness. The residue was dissolved in dichloromethane and washed with water, ice-cold 1 M hydrochloric acid, and saturated sodium bicarbonate solution. Evaporation of solvent left a syrup, which was purified on a column of silica gel using ethyl acetate–hexane (2:3, R_f = 0.16) as eluant, to get the title compound 1 (syrup, 4.38 g, 82% yield); $[\alpha]^{20}_D$ +85.8 ± 2° (*c* 0.96, $CHCl_3$); ^1H NMR ($CDCl_3$) δ 5.48 (d, *J* = 2.8 Hz, H-1α), 5.35 (m, H-3α), 5.33 (d, *J* = 3.3 Hz, H-4α), 5.24 (d, *J* = 3.3 Hz, H-4β), 4.99 (octet, *J* = 3.3, 4.6, 7.9 Hz, H-3β), 4.90 (dd, *J* = 2.4, 9.5, H-1β), 4.40 (t, *J* = 6.4 Hz, H-5α), 4.0–4.15 (m, H-6a, H-6b), 3.85 (t, *J* = 6.4 Hz, H-5β), 2.12, 2.04, and 1.97 (3 s, CH_3COO of α-anomer), 2.13, 2.04, and 1.99 (3 s, CH_3COO of β-anomer), 1.89 (broad m, H-2 of α- and β anomers); MS (calculated mass for $C_{12}H_{18}O_8$ 290.11) obsd *m/e* 273 (M − HO), 213.12, 153.09.

Methyl 2-Deoxy-3,4,6-tri-*O*-acetyl-α-D-*lyxo*-hexopyranoside (Methyl 2-Deoxy-3,4,6-tri-*O*-acetyl-α-D-galactopyranoside, 2). A solution of 3,4,6-tri-*O*-acetyl-D-galactal (11.0 g) in acetonitrile (110 mL) containing anhydrous lithium bromide (12 g), methanol (25 mL), 3-Å molecular sieves (4 g), and the acid resin (17 g) was stirred at room temperature for 4 h. The product was isolated as described for 1 and purified on a column of silica gel using ethyl acetate–hexane (1:4, R_f = 0.13 for α-anomer, 0.07 for β-anomer) as eluant to get the title compound 2 (10.9 g, 88.7% yield, α:β = 3:1): $[\alpha]^{20}_D$ (α-anomer, syrup) + 143 ± 2° (*c* 1.05, $CHCl_3$) [lit.[30] + 159° (*c* 1.0, benzene)]; (β-anomer, colorless solid) −2.1 ±2° (*c* 0.98, $CHCl_3$); mp 72–74 °C; ^1H NMR (α-anomer, $CDCl_3$) δ 5.30 (d, *J* = 2.8 Hz, H-4), 5.25 (m, *J* = 2.8, 4.8, 8.8 Hz, H-3), 4.88 (d, *J* = 2.8 Hz, H-1), 4.05–4.15 (m, H-6a,b, H-5), 3.33 (s, OCH_3), 2.11, 2.03, and 1.95 (3 s, CH_3COO), 2.05 (m, H-2_{eq}), 1.85 (m, H-2_{ax}); ^1H NMR (β-anomer, $CDCl_3$) δ 5.24 (d, *J* = 2.9 Hz, H-4), 4.97 (m, H-3), 4.45 (dd, *J* = 2.5, 9.3 Hz, H-1β), 4.17–4.16 (m, H-6a,b), 3.78 (m, H-5), 3.51 (s, OCH_3), 2.11, 2.02, and 1.98 (3 s, CH_3COO), 2.00–1.85 (m, H-$2_{ax,eq}$); MS (calcd mass for $C_{13}H_{20}O_8$ 304.12) obsd *m/e* 303.15 (M − 1), 273.15 (M − CH_3OH), 213.13, 153.10.

Allyl 2-Deoxy-3,4,6-tri-*O*-acetyl-α-D-*lyxo*-hexopyranoside (Allyl 2-Deoxy-3,4,6-tri-*O*-acetyl-α-D-galactopyranoside, 3). A solution of 3,4,6-tri-*O*-acetyl-D-galactal (5.0 g) in acetonitrile (50 mL) containing anhydrous lithium bromide (5.45 g), allyl alcohol (11.5 mL), 4-Å molecular sieves (4 g), and the acid resin (7.3 g) was stirred at room temperature for 30 min. The product was isolated as described for 1 and purified on a column of silica gel using ethyl acetate–hexane (1:4, $R_{f\alpha}$ = 0.15, $R_{f\beta}$ = 0.11) as eluant to get the title compound 3 (4.0 g) and minor β-glycoside (0.5 g, 74% combined yield): $[\alpha]^{20}_D$ (α-anomer) +126 ± 2° (*c* 1.03, $CHCl_3$); $[\alpha]^{20}D$ (β-anomer) −17.7 ± 2° (*c* 1.02, $CHCl_3$); ^1H NMR (α-anomer, $CDCl_3$) δ 5.88 (m, C*H*=C), 5.33–5.16 (H-4, H-3, C=CH_2), 5.04 (broad d, *J* = 3.0 Hz, H-1), 4.15 (m, H-5), 4.13 and 3.95 (m, O-CH_2), 4.07 (m, 2 H, H-6a,b), 2.11, 2.03, and 1.96 (3 s, CH_3COO), 2.07 (m, H-2_{eq}), 1.87 (m, H-2_{ax}); ^1H NMR (β-anomer, $CDCl_3$) δ 5.89 (m, C*H*=C), 5.27–5.19 (m, 2 H, CH_2=C), 5.23 (dd, *J* = 0.9, 2.7 Hz, H-4), 4.97 (m, H-3), 4.58 (m, higher order spin coupling due to chemical shift degeneracy of H-2_{ax} and H-2_{eq}), 4.36 (m, 1 H, OCH_2C=), 4.20–4.05 (m, 3 H, H-6a,b and OCH_2C=), 3.76 (sextet, *J* = 1.1, 6.4 Hz, H-5), 2.11, 2.03, and 1.98 (3 s, CH_3COO), 1.98–1.92 (H-2 ax and eq); MS (α-anomer) (calcd mass for $C_{15}H_{22}O_8$ 330.14) obsd *m/e* 329.04, 273.04, 213.04.

4-Pentenyl 2-Deoxy-3,4,6-tri-*O*-acetyl-α-D-*lyxo*-hexopyranoside (4). A solution of 3,4,6-tri-*O*-acetyl-D-galactal (3.6 g) in acetonitrile (40 mL), anhydrous lithium bromide (4.7 g), 4-penten-1-ol (4 mL), 4-Å molecular sieves (4 g), and the acid resin (5.1 g) was stirred at room temperature for 30 min. The product was isolated as described for 1 and purified on a column of silica gel using ethyl acetate–hexane (1:6, $R_{f\alpha}$ = 0.10, $R_{f\beta}$ = 0.07) as eluant to get the title compound (2.92 g) and minor β-glycoside (0.32 g, 68.3% combined yield): $[\alpha]^{20}_D$ (α-anomer) +126 ± 2° (*c* 1.03, $CHCl_3$); $[\alpha]^{20}D$ (β-anomer) −9.4 ± 2° (*c* 1.03, $CHCl_3$); ^1H NMR (α-anomer) δ 5.81 (m, C*H*=C), 5.33 (d, *J* = 2.5 Hz, H-4), 5.28 (m, *J* = 2.5, 4.4, 7.7 Hz, H-3), 4.94–5.06 [m, H-1 ($J_{1,2}$ = 3.3 Hz), C=CH_2], 4.15 (m, *J* = 1.5, 6.0 Hz, H-5), 4.10–4.06 (m, 2 H, H-6a,b), 3.65 and 3.40 (m, OCH_2), 2.13, 2.04, and 1.98 (3 s, CH_3COO), 2.10 (m, H-2_{eq}), 1.86 (m, *J* = 1.7, 5.5, 12.8 Hz, H-2_{ax}), 1.67 (m, 4 H, CH_2CH_2); ^1H NMR (300 MHz, $CDCl_3$) (β-anomer) δ 5.81 (m, 1 H, C*H*=C), 5.24 (broad d, *J* = 3.5 Hz, H-4), 5.14–4.93 (m, 3 H, CH_2=C, H-3), 4.54 (m, H-1, higher order multiplet patterns due to chemical shift degeneracy of H-2_{ax} and H-2_{eq}), 4.18 (dd, *J* = 6.5, 11.5 Hz, H-6a), 4.12 (dd, *J* = 7.0, 11.5 Hz, H-6b), 3.93 and 3.49 (m, 2 H, OCH_2), 3.79 (m, *J* = 1.5, 6.5 Hz, H-5), 2.14, 2.05, and 2.01 (3 s, CH_3COO), 2.20–1.90 (m, H-2_{ax}, H-2_{eq}, and OCCH_2C), 1.70 (m, 2 H, OCCCH_2C); MS (α-anomer) (calcd mass for $C_{17}H_{26}O_8$ 358.17) obsd *m/e* 571.33, 357.21, 299.19, 273.05, 213.11.

2-Deoxy-3,4,6-tri-*O*-acetyl-D-*arabino*-hexopyranose (2-Deoxy-3,4,6-tri-*O*-acetyl-D-glucopyranose, 5). To a solution 3,4,6-tri-*O*-acetyl-D-glucal (25.0 g) and lithium bromide hydrate (25.0 g) in acetonitrile (750 mL) were added AG 50W-X2 resin (25.0 g) and water (30 mL), and the mixture was stirred at room temperature for 4 h. The product was isolated as described for 1. Crystallization from ethyl acetate–hexane gave the title compound as colorless crystals (17.8 g, 66.8% yield): mp 106 °C (lit.[31] mp 104–105 °C); R_f = 0.15 (ethyl acetate–hexane, 2:3); $[\alpha]^{20}_D$ +71.2 ± 2° (*c* 1.06, $CHCl_3$); ^1H NMR δ 5.40 (broad d, *J* = 2.7 Hz, H-1α), 5.35 (m, *J* = 5.5, 9.2, 11.6 Hz, H-3α), 4.97–5.05 (t, *J* = 9.2 Hz, H-4α,β, m, H-3β), 4.94 (dd, *J* = 1.7, 8.2, H-1β), 4.18–4.28 (H-6a, H-5α), 4.10 (H-6bβ), 4.06 (H-6bα), 3.65 (m, H-5β), 2.38 (m, *J* = 2.1, 4.8, 12.3 Hz, H-2_{eq}β), 2.25 (m, *J* = 1.4, 5.3, 12.1, H-2_{eq}α), 1.79 (m, *J* = 3.4, 6.9, 12.1 Hz, H-2_{ax}α), 1.67 (m, H-2_{ax}β); MS (calculated mass for $C_{12}H_{18}O_8$ 290.11) obsd *m/e* 273.11 (M − HO), 213.10, 153.07.

5-(Methoxycarbonyl)pentyl 2-Deoxy-3,4,6-tri-*O*-acetyl-α-D-*arabino*-hexopyranoside (5-(Methoxycarbonyl)pentyl 2-Deoxy-3,4,6-tri-*O*-acetyl-α-D-glucopyranoside, 6). A solution of 3,4,6-tri-*O*-acetyl-D-glucal (5.0 g) in acetonitrile (60 mL) containing anhydrous lithium bromide (5.6 g), 5-(methoxycarbonyl)pentan-1-ol (5 mL), 4-Å molecular sieves (4 g), and the acid resin (7.6 g) was stirred at room temperature for 5 h. The product was isolated as described for 1 and purified on a column of silica gel using ethyl acetate–hexane (1:4 R_f = 0.21) as eluant to get the title compound (syrup, 5.3 g, 69% yield): $[\alpha]^{20}_D$ +76.2 ± 2° (*c* 0.98, $CHCl_3$); ^1H NMR ($CDCl_3$) δ 5.28 (m, *J* = 5.3, 9.4, 11.5 Hz, H-3), 4.94 (broad t, *J* = 9.8 Hz, H-4), 4.90 (broad d, *J* = 3.0 Hz, H-1), 4.27 (dd, *J* = 5.6, 12.2 Hz, H-6a), 4.02 (dd, *J* = 2.3, 12.2 Hz, H-6b), 3.92 (m, H-5), 3.65 (s, OCH_3), 3.62 and 3.32 (m, OCH_2), 2.31 (t, *J* = 7.3 Hz, CH_2COO), 2.20 (m, *J* = 1.2, 4.4, 12.9 Hz, H-2_{eq}), 2.06, 2.01, and 1.98 (3 s, CH_3COO), 1.78 (m, *J* = 3.7, 11.5, 12.9 Hz, H-2_{ax}), 1.63, 1.58, and 1.37 (m, 6 H, $CH_2CH_2CH_2$); MS (calcd mass 418.19) obsd *m/e* 419.23 (M + 1), 273.13, 213.14, 153.10.

1,2:3,4-Di-*O*-isopropylidene-6-*O*-(2-deoxy-3,4,6-tri-*O*-acetyl-α-D-*arabino*-hexopyranosyl)-α-D-galactopyranose (7). To a solution of 1,2:3,4-di-*O*-isopropylidene-α-D-galactopyranose (3.8 g) in anhydrous acetonitrile (100 mL) containing anhydrous lithium bromide (4.0 g), acid resin (2.5 g), and 4-Å molecular sieves was added a solution of 3,4,6-tri-*O*-acetyl-D-glucal (6.0 g) in acetonitrile (40 mL), and the solution was stirred under nitrogen for 8 days. The reaction mixture was worked up as described for 1 and the title compound was obtained (colorless solid, 2.5 g, 32.4% yield based on di-*O*-isopropylidene-D-galactopyranose) by purification on a column of silica gel using ethyl acetate–hexane (3:8, R_f = 0.11) as eluant: mp 96–97 °C; $[\alpha]^{20}_D$ +24.3 ± 2° (*c* 0.97, $CHCl_3$). ^1H NMR ($CDCl_3$) δ 5.51 (d, *J* = 4.0 Hz, H-1), 5.31 (m, *J* = 5.3, 9.4, 11.4 Hz, H-3′), 5.01 (m, 2 H, H-1′, H-4′, $J_{1',2'}$ − 4.2 Hz, $J_{4',3'}$ = 9.7 Hz), 4.62 (dd, *J* = 2.4, 7.9 Hz, H-3), 4.35 (m, H-6′a, H-6′b), 4.26 (dd, *J* = 1.8, 7.9 Hz, H-4), 4.04 (m, H-2, H-5′), 3.96 (m, *J* = 1.5, 6.4, 8.15 Hz, H-5), 3.73 (dd, *J* = 6.4, 10.4 Hz, H-6a), 3.66 (dd, *J* = 6.8, 10.4 Hz, H-6b), 2.28 (broad dd, *J* = 5.5, 13.0 Hz, H-2′$_{eq}$), 2.01, 2.04, 2.01 (3 s, $OCOCH_3$), 1.83 (m, *J* = 3.8, 11.9, 13.0 Hz, H-2′$_{ax}$), 1.56, 1.44, 1.35, and 1.34 (4 s, CH_3 of iso-

propylidene group); MS (calcd mass 532) obsd *m/e* 531.00, 516.97, 273.00, 213.00 (100).

Ethyl 2-Deoxy-3,4,6-tri-*O*-acetyl-1-thio-α,β-D-*arabino*-hexopyranoside (8). To a solution of 5 (1.0 g) in acetonitrile (30 mL) were added ethyl mercaptan (1.6 mL), acid resin (0.6 g), and lithium bromide hydrate (1.0 g), and the solution was stirred at room temperature for 18 h. The reaction mixture was worked up as described for 1 and the product was isolated by chromatography on a column of silica gel using ethyl acetate–hexane (1:4, R_f = 0.16 for α and 0.12 for β). The weight of α- and β-anomers were 0.34 and 0.17 g, respectively: mp (α-anomer) 51.5–52.5 °C, (β-anomer) 56–58 °C; $[\alpha]^{20}$D (α-anomer) +183.2 ± 2° (*c* 1.0, $CHCl_3$); $[\alpha]^{20}_D$ (β-anomer) −41.7 ± 2° (*c* 1.02, $CHCl_3$); ^{1}H NMR (α-anomer, $CDCl_3$) δ 5.44 (broad d, *J* = 5.5 Hz, H-1), 5.24 (m, *J* = 4.9, 9.4, 11.8 Hz, H-3), 4.97 (t, *J* = 9.4 Hz, H-4), 4.39 (m, H-5), 4.34 (dd, *J* = 4.6, 11.8 Hz, H-6a), 4.03 (dd, *J* = 2.0, 11.8 Hz, H-6b), 2.62 and 2.53 (m, 2 H, SCH_2), 2.26 (sextet, *J* = 1.3, 5.8, 13.6 Hz, H-2_{eq}), 2.16 (m, *J* = 5.8, 11.7, 13.6 Hz, H-2_{ax}), 2.18, 2.04, and 2.0 (3 s, CH_3COO), 1.28 (t, CH_3CH_2S); ^{1}H NMR (β-anomer, $CDCl_3$) δ 5.00 (m, 2 H, H-3, H-4), 4.64 (dd, *J* = 2.6, 11.5 Hz, H-1), 4.20 (dd, *J* = 5.1, 12.2 Hz, H-6a), 4.09 (dd, *J* = 2.6, 12.2 Hz, H-6b), 3.63 (m, H-5), 2.72 (m, 2 H, SCH_2), 2.37 (m, H-2_{eq}), 2.07, 2.03, and 2.02 (3 s, CH_3COO), 1.84 (broad dd, *J* = 11.3, 13.0 Hz, H-2_{ax}), 1.29 (t, CH_3CH_2S); MS (calcd mass = 334) obsd *m/e* 333.16, 273.17, 213.13.

2,6-Dideoxy-3,4-di-*O*-acetyl-L-*lyxo*-hexopyranose (2-Deoxy-3,4-di-*O*-acetyl-L-fucopyranose, 9). To a solution 3,4-di-*O*-acetyl-L-fucal (5.0 g) and lithium bromide hydrate (5.0 g) in acetonitrile (150 mL) were added Ag 50W-X2 resin (3.0 g) and water (6 mL), and the mixture was stirred at room temperature for 15 min. The product was isolated as described for 1. Purification by chromatography on a column of silica gel using ethyl acetate–hexane (3:8, R_f = 0.10) as eluant gave the title compound (colorless solid, 4.0 g, 73.8% yield); mp 98–99 °C; α:β = 9.4; $[\alpha]^{20}_D$ −57.6 ± 2° (*c*, 1.03, $CHCl_3$), ^{1}H NMR δ 5.45 (d, *J* = 3.2 Hz, H-1α), 5.35 (m, *J* = 3.2, 5.2, 8.0 Hz, H-3α), 5.19 (broad d, *J* = 3.2 Hz, H-4α), 5.10 (broad d, *J* = 3.2 Hz, H-4β), 4.98 (m, H-3β), 4.87 (dd, *J* = 1.6, 8.9 Hz, H-1β), 4.33 (H-5α), 3.73 (m, H-5β), 2.15 and 1.98 (2 s, CH_3COO of α-anomer), 2.17 and 2.00 (acetyl groups of β anomer), 2.04 and 1.86 (m, H-2), 1.20 (d, CH_3 (C6) of β-anomer), 1.13 (d, CH_3 (C6) of α-anomer); MS for anomeric mixture (calcd mass = 232) obsd *m/e* 231.13, 215.12, 155.09 (100).

Methyl 2,6-Dideoxy-3,4-di-*O*-acetyl-α-L-*lyxo*-hexopyranoside (Methyl 2-Deoxy-3,4-di-*O*-acetyl-α-L-fucopyranoside, 10). To a solution 3,4-di-*O*-acetyl-L-fucal (2.0 g) and anhydrous lithium bromide (2.2 g) in acetonitrile (20 mL) were added Ag 50W-X2 resin (2.5 g) and methanol (1 mL), and the reaction mixture was stirred at room temperature for 5 h. The product was isolated as described for 1. Purification by chromatography on a column of silica gel using ethyl acetate–hexane (3:7, R_f = 0.33 for α-anomer, 0.26 for β-anomer) as eluant gave the title compound (colorless solid, 1.6 g): mp 66.4 °C (lit.[29] mp 66.5–67.5 °C). The weight of the β-anomer was 0.33 g (syrup, 83.9% combined yield): $[\alpha]^{20}_D$ (α-anomer) −174.2 ± 2° (*c* 1.00, $CHCl_3$) (lit.[29] −166° (*c* 0.79, $CHCl_3$)]; $[\alpha]^{20}_D$ (β-anomer) −13.6 ± 2° (*c* 1.02, $CHCl_3$); ^{1}H NMR δ 5.24 (m, *J* = 2.9, 4.9, 7.8 Hz, H-3), 5.15 (dd, *J* = 1.2, 2.9 Hz, H-4), 4.83 (broad d, *J* = 3.4 Hz, H-1), 4.03 (m, H-5), 3.31 (s, OCH_3), 2.01 (m, *J* = 3.7, 10.0, 12.7 Hz, H-2_{ax}), 1.82 (m, H-2_{eq}), 2.13 and 1.95 (2 s, CH_3COO), 1.12 (d, *J* = 6.6 Hz, CH_3 (C6)); MS (calcd mass = 246) obsd *m/e* 245.18, 215.17, 155.13 (100).

2,6-Dideoxy-3,4-di-*O*-acetyl-L-*arabino*-hexopyranose (2-Deoxy-3,4-di-*O*-acetyl-L-rhamnopyranose, 11). To a solution 3,4-di-*O*-acetyl-L-rhamnal (5.0 g) and lithium bromide hydrate (5.0 g) in acetonitrile (150 mL) were added AG 50W-X2 resin (3.0 g) and water (6 mL), and the mixture was stirred at room temperature for 15 min. The product was isolated as described for 1. Purification by chromatography on a column of silica gel using ethyl acetate–hexane (3:8, R_f = 0.12) as eluant gave the title compound (pale brown solid, 3.75 g, 69.1% yield): mp 79–80.2 °C; α:β = 2:1; $[\alpha]^{20}_D$ −96.8 ± 2° (*c* 0.96, $CHCl_3$); ^{1}H NMR δ 5.36 (d, *J* = 3.0 Hz, H-1α), 5.33 (m, *J* = 5.1, 9.4, 11.1 Hz, H-3α), 4.98 (m, H-3β), 4.90 (dd, *J* = 1.7, 9.4 Hz, H-1β), 4.75 (t, *J* = 9.4 Hz, H-4), 4.12 (m, H-5α), 3.54 (m, H-5β), 2.39 (m, *J* = 2.0, 5.5, 12.2 Hz, H-$2\beta_{eq}$), 2.26 (m, *J* = 1.5, 5.5, 12.5 Hz, H-$2\alpha_{eq}$), 1.77 (m, *J* = 3.8, 11.1, 12.5 Hz, H-$2\alpha_{ax}$), 1.66 (m, *J* = 9.4, 12.2 Hz, H-$2\beta_{ax}$), 1.23 [d, *J* = 6.6 Hz, CH_3 (C6) of β-anomer], 1.17 [d, *J* = 6.6 Hz, CH_3 (C6) of α-anomer]; MS (calcd mass = 232) obsd *m/e* 231.13, 215.12, 155.09 (100).

5-(Methoxycarbonyl)pentyl 2-Deoxy-3,6-di-*O*-acetyl-4-*O*-(2,3,4,6-tetra-*O*-acetyl-β-D-galactopyranosyl)-α-D-*arabino*-hexopyranoside (12). A solution of lactal hexaacetate (18.3 g) in acetonitrile (100 mL) containing anhydrous lithium bromide (9.8 g), 5-(methoxycarbonyl)pentan-1-ol (10 mL), 4-Å molecular sieves (4 g), and the acid resin (10 g) was stirred at room temperature for 16 h. The reaction mixture was worked up as described for 1, and the crude syrup was dissolved in dichloromethane (100 mL) containing pyridine (25 mL) and acetic anhydride (25 mL). After 16 h, the reaction mixture was diluted with dichloromethane and washed with water, ice-cold 1 M hydrochloric acid, and saturated sodium bicarbonate solution. The product was purified by chromatography on a column of silica gel using ethyl acetate–hexane (2:3, R_f = 0.07) as eluant. The weight of the syrupy product was 13.6 g (59.1% yield): $[\alpha]^{20}_D$ +13.0 ± 2° (*c* 1.00, $CHCl_3$); ^{1}H NMR ($CDCl_3$) δ 5.33 (dd, *J* = 1.1, 3.5 Hz, H-4′), 5.27 (m, *J* = 5.1, 8.2, 10.9 Hz, H-3), 5.11 (dd, *J* = 8.0, 10.1 Hz, H-2′), 4.94 (dd, *J* = 3.5, 10.1 Hz, H-3′), 4.82 (broad d, *J* = 2.6 Hz, H-1), 4.54 (d, *J* = 8.2 Hz, H-1′), 4.33 (dd, *J* = 2.4, 12.0 Hz, H-6a), 4.13 (m, H-6′a, H-6′b), 4.04 (dd, *J* = 7.2, 12.0 Hz, H-6b), 3.85 (m, H-5, H-5′), 3.63 (s, $COOCH_3$) 3.63 (dd, *J* = 8.8, 9.2 Hz, H-4), 3.57 and 3.30 (m, OCH_2), 2.30 (t, *J* = 7.5 Hz, CH_2COO), 2.20 (m, H-2_{eq}), 2.04 (m, H-2_{ax}), 1.68–1.54 and 1.35 ($CCH_2CH_2CH_2$ of the aglycon); MS (calcd mass = 704.26) obsd *m/e* 729.22, 705.22, 501.12 (100).

Supplementary Material Available: 500-MHz proton NMR spectra of compounds 1–12 (13 pages). Ordering information is given on any current masthead page.

Synthesis of 2-[(Perfluoroalkyl)phenyl]propionic Acids

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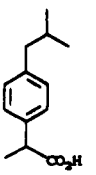
A structural unit common to many useful nonsteroidal antiinflammatory drugs is the 2-phenylpropionic acid moiety, from which the term "profen drugs" is derived. Profen drugs differ in the nature of the substituents on the aromatic ring.[1] Examples include ibuprofen (1), flurbiprofen (2), and ketoprofen (3). No profens have been reported, however, that bear a perfluoroalkyl-substituted phenyl group.



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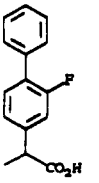

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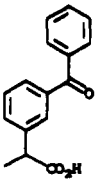

3

Herein is reported a synthetic route to 2-[(perfluoroalkyl)phenyl]propionic acids. The key intermediates are perfluoroalkylated cyclohexadienones **4**, **9a**, and **9b**. We previously reported synthesis of **4** by the novel addition of triethyl(trifluoromethyl)silane to 1,4-benzoquinone.[2] This versatile intermediate undergoes reactions similar to those undergone by quinone monoketals.[3] Fortunately,

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(2) Stahly, G. P.; Bell, D. R. *J. Org. Chem.* **1989**, *54*, 2873.

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