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OXIDATION OF CARBOHYDRATES WITH CHROMIC ACID

THE SYNTHESIS OF THE *delta*-DICARBONYL MONOSACCHARIDES 6-DEOXY-D-*xylo*-HEXOS-5-ULOSE AND 6,7-DIDEOXY-D-*xylo*-HEPTOS-5-ULOSE*†

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ABSTRACT

Addition of the alkyl Grignard reagents methylmagnesium iodide and ethylmagnesium bromide to the aldehyde 3-*O*-benzyl-1,2-*O*-isopropylidene-α-D-*xylo*-pentodialdo-1,4-furanose (**1**) gave a preponderance of the corresponding 6-deoxy- and 6,7-dideoxy-L-*ido* derivatives (**2** and **3**). Oxidation of these alcohols with chromic acid gave the 5-keto derivatives **6** and **7** in high yield. The benzyl group of **6** was cleaved by catalytic hydrogenolysis, and acid-catalyzed hydrolysis of the isopropylidene group afforded the *delta*-dicarbonyl monosaccharide 6-deoxy-D-*xylo*-hexos-5-ulose (**10**). The same sequence applied to **7** gave 6,7-dideoxy-D-*xylo*-heptos-5-ulose (**11**). An alternative route to **8** consisted in reversing the order of the oxidation and hydrogenolysis steps, starting with **2** or its D-*gluco* isomer **4**. In this sequence, chromic acid was used for selectively oxidizing the 5- (rather than the 3-) hydroxyl group of the L-idofuranose and D-glucofuranose derivatives **12** and **13**.

INTRODUCTION

During the past decade, considerable progress has been made in elucidating the biosynthetic routes to cyclitols[2]. In many instances, a *delta*-dicarbonyl monosaccharide, or its biochemical equivalent, has been predicated as being the direct precursor of the cyclohexane ring system. The naturally occurring monodeoxycyclitols (cyclohexanepentols) may also arise in this way, and Kindl[3] suggested that 6-deoxy-D-*xylo*-hexos-5-ulose (**10**) may be generated along the pathway leading from D-glucose to one such deoxycyclitol, namely, L-quercitol. In the present paper is presented a synthesis of the known sugar **10** and its next higher (previously unreported) homolog **11**. The unique characteristic of these syntheses is the highly successful application of the Jones reagent[4] for the generation of the ketonic carbonyl group.

**delta*-Dicarbonyl sugars. Part II. For Part I, see ref. 1.

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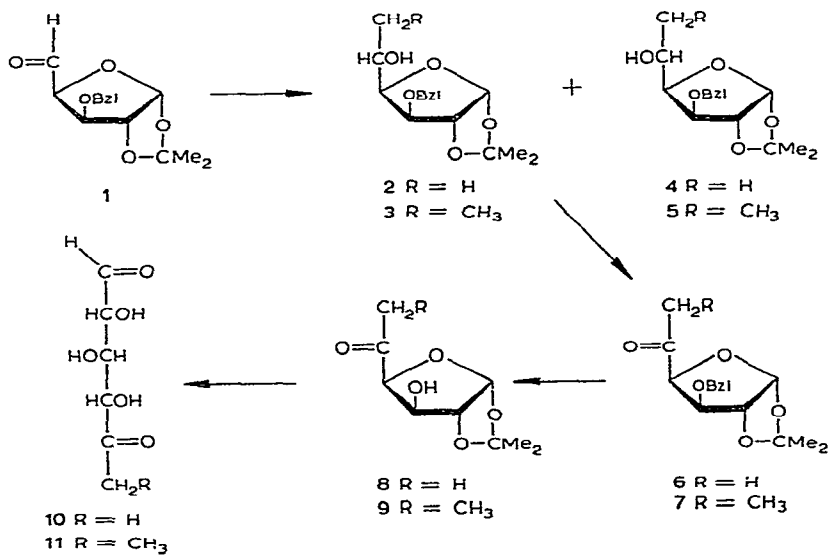
RESULTS

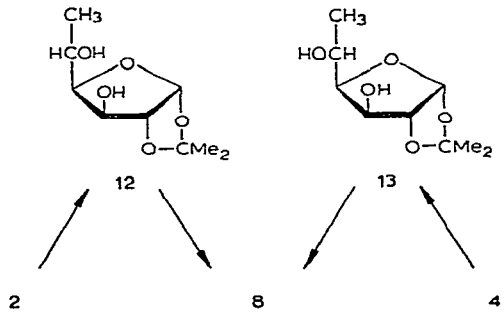
The addition of methylmagnesium iodide to 3-*O*-benzyl-1,2-*O*-isopropylidene-α-D-*xylo*-pentodialdo-1,4-furanose (**1**) gave a mixture of the diastereoisomeric L-*ido* (**2**) and D-*gluco* (**4**) alcohols (**2**:**4** = 2.3:1) which were separated by column chromatography on silica gel. In contrast, Inch reported[5] that this reaction gives a significantly smaller proportion of the D-*gluco* isomer (**2**:**4** = 7.5:1). The oxidation of **2** with chromic acid in acetone (the Jones reagent) at −5 to 0° was complete after 4 h, and gave the ketone **6** (97%) as the only organic product. The conversion of **2** into **6** was also accomplished with the chromic anhydride–pyridine complex[6] by employing a procedure patterned after ones reported earlier[7,8]. The reaction mixture, composed of the complex and **2** in dry pyridine, was stirred for five days at room temperature, and the pure ketone **6** was obtained in 43% yield after purification by column chromatography. Oxidation of **2** with methyl sulfoxide–acetic anhydride[9] at room temperature for two days produced a mixture from which the ketone **6** was also isolated. Although this material was chromatographically homogeneous, it still retained a strong odor of sulfide.

The benzyl group of **6** was readily removed by catalytic hydrogenolysis over freshly prepared palladium black to give **8**, and the hydrolysis of **8**, catalyzed by a cation-exchange resin (H^+), was complete after 24 h. Analysis of the syrupy product by t.l.c. on microcrystalline cellulose showed it to be a mixture of a major (R_F 0.63) and a minor (R_F 0.47) component. [Although attempts to crystallize this product were fruitless, it has been reported[10,11] that **10** is a crystalline compound, m.p. 125–126°.] Reacetonation of the mixture gave **8**, identified by comparison with authentic material, indicating that one of the products from the hydrolysis of **8** was



10. The hydrolysis of the ketone **9**, whose synthesis will be described, showed, in t.l.c. on microcrystalline cellulose, a profile similar to that resulting from the hydrolysis of **8**, namely, a major component (R_F 0.74) and a minor component (R_F 0.31). In this case, the proportion of the minor component was negligible, and reacetonation of the mixture regenerated the original ketone **9**. Therefore, the major hydrolysis product of **9** must be the free sugar **11**, and, by analogy, the major hydrolysis product of **8** must be **10**.

An alternative route to **8** was established by first removing the benzyl group of **2** or **4** by catalytic hydrogenolysis, and then selectively oxidizing the 5-hydroxyl group of **12** or **13**, respectively, with chromic acid in acetone. The precedent for this selective oxidation was formation of the D-*gluco* isomer (**4**) by use of the chromic anhydride–pyridine complex[8]. The product **8**, obtained from either **12** or **13**, was best purified by column chromatography in order to free it from a small proportion of an as-yet-unidentified, faster-moving component. This synthesis of **8**, although



successful, is not preferred over the first route described, because the crude product resulting from the selective oxidation of either **12** or **13** required column-chromatographic purification and was obtained in only moderate yield (70%). This yield, as compared to the 97% yield in the oxidation of **2** to **6**, is accounted for by the significant partitioning of **8** in the water layer during the ether-extraction step in the processing of the oxidation product.

Treatment of the aldehyde **1** with ethylmagnesium bromide gave a mixture of the major L-*ido* alcohol (**3**) and the minor D-*gluco* alcohol (**5**); these were efficiently separated by column chromatography. The ratio of isolated **3** to **5** was 3.3:1, as compared to 2.3:1 for **2** to **4**, and this indicates that the ethyl Grignard reagent in ether is more stereoselective in its addition to the aldehyde carbonyl group than is the methyl Grignard reagent. These configurational assignments are rationalized on the basis that the addition of a Grignard reagent to a 1,2-*O*-isopropylidene-α-D-*xylo*-pentodialdose derivative gives a preponderance of the L-*ido* isomer[5,12,13]. It is also noteworthy that both of the L-*ido* alcohols (**2** and **3**) are crystalline materials, whereas the D-*gluco* alcohols (**4** and **5**) are syrups. Furthermore, in all t.l.c. systems we employed, the D-*gluco* isomer moved significantly faster than the diastereoisomeric L-*ido* isomer.

The oxidation of **3** with chromic acid in acetone gave an almost quantitative yield (98%) of the ketone **7**, which had an n.m.r. spectrum characteristic of a compound bearing an isolated ethyl group. Catalytic hydrogenolysis of **7** over freshly prepared palladium black gave the debenzylated ketone **9** (97%).

DISCUSSION

The method most generally applied for the synthesis of 6-deoxyhexos-5-uloses has been by way of the acid-catalyzed hydrolysis of suitably protected 6-deoxyhex-5-enoses, *i.e.*, "5,6-glycals". The title compound **10** was prepared by procedures routed through both a furanoid[8] and a pyranoid 5,6-glycal[10,11], and, recently, 6-deoxy-D-*arabino*-hexofuranos-5-ulose, the sugar component[14] of the antibiotic Hygromycin A, was derived from methyl 2,3,4-tri-*O*-benzoyl-6-deoxy-α-D-*arabino*-hex-5-enopyranoside[15].

An alternative approach to the preparation of this class of compound requires oxidation of the 5-hydroxyl group of an appropriately protected furanoside to a ketone, followed by removal of the protecting groups. This approach has proved successful not only in the 6-deoxy series[5,7,13] but also in the preparation of D-*xylo*-hexos-5-ulose[16] and its corresponding 6-phosphoric ester[17]. Methyl sulfoxide–acetic anhydride was used for the formation of the keto function in the latter two compounds, and the chromic anhydride–pyridine complex was applied to the preparation of **10**. The addition of a methyl and phenyl (and, now, an ethyl) Grignard reagent to the aldehyde **1** suggests general applicability of the chain-extension step and emphasizes the versatility of the sequence. An additional advantage of this general sequence consists in the high yields and in the overall convenience in use of the chromic acid–acetone reagent for the oxidation of the 5-hydroxyl group.

EXPERIMENTAL

General methods. — Melting points were obtained with a Fisher–Johns melting-point apparatus and are uncorrected. Thin-layer chromatography (t.l.c.) of derivatized sugars was conducted on Silica Gel GF-254 (E. Merck, Darmstadt), and the components were visibilized by spraying with 20% sulfuric acid. Free sugars were detected on 250-μm, t.l.c. plates precoated with microcrystalline cellulose (Analtech, Inc., Newark, Delaware) by heating at 100° after spraying with an ammoniacal solution of silver nitrate[18]. Chromatographic solvent-systems employed are given as volume to volume ratios. Silica gel (0.05–0.2 mm; E. Merck) was used for all column-chromatographic separations. Optical rotations were measured with a Perkin–Elmer Model 141 Polarimeter at 20°, and i.r. spectra were recorded with a Perkin–Elmer Model 337 Grating Infrared Spectrophotometer. Proton magnetic resonance spectra were recorded with a Varian Model HA 60-IL n.m.r. spectrometer in solutions of chloroform-*d*, tetramethylsilane serving as the internal standard.

3-O-Benzyl-6-deoxy-1,2-O-isopropylidene-β-L-idofuranose (**2**) and *3-O-benzyl-6-deoxy-1,2-O-isopropylidene-α-D-glucofuranose* (**4**). — A solution of the aldehyde

1 (6.1 g) in anhydrous ethyl ether (70 ml) was added dropwise to an ether solution of methylmagnesium iodide which had been prepared by the addition of methyl iodide (7.5 ml) to a mixture of magnesium turnings (3.75 g) and anhydrous ethyl ether (100 ml). Following the procedure of Inch[5], the reaction mixture was refluxed for 1 h, and then processed to give a partly crystalline mass (5.9 g). This material was washed with several portions of ethyl ether, and the resulting white, crystalline **2** (1.43 g, m.p. 93–95°), separated from the washings by filtration, was seen by t.l.c. (7:3 benzene–ether) to be contaminated with a trace of the faster-moving D-*gluco* isomer **4**. Recrystallization from ether–hexane gave chromatographically pure **2**; m.p. 94–96°, $[\alpha]_D^{20}$ −63.8° (*c* 2.11, chloroform) {lit.[12] m.p. 93–94°, $[\alpha]_D^{25}$ −63.5° (*c* 1.3, chloroform); lit.[5] m.p. 97–98°, $[\alpha]_D^{23}$ −63° (*c* 1.3, chloroform)}, ν_{max}^{neat} 3450 cm^{-1} (OH); n.m.r. signals at δ 1.13 (d, $J_{5,6}$ 6.0 Hz, H-6), 1.33 and 1.50 [each s, $(CH_3)_2C$], 2.64 (s, OH), 3.94 (m; H-3, H-4, and H-5), 4.63 (d, $J_{1,2}$ 4.0 Hz, H-2), 4.43 and 4.70 (each d, J_{gem} 12 Hz, OCH_2)**, 6.0 (d, $J_{1,2}$ 4.0 Hz, H-1), and 7.33 (s, aromatic).

The ether washings were evaporated *in vacuo* to give a syrup which was chromatographed on a column of silica gel with 4:1 benzene–ether as the eluant. The chromatographic separation gave additional **2** (1.65 g, m.p. 95–97°); total yield 3.08 g (48%). The faster-migrating **4** was obtained as a syrup (1.32 g, 20%), $[\alpha]_D^{20}$ −64.3° (*c* 1.30, chloroform) {lit.[5] $[\alpha]_D^{23}$ −64° (*c* 4.2, chloroform)}, ν_{max}^{neat} 3450 cm^{-1} (OH); n.m.r. signals at δ 1.20 [d partially under the 1.33 $(CH_3)_2C$ signal, $J_{5,6}$ 6.0 Hz, H-6], 1.33 and 1.50 [each s, $(CH_3)_2C$], 2.24 (s, OH), 4.05 (m; H-3, H-4, and H-5), 4.53 and 4.73 (each d, J_{gem} 11.0 Hz, OCH_2), 4.65 (d, $J_{1,2}$ 4.0 Hz, H-2), 5.96 (d, $J_{1,2}$ 4.0 Hz, H-1), and 7.33 (s, aromatic).

*3-O-Benzyl-6,7-dideoxy-1,2-O-isopropylidene-β-*L-ido-*heptofuranose* (**3**) and *3-O-benzyl-6,7-dideoxy-1,2-O-isopropylidene-α-*D-gluco-*heptofuranose* (**5**). — A solution of the aldehyde **1** (6.6 g) in anhydrous ethyl ether (70 ml) was added slowly to an ether solution of ethylmagnesium bromide prepared by the dropwise addition of ethyl bromide (15 ml) to a mixture of magnesium turnings (3.9 g) and anhydrous ethyl ether (100 ml). The reaction mixture was refluxed for 1.5 h and then added, with stirring, to a cold, aqueous solution of ammonium chloride (25%, 70 ml). The resulting bilayer was diluted with ethyl ether (125 ml), and the organic layer was then separated, washed with additional aqueous ammonium chloride solution (25%, 50 ml), dried (magnesium sulfate), and evaporated *in vacuo* to a partly solid mass (6.6 g). T.l.c. with 4:1 benzene–ether showed a major, slower-moving component (**3**) and a minor, faster-moving component (**5**). The mixture was applied to a column of silica gel (200 g), and the components were eluted with 4:1 benzene–ether. The D-*gluco* isomer (**5**) was obtained as a clear, colorless syrup (0.95 g, 13%), $[\alpha]_D^{20}$ −40.2° (*c* 1.03, chloroform); ν_{max}^{neat} 3430 cm^{-1} (OH); n.m.r. signals at δ 1.00 (t, $J_{6,7}$ 6.5 Hz, H-7), 1.34 and 1.50 [each s, $(CH_3)_2C$ over the H-6 m], 2.17 (s, OH), 4.0 (m, three protons), 4.53 and 4.73 (each d, J_{gem} 12.0 Hz, OCH_2), 4.63 (partially obscured d, one furanose-ring proton), 5.97 (d, $J_{1,2}$ 4.0 Hz, H-1), and 7.30 (s, aromatic).

**The chemical shifts for the protons of this AB system have been calculated.

Anal. Calc. for $C_{17}H_{24}O_5$ (308.4): C, 66.21; H, 7.84. Found: C, 65.94; H, 7.77.

The L-*ido* isomer (**3**), obtained as white crystals (3.1 g, 43%, m.p. 71–72°), was purified by recrystallization from hexane; m.p. 73–74° and $[\alpha]_D^{20}$ −64.6° (*c* 1.04, chloroform); ν_{max}^{KBr} 3430 cm^{-1} (OH); n.m.r. signals at δ 1.00 (t, $J_{6,7}$ 6.5 Hz, H-7), 1.34 and 1.50 [each s, $(CH_3)_2C$ over the H-6 m], 2.95 (s, OH), 3.95 (m, three protons), 4.43 and 4.68 (each d, J_{gem} 12.0 Hz, OCH_2), 4.65 (d, J 3.0 Hz, one furanose-ring proton), 5.97 (d, $J_{1,2}$ 4.0 Hz, H-1), and 7.36 (s, aromatic).

Anal. Calc. for $C_{17}H_{24}O_5$ (308.4): C, 66.21; H, 7.84. Found: C, 66.18; H, 7.72.

*3-O-Benzyl-6-deoxy-1,2-O-isopropylidene-α-*D-xylo-*hexofuranos-5-ulose* (**6**). — *A. Oxidation of* **2** *with methyl sulfoxide–acetic anhydride.* To a solution of compound **2** (2.6 g) in methyl sulfoxide (12.5 ml) was added a mixture of acetic anhydride (5.0 ml) and methyl sulfoxide (17.5 ml). The reaction mixture was kept for 48 h in the dark at room temperature. T.l.c. with 3:1 benzene–ether then revealed that **2** had been converted into a mixture of the major, faster-moving product (**6**) and an unidentified, minor product. The reaction mixture was poured into water (400 ml), and the resulting bilayer was stirred overnight. The mixture was kept for an additional two days without being stirred, and the aqueous layer was decanted from the partly solid residue, which was then dissolved in dichloromethane (200 ml). This solution was washed with two 50-ml portions of saturated aqueous sodium hydrogen carbonate, dried (magnesium sulfate), and evaporated *in vacuo* to a syrup which crystallized. The crude product (2.2 g), combined with similar material (1.3 g) from two smaller scale oxidations, was applied to a column of silica gel (210 g) which was eluted with 9:1 benzene–ether. Although chromatographically pure, the ketone **6** (0.70 g) obtained from the early fractions still retained a strong odor of sulfide; m.p. 55–56° (lit.[7] m.p. 55–56°); ν_{max}^{neat} 1710 cm^{-1} (C=O), but no OH band at 3400 cm^{-1}. Most of the material (2.0 g) eluted from the column was **6** heavily contaminated with the very closely following, unidentified component.

B. Oxidation of **2** *with chromic anhydride–pyridine.* A solution of **2** (1.5 g) in pyridine (10 ml) was added with stirring, in a nitrogen atmosphere, to the cooled (ice bath) organometallic complex, prepared under nitrogen by the addition of chromic anhydride (1.7 g) to pyridine (50 ml) at 0–5°. The mixture was stirred for five days at room temperature; the dark brown precipitate was removed by filtration, and the filtrate was evaporated *in vacuo* to afford a brown solid. The residue was suspended in water (50 ml), and the suspension was extracted with three 75-ml portions of ethyl ether. The extracts were combined, and evaporated *in vacuo* to a syrup, and the residual pyridine was removed by azeotropic, vacuum distillation with water. The tan-colored, syrupy product (0.98 g) was seen by t.l.c. with 3:1 benzene–ether to consist of the ketone **6** and a component that moved very slowly. Chromatographic purification of the mixture on a column of silica gel (50 g) with 9:1 benzene–ether gave pure **6** (0.65 g, 43%).

C. Oxidation of **2** *with the Jones reagent.* A solution of **2** (0.68 g) in acetone (25 ml) was cooled to −60° in a Dry ice–acetone bath. After the addition of an

aliquot (1.0 ml) of the Jones reagent, prepared by the method of Djerassi *et al.*[19], the reaction mixture was allowed to warm to −5 to 0° during 1 h. Additional Jones reagent (0.5 ml) was added, and the temperature of the mixture was maintained at −5 to 0° for 1–2 h; t.l.c. analysis with 3:1 benzene–ether then indicated complete conversion of **2** into a single product (**6**). The mixture was diluted with ethyl ether (150 ml), and washed with three 75-ml portions of water. The aqueous washings were combined, and extracted with ethyl ether (100 ml), and the organic extracts were combined, dried (magnesium sulfate), and evaporated *in vacuo* to give chromatographically pure, syrupy **6** (0.66 g, 97%) which crystallized when nucleated; m.p. 53–55° and $[\alpha]_D^{20}$ −87.7° (*c* 1.01, chloroform) {lit.[7] $[\alpha]_D^{25}$ −89° (*c* 1.5, chloroform)}; n.m.r. signals at δ 1.33 and 1.50 [each s, $(CH_3)_2C$], 2.24 (s, H-6), 4.28 (d, *J* 3.5, furanose-ring proton), 4.60 (m, OCH_2 and two furanose-ring protons), 6.10 (d, $J_{1,2}$ 3.5 Hz, H-1), and 7.32 (s, aromatic).

3-O-Benzyl-6,7-dideoxy-1,2-O-isopropylidene-α-D-xylo-heptofuranos-5-ulose (**7**) *by oxidation of* **3** *with the Jones reagent.* — A solution of compound **3** (0.63 g) in acetone (25 ml) was cooled to −60°, and an aliquot (1.0 ml) of the Jones reagent was added. The reaction was completed, and the mixture processed as described for the conversion of **2** into **6**. The ketone **7** was isolated as a chromatographically pure syrup (0.61 g, 98%), as shown by t.l.c. with 6:1 benzene–ether. Analytically pure **7** (0.55 g) was obtained by column chromatography on silica gel, with 9:1 benzene–ether as the eluant; $[\alpha]_D^{20}$ −43.4° (*c* 0.90, chloroform); ν_{max}^{neat} 1710 cm^{-1}; n.m.r. signals at δ 1.00 (t, $J_{6,7}$ 7.0 Hz, H-7), 1.34 and 1.50 [each s, $(CH_3)_2C$]; 2.62 (q, $J_{6,7}$ 7.0 Hz, H-6), 4.28 and 4.68 (each d, *J* 3.5 Hz, two furanose-ring protons), 4.55 (m, OCH_2 and one furanose-ring proton), 6.08 (d, $J_{1,2}$ 3.5 Hz, H-1), and 7.30 (s, aromatic).

Anal. Calc. for $C_{17}H_{22}O_5$ (306.4): C, 66.65; H, 7.24. Found: C, 66.49; H, 7.50.

6-Deoxy-1,2-O-isopropylidene-β-L-idofuranose (**12**), by *hydrogenolysis of* **2**. — A solution of **2** (1.65 g) in ethanol (40 ml) was vigorously stirred for 3 h in a hydrogen atmosphere with freshly prepared, ethanol-washed, palladium black (0.70 g) generated from palladium chloride (Engelhard Industries, Inc., Newark, N.J.). The solution was decanted from the catalyst under a stream of nitrogen, and the catalyst was washed with ethanol. The ethanol solution and washings were combined, and evaporated *in vacuo* to give **12**, isolated as white crystals (1.11 g, 92%; m.p. 82–84°), that gave a single spot on a t.l.c. plate with 1:1 benzene–ether. (Wolfrom and Hanessian[12] conducted the hydrogenolysis with hydrogen at 300 lb. $in.^{-2}$ over palladium-on-charcoal in 4 h at 65–68°; they noted that the reaction failed with this catalyst at room temperature and 28 lb. $in.^{-2}$ during 24 h.) Recrystallization of the product from carbon tetrachloride raised the melting point to 84–86°; $[\alpha]_D^{20}$ −12.4° (*c* 2.42, chloroform) {lit.[20] m.p. 90–92°, $[\alpha]_D^{25}$ −7.1° (*c* 2.2, chloroform); lit.[21] m.p. 90–91°, $[\alpha]_D^{21}$ −12.9° (*c* 3.6, chloroform); lit.[12] m.p. 88–89°, $[\alpha]_D^{25}$ −7.0° (*c* 3.4, chloroform)}; ν_{max}^{neat} 3400 cm^{-1} (OH); n.m.r. signals at 1.34 (d, $J_{5,6}$ 6.0 Hz, H-6), 1.33 and 1.50 [each s, $(CH_3)_2C$], 3.75 (s, OH), 4.00 and 4.23 (each d, $J_{3,4}$ 3.0 Hz, H-4 and H-3), 4.00–4.25 (m, H-5 under the H-3 and H-4 signals), and 4.53 and 6.0 (each d, $J_{1,2}$ 4.0 Hz, H-2 and H-1).

6-Deoxy-1,2-O-isopropylidene-α-D-glucofuranose (**13**), *by hydrogenolysis of* **4**. — The benzyl group of compound **4** (1.74 g) was cleaved by catalytic hydrogenolysis as described for the preparation of **12**. Crude crystalline **13** (1.03 g, 82%; m.p. 68–75°) was obtained directly from the reaction mixture. Chromatography of the crude product on a column of silica gel eluted with ethyl ether gave pure **13**, m.p. 90–91° and $[\alpha]_D^{20}$ −24.2° (*c* 1.53, chloroform) {lit.[8] m.p. 87–89°, lit.[21] m.p. 90–92°, $[\alpha]_D^{22}$ −25.3° (*c* 2.06, chloroform)}; ν_{max}^{neat} 3400 cm^{-1} (OH); n.m.r. signals at δ 1.33 and 1.50 [each s, $(CH_3)_2C$], 1.36 (d, $J_{5,6}$ 6.0 Hz, H-6), 3.50 (s, OH), 3.94 and 4.33 (each d, $J_{3,4}$ 3.0 Hz, H-4 and H-3), 4.50 and 5.95 (each d, $J_{1,2}$ 4.0 Hz, H-2 and H-1), and 3.90–4.25 (m, H-5, under the H-3 and H-4 signals).

6-Deoxy-1,2-O-isopropylidene-α-D-xylo-hexofuranos-5-ulose (**8**) *by catalytic hydrogenolysis of* **6**. — A sample of compound **6** (0.66 g) in ethanol (30 ml) was converted into **8** in 16 h by catalytic hydrogenolysis over the palladium black from palladium chloride (0.80 g). The crude product (0.47 g, 97%), which appeared as a homogeneous material by t.l.c. with 1:1 benzene–ether, was recrystallized from benzene–hexane to give **8** as hard, white rosettes, m.p. 97–98° (after sublimation above 85°) and $[\alpha]_D^{20}$ −107° (*c* 0.69, chloroform); {lit.[8] m.p. 96–97° and $[\alpha]_D^{16}$ −104° (*c* 0.75, chloroform); lit.[11] m.p. 99–100°, $[\alpha]_D^{18}$ −107° (*c* 4.0, chloroform); lit.[13] m.p. 98–99° and $[\alpha]_D$ −102° (*c* 1.2, chloroform)}; ν_{max}^{KBr} 3450 (OH) and 1720 cm^{-1} (C=O); n.m.r. signals at δ 1.33 and 1.50 [each s, $(CH_3)_2C$], 2.30 (s, H-6), 2.95 (s, OH), 4.60 (m, three furanose-ring protons), and 6.09 (d, $J_{1,2}$ 3.5 Hz, H-1).

Oxidation of **13** *with the Jones reagent*. — A solution of compound **13** (0.43 g) in acetone (25 ml) at −60° was treated with the Jones reagent (1.0 ml), and the mixture was kept for 3 h at −5 to 0°. The crude product, consisting of **8** and a very minor, faster-moving component, was purified by column chromatography on silica gel with 1:1 benzene–ether to give the ketone **8**, indistinguishable from authentic material.

Oxidation of **12** *with the Jones reagent*. — Compound **12** (0.35 g) was converted into the ketone **8** (0.25 g, 70%) by means of the Jones reagent. A fast-moving, minor product (~5–10%) was indistinguishable by t.l.c. (with 1:2 benzene–ether) from the minor product formed in the oxidation of the D-*gluco* isomer **13**. Final purification was accomplished by column chromatography on silica gel with 1:1 benzene–ether.

6,7-Dideoxy-1,2-O-isopropylidene-α-D-xylo-heptofuranos-5-ulose (**9**) *by hydrogenolysis of* **7**. — The catalytic hydrogenolysis of **7** (0.63 g) in ethanol (10 ml) over freshly prepared palladium black (from 0.50 g of palladium chloride) was complete in 2 h. The debenzylated ketone (**9**) was obtained as a chromatographically homogeneous syrup (0.43 g, 97%) which crystallized after being kept for two days at room temperature. Recrystallization from ether–hexane gave analytically pure **9**, m.p. 85–86° and $[\alpha]_D^{20}$ −79.0° (*c* 0.74, chloroform), ν_{max}^{neat} 3400 (OH) and 1710 cm^{-1} (C=O); n.m.r. signals at δ 1.03 (t, $J_{6,7}$ 7.0 Hz, H-7), 1.33 and 1.50 [each s, $(CH_3)_2C$], 2.67 (q, $J_{6,7}$ 7.0 Hz, H-6), 3.03 (s, OH), 4.58 (m; H-2, H-3, and H-4), and 6.05 (s, $J_{1,2}$ 3.5 Hz, H-1).

Anal. Calc. for $C_{10}H_{16}O_5$ (216.2): C, 55.55; H, 7.46. Found: C, 55.66; H, 7.52.

6-Deoxy-D-xylo-*hexos-5-ulose* (**10**) *by acid-catalyzed hydrolysis of 6-deoxy-1,2-O-isopropylidene-α*-D-xylo-*hexofuranos-5-ulose* (**8**). — A solution of **8** (0.09 g) in water (3 ml) was kept for 24 h at 45–50°, without stirring, in the presence of AG 50W-X2 (H^+) (200–400 mesh) resin (1.3 ml) (Bio-Rad Laboratories, Richmond, California). Chromatography of a sample of the solution on t.l.c. plates of microcrystalline cellulose with ethyl acetate–pyridine–water (2:1:2, upper phase[22]) revealed the presence of the major component **10** (R_F 0.63) and an unidentified, streaking, minor component (R_F 0.47). The resin was removed by filtration, and the filtrate was freeze-dried to give a yellow syrup, $[\alpha]_D^{20}$ −20.2° (*c* 0.93, water) {lit.[11] m.p. 125–126°, $[\alpha]_D^{20}$ −34° (*c* 10, water)}. Reacetonation of **10** was accomplished by stirring a solution of crude, syrupy product in acetone (10 ml) containing a trace of sulfuric acid in the presence of anhydrous copper(II) sulfate (0.10 g) for 48 h; the sulfuric acid in the reaction mixture consisted of one drop of a solution of 0.1 ml of conc. sulfuric acid in 10 ml of acetone. The solid was then removed by filtration, and the filtrate was made neutral with Dowex 1-X (OH^-) (20–50 mesh) resin (1.5 ml) (Bio-Rad Laboratories). The major product was indistinguishable by t.l.c. (1:1 benzene–ether) from authentic **8**. The solvent was evaporated, and the residue was purified by column chromatography on silica gel, to give pure **8**, identical (mixed m.p., and i.r. spectrum) with authentic material.

6,7-Dideoxy-D-xylo-*heptos-5-ulose* (**11**) *by acid-catalyzed hydrolysis of 6,7-dideoxy-1,2-O-isopropylidene-α*-D-xylo-*heptofuranos-5-ulose* (**9**). — The procedure used for the preparation of **10** was employed for the removal of the isopropylidene group from **9** (0.10 g). T.l.c. on microcrystalline cellulose with ethyl acetate–pyridine–water (2:1:2, upper phase) showed that the reaction mixture consisted of a major component **11** (R_F 0.74) and a very minor, slower-moving component (R_F 0.31). The water was removed from the solution by freeze-drying, and the product was obtained as a light-yellow syrup, $[\alpha]_D^{20}$ −11.94° (*c* 0.72, water). Reacetonation of the syrupy product, followed by purification of the reaction mixture by column chromatography on silica gel, gave pure **9**, indistinguishable (mixed m.p., and i.r. spectrum) from authentic material.

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