900. *Structure and Reactivity of Anhydro-sugars. Part V.** 3-*Deoxy*-D-ribo-*hexopyranose and* 4-*Deoxy*-D-xylo-*hexopyranose.*†

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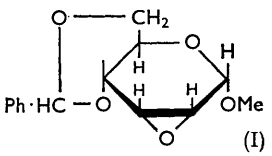
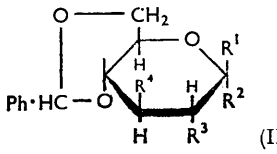
Methods for the synthesis of 3-deoxy-D-*ribo*-hexopyranose and 4-deoxy-D-*xylo*-hexopyranose have been examined and satisfactory syntheses of both substances and a range of derivatives are described. Comment is made on the value of these substances as intermediates in the synthesis of nucleosides, and of certain dideoxy-hexoses which have been found recently in natural products.

In connexion with other work in progress in our laboratory several methods have been examined for the preparation of 3-deoxy-D-*ribo*- and 4-deoxy-D-*xylo*-hexopyranose.

As sugar epoxides are useful intermediates for the synthesis of deoxy-sugars [1] they were studied initially. Prins [2] found that the Raney nickel-catalysed hydrogenolysis of methyl 2,3-anhydro-4,6-*O*-benzylidene-α-D-alloside (I) gave methyl 3-deoxy-α-D-*ribo*-hexopyranoside (" methyl 3-deoxy-α-D-glucopyranoside ") as the main product. No 2-deoxy-hexoside component was reported. A re-examination of this reaction, at temperatures somewhat higher than those adopted by Prins, revealed it to be more complex than reported originally.[2,3] Chromatographic examination of our product indicated that it was a mixture, and this was separated into three fractions by distillation. The most volatile fraction was contaminated with debenzylidenated starting material, but chromatographic analysis



(I)



(II)

* Part IV, *J.*, 1962, 1488.

† Commonly known as 3-deoxy- and 4-deoxy-D-glucose.

[1] Overend and Stacey, *Adv. Carbohydrate Chem.*, 1953, **8**, 45.

[2] Prins, *Helv. Chim. Acta*, 1946, **29**, 1.

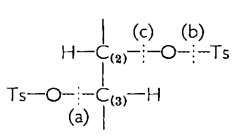
[3] See also Pratt and Richtmyer, *J. Amer. Chem. Soc.*, 1957, **79**, 2597.

indicated that it consisted mainly of methyl 2,3-dideoxy-α-D-*erythro*-hexoside. The heterogeneous nature of the other two fractions was revealed by ionophoresis, but not by chromatography. Both fractions consisted essentially of methyl 3-deoxy-α-D-*ribo*-hexoside, but each contained some methyl 2-deoxy-α-D-*ribo*-hexoside. The 3-deoxy-derivative was separated from each syrupy fraction as the crystalline 4,6-*O*-benzylidene acetal. Removal of the benzylidene group with 0·3% methanolic hydrogen chloride containing *p*-nitrophenylhydrazine afforded pure syrupy methyl 3-deoxy-α-D-*ribo*-hexoside which gave a 2,4,6-tri-*O*-acetyl derivative.

In view of these results other reactions with epoxides which lead to deoxy-hexosides were studied to determine whether they are more complex than described hitherto. With lithium aluminium hydride, the anhydride (I) and the mannoside analogue afforded, respectively, methyl 4,6-*O*-benzylidene-2-deoxy-α-D-*ribo*-hexoside and methyl 4,6-*O*-benzylidene-3-deoxy-α-D-*arabino*-hexoside, both in crystalline form, confirming the work of Prins.[4]

Vis and Karrer [5] reported that treatment of methyl 4,6-*O*-benzylidene-2,3-di-*O*-tosyl-α-D-glucoside (II; $R^1 = H$, $R^2 = OMe$, $R^3 = R^4 = OTs$) (Ts = $SO_2 \cdot C_6H_4 \cdot Me$-*p*) with lithium aluminium hydride in tetrahydrofuran gives methyl 4,6-*O*-benzylidene-3-deoxy-α-D-*ribo*-hexoside (II; $R^1 = R^4 = H$, $R^2 = OMe$, $R^3 = OH$) in good yield, an observation we have confirmed. With the β-anomer (II; $R^1 = OMe$, $R^2 = H$, $R^3 = R^4 = OTs$) in this reaction interesting results were obtained. The main product had stucture (II; $R^1 = OMe$, $R^2 = R^4 = H$, $R^3 = OH$), but this was formed in only 38% yield. In an attempt to improve the yield the reaction was repeated in dioxan. Again, the main product was this 3-deoxy-derivative, but the yield was even lower (22%). Chromatography revealed a second component. This was obtained crystalline and it was concluded that it was methyl 4,6-*O*-benzylidene-2,3-dideoxy-β-D-*erythro*-hexoside (II; $R^1 = OMe$, $R^2 = R^3 = R^4 = H$). Treatment of 1,2:5,6-di-*O*-isopropylidene-3-*O*-tosyl-D-glucofuranose with lithium aluminium hydride yielded only 1,2:5,6-di-*O*-isopropylidene-D-glucofuranose and no trace of a 3-deoxy-hexose derivative could be detected.

In the reaction with lithium aluminium hydride, bond fission in the ditosyl ester (II; $R^1 = H$, $R^2 = OMe$, $R^3 = R^4 = OTs$) occurs at the $C_{(3)}$–O bond (a), and at the O–S bond (b) of the 2-substituent (see A). The same pattern of bond cleavage obtains when this diester is treated with alkali, which affords the anhydride (I). However, since reduction of compound (II; $R^1 = H$, $R^2 = OMe$, $R^3 = R^4 = OTs$) by lithium aluminium hydride gives no 2-deoxy-hexoside, it is evident that the anhydride (I) is not an intermediate, it having been established that its hydride reduction affords methyl 2-deoxy-α-D-*ribo*-hexopyranoside. The bond cleavage of methyl 4,6-*O*-benzylidene-2,3-di-*O*-tosyl-β-D-glucoside follows predominantly the same course as that for the α-anomer, but apparently less readily. In addition some cleavage of both the $C_{(2)}$–O (c) and the $C_{(3)}$–O (a) bond occurs, leading to the 2,3-dideoxy-derivative (II; $R^1 = OMe$, $R^2 = R^3 = R^4 = H$). No analogy can be drawn in the patterns of bond cleavage induced by the action of alkali and by lithium aluminium hydride on methyl 4,6-*O*-benzylidene-2,3-di-*O*-tosyl-β-D-glucoside, as this ester was recovered quantitatively after treatment with alkali under conditions which convert the α-anomer into the anhydride (I) (see Newth [6] for a discussion of epoxide formation from di-*O*-sulphonyl compounds).



(A)

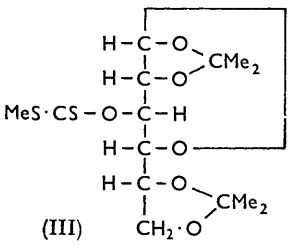
(Ts = $SO_2 \cdot C_6H_4 \cdot Me$)

Hydrolysis of methyl 4,6-*O*-benzylidene-3-deoxy-α- and -β-D-*ribo*-hexoside for chromatographic and ionophoretic examination, and to obtain the free sugars, was achieved best by heating them under reflux for one hour with Amberlite ion-exchange resin IR-120 (H^+) in aqueous suspension, leading to a 70% yield of the free 3-deoxy-sugar.

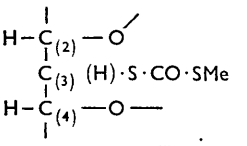
[4] Prins, *J. Amer. Chem. Soc.*, 1948, **70**, 3955.
[5] Vis and Karrer, *Helv. Chim. Acta*, 1954, **37**, 378.
[6] Newth, *Quart. Rev.*, 1959, **13**, 30.

Attention was directed next to the reaction sequence first described by Freudenberg and Wolf [7] and based on the readily accessible 1,2:5,6-di-*O*-isopropylidene-D-glucofuranose as initial material. We have improved and developed the method to a stage which makes it, in our opinion, the most satisfactory for the preparation in quantity of 3-deoxy-D-*ribo*-hexose. Contemporary with our work (see Hedgley [8]) was that of Černý and Pacák [9] who also improved the method.

The sodio-derivative of di-*O*-isopropylidene-D-glucofuranose is converted by successive treatment with carbon disulphide and methyl iodide into 1,2:5,6-di-*O*-isopropylidene-3-*O*-[(methylthio)thiocarbonyl]-D-glucofuranose (III). Freudenberg and Wolf found that distillation of the derivative (III) at atmospheric pressure resulted in rearrangement to



(III)



(IV)

1,2:5,6-di-*O*-isopropylidene-3-*S*-[(methylthio)carbonyl]-3-thio-D-hexofuranose (IV). (Although this compound is usually assigned the D-*gluco*-configuration, we are not aware of an unequivocal proof of its configuration.) This change constitutes a departure from the Chugaev-type reaction which might have been expected (cf. Foster and Wolfrom [10]).

We find that pyrolysis of compound (III) in a stream of carbon dioxide is more effective than Freudenberg's procedure for promoting the rearrangement, especially in large-scale preparations. Inevitably some decomposition occurs at the temperature used (300°) and also methanethiol is produced, presumably by a limited amount of olefin formation due to the normal Chugaev reaction, but the dithiocarbonate can be extracted with ethanol and obtained readily in crystalline form. In the conversion (III) → (IV) there is a hypsochromic displacement of $\lambda_{max.}$ and a diminution of $\varepsilon_{max.}$ in the ultraviolet absorption spectrum of the species involved, typical of the replacement of >C=S by >C=O. Measurement of these changes provided a sensitive quantitative check on the extent of the rearrangement and on the purity of the dithiocarbonate, and indeed spectrophotometric control of the rearrangement proved invaluable.

An improved yield is obtained if a solvent is employed. By heating compound (III) in diphenyl ether in a stream of nitrogen at 300° for 5 hr. and adopting a recycling procedure an overall yield of 48% of 1,2:5,6-di-*O*-isopropylidene-3-*S*-[(methylthio)carbonyl]-3-thio-D-hexofuranose can be obtained on a relatively large scale (an experiment on the 50-g. scale is described in the Experimental section, but larger amounts have been handled satisfactorily.) Černý and Pacák [9] have described how the dithiocarbonate is converted readily into 3-deoxy-1,2:5,6-di-*O*-isopropylidene-α-D-*ribo*-hexose by treatment with Raney nickel. In addition to the 3-deoxyhexose derivative, which is an oil, we find that a small amount of a crystalline compound is also produced. The latter substance does not contain sulphur, and after acid hydrolysis gives a reducing product chromatographically indistinguishable from glucose. A subsequent report will deal with its structure. Although both isopropylidene groups can be cleaved directly from 3-deoxy-1,2:5,6-di-*O*-isopropylidene-D-*ribo*-hexose by hydrolysis with aqueous acid or the acid form of an

[7] Freudenberg and Wolf, *Ber.*, 1927, **60**, 232.
[8] Hedgley, Ph.D. Thesis, University of Birmingham, 1956.
[9] Černý and Pacák, *Chem. listy*, 1955, **49**, 1848.
[10] Foster and Wolfrom, *J. Amer. Chem. Soc.*, 1956, **78**, 1399.

ion-exchange resin (Amberlite IR-120) it was more convenient to remove the groups stepwise, as crystallisation of 3-deoxy-D-*ribo*-hexopyranose then occurred more readily. Mild acid hydrolysis (0·01N-hydrochloric acid) gave crystalline 3-deoxy-1,2-*O*-isopropylidene-α-D-*ribo*-hexose in 82% yield (cf. Černý and Pacák,[9] who used nitric acid in ethyl acetate and obtained this derivative in only 20% yield). This was best converted quantitatively into 3-deoxy-D-*ribo*-hexose by the acid form of an ion-exchange resin. The hydrolysis can be followed by spectrophotometric estimation of the acetone liberated. The 3-deoxy-D-*ribo*-hexose so obtained crystallises directly in the α-pyranose form[11] without recourse to purification through the acetate as adopted by Pratt and Richtmyer.[3]

At present there is considerable interest in the chemistry of 3-deoxy-hexoses, since deoxyglucoses are being examined as modified substrates for enzymes which act on glucose, and the occurrence of 3,6-dideoxy-hexoses in some bacterial polysaccharides has been established.[12] Consequently a reliable synthesis in good yield of 3-deoxyglucose would be valuable. The present work has served to define the limitations of some of the possible routes.

4-Deoxy-D-*xylo*-hexopyranose (" 4-deoxy-D-glucose ") has been obtained from methyl 3,4-anhydro-α-D-galactoside. The anhydride, prepared as described by Buchanan,[13] was heated in methanol for 20 hours at 105° with Raney nickel in the presence of hydrogen (130 atmospheres). Chromatography revealed that the syrupy product contains two components in approximately equal amounts. On oxidation 0·52 mol. of periodate was consumed per mol. of syrup (calculated on the basis of the syrup's being a mixture of methyl monodeoxy-hexosides) (periodate-uptake estimations were made by the spectrophotometric method of Dixon and Lipkin[14]). From the method of preparation it was assumed that the components were methyl 3- and 4-deoxy-α-D-*xylo*-hexoside. Separation was achieved by conventional introduction of benzylidene groups, and crystalline samples of methyl 4,6-*O*-benzylidene-3-deoxy-α-D-*xylo*-hexoside (36% based on anhydride) and methyl 4-deoxy-α-D-*xylo*-hexoside (38% based on anhydride) were obtained. The physical constants of the 3-deoxy-hexoside were very similar to those given by Huber and Reichstein[15] for this compound which they prepared from methyl 2,3-anhydro-4,6-*O*-benzylidene-α-D-guloside. Methyl 4-deoxy-α-D-*xylo*-hexoside consumed 1·02 mol. of periodate and afforded a crystalline triacetate. Hydrolysis of an aqueous solution of methyl 4-deoxy-α-D-*xylo*-hexoside with the acid form of an ion-exchange resin gave crystalline 4-deoxy-D-*xylo*-hexopyranose which on the basis of polarimetric measurements is considered to be the β-form. It gives a smooth simple mutarotation curve (this sugar cannot exist in furanose forms). The electrophoretic mobility of 4-deoxy-D-*xylo*-hexose (borate buffer, pH 10) gave M_G 0·25. This value can be compared with those reported for 4-*O*-methyl-D-glucose and -D-galactose, which are, respectively, 0·24 and 0·27.[16] A preliminary account of this work has been published.[17] Dahlgard *et al.*[18] later described the preparation of " 4-deoxy-D-glucose " from methyl 3,4-anhydro-β-D-galactoside, a route which we have also examined; and an alternative synthesis was described recently by Černý *et al.*[19]

The action of other reagents on methyl 3,4-anhydro-α-D-galactoside was examined to determine whether they led to methyl 4-deoxy-α-D-*xylo*-hexoside in improved yield. (i) After treatment with hydrogen for 10 hours at room temperature in the presence of Adams catalyst the anhydride was recovered quantitatively. (ii) The action of lithium aluminium hydride on the 3,4-anhydride gave some methyl 4-deoxy-α-D-*xylo*-hexoside

[11] Cf. Anet, *Chem. and Ind.*, 1960, 345.
[12] See Westphal and Lüderitz, *Angew. Chem.*, 1960, **72**, 881.
[13] Buchanan, *J.*, 1958, (*a*) 995, (*b*) 2511.
[14] Dixon and Lipkin, *Analyt. Chem.*, 1954, **26**, 1092.
[15] Huber and Reichstein, *Helv. Chim. Acta*, 1948, **31**, 1645.
[16] Foster, *Adv. Carbohydrate Chem.*, 1957, **12**, 81.
[17] Hedgley, Mérész, Overend, and Rennie, *Chem. and Ind.*, 1960, 938.
[18] Dahlgard, Chastain, and Ru-Jen Lee Han, *J. Org. Chem.*, 1962, **27**, 929.
[19] Černý and Pacák, *Coll. Czech. Chem. Commun.*, 1962, **27**, 94; Černý, Pacák, and Stanek, *Chem. and Ind.*, 1961, 945.

(13%) but the main product was methyl 3-deoxy-α-D-*xylo*-hexoside (76%). There are reports [20] that the direction of epoxide scission by lithium aluminium hydride is changed by the addition of aluminium trichloride. However, addition of aluminium trichloride in the above experiment ($LiAlH_4 : AlCl_3 = 1 : 4$) had little effect on the amounts of 3- and 4-deoxy-hexoside produced. (iii) In a trial experiment methyl 3,4-anhydro-α-D-galactoside was treated with sodium thiomethoxide in methanol, and the syrupy product was desulphurised with Raney nickel. Analysis of the product by periodate oxidation indicated that it contained only 15% of methyl 4-deoxy-α-D-*xylo*-hexoside, and the main product was methyl 3-deoxy-α-D-*xylo*-hexoside. (iv) A syrupy mixture was obtained from the reaction between methyl 3,4-anhydro-α-D-galactoside and hydrogen bromide. Periodate oxidation indicated that it contained ~90% of methyl 3-bromo-3-deoxy-hexoside and only 10% of the required methyl 4-bromo-4-deoxy-hexoside. The uptake of periodate was slow (48 hours): Buchanan [13a] has noted a similar slow rate of oxidation of methyl 4-chloro-4-deoxy-α-D-glucoside. Conversion of the methyl bromodeoxy-hexoside mixture into a methyl deoxyhexoside mixture was achieved by treatment with hydrogen in the presence of Adams catalyst and triethylamine. In close agreement with the results obtained with the bromo-derivatives the mixture of methyl deoxy-hexosides consumed 0·11 mol. of periodate, but much more rapidly (7 hours). After introduction of a benzylidene group into the mixed methyl 3- and 4-bromodeoxy-hexosides it was possible to isolate syrupy methyl 4,6-*O*-benzylidene-3-bromo-3-deoxy-α-D-guloside which gave a crystalline 2-*O*-acetyl derivative. The bromine in this compound was removed by treatment with hydrogen and Adams catalyst and triethylamine. Acidic hydrolysis of the product afforded 3-deoxy-D-*xylo*-hexose.

4-Deoxy-D-*xylo*-hexose gave crystalline 2,3,6-tri-*O*-acetyl-4-deoxy-D-*xylo*-hexosyl bromide by way of the 1,2,3,6-tetra-*O*-acetate. The kinetics of solvolysis of this bromide and its use in the synthesis of potential antimetabolites of the nucleoside type have been investigated and will be described in detail later. Treatment of the glycosyl bromide with methanol, silver carbonate, and anhydrous calcium sulphate, and Zemplén deacetylation of the product, gave methyl 4-deoxy-β-D-*xylo*-hexoside. It is reasonable to assume that the glycosyl bromide has the α-configuration and that it takes part in a normal Koenigs–Knorr reaction. That the glycoside had, in fact, the β-configuration was proved by its alternative preparation from methyl 3,4-anhydro-β-D-galactoside. Instead of the original method of Helferich and Muller [21] it was found to be more convenient to prepare methyl 3,4-anhydro-β-D-galactoside by the preparative route used by Buchanan [13] to obtain the α-isomer. Methyl 2,3-di-*O*-benzoyl-4-*O*-tosyl-6-*O*-trityl-β-D-glucoside was detritylated and the product was converted into methyl 3,4-anhydro-β-D-galactoside by treatment with sodium methoxide. When the anhydride was heated under pressure with hydrogen in the presence of Raney nickel and the product separated as described for the α-form, methyl 4,6-*O*-benzylidene-3-deoxy- and methyl 4-deoxy-β-D-*xylo*-hexoside were obtained. The latter compound on hydrolysis gave 4-deoxy-D-*xylo*-hexose. Analysis by periodate oxidation indicated that on cleavage of the anhydride 28% of methyl 4-deoxy-hexoside was produced.

Methyl 4-deoxy-α-D-*xylo*-hexoside was converted into its 2,3-diacetate by sequential tritylation, acetylation, and detritylation. This diacetate was then used for the preparation of methyl 4,6-dideoxy-α-D-*xylo*-hexoside by conventional methods. The preparation of this compound is of interest in view of the isolation of the sugar chalcose as a degradation product of the antibiotic chalcomycin and the demonstration that this is a 4,6-dideoxy-3-*O*-methyl-hexose [22] which recently has been shown by nuclear magnetic resonance spectroscopy to have the D-*xylo*-configuration.[23]

[20] See Eliel and Rerick, *J. Amer. Chem. Soc.*, 1960, **82**, 1362.
[21] Helferich and Muller, *Ber.*, 1930, **63**, 2142.
[22] Woo, Dion, and Bartz, *J. Amer. Chem. Soc.*, 1961, **83**, 3352.
[23] Woo, Dion, and Johnson, *J. Amer. Chem. Soc.*, 1962, **84**, 1066.

Experimental

Catalytic Hydrogenolysis of Methyl 2,3-*Anhydro*-4,6-O-*benzylidene*-α-D-*alloside*.—A suspension of the anhydride (55 g.) and Raney nickel (*ca.* 50 g. of slurry) in methanol (40 ml.) was heated for 16 hr. with hydrogen in an autoclave. A maximum pressure of 130 atm. was attained at 160° ± 10°. Removal of the nickel and evaporation gave a syrup which was washed in aqueous solution (*ca.* 100 ml.) with chloroform (2 × 50 ml.). Evaporation at 12—15 mm. and distillation of the residue afforded three optically active fractions: (i) a mobile syrup (4·6 g.), b. p. 50—70° (bath temp.)/0·1 mm., (ii) a glass (16 g.), b. p. 110—150° (bath temp.)/0·1 mm., and (iii) a glass (4·6 g.), b. p. 150—170° (bath temp.)/0·1 mm. Paper-chromatographic examination revealed that fraction (iii) was apparently homogeneous and (ii) was almost pure, and that both contained methyl 3-deoxy-α-D-*ribo*-hexoside. Paper ionophoresis (borate buffer, pH 10) of fractions (ii) and (iii) and their hydrolysates (with N-sulphuric acid, 100°, 1 hr.) revealed an inhomogeneity undetected by chromatography. The main constituent in the hydrolysates (*i.e.*, 3-deoxy-D-*ribo*-hexose, M_G 0·79) was in both cases accompanied by 2-deoxy-D-*ribo*-hexose, M_G 0·58) as shown by reference to authentic substances. Fractions (ii) and (iii) therefore contained some methyl 2-deoxy-α-D-*ribo*-hexopyranoside. Separate portions of each fraction (0·5 g.), benzaldehyde (1 ml.), and anhydrous zinc chloride (0·25 g.) were shaken mechanically for 24 hr. and then poured into a mixture of water and light petroleum (b. p. 40—60°). The solid was collected and recrystallised from chloroform–light petroleum. The methyl 4,6-*O*-benzylidene-3-deoxy-α-D-*ribo*-hexoside obtained had m. p. 187°. The benzylidene group was removed by heating, under reflux for 5 hr., the acetal (5·76 g.) in methanol (40 ml.) with a suspension of *p*-nitrophenylhydrazine (3·6 g.) in 0·3% methanolic hydrogen chloride (40 ml.). Acetone (5 ml.) was added and heating was continued for a further hour. The cooled solution was poured into a large volume of water, and the mixture was filtered after 0·5 hr. The filtrate was washed with ether, deionised [Amberlite IR-4B(OH^-)], decolourised, and evaporated. The residue distilled as a colourless syrup (3·35 g., 87%), b. p. 150—170° (bath temp.)/0·1 mm., $[\alpha]_D$ +125·1° (*c* 2·3 in H_2O) (Prins [2] reported the preparation of methyl 3-deoxy-α-D-*ribo*-hexoside but cited no constants), which gave an oily 2,4,6-tri-*O*-acetyl derivative, b. p. 108—110°/0·25 mm. (Found: C, 51·5; H, 6·53; O, 42·1. Calc. for $C_{13}H_{20}O_8$: C, 51·3; H, 6·6; O, 42·1%).

Paper chromatography of fraction (i) revealed that it contained four substances (R_F 0·39, 0·59, 0·70, and 0·75; the solvent system was the organic phase of a mixture of butanol–ethanol–water, 4 : 1 : 5). After hydrolysis (N-sulphuric acid, 100°, 1 hr.), four main components and traces of a fifth {R_F 0·13 (faint), 0·30, 0·36, 0·45, and 0·53 (the solvent system was the organic phase of a mixture of butanol–ethanol–water, 4 : 1 : 5)} were detected. Debenzylidenated starting material accounted for the component with R_F 0·59 in fraction (i) (comparison with reference compound) and this substance was responsible for the trace of glucose (R_F 0·13) that occurred in the hydrolysate. It was observed that one constituent in the hydrolysate of fraction (i) had the same R_F value as 2,3-dideoxy-D-glucose (0·53). Support for the identity of these compounds came from ionophoretic measurements in borate buffer (pH 10) and implied the presence of methyl 2,3-dideoxy-α-D-*erythro*-hexoside (R_F 0·75) in fraction (i). The component with R_F 0·39 was methyl 3-deoxy-α-D-*ribo*-hexoside, but the identity of the component with R_F 0·70 was not established. Benzylidenation of fraction (i) gave an intractable syrup.

Action of Lithium Aluminium Hydride on Methyl 4,6-O-*Benzylidene*-2,3-*di*-O-*tosyl*-β-D-*glucoside*.—(i) A solution of the ditosyl ester (10 g.) in tetrahydrofuran (60 ml.) was added dropwise to a cooled suspension of lithium aluminium hydride (2 g.) in tetrahydrofuran (25 ml.). After being heated under reflux for 16 hr. the mixture was evaporated almost to dryness. The excess of hydride was destroyed by cautious addition of water (70 ml.) containing Rochelle salt (40 g.). The suspension was extracted thoroughly with ether, and the extract was washed with water, dried (K_2CO_3), and evaporated. The residue was precipitated repeatedly from ethereal solution with light petroleum (b. p. 40—60°). Eventually the material crystallised and was recrystallised from dioxan–light petroleum, to give colourless needles (1·72 g., 38·2%), m. p. 165°, $[\alpha]_D^{18}$ +59·5° (*c* 4·1 in $CHCl_3$) (Found: C, 59·2; H, 6·9. $C_{14}H_{18}O_5$ requires C, 63·1; H, 6·8%). Hydrolysis (N-sulphuric acid, 1 hr.) afforded benzaldehyde and a reducing sugar identical in chromatographic [solvent system: the organic phase of a butan-1-ol–ethanol–water (4 : 1 : 5, v/v) mixture] and ionophoretic (in borate buffer, pH 10) behaviour with authentic

3-deoxy-D-*ribo*-hexose (R_F 0·30; M_G 0·79). On this evidence the crystalline product was considered to be *methyl* 4,6-O-*benzylidene*-3-*deoxy*-β-D-ribo-*hexoside*.

(ii) The ditosyl ester (5 g.) and lithium aluminium hydride (2 g.) in anhydrous dioxan (55 ml.) were treated as described above. Removal of the dioxan and the excess of hydride was followed by successive addition of chloroform (50 ml.) and sufficient 2N-sulphuric acid to dissolve the solid at the liquid–liquid interface. The layers were separated and the aqueous phase was extracted with chloroform. The combined chloroform layer and extract were washed once with saturated aqueous sodium hydrogen carbonate and dried (K_2CO_3). The residue from evaporation was washed with light petroleum (b. p. 40—60°) and passed in hot ethanol through a pad of charcoal. On storage, prismatic needles (A) were deposited from the filtrate. These were collected and the mother-liquors were evaporated to afford more solid material (B).

After recrystallisation twice from tetrahydrofuran–ethanol the crystals (A) (0·02 g.) had m. p. 106—107°, $[\alpha]_D^{18}$ −58·8° (*c* 2·55 in $CHCl_3$) (Found: C, 68·2; H, 7·3. $C_{14}H_{18}O_4$ requires C, 67·2; H, 7·3%). This sulphur-free compound, gave no colour with tetranitromethane in chloroform. Hydrolysis (N-sulphuric acid, 1 hr., 100°) released benzaldehyde and afforded a single reducing sugar with R_F 0·53 (cf. R_F: D-glucose, 0·12; 2-deoxy-D-*arabino*-hexose, 0·30; 3-deoxy-D-*ribo*-hexose, 0·30; 2,3-dideoxy-D-*erythro*-hexose, 0·53) on paper chromatography in the organic phase of a butan-1-ol–ethanol–water (4 : 1 : 1, v/v) mixture. On ionophoresis in borate buffer (pH 10), the hydrolysis product had M_G 0·27 (cf. M_G 2-deoxy-D-*arabino*-hexose, 0·3; 3-deoxy-D-*ribo*-hexose, 0·79). It was concluded that compound A was methyl 4,6-*O*-benzylidene-2,3-dideoxy-β-D-*erythro*-hexoside. Compound B was purified with difficulty by recrystallisation from tetrahydrofuran–light petroleum (b. p. 60—80°). Colourless needles (0·5 g., 22%) were obtained, that had m. p. 164—165° alone or in admixture with authentic methyl 4,6-*O*-benzylidene-3-deoxy-β-D-*ribo*-hexoside.

1,2:5,6-*Di*-O-*isopropylidene*-3-S-[(*methylthio*)*carbonyl*]-3-*thio*-D-*hexofuranose*.—(*a*) 1,2:5,6-Di-*O*-isopropylidene-3-*O*-[(methylthio)thiocarbonyl]-D-glucofuranose (1·5 g.) [m. p. 61°, $\lambda_{max.}$ 283 mμ (ε 8000), obtained in 66% yield from 1,2:5,6-di-*O*-isopropylidene-D-glucofuranose] in a Pyrex tube was agitated by a stream of carbon dioxide. The tube, supported above a fused-salt bath (KNO_3–$NaNO_2$, 10 : 7), had an outlet leading, through an air-condenser, to a trap containing concentrated aqueous sodium hydroxide. The bath was heated to 290—300°, and then the tube was lowered into it for 15—20 min. After cooling, the contents of the tube were replaced by a fresh batch of material, and in this way 26 g. of the substance were pyrolysed. The carbon dioxide stream was maintained even during the cooling stage and served to sweep occluded gaseous by-products into the trap. The combined batches of pyrolysate were treated with charcoal in hot ethanol, and then recrystallised. The dithiocarbonate (8·2 g., 31%) was obtained as colourless needles, m. p. 143—144°, $[\alpha]_D^{18}$ −61·2° (*c* 3·6 in $CHCl_3$), $\lambda_{max.}$ 249 mμ (ε 3700) {Freudenberg and Wolf [7] give m. p. 142°, $[\alpha]_{578}^{16}$ −59·91° (in tetrachloroethane) for this compound}.

(*b*) 1,2:5,6-Di-*O*-isopropylidene-3-*O*-[(methylthio)thiocarbonyl]-D-glucofuranose (25 g.) in diphenyl ether (200 g.) was heated at 300° for 5 hr. in a stream of nitrogen. The dark solution was distilled, to give two fractions, b. p. 89—90°/2 mm. and 170—175°/2 mm., respectively. The lower-boiling fraction was diphenyl ether admixed with unchanged material and was charged with a further batch (25 g.) of the material for reheating for 5 hr. The syrupy less volatile fraction (19 g.) was dissolved in ethanol, from which separated crystals of the dithiocarbonate (7·1 g.), m. p. 142°. The re-cycled xanthate ester gave a second crop of crystalline dithiocarbonate (11·7 g.). The overall yield of rearranged product was 37·6%.

(*c*) The above derivative (58 g.) in diphenyl ether (60 g.) was heated at 300° for 5 hr. in a stream of nitrogen, and the products were separated by distillation as described above. The viscous fraction was crystallised from ethanol, and the mother-liquors were evaporated. The syrupy residue was added to the lower-boiling fraction for a further 5 hours' heating. This re-cycling procedure was repeated five times, to give a 48% overall yield of dithiocarbonate.

3-*Deoxy*-1,2:5,6-*di*-O-*isopropylidene*-D-ribo-*hexofuranose*.—1,2:5,6-Di-*O*-isopropylidene-3-*S*-[(methylthio)carbonyl]-3-thio-D-hexofuranose (36 g.) in 90% ethanol (1 l.) was heated under reflux for 6 hr. with Raney nickel (570 g. of wet slurry). A further amount (100 g.) of nickel was then added and heating was continued for a further 5 hr. Filtration followed by evaporation yielded a sulphur-free residue which was distilled, to give two fractions, (i) 3-deoxy-1,2:5,6-di-*O*-isopropylidene-D-*ribo*-hexofuranose (16·2 g., 65%), a colourless oil, b. p. 74—78°/

0·3 mm., n_D^{18} 1·4523, $[\alpha]_D^{18}$ −5·78° (*c* 4·2 in EtOH) {Černý and Pacák [9] give n_D^{21} 1·4513, $[\alpha]_D^{18}$ −8·6° (*c* 3·7 in EtOH)}, and (ii) (~0·25 g.), b. p. 82—86°/0·01 mm. m. p. 41—45°.

3-*Deoxy*-1,2-O-*isopropylidene*-D-ribo-*hexofuranose*.—3-Deoxy-1,2:5,6-di-*O*-isopropylidene-D-*ribo*-hexofuranose (7·29 g.) was dissolved in 0·01N-hydrochloric acid (500 ml.) and the intensity of the absorption at 263 mμ was measured at intervals. After 6 hr. at room temperature the optical density became constant and sodium hydrogen carbonate was added to neutralise the acid. The residue from evaporation was distilled (b. p. 135—137°/0·2 mm.). The distillate solidified and recrystallised from chloroform–light petroleum (b. p. 60—80°) as colourless needles (5·0 g., 82%), m. p. 84°. Černý and Pacák [9] give m. p. 84° for 3-deoxy-1,2-*O*-isopropylidene-D-*ribo*-hexofuranose.

3-*Deoxy*-D-ribo-*hexose*.—An aqueous solution (250 ml.) of 3-deoxy-1,2-*O*-isopropylidene-D-*ribo*-hexofuranose (2·04 g.) was shaken with an ion-exchange resin [IR-120 (H^+)] (0·2 g.) at room temperature for 8 days. (The hydrolysis was followed spectrophotometrically.) The resin was removed, the solution evaporated at 12—15 mm., and ethanol distilled over the residue, which crystallised spontaneously after several days. 3-Deoxy-α-D-*ribo*-hexopyranose (1·55 g., 94%) had m. p. 108—111°, $[\alpha]_D$ +29·0° (*c* 1·0 in H_2O) constant after 3·5 hr. Pratt and Richtmyer [3] give m. p. 105—107°, $[\alpha]_D$ +32·2° (*c* 1·0 in H_2O) constant after 3 hr. Anet [11] gives m. p. 137°, $[\alpha]_D^{25}$ +30·4° (in H_2O) for the β-anomer.

Treatment of Methyl 3,4-*Anhydro*-α-D-*galactoside with Hydrogen in the Presence of Raney Nickel*.—The anhydride (25 g.) in dry methanol (400 ml.) was heated at 105° for 20 hr. in 130 atm. of hydrogen in the presence of Raney nickel (3·5 g.). Removal of catalyst and solvent gave a viscous syrup which was shaken for 24 hr. with benzaldehyde (60 ml.) and zinc chloride (5 g.). After dilution with methanol (200 ml.) the mixture was poured into water (75 ml.) containing an excess of potassium carbonate. (In all subsequent operations solutions were maintained at pH 8.) After filtration the residue was extracted with hot methanol (4 × 100 ml.), and the extract was added to the filtrate. The solution was evaporated and water was distilled over the residue to remove benzaldehyde. The residue was partitioned between chloroform (50 ml.) and water (50 ml.). The aqueous phase was separated and washed with chloroform (20 ml.), and the chloroform phase was washed with water (20 ml.). In each case the washings were added to the appropriate phase. Evaporation of the aqueous layer and washings gave a residue over which benzene was evaporated. The solid material obtained was dried *in vacuo* over phosphoric oxide and then extracted with hot pyridine (4 × 25 ml.). Evaporation of the extract afforded a syrupy residue which crystallised on trituration with ethyl acetate. Recrystallisation from ethyl acetate afforded *methyl* 4-*deoxy*-α-D-xylo-*hexoside* (9·4 g., 38%) as colourless prisms, m. p. 90°, $[\alpha]_D$ +168·2° (*c* 0·86 in MeOH) (Found: C, 47·4; H, 7·8; O, 44·7; OMe, 17·4. $C_7H_{14}O_5$ requires C, 47·2; H, 7·9; O, 44·9; OMe, 17·4%). This substance consumed 1·02 mol. of periodate in 3 hr. (determination by the spectrophotometric method of Dixon and Lipkin [14]). It formed a *triacetate* which recrystallised from chloroform–light petroleum (b. p. 60—80°) as colourless cubes (0·72 g., 85%), m. p. 74°, $[\alpha]_D$ +135·2° (*c* 0·9 in $CHCl_3$) (Found: C, 51·2; H, 6·6; O, 42·0. $C_{13}H_{20}O_8$ requires C, 51·2; H, 6·6; O, 42·0%).

Evaporation of the dried (Na_2SO_4) chloroform solution gave a solid which after recrystallisation from chloroform–light petroleum (b. p. 60—80°) afforded methyl 4,6-*O*-benzylidene-3-deoxy-α-D-*xylo*-hexoside (11·3 g., 36%), m. p. 163—164°, $[\alpha]_D$ +93·8° (*c* 1·07 in $CHCl_3$) (Found: C, 62·95; H, 7·05; O, 29·6. Calc. for $C_{14}H_{18}O_5$: C, 63·1; H, 6·8; O, 30·0%). Huber and Reichstein [15] give m. p. 168—169°, $[\alpha]_D$ +94·4° (in $CHCl_3$), for this compound as prepared from methyl 2,3-anhydro-4,6-*O*-benzylidene-α-D-guloside.

4-*Deoxy*-D-xylo-*hexose*.—Methyl 4-deoxy-α-D-*xylo*-hexoside (2·0 g.) in water (30 ml.) was heated under reflux with Amberlite ion-exchange resin IR-120 (H^+) (1 g.). The change in optical rotation was followed until a constant value was obtained (6 hr.). Filtration and evaporation gave a clear syrup which slowly crystallised. The solid was extracted with a small amount of hot ethyl acetate (10 ml.) to remove unchanged glycoside and was then recrystallised from a large volume of ethyl acetate as colourless rhombs, m. p. 131—132°, $[\alpha]_D$ +44° (after 3 min.) ⟶ +60·3° (equilib. after 3·5 hr.) (*c* 2·4 in H_2O), of 4-*deoxy*-D-xylo-*hexose* (Found: C, 44·2; H, 7·4. $C_6H_{12}O_5$ requires C, 43·9; H, 7·4%).

Treatment of Methyl 3,4-*Anhydro*-α-D-*galactoside with Lithium Aluminium Hydride*.—A flask containing a suspension of lithium aluminium hydride (0·75 g.) in dry ether (75 ml.) was attached to a Soxhlet extraction unit in the thimble of which had been placed methyl

3,4-anhydro-α-D-galactoside (1 g.). A guard tube ($CaCl_2$) was attached and the mixture was boiled for 40 hr. The excess of lithium aluminium hydride was destroyed with cold water, carbon dioxide was passed in, and the mixture evaporated to dryness. Benzene (2 × 20 ml.) was distilled over the residue which was finally dried over phosphoric oxide. The solid was powdered and extracted with hot ethyl acetate (3 × 30 ml.). Concentration of the extract gave crystals which after recrystallisation from ethyl acetate yielded methyl 3-deoxy-α-D-*xylo*-hexopyranoside (650 mg., 65%) as prisms, m. p. 160—161°, $[\alpha]_D$ +140·5° (*c* 1·4 in MeOH) {Huber and Reichstein [15] give m. p. 162—163°, $[\alpha]_D$ +143·1 ± 2° (*c* 1·25 in MeOH)}. Further extraction (Soxhlet) of the solid material with ethyl acetate yielded (after recrystallisation from ethyl acetate) more of the 3-deoxy-*xylo*-hexoside (110 mg., total yield 76%). Concentration of the mother-liquors and recrystallisation (twice) of the residue from ethyl acetate–light petroleum (b. p. 60—80°) (2 : 1) gave methyl 4-deoxy-α-D-*xylo*-hexoside (13 mg., 13%), m. p. 90°.

Treatment of Methyl 3,4-Anhydro-α-D-galactoside with Hydrogen Bromide.—A solution of the 3,4-anhydride (3·3 g.) and 60% aqueous hydrogen bromide (15 ml.) in acetone (400 ml.) and water (25 ml.) was heated under reflux for 4 hr. After neutralisation with lead carbonate, filtration, and evaporation the syrupy residue was dried by azeotropic distillation of benzene, followed by storage *in vacuo* over phosphoric oxide. From a hot ethyl acetate extract (3 × 40 ml.) a syrup (3·5 g.) (A) was obtained by evaporation. This syrup consumed 0·096 mol. of periodate in 60 hr. An aqueous solution (3 ml.) of the syrup (A) (100 mg.) containing triethylamine (0·1 ml.) was treated for 4 hr. with hydrogen and Adams catalyst at atmospheric pressure at room temperature. After filtration and evaporation the syrupy residue consumed 0·11 mol. of periodate in 7 hr.

Syrup (A) (3·3 g.), benzaldehyde (15 ml.), and anhydrous zinc chloride (1 g.) were shaken together for 24 hr. After addition of methanol (50 ml.) and water (25 ml.) containing sufficient sodium hydrogen carbonate to maintain pH 8, the mixture was evaporated to dryness and re-evaporated after further addition of water (10 ml.). An aqueous solution (20 ml.) of the residue was extracted with chloroform (4 × 25 ml.). The extract was washed with water (10 ml.), treated with charcoal, and dried (Na_2SO_4). Evaporation gave a syrup (2·4 g.), $[\alpha]_D$ +52·5° (*c* 1·1 in $CHCl_3$), a portion (1·5 g.) of which was treated with acetic anhydride and pyridine for 20 hr. at room temperature. *Methyl 2-O-acetyl-4,6-O-benzylidene-3-bromo-3-deoxy-α-D-guloside* (1·35 g.) crystallised on trituration with light petroleum (b. p. 60—80°) and recrystallised from chloroform–light petroleum (b. p. 60—80°) as needles, m. p. 128—129°, $[\alpha]_D$ +67·5° (*c* 0·75 in $CHCl_3$) (Found: C, 50·6; H, 4·96; Br, 19·9; O, 24·6. $C_{16}H_{19}BrO_6$ requires C, 49·6; H, 4·95; Br, 20·6; O, 24·8%). The acetate (100 mg.) in methanol (5 ml.) containing triethylamine (0·5 ml.) was treated at room temperature and pressure with hydrogen and Adams catalyst. After working-up, a syrup was obtained which in aqueous solution (1 ml.) was hydrolysed at 90° for 3 hr. with Amerlite IR-120 (H^+) resin. The reducing solution was shown by paper chromatography in two solvent systems and by paper ionophoresis in borate buffer (pH 10) to be homogeneous and the component present was identical in all respects with an authentic sample of 3-deoxy-D-*xylo*-hexose.

1,2,3,6-*Tetra*-O-*acetyl*-4-*deoxy*-D-xylo-*hexose*.—Acetic anhydride (4·5 g.) in chloroform (5 ml.) was added dropwise with stirring to a cooled solution (0°) of 4-deoxy-D-*xylo*-hexose (1·5 g.) in dry pyridine (8 ml.) After storage at 3° for 40 hr. water (0·5 ml.) was added and after a further 30 min. more ice-cold water (50 ml.) was added. The chlofororm layer was separated and the aqueous phase was extracted with chloroform (3 × 10 ml.). The tetra-acetate was isolated in standard fashion from the combined chloroform layer and extract. After recrystallisation from chloroform–light petroleum (b. p. 60—80°) 1,2,3,6-*tetra*-O-*acetyl*-4-*deoxy*-D-xylo-*hexose* (2·3 g., 76%) was obtained as fine prisms, m. p. 110—111°, $[\alpha]_D$ +8·8° (*c* 1·02 in $CHCl_3$) (Found: C, 50·2; H, 6·1; O, 43·7. $C_{14}H_{20}O_9$ requires C, 50·6; H, 6·1; O, 43·3%).

2,3,6-*Tri*-O-*acetyl*-4-*deoxy*-D-xylo-*hexosyl Bromide*.—A 50% w/v solution of hydrogen bromide in acetic acid (8 ml.) was added dropwise at 0° to 1,2,3,6-tetra-*O*-acetyl-4-deoxy-D-*xylo*-hexose (1·1 g.) in glacial acetic acid (8 ml.). After 2·5 hr. at room temperature, chloroform (50 ml.) was added and the solution was extracted with ice-cold water (50 ml.). The chloroform layer was separated and the aqueous layer was extracted with chloroform (3 × 20 ml.). The chloroform solution was washed free from acid with ice-cold water, dried (Na_2SO_4), and evaporated at 40° to a yellow oil, which crystallised on trituration with dry light petroleum (b. p. 60—80°). After being washed by decantation with the same solvent (3 × 20 ml.) the solid

was recrystallised from light petroleum (b. p. 60—80°)–ether, to give the glucosyl bromide as cubes (0·85 g., 73%), m. p. 83—84°. As the material decomposed on storage it was not possible to obtain an accurate elemental analysis.

Methyl 4-*Deoxy*-β-D-xylo-*hexoside*.—A mixture of 2,3,6-tri-*O*-acetyl-4-deoxy-D-*xylo*-hexosyl bromide (0·8 g.), anhydrous calcium sulphate (Drierite; 10 g.), freshly prepared silver carbonate (7 g.), and dry methanol (150 ml.) was shaken for 40 hr. at room temperature in a darkened flask. After filtration and washing of the residue with methanol, the solution was passed repeatedly through a Celite pad to remove finely divided material. After treatment with charcoal, evaporation gave a syrup which crystallised on trituration wih light petroleum (b. p. 60—80°) containing ether (5%). Recrystallisation from the same solvent afforded prisms (0·47 g., 68%), m. p. 59—60°, $[\alpha]_D$ −23·3° (*c* 1·2 in $CHCl_3$). A portion (0·4 g.) was dissolved in dry methanol (30 ml.) containing a trace of sodium. Working-up by the usual procedure for a Zemplén deacetylation gave methyl 4-deoxy-β-D-*xylo*-hexoside (190 mg., 83%) which after recrystallisation from ethyl acetate had m. p. 145—146°, $[\alpha]_D$ −35·7° (*c* 0·8 in H_2O) (Found: C, 47·5; H, 8·2. Calc. for $C_7H_{14}O_5$: C, 47·2; H, 7·9%). Dahlgard *et al.*[18] give m. p. 143°, $[\alpha]_D^{25}$ −35·5° (in H_2O).

Methyl 2,3,-*Di*-O-*benzoyl*-4-O-*tosyl*-6-O-*trityl*-β-D-*glucoside*.—Methyl 2,3-di-*O*-benzoyl-β-D-glucoside (33 g.) in dry pyridine (75 ml.) was treated for 2 hr. at 100° with trityl chloride (24·5 g.), cooled, and toluene-*p*-sulphonyl chloride (24 g.) added. After heating to effect dissolution, and storage at 38° for 3·5 days, the solution was poured into water (2 l.) and sufficient chloroform was added to dissolve the sticky solid which separated. After being stirred for 2·5 hr. the chloroform was separated and washed successively with N-hydrochloric acid, dilute sodium hydrogen carbonate solution, and water. The solution was dried (Na_2SO_4) and evaporated. Methanol was added slowly to the syrupy residue until a permanent precipitate was obtained. This was collected and washed with a small volume of methanol. The *product* was difficult to crystallise without concomitant detritylation, but a sample recrystallised satisfactorily from chloroform–methanol, then having m. p. 107—108°, $[\alpha]_D$ +15·6° (*c* 1·6 in $CHCl_3$) (Found: C, 70·4; H, 5·4. $C_{47}H_{42}O_{10}S$ requires C, 70·7; H, 5·3%).

Methyl 2,3-*Di*-O-*benzoyl*-4-O-*tosyl*-β-D-*glucoside*.—Hydrogen bromide in glacial acetic acid (10 ml.; 50% w/v) was added at 5° to the 6-*O*-trityl ether (25 g.) in acetic acid (100 ml.). A white solid was formed immediately and was filtered off after 5 min. The filtrate was poured into water (600 ml.), and the precipitate was dissolved in chloroform. The washed (dilute sodium hydrogen carbonate solution) and dried (Na_2SO_4) chloroform solution was evaporated and the residue was recrystallised from ethanol. *Methyl* 2,3-*di*-O-*benzoyl*-4-O-*tosyl*-β-D-*glucoside* had m. p. 143—145°, $[\alpha]_D$ +31·5° (*c* 1·1 in $CHCl_3$) (Found: C, 60·4; H, 5·2; O, 28·8; S, 5·4. $C_{28}H_{28}O_{10}S$ requires C, 60·4; H, 5·1; O, 28·8; S, 5·8%).

Methyl 3,4-*Anhydro*-β-D-*galactoside*.—Dry methanol (75 ml.) containing sodium (0·65 g.) was added dropwise during 1 hr. to methyl 2,3-di-*O*-benzoyl-4-*O*-tosyl-β-D-glucoside (12 g.) in chloroform (75 ml.) at 0°. The solution was stored at 0° overnight and then carbon dioxide was bubbled through the liquid. The filtered solution was evaporated to dryness at 45° and the residue was washed successively in aqueous solution (75 ml.) with light petroleum (b. p. 60—80°) (50 ml.) and ethyl acetate (25 ml.). The aqueous solution was evaporated to dryness and the residue extracted with a 1 : 1 (v/v) mixture of ethyl acetate and light petroleum (b. p. 60—80°). As the extract cooled, the anhydride (2·6 g., 69%) separated and was collected. After recrystallisation from ethyl acetate it had m. p. 155—156°, $[\alpha]_D$ −116° (*c* 0·6 in H_2O). Helferich and Muller [21] give m. p. 158°, $[\alpha]_D$ −118° (in H_2O) for this compound.

Treatment of Methyl 3,4-*Anhydro*-β-D-*galactoside with Hydrogen in the Presence of Raney Nickel*.—A methanol solution (100 ml.) of the anhydride (2·5 g.) was heated for 16 hr. at 120° in 125 atmospheres of hydrogen in the presence of Raney nickel (1·5 g.). After filtration through kieselguhr–carbon the solution was evaporated to a colourless syrup (2·35 g.) (A). Careful crystallisation from warm ethyl acetate gave methyl 3-deoxy-β-D-*xylo*-hexopyranoside (120 mg.) as prisms, m. p. 172—173°, $[\alpha]_D$ −70·3° (*c* 1·0 in H_2O) {Dahlgard *et al.*[18] give m. p. 173—174°, $[\alpha]_D^{25}$ −69·4° (in H_2O)}. The compound consumed no periodate during 5 hr.

Periodate oxidation of syrup A led to the uptake of 0·28 mol. of oxidant.

The syrup A (2·0 g.) was treated with benzaldehyde (15 ml.) and anhydrous zinc chloride (1 g.), and the mixture was separated as for the α-series. From the aqueous phase a syrup was obtained which crystallised on trituration with ethyl acetate. Recrystallisation from ethyl acetate gave methyl 4-deoxy-β-D-*xylo*-hexoside as prisms (0·25 g., 10%), m. p. 142—143°

alone or in admixture with the material obtained from 2,3,4,6-tetra-*O*-acetyl-4-deoxy-D-glucosyl bromide as described above, $[\alpha]_D$ −34·7° (*c* 0·7 in H_2O). The glycoside consumed 0·99 mol. of periodate. From the chloroform phase of the benzylidenation mixture methyl 4,6-*O*-benzylidene-3-deoxy-β-D-*xylo*-hexoside (1·6 g.) was obtained and it recrystallised from chloroform–light petroleum (b. p. 60—80°) as fine needles, m. p. 206—207°, $[\alpha]_D$ −90·5° (*c* 2·2 in $CHCl_3$) (Found: C, 63·6; H, 6·75; O, 29·5. Calc. for $C_{14}H_{18}O_5$: C, 63·1; H, 6·8; O, 30·0%). Dahlgard *et al.*[18] give m. p. 211°, $[\alpha]_D^{23}$ −90·3°.

Methyl 2,3-*Di*-O-*acetyl*-4-*deoxy*-α-D-xylo-*hexoside*.—Methyl 4-deoxy-α-D-*xylo*-hexoside (1·8 g.) and trityl chloride (2·8 g.) in pyridine (10 ml.) were mixed at room temperature and after 24 hr. they were heated under anhydrous conditions at 100° for 0·5 hr. The mixture was diluted with pyridine (10 ml.) and acetic anhydride (5 ml.). After 24 hr. at room temperature water (0·2 ml.) was added and the mixture was poured on ice (50 g.). The gummy precipitate was dissolved in chloroform (20 ml.), and the aqueous solution was extracted with chloroform (3 × 25 ml.). The combined chloroform extracts were washed successively with ice-cold 0·5N-hydrochloric acid, dilute aqueous sodium hydrogen carbonate, and water, and dried (Na_2SO_4). Evaporation afforded a pale yellow syrup (5·0 g.), $[\alpha]_D$ +63·8° (*c* 3·45 in $CHCl_3$). This syrup (4·8 g.) was treated in glacial acetic acid (15 ml.) at 0° with a 50% w/v solution of hydrogen bromide in acetic acid (4·8 ml.). After being shaken for 5 min., the mixture was filtered and the residue was washed with acetic acid (3 × 5 ml.). After dilution with chloroform (100 ml.) the solution was washed with water (100 ml.). The aqueous solution was extracted with chloroform (2 × 25 ml.). The extract was washed free from acid with sodium hydrogen carbonate. After further washing with water and drying (Na_2SO_4), the solution was evaporated to a syrup (1·7 g.) which on distillation afforded *methyl* 2,3-*di*-O-*acetyl*-4-*deoxy*-α-D-xylo-*hexoside* as a clear glass, b. p. 120—123°/0·1 mm., $[\alpha]_D$ +137·5° (*c* 1·2 in $CHCl_3$) (Found: C, 51·2; H, 6·8; O, 42·3. $C_{11}H_{18}O_7$ requires C, 50·4; H, 6·9; O, 42·7%), $\nu_{max.}$ 3500 (OH) and 1755 (OAc) cm.$^{-1}$.

Methyl 4,6-*Dideoxy*-α-D-xylo-*hexoside*.—Methyl 2,3-di-*O*-acetyl-4-deoxy-α-D-*xylo*-hexoside (1·6 g.) in pyridine (15 ml.) was tosylated at 0° with tosyl chloride (0·75 g.) in pyridine (15 ml.). The syrupy product (2·25 g.) had $[\alpha]_D$ +102·5° (*c* 1·64 in $CHCl_3$) and showed absorption at 1750 (OAc), 1600 and 1500 (Ph) cm.$^{-1}$ but none at 3500 cm.$^{-1}$ (OH). This compound (2·1 g.) and anhydrous sodium iodide (1·5 g.) were heated in dry boiling ethyl methyl ketone (100 ml.) for 20 hr. Sodium toluene-*p*-sulphonate was filtered and the product isolated in the usual manner. A syrup (1·40 g.), $[\alpha]_D$ +121·2° (*c* 1·6 in $CHCl_3$), was obtained. This material (1·3 g.) in methanol (40 ml.) was treated with Adams catalyst, triethylamine (0·5 ml.), and hydrogen at atmospheric pressure and room temperature. Evaporation of the solvent and separation of triethylamine hydriodide from the residue gave a mobile oil (0·75 g.), b. p. 105—110°/0·1 mm., which in methanol (30 ml.) was treated with a small amount of sodium methoxide. After 20 hr. carbon dioxide was bubbled into the solution. Filtration and evaporation gave a syrup which was dried (P_2O_5) and extracted with ethyl acetate. Evaporation of the extract gave a syrup (0·40 g.) from which crystalline methyl 4-deoxy-α-D-*xylo*-hexoside was obtained by adding light petroleum (b. p. 60—80°) to a solution in ethyl acetate. The mother-liquors were concentrated and the process was repeated. Eventually material of m. p. 95—98° was obtained and after recrystallisation twice from ethyl acetate *methyl* 4,6-*dideoxy*-α-D-xylo-*hexoside* (140 mg.) was obtained as prisms, m. p. 103—104°, $[\alpha]_D$ +171° (*c* 1·0 in MeOH) (Found: C, 51·5; H, 8·8; O, 40·1. $C_7H_{14}O_4$ requires C, 51·8; H, 8·7; O, 39·46%).

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