and the mixture was stirred overnight at room temperature. Acidification preceded a workup of washing by water and thiosulfate and of solvent drying and evaporation. A yellowish red liquid (6.80 g) was obtained: bp 43 °C (17 torr) [lit.[12] bp 54 °C (26 torr)]; IR (neat) 2990, 2980, 2940, 2270, 1560, 1385, 1340 cm^{-1}; ^1H NMR (CCl_4) δ 0.85–1.8 (m, 5 H), 2.2–2.5 (t, 2 H).

(b) Oxidation of 7. The 1-iodo-1-pentyne (1.94 g, 10 mmol) was oxidized as before in dry methanol (100 mL) with I_2 (5.08 g, 20 mmol) and I_2O_5 (1.67 g, 5 mmol). A red oil (1.81 g) was obtained: IR (neat) 2980, 2970, 2880, 1750, 1735, 1465, 1265, 1215, 1120, 1050 cm^{-1}; ^1H NMR (CCl_4) δ 0.8–1.9 (m, OH), 2.47–2.82 (m, 4 H), 3.15 (s, 8 H), 3.67 (s, 4 H), 3.8 (s, 1 H). A quantitative estimate by NMR for this mixture indicated 48% of **6**, 9% of the corresponding keto ester, and 43% of **7**.

Registry No. 1, 637-44-5; 2, 85810-81-7; 3, 932-88-7; 4, 88131-14-0; 6, 63608-61-7; 7, 14752-61-5; I_2O_5, 12029-98-0; I_2, 7553-56-2; α,β,β-triiodostyrene, 16141-17-6; α-iodo-β-methoxyphenylpropionic acid, 88131-15-1; phenylacetylene, 536-74-3; *trans*-cinnamic acid, 140-10-3; 2-hexynoic acid, 764-33-0; methyl 2-hexynoate, 18937-79-6; 1-pentyne, 627-19-0; methyl phenylglycoxylate, 15206-55-0; benzoylformic acid, 611-73-4.

Routes to *C*-Glycopyranosides via Sigmatropic Rearrangements[1a]

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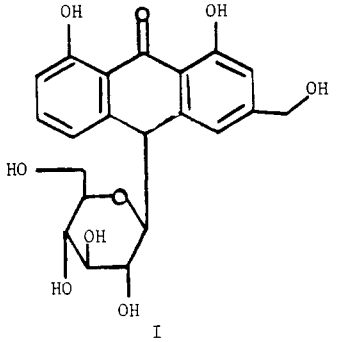
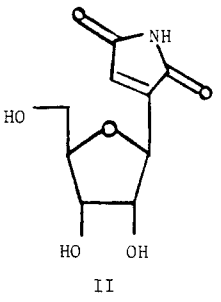
Claisen rearrangements have been applied to 1,5-anhydro-4,6-*O*-benzylidene-1,2-dideoxy-D-*ribo*-hex-1-enitol (1). The classical procedure succeeds, but the overall process is unsatisfactory because of the low conversion to the vinyl ether intermediate. Best results were had with the Eschenmoser procedure, and the *N,N*-dimethyl(hex-2′-enopyranosyl)acetamide produced, **7**, can be converted into the corresponding ethyl ester. However reduction of **7** with lithium triethoxyaluminum hydride gave the β-aldehyde **8** as the major product, indicating the ease with which these systems will anomerize. Attempts to apply the Still [2,3] sigmatropic rearrangement to **1** gave only modest yields of the desired hydroxymethyl product **12**. A more successful route to this substance was provided by reduction of the nitrile obtained from reacting tri-*O*-acetyl-D-glucal (**13**) with diethylaluminum cyanide.

2,6-Dialkylated pyran residues have been identified as components of natural products formally classified as carbohydrates for several years. One of the earliest known is barbaloin (I).[4] The comparable 2,5-dialkylfurans, al-



I



II

though later arrivals, have attracted more attention because of their presence in some biologically important *C*-nucleosides such as shodowmycin II.[5] Some of the most structurally intricate natural products isolated recently have been found to incorporatel 2,6-dialkylated pyran rings, and hence syntheses of this entity have been deemed worthy of attention.[6] Results with the furan counterparts have indicated that sugar-based syntheses of *C*-glycofuranosides could be highly stereocontrolled,[7] and hence we were interested in developing routes to *C*-glycopyranosides from hexopyrano sugar derivatives. In this and the accompanying paper[8] we discuss some of our recent results.

In choosing systems for study we noted that unsaturated sugars have proven to be versatile synthetic intermediates for carbohydrate[9] and noncarbohydrate[10] objectives, and hence we decided to make provisions for inclusion of olefinic residues in our *C*-glycopyranosides. The Claisen rearrangment had been first applied to unsaturated sugars

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(3) We are grateful for support (a) in the U.S.A. to the National Cancer Institute (Grant CA 28192) and (b) in Canada to the Natural Sciences and Engineering Research Council.

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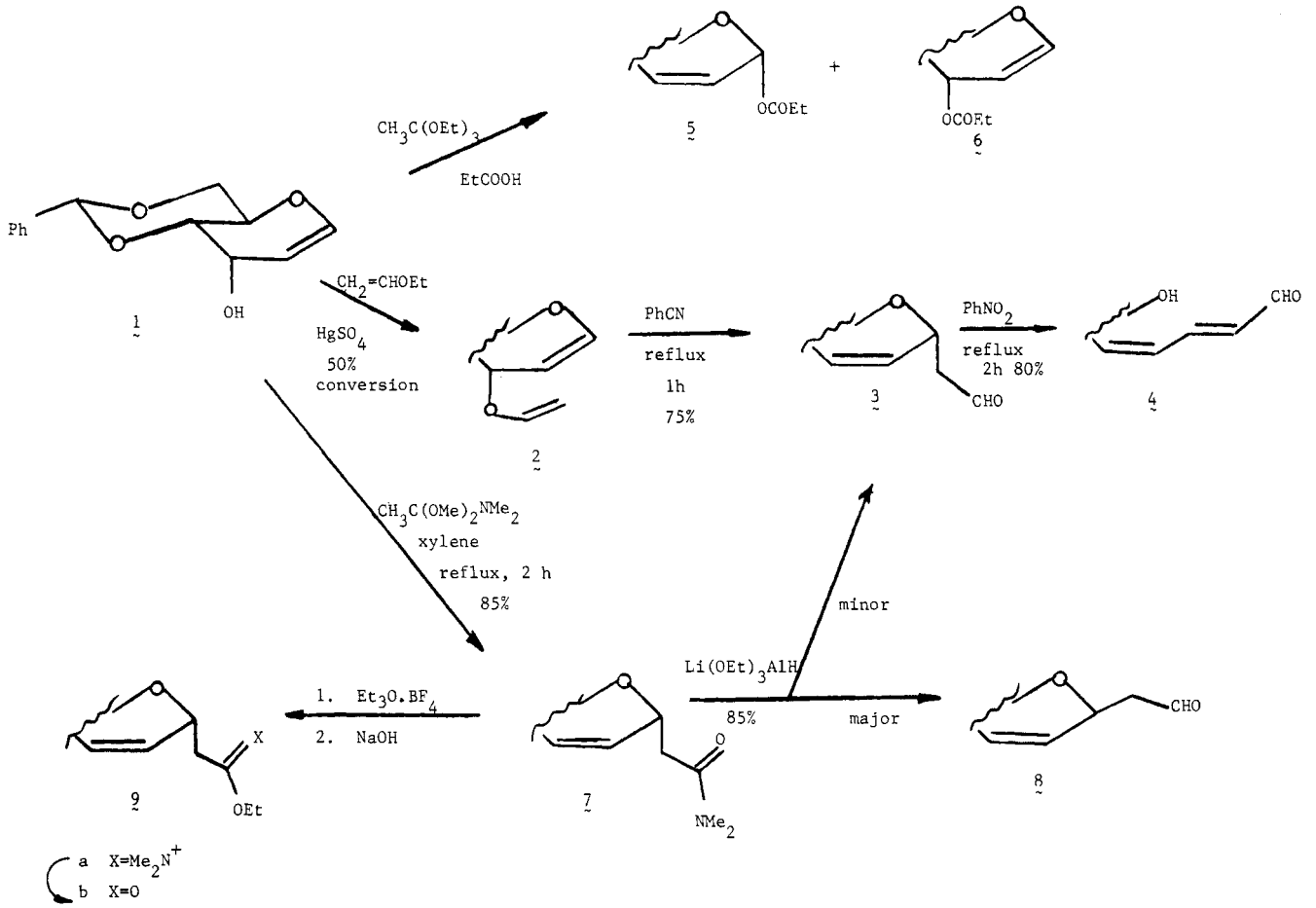
0022-3263/84/1949-0518$01.50/0

Scheme I



by Ferrier for C-alkylation at C-2 or C-4.[11] Ireland subsequently applied his version of the rearrangement for alkylation at the anomeric center.[12]

The glycal **1**, which can be prepared from D-glucose in six steps in 70% overall yield,[13] was chosen as the substrate for examination. Application of the classical version,[11,14] of the Claisen rearrangement to **1** did succeed, but two problems were encountered. One of these was that in refluxing nitromethane (210 °C), the usual solvent,[11] the product from vinyl ether **2** was the dienic aldehyde **4** (Scheme I), the structure of which followed from its spectroscopic properties, including the free hydroxyl group and unsaturated aldehyde. We surmised that **4** was a thermolysis product of the desired aldehyde, and so lower boiling solvents were examined. Refluxing xylene left **2** unchanged; however, with benzonitrile (185 °C) rearrangement to **3** went smoothly in 75% yield.

The other problem could not be solved as easily. Thus the vinylation step, **1** → **2**, could not be made to go beyond 50% completion, a not uncommon problem.[15] Unreacted **1** could, of course, be recovered, but the process was not althogether satisfactory.

Modified versions of the Claisen rearrangement were therefore examined. The operationally simple Johnson version[16] gave a mixture of propionate esters **5** and **6**. The latter probably arises by acyl migration in the former, although we did not attempt to establish this. The Ireland version[11] was also exammined, but in our hands the Eschenmoser version[17] was most successful. Thus the crystalline amide **7** was obtained in 85% yield.

Configurational correlation of aldehyde **3** and amide **7** was deemed necessary in view of the ease with which *C*-glycosides such as these can anomerize (vide infra).[18] A variety of recommended prescriptions for amide to aldehyde conversions[19] left compound **7** untouched. On the other hand, lithium triethoxyaluminum hydride[20] did bring about a reaction, but the product was a mixture of the aldehydes **3** and **8**, the latter predominating. The surprisingly facile anomerization leading to **8** could not be forestalled by use of even extremely dry reagents. The amide **7** was transformed into ester **9b** via the salt **9a** as indicated in Scheme I.

The assignments of α and β configurations to **3** and **8** follow from the key ^{1}H NMR parameters for H-1 (4.84 and 4.65 ppm, respectively) and for CH_2CHO (2.61–2.90 and 1.8–2.3 ppm, respectively). We have found that for such anomeric pairs, both H-1 and the appended CH_2 group resonate at higher frequencies in the β anomers (Chart I).

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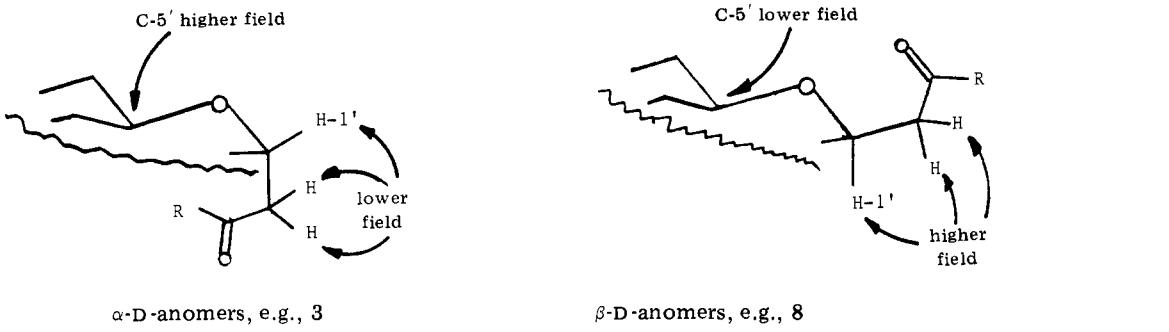
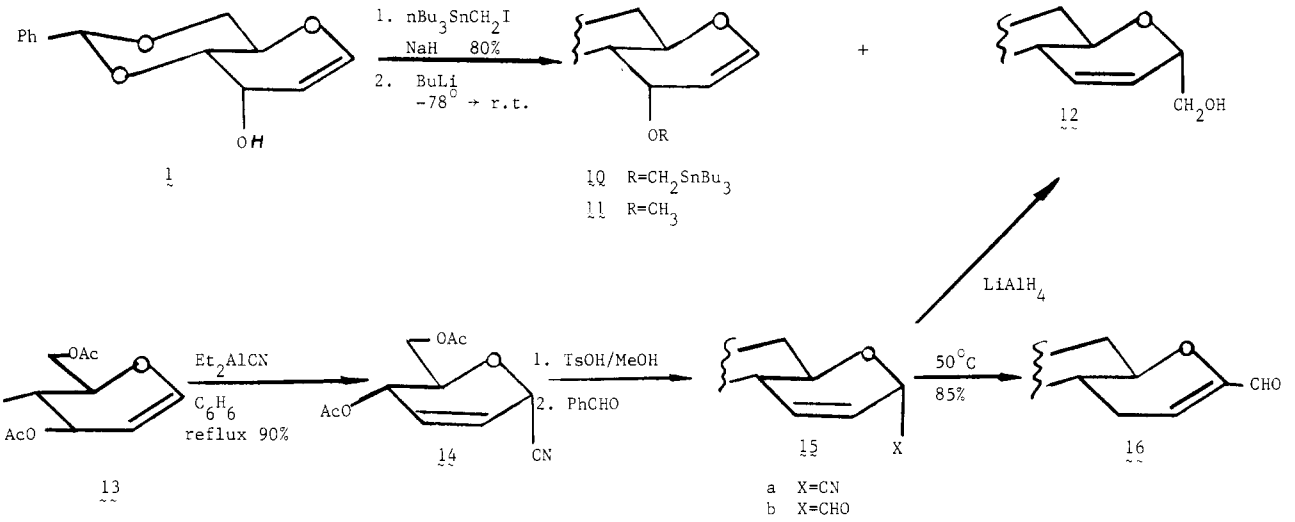
(20) Brown, H. C.; Weissman, J. *Am. Chem. Soc.* **1965**, *87*, 5614.

Chart I



α-D-anomers, e.g., 3 β-D-anomers, e.g., 8

Scheme II



This situation is discussed more fully in the accompanying paper.[8]

The introduction of a one-carbon functionalized substituent at C-1 was also examined.[21,22] Still has developed an elegant procedure for preparation of homoallyl primary alcohols by a [2,3] sigmatropic rearrangement process.[23] The required (tri-*n*-butylstannyl)methyl ether **10** was prepared in 80% yield by treatment of **1** with (tri-*n*-butylstannyl)methyl iodide in the presence of HMPA. However, the product from lithiation of **10** at −78 °C and warming to room temperature was a 3:1 mixture of the methyl ether **11** and the desired primary alcohol **12** (Scheme II). Experimental conditions could not be found to afford the primary alcohol **12** predominantly and so other routes were explored.

The Lewis acid catalyzed reaction of acetylated glycals, known as the Ferrier reaction,[24] has been successfully applied recently for attaching carbon substituents at the anomeric center.[25] Reagents such as diethylaluminum cyanide have the double advantage of being Lewis acids as well as providing a nucleophile. Hence, the reaction of tri-*O*-acetyl-D-glucal (**13**) with this reagent in refluxing benzene was examined. The product, obtained in 95% yield, consisted of the α-nitrile **14** with less than 2% of the corresponding β anomer.

While our work was in progress, Grynkiewicz and BeMiller reported that compound **14** could be obtained from reaction of **13** with trimethylsilyl cyanide and boron trifluoride etherate.[26] Their material had physical constants identical with ours.

Correlation of the nitrile **14** with the product from the Still rearrangement, **12**, was carried on as shown in Scheme II. It is of interest to note that prolonged heating of aldehyde **15b** causes a prototropic shift to give the conjugated isomer **16**.

In summary, the experiments reported in this paper support the previously reported study of Ireland and coworkers[12] in showing that α-D-*C*-glycopyranosides can be prepared in excellent yields by [3,3] sigmatropic rearrangements. While the yield in the corresponding [2,3] rearrangement was not encouraging, the desired product, **12**, was obtainable in excellent yield by an alternative route involving the nitrile **14**. Related studies in the accompanying paper[8] will outline routes to the corresponding β-D anomers.

Experimental Section

General Methods. Melting points were determined in capillary tubes in a Büchi Model 510 and are uncorrected. Elemental analyses were performed either by Guelph Chemical Labs, Guelph, Ontario, or by Dr. F. Kasler, Department of Chemistry, University of Maryland. ^{1}H NMR spectra were determined in deuteriochloroform with internal tetramethylsilane as the standard, unless otherwise stated, on one of the following spectrometers: Varian T-60, Varian EM-360, Perkin-Elmer R-12B, Bruker WP-80, Varian XL-100, Varian XL-200, Varian HR-220, Varian XL-360, or Bruker WH-400. ^{13}C NMR spectra were determined on a Varian XL-100. Coupling constants were measured directly from the spectra or calculated from the peak listings. IR spectra were

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determined on either a Beckman IR-10 or a Perkin-Elmer 298 spectrometer. Neat samples were smeared on sodium chloride plates and solutions were placed in sodium chloride cells. Low-resolution mass spectra were run on a Hitachi/Perkin-Elmer RMH-2, and high-resolution mass spectra were determined with a VG 7070F. Optical rotations were determined on a Perkin-Elmer 241 polarimeter. GLC was performed on a Hewlett-Packard 5730A gas chromatograph with a stainless steel column (6 ft × $^1/_8$ in.) packed with 3% OV-170n on Chromasorb WHP. The detector and injector temperatures were 260 and 230 °C, respectively. The helium flow rate was 25 mL/min. Ratios were determined by measuring peak areas. TLC was performed by using aluminum plates precoated with silica gel (HF-254, 0.2 mm thickness) containing a fluorescent indicator (E. Merck, CAT. 5539). The following solvent systems were used: (A) ethyl acetate–petroleum ether (bp 30–60 °C), 10:90; (B) ethyl acetate–petroleum ether (bp 30–60 °C), 20:80; (C) ethyl acetate–petroleum ether (bp 30–60 °C), 33:67; (D) ethyl acetate–petroleum ether (bp 30–60 °C), 50:50; (E) ethyl acetate; (F) methanol–methylene chloride, 90:10. The chromatograms were viewed under a UV light (254 nm), sprayed with concentrated sulfuric acid, and heated until charring occurred. PTLC was done by using glass plates (20 cm × 20 cm) coated with silica gel (PF-254, E. Merck) and the above-mentioned solvent systems. Column chromatography was carried out by using silica gel (E. Merck, 70–230 or 230–400 mesh ASTM).

1,5-Anhydro-4,6-*O*-benzylidene-1,2-dideoxy-3-*O*-vinyl-D-*ribo*-hex-1-enitol (2). A solution of the allylic alcohol 1[13] (1.0 g) in ethyl vinyl ether (300 mL) was stirred with a catalytic amount of mercuric sulfate for 1 day. The solution was then washed with a saturated solution of sodium bicarbonate and dried over sodium sulfate. Evaporation of the solvent gave a 50:50 mixture of the starting material and **2**. The desired compound **2** was isolated by column chromatography on silica gel eluted with solvent A. For **2**: mp 79.5–80 °C (recrystallized from diethyl ether–petroleum ether); TLC F_f 0.42 (A); $[\alpha]^{20}_D$ +74.7° (*c* 0.4, $CHCl_3$); ^1H NMR (60 MHz) δ 3.8–4.2 (m, 5, H-3, H-4, H-5, H-6, H-6′), 4.4–4.6 (m, 2, CH=CH_2), 5.1 (br t, $J_{1,2} = J_{2,3} = 6.0$ Hz, H-2), 5.6 (s, 1, PhC*H*), 6.3–6.7 (m, 1-CH=CH_2, H-1). Anal. Calcd for $C_{15}H_{16}O_4$: C, 69.23; H, 6.15. Found: C, 69.38; H, 6.20.

2-(4′,6′-*O*-Benzylidene-2′,3′-dideoxy-α-D-*erythro*-hex-2′-enopyranoxyl)acetaldehyde (3). A solution of the allyl ether **2** (0.30 g) in dry benzonitrile (10 mL) was refluxed for 1 h, which caused disappearance of the starting material. The solvent was evaporated under vacuum to give **3**: 0.23 g (75%); a syrup; TLC R_f 0.50 (D); $[\alpha]^{20}_D$ +96.5° (*c* 0.65, CH_3OH); IR ($CHCl_3$) 1735 (CHO) cm^{-1}; ^1H NMR (220 MHz) δ 2.61 (m, 1, H-2a), 2.90 (ddd, 1, $J_{2a,2b} = 16.0$ Hz, $J_{2b,1'} = 2.0$ Hz, $J_{1,2b} = 9.0$ Hz, H-2b), 3.5–4.4 (m, 4, H-4′, H-5′, H-6′a, H-6′e), 4.84 (m, 1, H-1′), 5.52 (s, 1, PhCH), 5.9 (m, 1, H-3′), 6.05 (br d, $J_{2,3} = 10$ Hz, H-2′), 7.4–7.55 (m, 5, C_6H_5), 9.95 (d, 1, H-1); HRMS, calcd for $C_{15}H_{16}O_4$ *m/e* 260.1048, found *m/e* 260.1028.

6,8-*O*-Benzylidene-2,3,4,5-tetradeoxy-*aldehydo*-D-*erythro*-octa-2(*E*),4(*Z*)-dienose (4). Compound **2** (0.50 g) was refluxed in nitrobenzene (10 mL) for 2 h under anhydrous conditions. The solvent was evaporated by using an oil pump, and the title compound **4** (0.4 g, 80%) was obtained as a syrup: TLC R_f 0.28 (D); $[\alpha]^{20}_D$ −223.5° (*c* 0.8, CH_3OH); IR ($CHCl_3$) 1680 (α,β-unsaturated aldehyde) cm^{-1}; ^1H NMR (220 MHz) δ 3.68–3.80 (m, 2, H-7, H-8a), 4.39 (m, 1, H-8e), 4.65 (dd, 1, $J_{5,6} = J_{6,7} = 8.0$ Hz, H-6), 5.65 (s, 1, H-9), 6.05 (dd, 1, $J_{4,5} = 11.0$ Hz, H-5), 6.20 (dd, 1, $J_{2,3} = 15.0$ Hz, $J_{1,2} = 8.0$ Hz, H-2), 6.55 (dd, 1, $J_{3,4} = 11.0$ Hz, H-4), 7.70 (dd, 1, H-3), 9.70 (d, 1, H-1); HRMS, calcd for $C_{15}H_{16}O_4$ *m/e* 260.1048, found *m/e* 260.1023.

***N,N*-Dimethyl(4′,6′-*O*-benzylidene-2′,3′-dideoxy-α-D-*erythro*-hex-2′-enopyranosyl)acetamide (7).** A solution of the allylic alcohol 1[13] (2.34 g, 10.0 mmol) and *N,N*-dimethylacetamide dimethyl acetal (3.0 g, 20 mmol) in dry xylene (200 mL) was refluxed for 2 h under argon by using a calcium chloride filled Soxhlet as a methanol trap. Evaporation of the solvent gave **7** (3.0 g, 85%) as a crystalline compound: mp 108.5–109 °C (recrystallized from petroleum ether); TLC R_f 0.15 (D); $[\alpha]^{20}_D$ +55.97° (*c* 0.85, MeOH); ^1H NMR (220 MHz) δ 2.52 (dd, 1, $J_{2a,2b} = 14.5$ Hz, $J_{1,2a} = 5.5$ Hz, H-2a), 2.85 (dd, 1, $J_{1,2b} = 7.5$ Hz, H-2b), 2.90 and 2.95 (2 s, 6, $CON(CH_3)_2$), 3.53 (m, 1, H-5′), 3.80 (t, 1, $J_{6'a,6'e} = J_{6'a,5'} = 10.0$ Hz, H-6′a), 4.84 (m, 1, H-1′), 5.54 (s, 1 PhC*H*), 5.78 (dt, 1, $J_{2',3'} = 10.0$ Hz, $J_{3',4'} = J_{1',3'} = 2.0$ Hz, H-3′), 6.03 (br d 1, H-2′), 7.3–7.5 (m, 5, C_6H_5); ^{13}C NMR (25.2 Hz) δ 35.237 (C-2a), 36.73 and 37.127 (NCH_3), 65.824 (C-5′) 69.485 (C-6′), 71.313 (C-1′), 74.958 (C-4′), 101.61 (PhCH). Anal. Calcd for $C_{17}H_{21}O_4N$: C, 67.32; H, 6.93; N, 4.62. Found: C, 67.29; H, 6.94; N, 4.59.

2-(4′,6′-*O*-Benzylidene-2′,3′-dideoxy-β-D-*erythro*-hex-2′-enopyranosyl)acetaldehyde (8). A solution of amide **7** (0.75 g, 2.5 mmol) in dry diethyl ether (50 mL) was cooled to 0 °C. To this was added a solution of lithium triethoxyaluminum hydride in THF (3.0 mmol), and the reaction mixture was stirred for 1 h. The reaction mixture was processed in the usual manner and evaporation gave a mixture of **3** (8 mg, 10%) and **8** (44 mg, 90%) which were separated by using solvent D. For **8**: mp 91.9 °C (hexane–ethyl acetate; TLC R_f 0.45 (D); $[\alpha]^{20}_D$ +37.0° (*c* 1.5, $CHCl_3$); ^1H NMR (200 MHz) δ 1.6–2.1 (m, 2, CH_2CHO) 3.5–3.8 (m, 3, H-5, H-6′, H-6″), 4.20 (m, 1, H-4), 5.02 (m, 1, H-1), 5.55 (s, 1, PhC*H*), 5.65 (m, 1, $J_{2,3} = 10$ Hz, H.3), 5.95 (br d, 1, H-6), 7.3–7.5 (m, 5, C_6H_5), 9.25 (d, 1, CHO). Anal. Calcd for $C_{15}H_{16}O_4$: C, 69.22; H, 6.20. Found: C, 69.28; H, 6.18.

Ethyl (4′,6′-*O*-Benzylidene-2′,3′-dideoxy-α-D-*erythro*-hex-2′-enopyranosyl)acetate (9b). The amide **7** (1.5 g, 5.0 mmol) was kept with Meerwein's reagent[27] (0.9 g, 5.0 mmol) in methylene chloride (20 mL) overnight during which the solution turned deep yellow. The solvent was evaporated to give the salt **9a**: TLC R_f 0.0 (E); ^1H NMR (60 MHz) δ 1.6 (t, 3, $J = 7.0$ Hz, CH_3CH$_2$), 3.22 and 3.45 (s, 6, $(CH_3)_2N$), 5.50 (s, 1, PhC*H*), 5.95 (m, 1, H-3′), 6.10 (m, 1, H-2′). The salt **9a** was dissolved in a 1:1 mixture of benzonitrile and water (20 mL) and hydrolyzed with 1 N sodium hydroxide over 0.5 h. The solution was then dried over sodium sulfate to afford a 1:1 mixture of amide **7** and ester **9b** (1.40 g, 90%) as a syrup which was column chromatographed on silica gel by elution with solvent D. For **9b**: TLC R_f 0.70 (D); $[\alpha]^{20}_D$ +46.2° (*c* 1.39 $CHCl_3$); ^1H NMR (220 MHz) δ 1.29 (t, 3, $J = 7.0$ Hz, OCH_2CH_3), 2.50 (AB q, 1, $J_{a,b} = 16.0$ Hz, $J_{1,2a} = 5.0$ Hz, H-2a), 2.73 (AB q, 1, $J_{1',2b} = 8.0$ Hz, H-2b), 3.5–4.0 and 4.1–4.30 (m, 6, H-4′, H-5′, H-6a′, H-6e′, OCH_2CH$_3$), 4.90 (m, 1, H-1′), 5.54 (s, 1, PhC*H*), 5.70 (td, 1, $J_{2',3'} = 10.0$ Hz, $J_{3',4'} = 2.0$ Hz, H-3′), 6.0 (br d, 1, H-2′), 7.45–7.55 (m, 5, C_6H_5); HRMS, calcd for $C_{17}H_{20}O_5$ *m/e* 304.131 05, found *m/e* 304.130 86.

4,6-Di-*O*-acetyl-2,3-dideoxy-α-D-*erythro*-hex-2-enopyranosyl Cyanide (14). A solution of tri-*O*-acetyl-D-glucal (**13**; 0.27 g, 0.98 mmol) in dry benzene (10 mL) was refluxed for 2 h with diethylaluminum cyanide (1 mL, 18 M) under argon. The solution was then cooled, and water was added dropwise. The mixture was filtered through a sintered-glass filter and dried over sodium sulfate. Evaporation of the solvent gave a mixture of **14** and its corresponding β anomer in the ratio of (9:1). After recrystallization from ether–petroleum ether **14** was obtained pure: 0.21 g (90%); mp 90–91 °C; R_f 0.62 (D); $[\alpha]^{20}_D$ −13.0° (*c* 1.2, $CHCl_3$); ^1H NMR (200 MHz) δ 4.20 (m, 2, H-6a, H-6e), 4.10 (td, 1, $J_{5,6a} = J_{5,6e} = 4.0$ Hz, $J_{4,5} = 9.6$ Hz, H-5), 5.2 (m, 1, H-1), 5.35 (ddd, 1, $J_{3,4} = 3.3$ Hz, $J_{2,4} = 2.0$ Hz, H-4), 5.90 (ddd, 1, $J_{2,3} = 10$ Hz, $J_{1,3} = 2.0$ Hz, H-3), 6.10 (td, 1, $J_{1,2} = 1.8$ Hz, H-2). Anal. Calcd for $C_{11}H_{13}NO_5$: C, 55.23; H, 5.47. Found: C, 55.28; H, 5.52.

Compound **14** has recently been prepared by reaction of **13** with Me_3SiCN and $BF_3{\cdot}OEt_2$. Reported physical constants are mp 91 °C and $[\alpha]^{20}_D$ −16°.[24]

4,6-*O*-Benzylidene-2,3-dideoxy-α-D-*erythro*-hex-2-enopyranosyl Cyanide (15a). A solution of **14** (1.0 g mmol) in absolute methanol (50 mL) was stirred at room temperature with a catalytic amount of *p*-TsOH for 24 h. The solution was then neutralized with barium carbonate, filtered, and evaporated to give a syrupy, polar product R_f 0.25 (D), presumed to be deacetylated product **14**. The material (0.2 g) was dissolved in benzaldehyde (3 mL) and shaken with zinc chloride (0.15 g) for 3 h. The reaction mixture was then poured into ice, and the precipitate was washed several times with water and then with petroleum ether and then sucked dry by vacuum filtration. Compound **15a** was recrystallized from methanol: mp. 165–166°; TLC R_f 0.65 (D) $[\alpha]^{20}_D$ −4.0° (*c* 0.22, $CHCl_3$); ^1H NMR (200 MHz) δ 3.8 (m, 2, H-6, H-6′), 4.2 (m, 1, H-5), 4.4 (br dt, 1, $J_{4,5} = 11.0$ Hz, $J_{3,4} = 2.8$ Hz, H-4), 5.08 (m, 1, H-1), 5.6 (s, 1, PhCH), 5.7 (br dt 1, $J_{2,3} = 10$ Hz, H-3), 6.25 (br d, 1, H-2), 7.4 (m, 5, C_6H_5). Anal.

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Calcd for $C_{14}H_{13}NO_3$: C, 69.12; H, 5.38. Found: C, 69.16; H, 5.37.

5,7-*O*-Benzylidene-2,6-anhydro-3,4-dideoxy-*aldehydo*-D-*arabino*-hept-3-enose (15b). The nitrile **15a** (0.30 g, 1.23 mmol) was dissolved in dry diethyl ether (50 mL) and cooled to 0 °C. To this was added diisobutylaluminium hydride (3 mL of a 25% solution in toluene), and the reaction mixture was stirred for 1 h. A saturated solution of ammonium chloride was then added, and the solution was filtered and dried. Evaporation of the solvent gave **15b** (0.25 g, 85%) as a syrup which exhibited the following characteristics: TLC R_f 0.63 (D); $[\alpha]^{20}_D$ −9.0° (*c* 0.26, $CHCl_3$); ^1H NMR (200 MHz) δ 3.78 (m, 2, H-6, H-6′), 4.2 (m, 1, H-5), 4.42 (m, 1, $J_{4,5}$ = 10.8 Hz, H-4), 5.0 (m, 1, H-1), 5.6 (s, 1, PhC*H*), 5.75 (m, 1, $J_{2,3}$ = 10.0 Hz, H-3), 6.20 (br d, 1, H-2). Anal. Calcd for $C_{14}H_{14}O_4$; C, 68.28; H, 5.73. Found: C, 68.34; H, 5.78.

5,7-*O*-Benzylidene-2,6-anhydro-3,4-dideoxy-*aldehydo*-D-*erythro*-hept-2-enose (16). A solution of compound **15b** (0.5 g, 2.0 mmol) in diethyl ether (50 mL) was evaporated in vacuo by using a rotary evaporator and a water bath ~50 °C. Gentle heating was continued until TLC (D) analysis of a sample of the residue showed that **15b** had been transformed completely into a less polar product (0.43 g, 85%). For **16**: mp 143–144 °C (recrystallized from ether–petroleum ether); TLC R_f 0.65 (D); $[\alpha]^{20}_D$ +47.0° (*c* 1.10, $CHCl_3$); ^1H NMR (60 MHz) δ 2.6 (m, 2, H-3, H-3′), 3.8–4.6 (m, 4, H-4, H-5, H-6, H-6′), 5.6 (s, 1, PhCH), 5.9 (br t, 1, $J_{2,3}$ = $J_{2,3}$ = 4.0 Hz, H-2), 7.4 (m, 5, C_6H_5), 9.2 (s, 1, CHO). Anal. Calcd for $C_{14}H_{14}O_4$; C, 68.28; H, 5.73. Found: C, 68.38; H, 5.79.

5,7-*O*-Benzylidene-2,6-anhydro-3,4-dideoxy-D-*arabino*-hept-3-enitol (12). (a) To a solution of the aldehyde **15b** (0.10 g mmol) in dry THF (20 mL) was added lithium aluminium hydride (0.04 g), and the resulting solution was stirred for 0.5 h. The reaction mixutre was processed in the usual manner, and evaporation gave **12** as a syrup.

(b) A solution of glycal **1** (0.235 g, 1.0 mmol) in tetrahydrofuran (50 mL) was stirred at room temperature for 1 h with sodium hydride (0.03 g, 1.25 mmol). To this HMPA (3 mL) was added followed by *n*-Bu_3SnCH_2I[23] (0.430 g, 1.0 mmol), and the reaction mixture was stirred for an additional 6 h. Methanol was added, and the solution was evaporated to dryness. Column chromatography afforded the stannylmethyl ether **10**: 80% yield; R_f 0.72 (B). The stannylmethyl ether **10** (0.27 g, 0.5 mmol) was dissolved in dry THF (50 mL) and cooled to −78 °C under argon. *n*-Butyllithium (1.5 mmol) was added, and after 0.5 h the reaction mixture was warmed to room temperature. The mixture was diluted with diethyl ether, washed with water, and dried over sodium sulfate. Evaporation of solvent gave a mixture of **11** and **12** (in 3:1 ratio) which was separated by column chromatography with 1:1 petroleum ether/ethyl acetate. Compound **12** showed following characteristics: R_f 0.15 (D); $[\alpha]^{20}_D$ −7.6° (*c* 1.2, $CHCl_3$); ^1H NMR (200 MHz) δ 3.45 (m, 2, H-1), 4.32 (m, 1, H-1′), 5.58 (s, 1, PhC*H*), 5.80 (m, 1, $J_{2,3}$ = 10.2 Hz, H-3), 6.15 (m, 1, H-2). Anal. Calcd for $C_{14}H_{16}O_4$: C, 67.73; H, 6.50. Found: C, 67.65; H, 6.53.

Registry No. **1**, 5987-33-7; **2**, 88180-31-8; **3**, 88200-24-2; **4**, 88180-32-9; **5**, 72233-94-4; **6**, 88243-83-8; **7**, 72233-96-6; **8**, 88180-33-0; **9a**, 88180-35-2; **9b**, 88180-34-1; **10**, 72246-03-8; **11**, 16697-45-3; **12**, 72233-97-7; **13**, 52485-06-0; **14**, 83938-00-5; **14** (deacetyl), 88180-36-3; **15a**, 88180-37-4; **15b**, 88180-38-5; **16**, 88180-39-6; ethyl vinyl ether, 109-92-2; diethylaluminum cyanide, 5804-85-3.

Stereocontrolled Routes to Functionalized *C*-Glycopyranosides[1]

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4,6-*O*-Ethylidene-D-glucopyranose (1) reacts with an acid-washed, stabilized Wittig reagent to give the *trans*-oct-2-enoate **2** in excellent yield. Cyclization is effected by treatment with dilute base, and after 1 h, a 1:1 mixture of anomers exists which is the optimum concentration of the α-D form. Continuing base treatment for 5 h leads to the β-D anomer exclusively. α-D-*C*-Glycopyranosides can be obtained as predominant products by Lewis acid catalyzed condensation of acetylated glycals with siloxyalkenes, and anomerization to the β-D forms can be effected with potassium *tert*-butoxide. For a given pair of these anomers, ^1H or ^{13}C NMR parameters can be used for assigning configuration α or β.

In the accompanying paper[4] we describe some of our work on the development on stereocontrolled routes to functionalized *C*-glycopyranosides by means of [3,3] or [2,3] sigmatropic rearrangements. These processes ensured the stereochemistry of the product, and in many cases the yields were excellent. Nevertheless, in the hope of providing a greater range of products, other routes have been examined, and these are reported herein.

Chain Extension. The pioneering work of Zhdanov on application of the Wittig reaction for carbohydrate chain extension[5] paved the way for the development of routes to *C*-glycofuranosides from glycofuranoses.[6] Having utilized this methodology for our work on nonactic acid,[7] we were prompted to examine comparable routes to *C*-glycopyranosides. 4,6-*O*-Ethylidene-D-glucopyranose (**1**) was a readily accessible starting material,[8] and its chain extension to the *trans*-octenoate **2** in 87% yield was achieved (see Scheme I). Premature in situ cyclization[5] could be averted by subjecting the phosphorane to an acid wash prior to use (see Experimental Section). Following Zhdanov's lead,[5] we cyclized **2** with base, the process being

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