Deoxy-sugars. Part XXV. Structure and Reactivity of Anhydro-sugars. Part II.† Derivatives of* 3 : 6-*Anhydro*-D-*mannose,* 3 : 6-*Anhydro*-2-*deoxy*-D-*galactose, and* 3 : 6-*Anhydro*-2-*deoxy*-D-*glucose.*

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Syntheses are described of methyl 3 : 6-anhydro-2-deoxy-α-D-glucopyranoside and -D-galactopyranoside and of the corresponding 4-methyl ether derivatives. Likewise, methyl 3 : 6-anhydro-α- and -β-D-mannopyranoside and their 2 : 4-di-*O*-methyl derivatives have been prepared. The action of acids on these compounds has been studied and the structures of transformation products have been established. Results obtained in this investigation are discussed with reference to the well-known behaviour towards acidic reagents shown by methyl 3 : 6-anhydro-α-D-glucoside and -D-galactoside (cf. *J.*, 1940, 620; 1941, 88).

IT is well known (Ohle and Thiel, *Ber.*, 1933, **66**, 528; Haworth, Jackson, and Smith, *J.*, 1940, 620; Haworth, Owen, and Smith, *J.*, 1941, 88) that alkali treatment of the 6-*O*-toluene-*p*-sulphonyl derivative of methyl α-D-glucoside or -D-galactoside affords methyl 3 : 6-anhydro-α-D-glucoside and methyl 3 : 6-anhydro-α-D-galactoside respectively. This paper outlines methods for the synthesis of corresponding derivatives from 2-deoxy-D-glucose and 2-deoxy-D-galactose since it was of some interest to discover the influence of the 2-deoxy-group on 3 : 6-anhydro-rings. Methyl 3 : 6-anhydro-α- and -β-D-mannopyranoside have also been prepared and their reactions studied.

Toluene-*p*-sulphonylation under mild conditions of methyl 2-deoxy-α-D-galactoside afforded syrupy methyl 2-deoxy-6-*O*-toluene-*p*-sulphonyl-α-D-galactoside which was converted into crystalline methyl 3 : 6-anhydro-2-deoxy-α-D-galactoside (I) by sodium hydroxide in ethanol. The anhydro-sugar (I) can be characterised as its crystalline 4-*O*-toluene-*p*-sulphonyl derivative. When the above 6-toluene-*p*-sulphonate was heated with sodium

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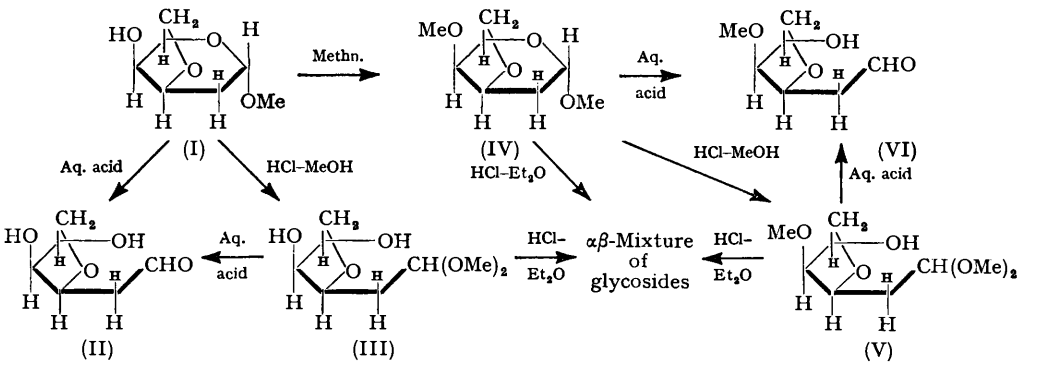
iodide in dry acetone, an exchange reaction occurred and sodium toluene-*p*-sulphonate (80%) was precipitated. The conditions were such that an exchange reaction would be expected only with primary toluene-*p*-sulphonyloxy-groups. This evidence coupled with the conversion of the toluene-*p*-sulphonyl derivative into the stable 3 : 6-anhydro-compound (I) indicated that toluene-*p*-sulphonylation of methyl 2-deoxy-α-D-galactoside occurred at position 6, and it follows that the configuration of (I) was correctly assigned.

Similarly, methyl 2-deoxy-α-D-glucoside (Hughes, Overend, and Stacey, *J.*, 1949, 2846) was converted into methyl 3 : 6-anhydro-2-deoxy-α-D-glucoside (VII), and methyl 3 : 6-anhydro-α-D-mannopyranoside (XVIII) was formed from methyl α-D-mannopyranoside. Heating methyl α-D-mannopyranoside with methanolic hydrogen chloride converted it into methyl αβ-D-mannopyranoside from which the β-isomer was isolated as the 2 : 3 : 4 : 6-tetra-acetate. Deacetylation afforded methyl β-D-mannopyranoside which was converted in poor yield into the 3 : 6-anhydro-derivative (XIX). It was best isolated as its 2 : 4-di-*O*-methyl derivative (XX).

On treatment with dilute sulphuric acid at room temperature, the galactose derivative (I) was rapidly hydrolysed and 3 : 6-anhydro-2-deoxy-D-galactose was formed. The properties of this indicate that it exists in the open-chain (*aldehydo*-)form (II) and in this respect it resembles 3 : 6-anhydro-D-galactose (Haworth, Jackson, and Smith, *loc. cit.*). The anhydro-galactoside (I) was hydrolysed much more rapidly than was methyl 2-deoxy-α-D-galactoside (cf. Foster, Overend, and Stacey, *J.*, 1951, 974), and so presumably introduction into the latter molecule of a hydrofuran ring causes considerable strain. Scission of the pyran ring also occurred when (I) was treated with an excess of methanolic hydrogen chloride : 3 : 6-anhydro-2-deoxy-D-galactose dimethyl acetal (III) was formed. Acidic reagents rapidly hydrolysed the acetal (III) to the aldehyde (II), while ethereal or chloroformic hydrogen chloride transformed it into an αβ-mixture of the methyl 3 : 6-anhydro-2-deoxy-D-galactopyranosides. Attempts to prepare 3 : 6-anhydro-2-deoxy-D-galactono-γ-lactone were unsuccessful. Bromine readily oxidised the *aldehydo*-sugar (II) to a galactonic acid derivative which could not be lactonised, a result which is not surprising, since the 4-hydroxyl group is sterically hindered in the 3 : 6-anhydro-galactose series (cf. Haworth, Owen, and Smith, *loc. cit.*).

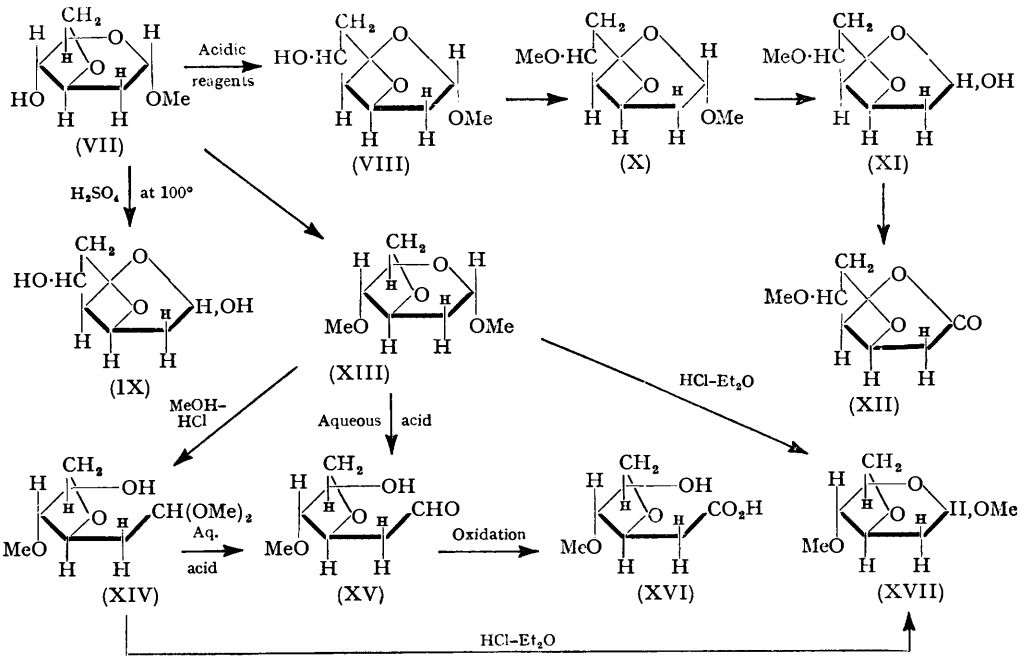


Methylation of the anhydro-galactoside (I) yielded the 4-methyl ether (IV), which was hydrolysed by dilute sulphuric acid at about the same rate as (I), giving 3 : 6-anhydro-2-deoxy-4-*O*-methyl-D-galactose (VI). Methanolic hydrogen chloride converted the ether (IV) into the dimethyl acetal (V) which was hydrolysed to the aldehyde (VI) by aqueous acid. Both the galactoside (IV) and the acetal (V) are rapidly changed into methyl 3 : 6-anhydro-2-deoxy-4-*O*-methyl-αβ-D-galactoside by hydrogen chloride in anhydrous ether. From calculations based on Hudson's rules (Hudson, *J. Amer. Chem. Soc.*, 1909, **31**, 66), it seems that the αβ-mixture of glycosides is composed of about 70% of the α- and 30% of the β-isomer. The reactions described closely parallel the results obtained by Haworth and his co-workers (*loc. cit.*) with methyl 3 : 6-anhydro-α-D-galactopyranoside and its 2 : 4-di-*O*-methyl derivative, except that acidic treatment of methyl 3 : 6-anhydro-2 : 4-di-*O*-

methyl-α-D-galactoside and 3 : 6-anhydro-2 : 4-di-*O*-methyl-*aldehydo*-D-galactose gave methyl 3 : 6-anhydro-2 : 4-di-*O*-methyl-β-D-galactoside, whereas with the 2-deoxy-analogues (IV and V) an αβ-mixture of glycosides was formed with the α-isomer as the major component.

The remarkable conversion of α- and β-forms of methyl 3 : 6-anhydroglucopyranoside into the more stable α- and β-methyl 3 : 6-anhydroglucofuranoside with acids (Haworth, Owen, and Smith, *J.*, 1941, 88) has now been found to occur in the corresponding 2-deoxyglucose series; methyl 3 : 6-anhydro-2-deoxy-α-D-glucopyranoside (VII) was isomerised almost instantaneously by hydrogen chloride in methanol or chloroform to methyl 3 : 6-anhydro-2-deoxy-α-D-glucofuranoside (VIII). Under the conditions employed, it is extremely unlikely that the free sugar is formed as an intermediate. The same change (VII ⟶ VIII) can be achieved, but at a slower rate, by use of dilute aqueous sulphuric acid. Acid treatment of the pyranoside (VII) under more drastic conditions affords 3 : 6-anhydro-2-deoxy-D-glucose (IX), the properties of which lead us to believe that it exists in the furanose form. For this reason and also because of the closely similar behaviour of (VII) and methyl 3 : 6-anhydro-α-D-glucopyranoside towards acids, the furanoside (VIII) is considered to have the α-configuration [cf. the change of methyl 3 : 6-anhydro-α-D-glucopyranoside to methyl 3 : 6-anhydro-α-D-glucofuranoside (Haworth, Owen, and Smith, *loc. cit.*)]. The furanose nature of (VIII) was proved by the standard conversions, *e.g.*, the changes (VIII ⟶ X ⟶ XI ⟶ XII). The lactone (XII) was stable in aqueous solution for several days and was thus of the stable 1 : 4(γ)-type, namely, 3 : 6-anhydro-2-deoxy-5-*O*-methyl-D-glucono-γ-lactone, thereby furnishing evidence of the furanose nature of (VIII).

When methyl 3 : 6-anhydro-2 : 4-di-*O*-methyl-α-D-glucoside is treated with acid, a pyranose to furanose conversion is not possible, and Haworth, Owen, and Smith (*loc. cit.*)



demonstrated that the product was the β-glycoside. This change was analogous to that observed with the corresponding compound in the galactose series.

Methyl 3 : 6-anhydro-2-deoxy-4-*O*-methyl-α-D-glucopyranoside (XIII) was converted immediately by anomerisation into an αβ-mixture (XVII) of glycosides by hydrogen chloride in ether or chloroform. From its optical rotation the glycoside mixture apparently con-

tained 55% of (XIII) and 45% of the β-anomer. When the α-glucoside (XIII) was treated with an excess of methanolic hydrogen chloride, 3 : 6-anhydro-2-deoxy-4-*O*-methyl-D-glucose dimethyl acetal (XIV) was formed by fission of the pyran ring : in this respect the glucoside (XIII) and the galactoside (IV) behave analogously. The acetal (XIV) was readily converted by aqueous acid into 3 : 6-anhydro-2-deoxy-4-*O*-methyl-D-glucose (XV) which can also be obtained directly from the glucoside (XIII).

The behaviour of 3 : 6-anhydro-2-deoxy-4-*O*-methyl-D-glucose towards Schiff's reagent indicates that an appreciable amount must be present in the open-chain (*aldehydo*-)form (XV). Oxidation with bromine yielded the gluconic acid (XVI), which did not lactonise [cf. conversion of (XI) into the lactone (XII)], incidentally providing further evidence of the relative stability of furanose derivatives of 3 : 6-anhydrohexoses. Hydrogen chloride in ether converted the acetal (XIV) into the glucoside (XVII), the proportions of the two anomers in the αβ-mixture being approximately the same as from the glucoside (XIII).

From the foregoing account it is aparent that the behaviour of methyl 3 : 6-anhydro-2-deoxy-α-D-glucopyranoside (VII) and its 4-*O*-methyl derivative (XIII) is very similar to that of methyl 3 : 6-anhydro-α-D-glucopyranoside and its 2 : 4-di-*O*-methyl ether. In general the reactions of the 3 : 6-anhydro-2-deoxyhexoses are faster than of the 3 : 6-anhydrohexoses, and in this respect conform to the usual results obtained when reaction rates of hexoses and 2-deoxyhexoses are compared.

To calculate the proportions of α- and β-forms in the mixture (XVII) it is necessary to assume that Hudson's second isorotation rule (*loc. cit.*) is applicable to the methyl 3 : 6-anhydro-2-deoxy-4-*O*-methyl-D-hexosides. This is probable since it can be shown, by calculations based on optical-rotation data reported in the literature, that the rule is applicable to methyl 3 : 6-anhydro-D-hexosides and their 2 : 4-di-*O*-methyl derivatives.

A similar study has been carried out with methyl 3 : 6-anhydro-α- and -β-D-mannopyranoside. Methyl 3 : 6-anhydro-α-D-mannopyranoside (XVIII) is unaffected by 0·1N-sulphuric acid at room temperature, but is converted slowly but in high yield by methanolic hydrogen chloride into methyl 3 : 6-anhydro-α-D-mannofuranoside (XXII), which was prepared by Valentin (*Coll. Czech. Chem. Comm.*, 1934, **6**, 354) by treatment of 3 : 6-anhydro-D-mannofuranose (XXIII) with hydrogen chloride in methanol. We obtained further proof of the furanose nature of the product (XXII) by converting it by the reactions (XXII ⟶ XXIV ⟶ XXV ⟶ XXVI) into a stable lactone of the 1 : 4γ-type. It was 3 : 6-anhydro-2 : 5-di-*O*-methyl-D-mannono-γ-lactone (XXVI), thereby indicating that the initial material (XXII) must have been a methyl 3 : 6-anhydroglycofuranoside.

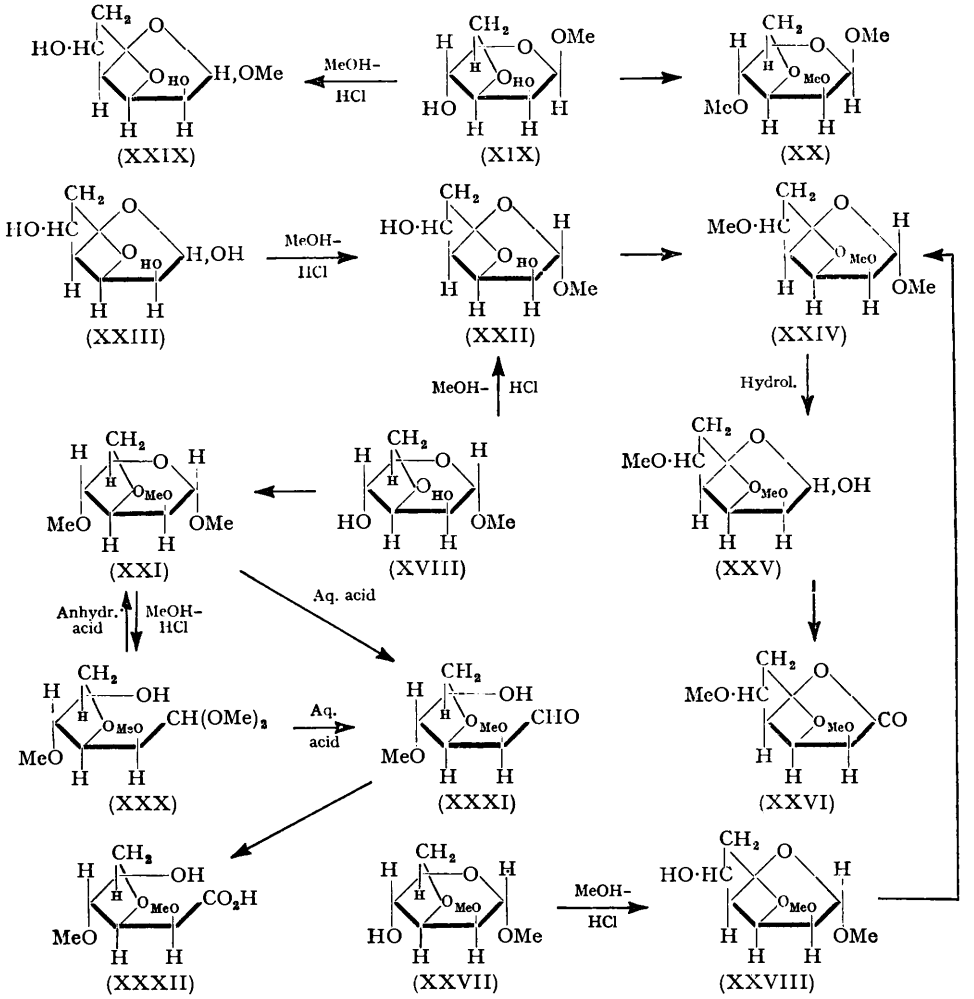
Methyl 3 : 6-anhydro-2-*O*-methyl-α-D-mannopyranoside (XXVII) (Foster, Smith, and Stacey, unpublished work) behaved with methanolic hydrogen chloride analogously to its parent (XVIII) and was converted mainly into the α-furanoside (XXVIII), the structure of which followed from transformation into the 2 : 5-di-*O*-methyl-αβ-pyranoside (cf. XXIV) and thence into the lactone (XXVI). Methyl 3 : 6-anhydro-β-D-mannopyranoside (XIX) on the other hand was rapidly converted by methanolic hydrogen chloride into methyl 3 : 6-anhydro-αβ-D-mannofuranoside (XXIX). Conversion of the β-pyranoside (XIX) into the furanoside is very much faster than that of the α-pyranoside (XVIII) and it appears that the former is therefore under greater strain (for a full discussion see the following paper).

Comparison of these results with those of Haworth, Owen, and Smith (*loc. cit.*) indicates that in the 3 : 6-anhydro-α-D-mannose series the compounds mentioned are under considerably less strain than those in the 3 : 6-anhydro-α-D-glucose series, as is to be expected from the conformational analysis of the various structures (see the following paper). Whereas the β-methyl glycoside of 3 : 6-anhydro-D-mannose is under greater strain than the α-isomer, the opposite is found with derivatives of 3 : 6-anhydro-D-glucose (Haworth, Owen, and Smith, *loc. cit.*).

When the pyranose ⟶ furanose transformation was prevented by using methyl 3 : 6-anhydro-2 : 4-di-*O*-methyl-α- and -β-D-mannopyranoside (XXI and XX respectively) it was found that (*a*) 1% methanolic hydrogen chloride converted the α-anomer (XXI) into a mixture (A) of 3 : 6-anhydro-2 : 4-di-*O*-methyl-*aldehydo*-D-mannose dimethyl acetal (XXX) (*ca.* 67%) and methyl 3 : 6-anhydro-2 : 4-di-*O*-methyl-αβ-D-mannopyranoside (*ca.* 33%), and (*b*) ethereal hydrogen chloride converted the β-anomer (XX) into presumably methyl

3 : 6-anhydro-2 : 4-di-*O*-methyl-αβ-D-mannopyranoside. Addition of acidic reagents under anhydrous conditions to the mixture (A) immediately converted it completely into the α-form (XXI), whereas aqueous acid hydrolysed the acetal grouping and yielded 3 : 6-anhydro-2 : 4-di-*O*-methyl-*aldehydo*-D-mannose (XXXI). The last compound was also prepared from the α-pyranoside (XXI) by aqueous acid: this pyranoside (XXI) was hydrolysed more rapidly than the furanoside analogue (XXIV). The properties of the sugar formulated as (XXXI) indicate that it exists essentially in the open-chain form: oxidation yielded 3 : 6-anhydro-2 : 4-di-*O*-methyl-D-mannonic acid (XXXII) which could not be converted into a lactone.

The product obtained from the β-mannopyranoside (XX) by hydrogen chloride in ether was a non-reducing colourless syrup which partly solidified on nucleation with the α-anomer



(XXI). A comparison of the infra-red spectra of the anomers and this product over the frequency range 700—1010 cm.$^{-1}$ indicates that the reaction product contains a considerable amount of the α-isomer (XXI) (see Table) and so presumably it is an αβ-mixture of methyl 3 : 6-anhydro-2 : 4-di-*O*-methyl-D-mannopyranosides (see Barker, Bourne, Stacey, and Whiffen, *Chem. and Ind.*, 1952, 1156; *J.*, 1954, 171). This slow conversion of the β-glycoside (XX) into the α-glycoside (XXI) under the action of hydrogen chloride in ether is in

good agreement with the result predictable from the concept of non-bonded interactions in the sugar series (following paper).

Compound	Frequencies ($cm.^{-1}$) of absorption peaks								
(XXI)	1003	966	935	901	876	854	811	752	—
(XX) after acid treatment ...	1004	961	935	901	878	856	810	773	751
(XX) before acid treatment ...	997	956	901	892	876	859	826	775	753

Whereas the α-mannopyranoside (XXI) is unaffected by 0·1N-sulphuric acid at room temperature even after 60 hours, the corresponding derivative of methyl 3 : 6-anhydro-α-D-glucoside is completely hydrolysed under these conditions in 8 hours (Haworth *et al.*, *loc. cit.*). This is a further illustration of the greater instability of pyranose derivatives of 3 : 6-anhyro-D-glucose compared with those of 3 : 6-anhydro-D-mannose. In the same way we have the fact that the action of methanolic hydrogen chloride on methyl 3 : 6-anhydro-2 : 4-di-*O*-methyl-α-D-glucopyranoside yields mainly 3 : 6-anhydro-2 : 4-di-*O*-methyl-D-glucose dimethyl acetal, whereas the mannose derivative (XXI) under the same conditions gives the dimethyl acetal (XXX) mixed with a considerable amount of unchanged starting material.

Experimental

Preparation of 3 : 6-*Anhydro-sugars.*—(a) *Methyl* 3 : 6-*anhydro*-2-*deoxy*-α-D-*galactoside* (I). To an ice-cold solution of methyl 2-deoxy-α-D-galactoside (1·80 g.) in dry pyridine (4 ml.), a cooled solution of toluene-*p*-sulphonyl chloride (1·80 g.) in dry pyridine (5 ml.) was added during 1 hr. The mixture was kept for 24 hr. at 0° and then the product was isolated in the usual fashion. The syrupy methyl 2-deoxy-6-*O*-toluene-*p*-sulphonyl-α-D-galactoside {2·10 g.; $[\alpha]_D^{19}$ +79° (*c*, 5·0 in EtOH)} in ethanol (80 ml.) was treated at 60° for 1 hr. with N-sodium hydroxide (6·4 ml.). The solution was neutralised with carbon dioxide and evaporated to dryness. The solid residue was extracted exhaustively with acetone, and the extract was concentrated to a semi-solid residue which was re-extracted with ethyl acetate. Filtration and re-evaporation afforded an amorphous residue which on distillation gave a colourless liquid (0·6 g., 40%), b. p. 120° (bath-temp.)/0·01 mm., which solidified. Recrystallisation from ether gave *methyl* 3 : 6-*anhydro*-2-*deoxy*-α-D-*galactoside* as colourless plates, m. p. 80°, $[\alpha]_D^{15}$ +98° (*c*, 0·78 in H_2O) (Found : C, 52·4; H, 7·7; OMe, 19·8. $C_7H_{12}O_4$ requires C, 52·5; H, 7·5; OMe, 19·4%). This compound (60 mg.) could readily be converted into its 4-O-*toluene*-p-*sulphonyl* derivative (80 mg.) which after recrystallisation from methanol was obtained as a white solid, m. p. 98° (sinters at 88°), $[\alpha]_D^{19}$ +45·6° (*c*, 0·92 in $CHCl_3$) (Found : C, 53·6; H, 5·9; S, 10·2. $C_{14}H_{18}O_6S$ requires C, 53·5; H, 5·7; S, 10·2%). In similar fashion a *methyl* 3 : 6-*anhydro*-2-*deoxy*-αβ-D-*galactoside* (0·22 g., 40%) was obtained as a colourless syrup, b. p. 116—120° (bath-temp.)/0·01 mm., $[\alpha]_D^{19}$ +65° (*c*, 1·5 in H_2O) (Found: C, 52·67; H, 7·7; OMe, 19·7%), from methyl 2-deoxy-6-*O*-toluene-*p*-sulphonyl-αβ-D-galactoside (1·06 g.; $[\alpha]_D^{19}$ +70°).

(b) *Methyl* 3 : 6-*anhydro*-2-*deoxy*-α-D-*glucopyranoside* (VII). Toluene-*p*-sulphonyl chloride (1·532 g.) was added during 1 hr. to an ice-cold solution of methyl 2-deoxy-α-D-glucopyranoside (1·532 g.) (Hughes, Overend, and Stacey, *J.*, 1949, 2848) in dry pyridine (15 ml.). After being kept at 0° for 12 hr. and at room temperature for a further 4 hr. the product was isolated in the usual manner. A solution of the compound (1·5 g.) in ethanol (80 ml.) was treated with N-sodium hydroxide (12 ml.) at 85° for 1·5 hr. A solid resulted and was isolated as described above. Recrystallisation from ether yielded *methyl* 3 : 6-*anhydro*-2-*deoxy*-α-D-*glucopyranoside* (0·5 g., 36%), m. p. 98°, $[\alpha]_D^{20}$ +59·2° (*c*, 2·63 in H_2O) (Found : C, 52·4; H, 7·7; OMe, 19·5%).

(c) *Methyl* 3 : 6-*anhydro*-α-D-*mannopyranoside* (XVIII). Methyl α-D-mannopyranoside (17·62 g.) was converted into its 6-*O*-toluene-*p*-sulphonyl derivative (20 g.) by treatment with toluene-*p*-sulphonyl chloride (17·25 g.) in dry pyridine (200 ml.) for 24 hr. at 0° and thereafter at room temperature for a further hour. The crude ester (20 g.) in ethanol (150 ml.) was converted into methyl 3 : 6-anhydro-α-D-mannopyranoside by allowing it to stand at 0° for 12 hr. and then at 80—85° for 1 hr. with N-sodium hydroxide (75 ml.). The anhydro-compound, isolated as already described, was obtained as colourless crystals (5·0 g.) which after recrystallisation from acetone–ethyl acetate had m. p. 131°, $[\alpha]_D^{15}$ +97° (*c*, 1·4 in H_2O). Valentin (*Coll. Czech. Chem. Comm.*, 1934, **6**, 354) reports m. p. 130—132° and $[\alpha]_D$ +97·1° (in H_2O).

(d) *Methyl* 3 : 6-*anhydro*-β-D-*mannopyranoside* (XIX). In like fashion methyl β-D-mannopyranoside (2·25 g.) was converted *via* its crude 6-toluene-*p*-sulphonate into crude methyl 3 : 6-anhydro-β-D-mannopyranoside (1·0 g.) (A). Attempted distillation of a portion of the

crude syrup (A) (0·4 g.) afforded a small amount of colourless distillate (30 mg., 3·5%), b. p. 160—170° (bath-temp.)/0·01 mm., n^{19} 1·5020, but the main bulk of the material underwent decomposition in the distillation flask. The distillate crystallised on trituration with ethyl acetate, and after recrystallisation from this solvent, *methyl* 3 : 6-*anhydro*-β-D-*mannopyranoside* was obtained having m. p. 103° and $[\alpha]_D^{18}$ −96° (*c*, 0·3 in H_2O) (Found : C, 47·8; H, 7·07; OMe, 18·3. $C_7H_{12}O_5$ requires C, 47·7; H, 6·82; OMe, 17·6%).

The remainder of the syrup (A) (0·6 g.) was methylated twice by the Purdie procedure. Concentration of a chloroform extract of the product gave a dark syrup which distilled as a pale yellow liquid (60 mg.), b. p. 120—130°/0·01 mm., which from elemental analysis was a *methyl* 3 : 6-*anhydromono*-O-*methyl*-β-D-*mannopyranoside* (Found : C, 50·9; H, 7·25; OMe, 33·2. $C_8H_{14}O_5$ requires C, 50·5; H, 7·4; OMe, 32·6%). Further methylation of this liquid by the Freudenberg method yielded *methyl* 3 : 6-*anhydro*-2 : 4-*di*-O-*methyl*-β-D-*mannopyranoside* (20 mg.) as a colourless liquid, b. p. 90—100° (bath-temp.)/0·01 mm., $[\alpha]_D^{20}$ −75° (*c*, 0·4 in MeOH), $[\alpha]_D^{24}$ −70° (*c*, 0·57 in Et_2O) (Found : C, 52·5; H, 8·21. $C_9H_{16}O_5$ requires C, 52·9; H, 7·84%).

The experiment was repeated with 0·97 g. of methyl β-D-mannopyranoside but no attempt was made to isolate methyl 3 : 6-anhydro-β-D-mannopyranoside in pure form. Instead, the crude product was methylated by the Freudenberg method and methyl 3 : 6-anhydro-2 : 4-di-*O*-methyl-β-D-mannoside (0·09 g., 9%) was obtained as a practically colourless liquid, $[\alpha]_D^{24}$ −71° (*c*, 0·6 in Et_2O), n^{27} 1·4553 (Found : C, 52·6; H, 8·2%).

Conversion of Methyl 3 : 6-*Anhydro*-D-*hexopyranosides into the Corresponding Methyl* 3 : 6-*Anhydro*-D-*hexofuranosides*.—(a) *Methyl* 3 : 6-*anhydro*-2-*deoxy*-α-D-*glucofuranoside* (VIII). (1) With 0·1N-sulphuric acid. When 0·1N-sulphuric acid was added at room temperature to methyl 3 : 6-anhydro-2-deoxy-α-D-glucopyranoside (0·262 g.), $[\alpha]_D$ changed from +59·2° to +105° in 12 min. The solution was then neutralised ($BaCO_3$), filtered, and evaporated under diminished pressure to dryness. The residue was extracted with dry methanol and re-evaporation afforded a syrup which on distillation gave *methyl* 3 : 6-*anhydro*-2-*deoxy*-α-D-*glucofuranoside* (0·172 g., 66%) as a colourless liquid, b. p. 100° (bath-temp.)/0·05 mm., n^{19} 1·4745, $[\alpha]_D^{19}$ +111° (*c*, 2·1 in H_2O) (Found : C, 52·5; H, 7·7; OMe, 19·0. $C_7H_{12}O_4$ requires C, 52·5; H, 7·5; OMe, 19·4%).

When methyl 3 : 6-anhydro-2-deoxy-α-D-glucopyranoside (0·6 g.) was heated in 0·1N-sulphuric acid for 1 hr. at 100° the product was 3 : 6-*anhydro*-2-*deoxy*-D-*glucose* (0·38 g., 70%) which was obtained as a colourless syrup, b. p. 120—130° (bath-temp.)/0·05 mm., n^{23} 1·4928, $[\alpha]_D^{20}$ +37·1° (*c*, 1·24 in H_2O) (Found : C, 48·4; H, 7·13. $C_6H_{10}O_4$ requires C, 49·3; H, 6·8%).

(ii) With methanolic hydrogen chloride. Methyl 3 : 6-anhydro-2-deoxy-α-D-glucopyranoside (1·27 g.), dissolved in dry methanol (20 ml.), was treated with 13% methanolic hydrogen chloride (1·0 ml.) at room temperature ($[\alpha]_D$ +60° ⟶ +109° immediately after addition of the acid). Neutralisation with silver carbonate, filtration, removal of the solvent, and distillation gave the product (0·94 g.) as a colourless liquid, b. p. 100° (bath-temp.)/0·05 mm., n^{20}, 1·4744, $[\alpha]_D^{20}$ +112° (*c*, 2·0 in H_2O).

(iii) With chloroformic hydrogen chloride. Essentially similar results were obtained when a dry chloroform solution (1·0 ml.) of the methyl glycopyranoside (10 mg.) was treated with chloroform saturated with dry hydrogen chloride (1 drop). The product had n^{20} 1·4740 and $[\alpha]_D^{20}$ +108° (*c*, 0·5 in H_2O).

(b) *Methyl* 3 : 6-*anhydro*-α-D-*mannofuranoside* (XXII). Methyl 3 : 6-anhydro-α-D-mannopyranoside (0·5 g.) was dissolved in 1% methanolic hydrogen chloride (5·0 ml.). Polarimetric observation indicated that the ensuing reaction was complete in 20 hr. After neutralisation (Ag_2CO_3), filtration, and concentration, the residue was decolorised (charcoal) and then distilled. The colourless distillate (0·4 g.), b. p. 113—115° (bath-temp.)/0·02 mm., crystallised on trituration with ethyl acetate and, after recrystallisation from the same solvent, methyl 3 : 6-anhydro-α-D-mannofuranoside was obtained, having m. p. 86° and $[\alpha]_D^{15}$ +156° (*c*, 0·9 in H_2O) (Found : C, 47·7; H, 6·9. Calc. for $C_7H_{12}O_5$: C, 47·7; H, 6·8%). Valentin (*loc. cit.*) reports m. p. 85° and $[\alpha]_D$ +157°.

(c) *Methyl* 3 : 6-*anhydro*-αβ-D-*mannofuranoside*. A solution of methyl 3 : 6-anhydro-β-D-mannopyranoside [10 mg.; $[\alpha]_D^{18}$ −96° (*c*, 1·0 in MeOH)] in 1% methanolic hydrogen chloride (1·0 ml.) was kept at room temperature for 1 hr. ($[\alpha]_D^{18}$ = +107° after this period) and then neutralised (Ag_2CO_3). Removal of the solvent gave a colourless, non-reducing syrup, $[\alpha]_D^{18}$ +110° (*c*, 1·0 in H_2O), which did not crystallise but became gummy on being seeded with methyl 3 : 6-anhydro-α-D-mannofuranoside. It was *methyl* 3 : 6-*anhydro*-αβ-D-*mannofuranoside* (Found : OMe, 18·1. $C_7H_{12}O_5$ requires OMe, 17·6%).

(d) *Methyl* 3 : 6-*anhydro*-2-O-*methyl*-α-D-*mannofuranoside* (XXVIII). Likewise, treatment of methyl 3 : 6-anhydro-2-*O*-methyl-α-D-mannopyranoside (0·5 g.) with 1% methanolic hydro-

gen chloride afforded *methyl* 3 : 6-*anhydro*-2-O-*methyl*-α(β ?)-D-*mannofuranoside* as a straw-coloured liquid, b. p. 160° (bath-temp.)/0·03 mm., n^{20} 1·4755, $[\alpha]_D^{16}$ +119° (*c*, 0·75 in H_2O) (Found: C, 49·2; H, 7·5; OMe, 31·6. $C_8H_{14}O_5$ requires C, 50·5; H, 7·37; OMe, 32·6%). Purdie methylation of this compound gave methyl 3 : 6-anhydro-2 : 5-di-*O*-methyl-αβ-D-mannofuranoside (XXIV is α-analogue) as a colourless liquid, b. p. 90—95° (bath-temp.)/0·01 mm., n^{15} 1·4612, $[\alpha]_D^{15}$ +178° (*c*, 1·5 in H_2O) (Found: OMe, 46·0%).

Methylation Experiments.—(a) *Methyl* 3 : 6-*anhydro*-2-*deoxy*-4-O-*methyl*-α-D-*galactoside* (IV). Sodium (0·5 g.) was added to a vigorously stirred solution of methyl 3 : 6-anhydro-2-deoxy-α-D-galactopyranoside (1·0 g.) in liquid ammonia (30 ml.), and after 1 hr. methyl iodide (10 ml.) was added during a further hour. Ammonia was removed by aeration and the residue was extracted exhaustively with chloroform. The extract was filtered and evaporated under diminished pressure. The residue was re-extracted with ether, and ethereal solution was concentrated to small bulk, and methanol added. After decolorisation (charcoal) the solution was evaporated and the residue distilled. *Methyl* 3 : 6-*anhydro*-2-*deoxy*-4-*O*-*methyl*-α-D-*galactoside* (0·8 g., 73%) was obtained as a colourless liquid, b. p. 70—74° (bath-temp.)/0·05 mm., n^{19} 1·4650, $[\alpha]_D^{19}$ +81·5° (*c*, 1·78 in H_2O) (Found: C, 55·3; H, 7·98; OMe, 34·9. $C_8H_{14}O_4$ requires C, 55·2; H, 8·05; OMe, 35·6%).

(b) *Methyl* 3 : 6-*anhydro*-2-*deoxy*-4-O-*methyl*-α-D-*glucopyranoside* (XIII). Methyl 3 : 6-anhydro-2-deoxy-α-D-glucopyranoside (1·52 g.) was dissolved in liquid ammonia (20 ml.) containing sodium (1·0 g.) and was methylated with methyl iodide (10 ml.). Stirring was continued for a further 12 hr. and the product was isolated as described for the galactose isomer. *Methyl* 3 : 6-*anhydro*-2-*deoxy*-4-O-*methyl*-α-D-*glucoside* (1·35 g., 82%) was obtained as a colourless liquid, b. p. 96° (bath-temp.)/0·03 mm., n^{19} 1·4626, $[\alpha]_D^{21}$ +58° (*c*, 2·64 in H_2O), which crystallised. After recrystallisation from ether the compound had m. p. 60° and $[\alpha]_D^{20}$ +60° (*c*, 1·2 in MeOH) (Found: C, 55·6; H, 8·12; OMe, 35·1. $C_8H_{14}O_4$ requires C, 55·2; H, 8·05; OMe, 35·6%).

(c) *Methyl* 3 : 6-*anhydro*-2-*deoxy*-5-O-*methyl*-α-D-*glucofuranoside* (X). In similar fashion methyl 3 : 6-anhydro-2-deoxy-α-D-glucofuranoside (0·9 g.) was converted into its 5-O-*methyl* derivative (0·66 g., 65%) which was isolated as a colourless mobile liquid, b. p. 80° (bath-temp.)/0·7 mm., n^{20} 1·4532, $[\alpha]_D^{18}$ +135° (*c*, 2·56 in H_2O) (Found: C, 55·7; H, 8·04; OMe, 35·0%).

(d) *Methyl* 3 : 6-*anhydro*-2 : 4-*di*-O-*methyl*-α-D-*mannopyranoside* (XXI). Methyl 3 : 6-anhydro-α-D-mannopyranoside (2·0 g.), dissolved in a small amount of dry acetone, was methylated twice according to Purdie's procedure. The 2 : 4-di-*O*-methyl derivative (1·6 g., 70%) was obtained as a colourless liquid, b. p. 120° (bath-temp.)/0·2 mm., which crystallised [m. p. 32°; $[\alpha]_D^{20}$ +105° (*c*, 1·1 in H_2O) (Found: OMe, 46·1. Calc. for $C_9H_{16}O_5$: OMe, 45·6%)]. One of us (A.B.F.) had previously prepared this compound in collaboration with Professors M. Stacey and F. Smith, and the substance had m. p. 32—33° and $[\alpha]_D$ +104·1° (*c*, 1·4 in H_2O).

(e) *Methyl* 3 : 6-*anhydro*-2 : 5-*di*-O-*methyl*-α-D-*mannofuranoside* (XXIV). Likewise, Purdie methylation of methyl 3 : 6-anhydro-α-D-mannofuranoside (1·0 g.) afforded the 2 : 5-*di*-O-*methyl* ether (0·8 g., 70%) as a colourless liquid, b. p. 90° (bath-temp.)/0·2 mm., n^{14} 1·4610, $[\alpha]_D^{15}$ +204° (*c*, 0·8 in H_2O) (Found: C, 53·4; H, 7·8; OMe, 45·7. $C_9H_{16}O_5$ requires C, 53·0; H, 7·8; OMe, 45·6%).

Treatments with Methanolic, Ethereal, or Chloroformic Hydrogen Chloride.—(a) *Methyl* 3 : 6-*anhydro*-2-*deoxy*-α-D-*galactoside and its* 4-O-*methyl derivative*. Methanolic hydrogen chloride [1·0 ml. of a 13% (by weight) solution] was added to a solution of methyl 3 : 6-anhydro-2-deoxy-α-D-galactoside (0·327 g.) in dry methanol (10 ml.) ($[\alpha]_D^{19}$ +107° ⟶ +41·6°). The solution was neutralised (Ag_2CO_3), filtered and evaporated under diminished pressure after decolorisation. 3 : 6-*Anhydro*-2-*deoxy*-aldehydo-D-*galactose dimethyl acetal* (III) (0·31 g., 80%) was obtained as a colourless syrup having $[\alpha]_D^{12}$ +18·3° (*c*, 2·9 in H_2O) and n^{20} 1·4755 (Found: OMe, 31·9. $C_8H_{16}O_5$ requires OMe, 32·3%).

Likewise, methyl 3 : 6-anhydro-2-deoxy-4-*O*-methyl-α-D-galactoside (0·295 g.) in methanolic solution (20 ml.) on treatment with 13% methanolic hydrogen chloride (2 ml.) was converted in 60 seconds ($[\alpha]_D$ +93° ⟶ +45°] into 3 : 6-*anhydro*-2-*deoxy*-4-O-*methyl*-aldehydo-D-*galactose dimethyl acetal* (V) (0·19 g., 56%) which was isolated and purified in the usual manner and finally obtained as a colourless non-reducing liquid, $[\alpha]_D^{20}$ +42·3° (*c*, 1·47 in H_2O) (Found: OMe, 44·9. $C_9H_{18}O_5$ requires OMe, 45·1%). When this compound (50 mg.) was treated with ethereal 2·4N-hydrogen chloride (2 drops) it was rapidly converted into methyl 3 : 6-anhydro-2-deoxy-4-*O*-methyl-αβ-D-galactopyranoside, $[\alpha]_D^{19}$ +10° (*c*, 1·0 in H_2O) (Found: OMe, 35·8%). A similar change was effected by chloroformic hydrogen chloride. When methyl 3 : 6-anhydro-2-deoxy-4-*O*-methyl-α-D-galactoside (13·8 mg.) was treated with ethereal hydrogen chloride

(0·17N; 1 ml.) it yielded the corresponding αβ-glycoside in syrupy form, $[\alpha]_D^{19}$ +23·2° (*c*, 1·7 in H_2O) (Found: OMe, 35·3%). During the isolation the solution was evaporated over soda-lime in a vacuum-desiccator and ether (1 ml. portions) was evaporated thrice over the syrupy residue to ensure complete removal of the acid.

(b) 3 : 6-*Anhydro*-2-*deoxy*-aldehydo-D-*galactose dimethyl acetal*. The dimethyl acetal (150 mg.) was treated with ethereal 0·17N-hydrogen chloride (1·0 ml.), and the solution was evaporated over soda-lime *in vacuo* as described above. Distillation of the residue afforded methyl 3 : 6-anhydro-2-deoxy-αβ-D-galactopyranoside (50 mg.) as a colourless oil, b. p. 116—120° (bath-temp.)/0·01 mm., $[\alpha]_D^{19}$ +20° (*c*, 1·6 in H_2O) (Found: OMe, 19 6%).

(c) *Methyl* 3 : 6-*anhydro*-2-*deoxy*-4-O-*methyl*-α-D-*glucoside*. A solution of the named glucoside (0·33 g.) in methanol (5 ml.) was treated with 6% methanolic hydrogen chloride (1 ml.) {$[\alpha]_D$ +60° ⟶ +5·25° exceedingly rapidly}. Neutralisation (Ag_2CO_3), followed by filtration and evaporation of the solution, afforded a residue which on distillation gave 3 : 6-*anhydro*-2-*deoxy*-4-O-*methyl*-aldehydo-D-*glucose dimethyl acetal* (XIV) (0·23 g., 60%) as a colourless liquid, b. p. 100—105° (bath-temp.)/0·05 mm., n^{18} 1·4567, $[\alpha]_D^{19}$ −3·3° (*c*, 1·22 in H_2O) (Found: C, 51·7; H, 8·75; OMe, 44·7. $C_9H_{18}O_5$ requires C, 52·4; H, 8·74; OMe, 45·1%). On treatment of methyl 3 : 6-anhydro-2-deoxy-4-*O*-methyl-α-D-glucoside (74 mg.) in chloroform (5 ml.) with dry hydrogen chloride the specific rotation changed immediately from +55° to −20°. Neutralisation followed by filtration and evaporation gave a colourless non-reducing syrup, $[\alpha]_D^{20}$ −31·7° (*c*, 1·5 in EtOH) (Found: OMe, 35·2%), which partly crystallised when nucleated with the initial material. Application of Hudson's isorotation rule gives a theoretical value of $[\alpha]_D$ −130° for methyl 3 : 6-anhydro-2-deoxy-4-*O*-methyl-β-D-glucoside (cf. p. 3769).

Similarly methyl 3 : 6-anhydro-2-deoxy-4-*O*-methyl-α-D-glucoside (20 mg.) was converted into the αβ-mixture {$[\alpha]_D^{18}$ −30° (*c*, 0·2 in EtOH)} by ethereal 5N-hydrogen chloride (1 ml.). Likewise, methyl 3 : 6-anhydro-2-deoxy-4-*O*-methyl-αβ-D-glucopyranoside, $[\alpha]_D^{19}$ −29° (*c*, 0·5 in EtOH) (Found: OMe, 34·8%), was formed when 3 : 6-anhydro-2-deoxy-4-*O*-methyl-*aldehydo*-D-glucose dimethyl acetal (60 mg.) was dissolved in ethereal 1·7N-hydrogen chloride (1 ml.).

(d) *Methyl* 3 : 6-*anhydro*-2 : 4-*di*-O-*methyl*-α-D-*mannoside*. A solution of the methylated anhydromannoside (0·13 g.) in 1% methanolic hydrogen chloride (5 ml.) was kept at room temperature for 120 hr. and then was worked up in the usual way. A syrup was obtained which from its behaviour and elemental analysis was apparently a mixture of 3 : 6-anhydro-2 : 4-di-*O*-methyl-*aldehydo*-D-mannose dimethyl acetal (*ca.* 67%) and methyl 3 : 6-anhydro-2 : 4-di-*O*-methyl-αβ-D-mannoside (*ca.* 33%) (For the mixture, Found: C, 51·6; H, 7·9; OMe, 49·9%).

When methyl 3 : 6-anhydro-2 : 4-di-*O*-methyl-α-D-mannoside (16·3 mg.) was treated with ethereal 1·7N-hydrogen chloride (2 drops) for 1 min. at room temperature no reaction occurred and the starting material was recovered unchanged. A similar result was obtained when the amount of ethereal hydrogen chloride used was increased (to 1 ml.) and its time of action extended to several hours. Likewise substitution of chloroform for ether was ineffectual in promoting reaction.

(e) *Methyl* 3 : 6-*anhydro*-2 : 4-*di*-O-*methyl*-β-D-*mannoside*. A solution of the mannoside (50 mg.) in dry ether (4 ml.) was treated with ethereal 1·7N-hydrogen chloride (1 ml.). The ensuing reaction, followed polarimetrically, was essentially complete in 14 hr. The product was worked up in the standard fashion and a colourless non-reducing syrup (20 mg.) was obtained. This did not restore the colour to Schiff's reagent, and became gummy on nucleation with methyl 3 : 6-anhydro-2 : 4-di-*O*-methyl-α-D-mannopyranoside. Infra-red spectrographs indicated that the product contained a considerable proportion of methyl 3 : 6-anhydro-2 : 4-di-*O*-methyl-α-D-mannopyranoside.

3 : 6-*Anhydro*-2-*deoxy*-D-*galactose* (II).—An aqueous solution of methyl 3 : 6-anhydro-2-deoxy-α-D-galactoside (0·5 g.) was treated with 2N-sulphuric acid (1 ml.) for 105 min. Thereafter the solution was neutralised ($BaCO_3$), filtered, and evaporated to dryness under reduced pressure. The residue was extracted with water, and the extract evaporated. The syrupy residue was extracted with acetone. Removal of the solvent from this extract afforded a colourless syrup (0·39 g.), n^{15} 1·4977, $[\alpha]_D^{20}$ +23·8° (*c*, 3·61 in H_2O), which readily reduced warm Fehling's solution and rapidly restored the colour to Schiff's reagent. It was most probably 3 : 6-*anhydro*-2-*deoxy*-D-*galactose* (Found: C, 49·1; H, 7·0. $C_6H_{10}O_4$ requires C, 49·3; H, 6·85%).

A similar syrup (0·15 g.), n^{18} 1·4981, $[\alpha]_D^{19}$ +25·5° (*c*, 1·5 in H_2O), was obtained by treating 3 : 6-anhydro-2-deoxy-D-galactose dimethyl acetal (0·29 g.) in water (10 ml.) with N-sulphuric acid (1 ml.) for 4 hr.

3 : 6-*Anhydro*-2-*deoxy*-4-O-*methyl*-D-*galactose* (VI).—Hydrolysis of methyl 3 : 6-anhydro-2-deoxy-4-*O*-methyl-α-D-galactoside (66 mg.) with 0·1N-sulphuric acid (5 ml.) for 30 min. gave

3 : 6-*anhydro*-2-*deoxy*-4-O-*methyl*-D-*galactose* (41 mg.) as a colourless glass, $[\alpha]_D^{20}$ +37·5° (*c*, 1·0 in H_2O) (Found : OMe, 19·7. $C_7H_{12}O_4$ requires OMe, 19·4%). The same compound, $[\alpha]_D^{19}$ +36·5° (*c*, 0·5 in H_2O) (Found : OMe, 19·8%), was prepared by hydrolysis of 3 : 6-anhydro-2-deoxy-4-*O*-methyl-*aldehydo*-D-galactose dimethyl acetal (130 mg.) with 0·1N-sulphuric acid (5 ml.).

The amorphous material readily reduced warm Fehling's solution and immediately restored the colour to Schiff's reagent.

3 : 6-*Anhydro*-2-*deoxy*-4-O-*methyl*-D-*glucose* (XV).—Hydrolysis of methyl 3 : 6-anhydro-2-deoxy-4-*O*-methyl-α-D-glucoside (0·53 g.) with 0·1N-sulphuric acid (21 ml.) was complete in 1 hr. The solution was neutralised with barium carbonate, and the product isolated in the usual manner. 3 : 6-*Anhydro*-2-*deoxy*-4-O-*methyl*-D-*glucose* (0·33 g., 70%) was obtained as a colourless hygroscopic syrup which was reducing towards Fehling's solution and restored the colour to Schiff's reagent in the cold. It had b. p. 126° (bath-temp.)/0·2 mm., n^{15} 1·4717, $[\alpha]_D^{18}$ −24·6° (*c*, 2·36 in H_2O) (Found : C, 51·6; H, 8·15; OMe, 19·0. $C_7H_{12}O_4$ requires C, 52·5; H, 7·5; OMe, 19·4%). The same compound was obtained by hydrolysis of 3 : 6-anhydro-2-deoxy-4-*O*-methyl-*aldehydo*-D-glucose dimethyl acetal (61 mg.) with 0·1N-sulphuric acid (6 ml.) for 30 min.

Oxidation of this substance (0·12 g.) in water (10 ml.) with bromine (1·0 ml.) for 7 days at 30° yielded 3 : 6-*anhydro*-2-*deoxy*-4-O-*methyl*-D-*gluconic acid* (XVI) as a pale yellow syrup, b. p. 170° (bath-temp.)/0·01 mm., $[\alpha]_D^{19}$ −21° (*c*, 2 in H_2O) (Found : C, 47·0; H, 7·8. $C_7H_{12}O_5$ requires C, 47·7; H, 6·82%).

3 : 6-*Anhydro*-2-*deoxy*-5-O-*methyl*-D-*glucose*.—Methyl 3 : 6-anhydro-2-deoxy-5-*O*-methyl-α-D-glucofuranoside (0·51 g.) undergoes slow hydrolysis in 0·1N-sulphuric acid (20 ml.) at room temperature, the change in specific rotation being from +136° to +117° in 15 hr. At 100° the specific rotation changed to +73° during 15 min. and remained constant during further heating. The solution was neutralised and worked up as previously described. 3 : 6-*Anhydro*-2-*deoxy*-5-O-*methyl*-D-*glucose* (0·24 g., 54%) was obtained as a strongly reducing colourless syrup, b. p. 118° (bath-temperature)/0·05 mm., n^{25} 1·4530, $[\alpha]_D^{20}$ +90° (*c*, 1·7 in H_2O) (Found : C, 52·23; H, 7·2; OMe, 19·1%).

Oxidation of this sugar (170 mg.) in water (10 ml.) with bromine (1 ml.) at 30° for 7 days afforded 3 : 6-*anhydro*-2-*deoxy*-5-O-*methyl*-D-*glucono*-γ-*lactone* (XII), m. p. 68°, $[\alpha]_D^{18}$ +100° (*c*, 1·44 in H_2O) (const. for 6 days) (Found : C, 52·6; H, 6·17. $C_7H_{10}O_4$ requires C, 53·2; H, 6·33%).

3 : 6-*Anhydro*-2 : 4-*di*-O-*methyl*-aldehydo-D-*mannose* (XXXI).—Methyl 3 : 6-anhydro-2 : 4-di-*O*-methyl-α-D-mannopyranoside (1·48 g.) was heated at 100° in 0·1N-sulphuric acid (21 ml.). The specific rotation of the substance decreased evenly during 1·5 hr. ($[\alpha]_D$ +104° ⟶ +60°). The solution was neutralised ($BaCO_3$) and the product isolated by the normal procedure. 3 : 6-*Anhydro*-2 : 4-*di*-O-*methyl*-aldehydo-D-*mannose* was obtained as a colourless syrup (1·1 g., 80%), b. p. 112—116° (bath-temp.)/0·01 mm., n^{19} 1·4845, $[\alpha]_D^{19}$ +57·4° (*c*, 4·39 in H_2O) (Found : C, 49·7; H, 7·5; OMe, 33·0. $C_8H_{14}O_5$ requires C, 50·5; H, 7·4; OMe, 32·6%). An aqueous solution of the compound reduced warm Fehling's solution and rapidly restored the colour to Schiff's reagent.

In like fashion 3 : 6-*anhydro*-2 : 5-*di*-O-*methyl*-D-*mannofuranose* (XXV) (0·3 g., 50%) was obtained by hydrolysis of an aqueous solution (20 ml.) of methyl 3 : 6-anhydro-2 : 5-di-*O*-methyl-α-D-mannofuranoside (0·614 g.) with N-sulphuric acid (1·0 ml.), at 100° for 3·5 hr. The product was obtained as a colourless liquid, b. p. 145° (bath-temp.)/0·05 mm., n^{19} 1·4780, $[\alpha]_D^{18}$ +163° (*c*, 1·2 in H_2O) (const. for 2 days) (Found : OMe, 33·2%). The material was strongly reducing to Fehling's solution and slowly restored the colour to Schiff's reagent.

3 : 6-*Anhydro*-2 : 4-*di*-O-*methyl*-D-*mannonic Acid* (XXXII).—3 : 6-Anhydro-2 : 4-di-*O*-methyl-*aldehydo*-D-mannose (0·44 g.) was treated with bromine as previously described. Extraction of the product by the usual methods gave 3 : 6-*anhydro*-2 : 4-*di*-O-*methyl*-D-*mannonic acid* (0·4 g., 84%) as a colourless glass, $[\alpha]_D^{19}$ −10·2° (*c*, 0·6 in H_2O) (Found : OMe, 30·5. $C_8H_{14}O_6$ requires OMe, 30·1%). In an attempt to lactonise the acid (0·2 g.) it was maintained at 150°/0·05 mm. for 2 hr. and then distilled. The straw-coloured distillate, b. p. 180° (bath-temp.)/0·01 mm., $[\alpha]_D^{20}$ −11·0° (*c*, 0·45 in H_2O) (Found : OMe, 30·6%), was unchanged starting material.

3 : 6-*Anhydro*-2 : 5-*di*-O-*methyl*-D-*mannono*-γ-*lactone* (XXVI).—A solution of 3 : 6-anhydro-2 : 5-di-*O*-methyl-D-mannofuranose (0·2 g.) in water (10 ml.) was oxidised with bromine (1·0 ml.) at 40° for 4 days. Excess of bromine was removed by aeration and hydrogen bromide was eliminated by addition of silver oxide and subsequent filtration. Evaporation afforded a syrupy residue which was extracted with methanol. From this extract a solid material was isolated which on recrystallisation from ethanol gave 3 : 6-*anhydro*-2 : 5-*di*-O-*methyl*-D-*mannono*-γ-*lactone* (0·19 g., 96%) as colourless crystals, m. p. 118°, $[\alpha]_D^{20}$ +219° (*c*, 0·85 in H_2O) (const. for

2 days) (Found : C, 50·8; H, 6·47; OMe, 32·5. $C_8H_{12}O_5$ requires C, 51·1; H, 6·37; OMe, 33·0%).

*Treatment of Methyl 2-Deoxy-6-O-toluene-*p*-sulphonyl-α-*D*-galactoside with Sodium Iodide in Acetone.*—The toluene-*p*-sulphonyl derivative (0·264 g.) and sodium iodide (0·18 g.) were heated together in acetone solution (2·5 ml.) for 4 hr. at 80—90°. Thereafter the precipitate of sodium toluene-*p*-sulphonate was collected quantitatively in a sintered-glass crucible and was weighed after being washed with acetone and dried. The amount of precipitate (0·125 g.) (uncorrected for solubility losses) corresponded to an 80% exchange of the toluene-*p*-sulphonyloxy-group.

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