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THE SYNTHESIS OF METHYL 6-DEOXY-2,3-*O*-ISOPROPYLIDENE-α-D-*ribo*-HEXOPYRANOSID-4-ULOSE

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ABSTRACT

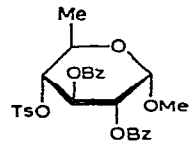
Methyl 6-deoxy-2,3-*O*-isopropylidene-α-D-hexopyranosides having the *gulo* (**6**) and the *allo* (**15**) structures have been synthesised from methyl 4,6-*O*-benzylidene-α-D-glucopyranoside, and each has been oxidised with ruthenium tetraoxide to give methyl 6-deoxy-2,3-*O*-isopropylidene-α-D-*ribo*-hexopyranosid-4-ulose (**16**). The two synthetic routes have been compared. Reduction of the 4-ulose **16** with sodium borohydride gives the alloside derivative **15**. 6-Deoxy-D-gulose gives the β-D-pyranose tetra-acetate (**9**) upon acetylation, and the 2,3-*O*-isopropylidene-β-D-furanose (**7**) upon acetonation.

INTRODUCTION

In order to extend our investigations into the photochemistry of pyranosid-4-uloses[1], it was necessary to synthesise methyl 6-deoxy-2,3-*O*-isopropylidene-α-D-*ribo*-hexopyranosid-4-ulose (**16**). This compound could be prepared by oxidation of methyl 6-deoxy-2,3-*O*-isopropylidene-α-D-hexopyranosides having either the *allo* or *gulo* structures. We have studied both synthetic routes, employing methyl 4,6-*O*-benzylidene-α-D-glucopyranoside as the starting material in each case.

RESULTS AND DISCUSSION

Guloside route. The 4,6-*O*-benzylidene derivative of methyl α-D-glucopyranoside was converted into its 2,3-di-*O*-benzoyl-6-deoxy-4-*O*-*p*-tolylsulphonyl derivative (**1**) by five conventional synthetic steps[2–4] in an overall yield of 42%. Treatment of the sulphonate **1** with base gave methyl 3,4-anhydro-6-deoxy-α-D-galactopyranoside[4] (**2**) which was readily converted into its 2-acetate (**3**) (48% from compound **1**). The key step in this synthesis is the acid-catalysed opening of the epoxide ring in compound **3**, in which the propensity of the neighbouring acetoxyl group to participate is exploited to direct the stereochemistry in the desired direction. Buchanan and his co-workers[3,5] have shown that the acetoxyl group in the 6-*O*-benzyl and 6-*O*-trityl derivatives of 2-*O*-acetyl-3,4-anhydro-α-D-galactopyranoside could be used to control their hydrolyses to give gulosides.



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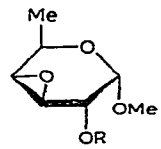

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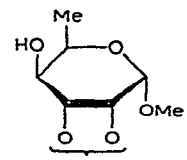

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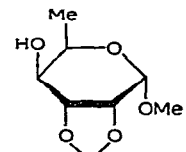

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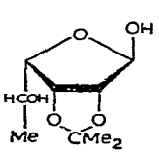
Treatment of the 6-deoxy analogue (3) with aqueous acetic acid at 100° afforded, within 30 min, ring-opened products comprising approximately nine parts of the guloside acetate(s) **4** and one part the gulose acetate(s). The composition of this mixture was determined by g.l.c. and by n.m.r. spectroscopic analysis on the per-acetate mixture obtained after the epoxide-cleavage products had been completely acetylated. For this determination, an authentic sample of 6-deoxygulose tetra-acetate was prepared from a small portion of the guloside–gulose acetate mixture, by sequential acid-catalysed hydrolysis and acetylation.

The crystalline 1,2,3,4-tetra-*O*-acetyl-6-deoxy-β-D-gulopyranose[6] (**9**) so obtained was readily characterised from its elemental analysis, mass-spectral molecular weight, and n.m.r. spectrum, which did not exhibit an aglycon methyl signal, but showed signals for four OAc groups, a C-5 methyl group, and five ring protons that could all be assigned. The β-D-*gulo* structure was established from the couplings of the ring protons, which were $J_{1,2}$ 8.5, $J_{2,3}$ 3.2, $J_{3,4}$ 3.5, and $J_{4,5}$ 1.5 Hz, and these compare in the expected way with those of the 6-deoxy-α-D-gulopyranoside triacetate (**8**) ($J_{1,2}$ 4.0, $J_{2,3}$ 4.0, $J_{3,4}$ 4.0, $J_{4,5}$ 1.7 Hz). Furthermore, the splitting of the signal for the anomeric proton is very close to the $J_{1,2}$ value of 8.3 Hz reported by Lemieux and Stevens[7] for β-D-gulose penta-acetate, and the optical rotation values are also similar (+2.4° for β-D-gulose penta-acetate and +11° for the 6-deoxy analogue **9**; *cf.* +87° for α-D-gulose penta-acetate[8]).



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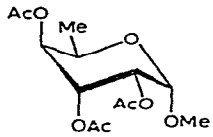

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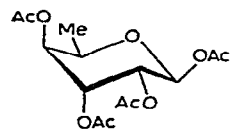

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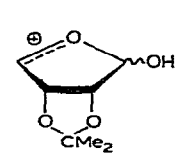

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Since the 6-deoxyguloside monoacetate(s) (**4**) were only slightly contaminated with the gulose derivative, this impure mono-acetate mixture was used for the next stage of the synthesis. The ester grouping was removed with sodium methoxide, and the crude product **5** was treated with acetone and phosphorus pentaoxide[9]. Two compounds, present in the ratio of 2:1, were isolated from the product mixture by column chromatography. The major component (R_F 0.5) was the desired compound, methyl 6-deoxy-2,3-*O*-isopropylidene-α-D-gulopyranoside (**6**). Its n.m.r. spectrum showed H-1 as a doublet ($J_{1,2}$ 4.0 Hz), signals for four other ring protons which could

not be analysed (in the 60-MHz spectrum) by first-order means, and the C-5 methyl group as a high-field doublet (J 7.0 Hz). The isopropylidene and aglycon methyl groups gave sharp singlets at the expected chemical shifts and the hydroxyl-proton signal was established by exchange with D_2O; this assignment was confirmed by the i.r. band at 3500 cm^{-1}. The mass spectrum contained a peak at *m/e* 203 for the $(M^+ - Me)$ ion, which is typical of an isopropylidene derivative[10], and several other fragment ions which were consistent with the proposed structure.

The minor component *X* (R_F 0.3) was shown not to be a methyl glycoside by its n.m.r. spectrum, which clearly indicated that it was a 6-deoxy-dihydroxy-*O*-isopropylidene derivative. All the other signals in the spectrum were well resolved and could be analysed by first-order methods. Compound *X* was assigned the 6-deoxy-*gulo* structure because it could be prepared by acetonating 6-deoxygulose; furthermore, acetylation of a hydrolysed specimen of *X* gave 6-deoxygulose tetra-acetate (**9**). The points of attachment of the isopropylidene unit were shown to be at O-2 and O-3 of the sugar ring, because the compound exhibited reducing properties with ammoniacal silver nitrate.

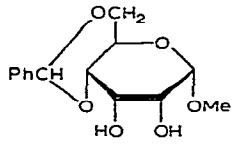
A compound satisfying these requirements could be either 6-deoxy-2,3-*O*-isopropylidene-β-D-gulofuranose (**7**) or its pyranoid form. The former appears more likely since the mass spectrum of *X* exhibited a substantial peak at *m/e* 159, corresponding to the ion **10** which is diagnostic of a furanoid derivative[10] (for example, a similar peak was found in the mass spectrum of 6-deoxy-1,2-*O*-isopropylidene-α-D-glucofuranose). A peak of low intensity at *m/e* 187, due to the $(M^+ - OH)$ ion, was also present. This type of ion has been observed[11,12] in the mass spectrum of other furanose derivatives that were unprotected at C-1.

A furanose structure for compound *X* was further indicated by the unsplit signal for the anomeric proton seen in its n.m.r. spectrum ($CDCl_3$). A similar signal ($J_{1,2}$ <0.5 Hz) was shown by 2,3:5,6-di-*O*-isopropylidene-β-D-allofuranose which is locked as a furanose derivative[11].

Equilibrium between furanoid and pyranoid forms has been studied[13,14] for a system closely related to *X*, namely, 6-deoxy-2,3-*O*-isopropylidene-L-mannose, which has been shown by Angyal *et al.*[14] to exist preferentially (65%) in the furanoid form. Similar methods of estimation indicated that there was less than 10% of the 6-deoxy-gulopyranose derivative present in the sample of *X*. Smaller amounts of the pyranoid form would be expected at equilibrium with the 6-deoxygulose derivative than was found in the 6-deoxymannose derivative, because it is known[15] that the gulopyranose structure is less favoured than the mannopyranose structure.

Alloside route. Methyl 4,6-*O*-benzylidene-α-D-allopyranoside (**11**) was prepared from the analogous *gluco* derivative in four conventional synthetic steps[16] in 51% overall yield. Treatment[17] of the allopyranoside **11** with *N*-bromosuccinimide gave mainly the 6-bromo-4-benzoate **12** which was reduced (without prior purification) with Raney nickel to the 6-deoxy-4-benzoate **13**. This compound was not isolated but directly treated with acetone and phosphorus pentaoxide[9] to give, after column chromatography, a crystalline compound in 31% overall yield. This had an elemental

analysis and i.r. and n.m.r. spectral data consistent with the expected methyl 4-*O*-benzoyl-6-deoxy-2,3-*O*-isopropylidene-α-D-allopyranoside (**14**) structure. In particular the n.m.r. spectrum had resonances for a phenyl group, four methyl groups [two singlets from those in the isopropylidene group, one singlet from the aglycon methyl, and one doublet (*J* 6.3 Hz) from the C-5 methyl], and five ring protons. The coupling constants ($J_{1,2}$ 5.2, $J_{2,3}$ 5.2, $J_{3,4}$ 4.5, and $J_{4,5}$ 10.2 Hz) corroborated the α-D-allopyrano configuration proposed, and the low-field chemical shift of H-4 clearly indicated that the compound was a 4-benzoate. This material was debenzoylated to give (94%) methyl 6-deoxy-2,3-*O*-isopropylidene-α-D-allopyranoside (**15**), which was oxidised without purification.



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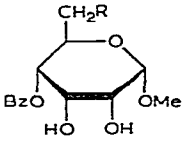

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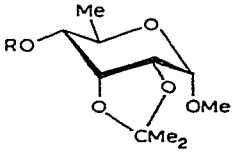
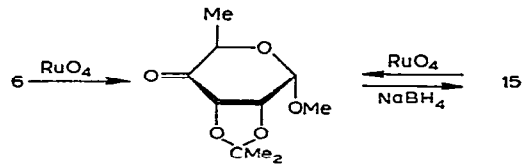


14 R = Bz
15 R = H

Oxidation. The methyl 6-deoxy-2,3-*O*-isopropylidenehexopyranosides having the *gulo* and *allo* configurations (**6** and **15**) were oxidised with ruthenium tetraoxide[18] to give the same pyranosidulose (**16**) in very similar yields (~80%). The elemental analysis and mass-spectral molecular weight of the product were correct for the proposed compound and the absorptions at ν_{max} 1740 cm^{-1} and λ_{max} 285 nm (ε 240) were typical for a ketone carbonyl group in this class of compounds. The n.m.r. spectrum exhibited the expected resonances (three singlets and one doublet) for four Me groups and four ring protons. The couplings, $J_{1,2}$ 3.8, $J_{2,3}$ 9.0, and $J_{3,5}$ 1.2 Hz, were compatible with the α-D-*ribo*-hexopyrano structure **16**, although $J_{2,3}$ was larger than the coupling usually found between *cis*-vicinal hydrogen atoms situated at the junction of the two ring systems present in compound **16**. The formation of one 4-ulose from the C-4 epimeric glycoside derivatives also supports, but does not prove, the proposed structure (**16**), since isomerisation at the carbon atoms adjacent to the carbonyl group could have occurred. The C-5 position would be the more susceptible to epimerisation, but this possibility can be rejected since authentic methyl 6-deoxy-2,3-*O*-isopropylidene-β-L-*lyxo*-hexopyranosid-4-ulose is known[19]. Epimerisation at C-3 would be less favourable on steric grounds since it requires *trans*-fusion between the two rings; however, in the present case, it required consideration because the value of $J_{2,3}$ was unusually large. This possibility was excluded when reduction of the pyranosid-4-ulose **16** with sodium borohydride gave the 6-deoxyalloside derivative **15**. Therefore, the observed value of $J_{2,3}$ must indicate that the dihedral angle between H-2 and H-3 is small[21], and consequently the compound probably adopts a conformation close to the $^0S_4$ form[22] (**17**) rather than the $^4C_1$ form. These oxidations support our previous claim[20] that, unlike other oxidants in current use, ruthenium tetraoxide does not cause ketones to isomerise.



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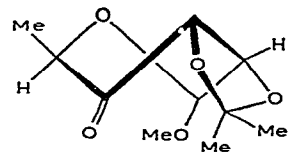

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Hydride reduction of ulose **16** should be stereoselective since the lower face of the pyranoid ring (see **17**) is sterically crowded, whereas the upper face is not[23]. This would prevent formation of the guloside derivative **6** and lead to the alloside derivative **15** as the preponderant product.

Some comparisons can be made between the two methods of preparing the pyranosid-4-ulose **16**. In our hands, the nine-stage synthesis *via* the alloside gave an overall yield of ~12%, which was greater than that obtained *via* the eleven-stage guloside route. The overall yield could not be determined accurately for the latter method, because the isolated yield in the conversion **5**→**6** was not determined. However, analytical measurements made at this stage of the multi-step synthesis gave 10% as the upper limit and 2% as the lower limit over the whole synthesis. The weak stage in the 6-deoxyguloside route was the isopropylidenation of compound **5**. It is possible that, with further study, the efficiency of this reaction could be improved and the side reaction, in which **7** was formed by loss of the C-1 methoxyl group, eliminated.

EXPERIMENTAL

U.v. spectra were measured for ethanolic solutions with a Perkin–Elmer Spectrophotometer model 402. I.r. spectra were measured for solids dispersed in potassium bromide or for gums smeared on sodium chloride discs with a Perkin–Elmer Infracord model 137. N.m.r. spectra were measured on Varian A60D, Varian HA220, or Jeol JMN-MH-100 instruments, and mass spectra were measured on an AEI MS9 instrument. Optical rotation determinations were made with a Bellingham and Stanley polarimeter.

Silica Gel G (Merck) was used for t.l.c. with the following solvent systems: benzene–ethyl acetate (*A* 1:1, *D* 4:1, *E* 3:2), ethyl ether (*B*), and chloroform–methanol (9:1, *C*). For g.l.c., a Varian Aerograph model 202B instrument was employed with hydrogen carrier-gas and a thermal-conductivity detector, using columns *A* 20 ft or *B* 10 ft, packed with Chromosorb W 60–80 mesh impregnated with 15% SE52.

*Methyl 3,4-anhydro-6-deoxy-α-*D*-galactopyranoside* (**2**). — Methyl 2,3-di-*O*-benzoyl-6-deoxy-4-*O*-*p*-tolylsulphonyl-α-D-glucopyranoside (**1**, 87 g) in dichloromethane (500 ml) was treated with M methanolic sodium methoxide (200 ml) at 0° for 16 h, according to the method of Járy and Čapek[4]. This afforded a waxy, crystalline product which was purified by sublimation to give **2** (20 g, 78%), m.p. 64–66°; lit.[4] m.p. 66–67°. N.m.r. data: τ 5.35 (*d*, $J_{1,2}$ 5.0 Hz), 6.20 (*q*, $J_{2,3}$ 1.0 Hz), 6.90 (*q*, $J_{3,4}$ 4.0 Hz), 6.75 (*q*, $J_{4,5}$ 1.0 Hz), 5.90 (*o*, $J_{5,Me}$ 7.0 Hz), 8.70 (*d*, $J_{Me,5}$ 7.0 Hz), 3.40 broad (*s*, OH, exchangeable with D_2O).

Methyl 2-O-acetyl-3,4-anhydro-6-deoxy-α-D-galactopyranoside (**3**). — The anhydride **2** (13 g) was acetylated in the usual[4] way to give a solid which, after recrystallisation from light petroleum (b.p. 40–60°), gave **3** (10 g, 61%), m.p. 107–109°; lit.[4] m.p. 113–115°. N.m.r. data: τ 5.20 (*s*, 2*H*, H-1,2), 6.85 (*q*, $J_{3,2}$ 1.0 Hz), 6.75 (*q*, $J_{4,3}$ 4.0 Hz), 5.85 (*o*, $J_{5,4}$ 1.0 Hz), 8.65 (*d*, $J_{Me,5}$ 7.0 Hz), 6.55 (*s*, OMe), 7.85 (*s*, OAc).

Methyl 2(3)-O-acetyl-6-deoxy-α-D-gulopyranoside (**4**). — The anhydro-acetate **3** (10 g) was heated at 100° in 80% aqueous acetic acid for 30 min. The aqueous acid was distilled off under diminished pressure and final traces of water were removed as an azeotrope with a 1:1 mixture of ethyl acetate and benzene (200 ml) to give a crude, crystalline product (10.5 g, 95%).

A small portion (0.2 g) of this syrup was completely acetylated to give a product (0.3 g) which exhibited n.m.r. signals at τ 3.70 (*d*, $J_{1,2}$ 8.5 Hz) and 6.82 (*s*) (see below) assignable to the H-1 of gulose tetra-acetate (**9**) and the OMe grouping of the guloside triacetate (**8**), respectively, indicating the presence of these compounds in the ratio ~1:9.

The acid-catalysed epoxide opening was monitored. Four samples (10 mg) of anhydro-acetate **3** were heated with aqueous acetic acid at 100° for 0.25, 0.5, 0.75, and 1.0 h. G.l.c. (column *B*) at 160° showed that 88, 98, 100, and 100% of the epoxide (*T* 6.6 min) had reacted during these periods to give the acetate **4** (*T* 17.8 min). The four samples were evaporated to dryness and each was treated with acetic anhydride (100 μl) and pyridine (100 μl) for 16 h. G.l.c. (column *A* at 200°) of these acetates showed that the proportion of gulose tetra-acetate (**9**, *T* 11.0 min) compared with guloside triacetate (**8**, *T* 7.3 min) increased with reaction time, reaching ~10% after 1 h.

The syrupy mixture of acetates (**4**, 7 g) was deacetylated with sodium methoxide (0.2 g) in methanol (100 ml) during 16 h at 20° and then neutralised with Amberlite IR-120(H^+) resin. Evaporation of the solvent gave a syrup (5.4 g, 95%) which contained the guloside **5**.

Methyl 6-deoxy-2,3-O-isopropylidene-α-D-gulopyranoside (**6**). — The crude guloside **5** (5.4 g) was vigorously stirred in anhydrous acetone (500 ml) with phosphorus pentaoxide for 1 h at 20°. The usual work-up gave a syrup (6.0 g, 95%), comprising three components, R_F 0.7 (trace), 0.5 (major), and 0.3 (solvent *A*), only the least mobile of which was strongly reducing towards ammoniacal silver nitrate. G.l.c. of the mixture (column *A*) at 130° revealed that the last two compounds had *T* 20.0 and 23.0 min, with peak areas in the ratio of 2:1, respectively.

Separation of a portion of this crude material by column chromatography afforded the most-mobile material as an oil, the n.m.r. spectrum of which could not be analysed. The second fraction was methyl 6-deoxy-2,3-*O*-isopropylidene-α-D-gulopyranoside (**6**, 0.9 g), ν_{max} 3500 cm^{-1} (OH), N.m.r. data (C_6D_6): τ 5.40 (*d*, $J_{1,2}$ 4.0 Hz), 6.22 (*m*, H-2), 6.00–5.60 (*m*, H-3,4,5), 8.85 (*d*, $J_{Me,5}$ 7.0 Hz), 6.80 (*s*, OMe), 7.50 broad (*s*, OH exchangeable with D_2O), 8.37 and 8.69 (2 *s*, CMe_2). Mass-spectral data: *m/e* 203 (10%) [M^+ – Me], 187 (3) (M^+ – OMe], 143 (7) (M^+ – (Me, $MeCO_2H$)],

100 (100) $[Me_2COCH{:}CHO]^+$, 85 (53) $[OCH{:}CHOCMe]^+$, 71 (60), 59 (70), 43 (93). The final fraction (*X*) was the isopropylidenated 6-deoxyhexofuranose **7**, ν_{max} 3500 cm^{-1} (OH). N.m.r. data (C_6D_6–C_5D_5N, 9:1, 100 MHz): τ 4.27 (*s*, H-1), 5.24 (*d*, $J_{2,3}$ 6.0 Hz), 5.47 (*q*, $J_{3,4}$ 3.0 Hz), 5.81 (*q*, $J_{4,5}$ 8.0 Hz), 5.62 (*o*, $J_{5,Me}$ 6.0 Hz), 8.61 (*d*, Me), 4.70 broad (*s*, 2OH), 8.59 and 8.82 (2 *s*, CMe_2); H-5 becomes a doublet ($J_{4,5}$ 8.0 Hz) when τ 8.61 was irradiated[6]. Mass-spectral data: *m/e* 189 (22%) $[M^+ - Me]$, 187 (1) $[M^+ - OH]$, 159 (4) $[M^+ - HOCHCH_3]$, 129 (16) $[HO\overset{+}{C}HC{:}CHOCMe_2O]$, 101 (22) $[CH_2OCMe_2O\overset{+}{C}H]^+$, 100 (18), 73 (76), 71 (37), 60 (46) $[Ac\overset{+}{O}H]$, 59 (100) $[Me_2\overset{+}{C}OH]$, 58 (38) $[Me_2CO]^+$, 57 (31), 45 (37), 43 (100).

*Methyl 2,3,4-tri-*O*-acetyl-6-deoxy-α-*D*-gulopyranoside* (**8**). — The mixture of guloside acetates (**4**) was acetylated with acetic anhydride in pyridine. The crude product had an n.m.r. spectrum (C_6D_6) which could be assigned to the guloside triacetate **8**: τ 5.22 (*d*, $J_{1,2}$ 4.0 Hz), 4.60 (*t*, $J_{2,3}$ 4.0 Hz), 4.43 (*t*, $J_{3,4}$ 4.0 Hz), 4.90 (*q*, $J_{4,5}$ 1.7 Hz), 5.60 (*o*, $J_{5,Me}$ 6.7 Hz), 8.90 (*d*, Me), 6.82 (*s*, OMe), 8.17, 8.20, and 8.29 (3 *s*, 3OAc); a doublet at τ 3.70 indicated that tetra-acetate **9** (~10%) was present.

*1,2,3,4-Tetra-*O*-acetyl-6-deoxy-β-*D*-gulopyranose* (**9**). — The syrupy mixture of guloside acetates (**4**, 0.1 g) was heated in 90% aqueous methanol with Amberlite IR-120(H^+) resin for 2 h. The hydrolysed product was then acetylated with acetic anhydride in pyridine to give an oil which partially crystallised during eight weeks at 0°. The acetate **9** had m.p. 133–135°, $[\alpha]_D$ +11° (*c* 2, chloroform), ν_{max} 1750 cm^{-1} (CO); lit.[6] m.p. 137–139°, $[\alpha]_D$ +5.2°. N.m.r. data (C_6D_6): τ 3.70 (*d*, $J_{1,2}$ 8.5 Hz), 4.51 (*q*, $J_{2,3}$ 3.2 Hz), 4.27 (*t*, $J_{3,4}$ 3.5 Hz), 5.08 (*q*, $J_{4,5}$ 1.5 Hz), 5.91 (*o*, $J_{5,Me}$ 6.5 Hz), 8.95 (*d*, Me), 8.28 and 8.43 (2 *s*, 2OAc), 1.65 (*s*, 2OAc).

6-Deoxygulose tetra-acetate (**9**, 45 mg) was deacetylated with sodium methoxide in methanol and the crude 6-deoxygulose (22 mg) was dissolved in acetone and treated with phosphorus pentaoxide. The product obtained gave only one spot on t.l.c. (R_F 0.3, solvent *A*) identical with **7** prepared above, and it also showed similar reducing properties with silver nitrate.

*Methyl 4,6-*O*-benzylidene-α-*D*-allopyranoside* (**11**). — A solution of methyl 4,6-*O*-benzylidene-2-*O*-*p*-tolylsulphonyl-α-D-allopyranoside[16] (180 g) in methanol (6 l) containing sodium methoxide (22 g) was photolysed in ten equal batches with a 450-watt lamp in the annular space of a quartz photolysis well[24]. After 18-h irradiation of each batch, t.l.c. (solvent *B*) showed that detosylation was complete. The solution was neutralised with carbon dioxide and then evaporated to ~500 ml, water (2.5 l) was added, and the product was extracted into dichloromethane (3 × 1 litre). Evaporation afforded **11** (107 g) which, after recrystallisation from light petroleum (b.p. 60–80°), gave crystals (92 g, 80%), m.p. 170–173°, R_F 0.5 (solvent *B*); lit.[16b] m.p. 175–177°. N.m.r. data: τ 5.28 (*d*, $J_{1,2}$ 4.0 Hz), 6.5–5.5 (*m*, H-2,3,4,5,6,6'), 6.58 (*s*, OMe), 7.0 broad (*s*, 2OH), 4.47 (*s*, $PhCHO_2$), 2.8–2.4 (*m*, Ph).

Methyl 4-O-benzoyl-6-deoxy-2,3-O-isopropylidene-α-D-allopyranoside (**14**). — Six batches of **11** (15 g) were heated under reflux in carbon tetrachloride (600 ml) containing[17] *N*-bromosuccinimide (11.5 g) and a suspension of barium carbonate (6 g). Evaporation of the solvent gave a syrup (107 g, 93%), R_F (solvent *C*) 0.6 (major), 0.5 (trace), and 0.8–0.9 (trace). A small portion of this product was purified by p.l.c. and the bromobenzoate **12** so obtained had ν_{max} 3500 (OH) and 1750 cm^{-1} (C=O). N.m.r. data: τ 5.15 (*d*, $J_{1,2}$ 4.0 Hz), 6.4–5.7 (*m*, H-2,3,5,6,6'), 5.10 (*q*, $J_{4,3}$ 2.5, $J_{4,5}$ 9.5 Hz), 5.55 broad (*s*, 2OH), 6.50 (*s*, OMe), 2.1–1.8 (*m*, 2*o*-H, Ph), 2.7–2.4 (*m*, 2*m*-H and *p*-H, Ph).

A solution of **12** (104 g) in methanol (600 ml) was hydrogenolysed in the presence of Raney nickel (prepared from nickel–aluminium alloy, 100 g) and barium carbonate (17.5 g). The solution was evaporated to a gum, which was then redissolved in dichloromethane. This solution was filtered and evaporated to give the syrupy deoxybenzoate **13** (63 g, 80%), the n.m.r. spectrum of which clearly showed, *inter alia*, a doublet at τ 8.7 for the CMe group.

The 6-deoxybenzoate **13** (21 g) was vigorously stirred in acetone (500 ml) with phosphorus pentaoxide (3 × 6 g) for 1.5 h at 20°. The usual work-up gave a syrup (23 g, 96%) composed of one major component R_F (solvent *D*) 0.4 and small amounts of at least four other components, R_F 0.5–0.7, three of which were present in crude **14**. Column chromatography gave methyl 4-*O*-benzoyl-6-deoxy-2,3-*O*-isopropylidene-α-D-allopyranoside (**14**; 10 g, 42%), m.p. 84–86° (from light petroleum, b.p. 60–80°), ν_{max} 1750 cm^{-1} (C=O). N.m.r. data (C_6D_6–C_5D_5N, 9:1): τ 5.55 (*d*, $J_{1,2}$ 5.2 Hz), 6.0 (*t*, $J_{2,3}$ 5.2 Hz), 5.30 (*q*, $J_{3,4}$ 4.5 Hz), 4.85 (*q*, $J_{4,5}$ 10.2 Hz), 5.58 (*o*, $J_{5,Me}$ 6.3 Hz), 8.77 (*d*, $J_{Me,5}$ 6.3 Hz), 6.82 (*s*, OMe), 8.27 and 8.75 (2 *s*, CMe_2), 1.8 (2H, Ph), and 2.85 (3H, Ph).

Anal. Calc. for $C_{17}H_{22}O_6$: C, 62.3; H, 6.9. Found: C, 62.2; H, 6.9.

The alloside benzoate **14** (3.1 g) was deacetylated during 16 h at 20° with sodium methoxide (0.2 g) in methanol (600 ml). The solution was then neutralised with Amberlite IR-120(H^+) resin and evaporated to give syrupy isopropylidene-alloside **15** (2 g, 94%), ν_{max} 3500 cm^{-1} (OH).

Methyl 6-deoxy-2,3-O-isopropylidene-α-D-ribo-hexopyranosid-4-ulose (**16**). — A solution of the guloside derivative **6** (0.7 g) in carbon tetrachloride (50 ml) was oxidised[18] with ruthenium tetraoxide (prepared from 0.65 g of ruthenium dioxide dihydrate and sodium periodate) during 1 h at room temperature. The oily product (0.56 g, 80%), R_F 0.9 (solvent *E*), distilled at 120°(bath)/0.1 × 133 Nm^{-2} to give **16** as a colourless syrup (0.45 g), ν_{max} 1740 cm^{-1} (C=O), λ_{max} 285 nm (ε 240). N.m.r. data (220 MHz): τ 4.93 (*d*, $J_{1,2}$ 3.8 Hz), 5.16 (*q*, $J_{2,3}$ 9.0 Hz), 5.23 (*q*, $J_{3,5}$ 1.2 Hz), 5.79 (*o*, $J_{5,Me}$ 7.5 Hz), 8.60 (*d*, Me), 4.48 (*s*, OMe), 8.44 and 8.57 (2 *s*, CMe_2). Mass-spectral data: *m/e* 201 [$M^+ - Me$].

Anal. Calc. for $C_{10}H_{16}O_5$: C, 55.5; H, 6.9. Found: C, 55.7; H, 7.7.

The alloside derivative **15** (2 g) was oxidised in similar fashion to give **16** (1.6 g, 80%).

A solution of **16** (50 mg) in methanol was treated with sodium borohydride

(20 mg) at room temperature for 0.5 h. The usual work-up gave a product (ν_{max} 3500 cm^{-1}) which, on analysis by g.l.c. (column *A*) at 130°, showed one peak with *T* 12 min. Authentic samples of methyl 6-deoxy-2,3-*O*-isopropylidene-α-D-hexopyranosides having the *gulo* and *allo* structures had *T* values of 20 and 12 min, respectively.

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