961. *Chemical Studies in the Biosynthesis of Purine Nucleotides. Part II.* The Synthesis of* N-*Glycyl*-D-*ribofuranosylamines.*

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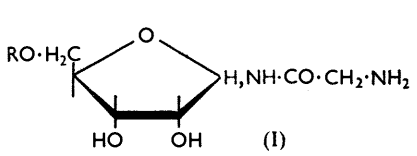
N-Glycyl-α- and -β-D-ribofuranosylamine (XII and its anomer) were synthesised in connection with studies on the synthesis of the natural purine nucleotide precursor " glycineamide ribotide " (I; R = PO_3H_2).

2 : 3 : 5-Tri-*O*-benzoyl-β-D-ribofuranosyl chloride (III) was converted into the β-azide (IV), then reduced to an unstable mixture of α- and β-forms of 2 : 3 : 5-tri-*O*-benzoyl-D-ribofuranosylamine (VIII). This reacted with benzyloxycarbonylglycyl chloride or with benzyloxycarbonylglycyl ethyl carbonate, and benzoyl groups were removed from the product. From the resulting mixture pure α- and β-forms of *N*-benzyloxycarbonylglycyl-D-ribofuranosylamine were separated by crystallisation. Hydrogenation yielded the *N*-glycyl compounds (XII and its anomer), conveniently isolated as their oxalates. The structure of these and intermediate products was confirmed by oxidation with periodate.

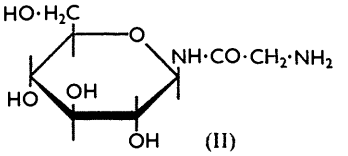
A method for the detection of *O*-acylated carbohydrate derivatives on paper chromatograms is described.

N-Glycyl-D-ribofuranosylamine 5-phosphate (" glycineamide ribotide ") (I; R = PO_3H_2) is believed to be an intermediate in the early stages of purine nucleotide biosynthesis. A compound with this structure has been isolated from natural sources [1,2,3] and shown to accumulate in systems where purine nucleotide synthesis has been inhibited at later stages. Although the purine nucleotides are β-glycosides, the configuration of the glycosyl residue in the precursor (I; R = PO_3H_2) has not been established. The synthesis of α- and β-forms of the riboside (I; R = H) and the corresponding phosphate (I; R = PO_3H_2) was of interest in connection with enzyme studies on the biosynthetic processes. Only one form of the phosphate is known to occur naturally, but when acidic conditions are used in its isolation two separable isomers are formed.[1] In suitable circumstances, both isomers are nucleotide precursors and it was thought that synthetic compounds with known configuration would assist in studies on the mechanism of their enzymic utilisation.

In Part I the synthesis of the model compound *N*-glycyl-β-D-glucopyranosylamine (II) was described.[4] The methods developed earlier have now been applied to the synthesis of ribofuranosyl derivatives. A preliminary account of this work has been published.[5]



(I)



(II)

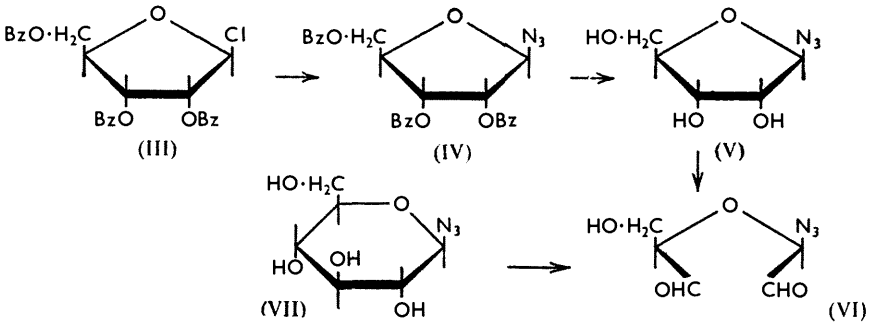
A convenient synthesis of the glucosylamine (II) involved reaction between 2 : 3 : 4 : 6-tetra-*O*-acetyl-β-D-glucopyranosylamine and a suitable derivative of glycine. For a similar synthesis of the ribofuranosyl analogue (I; R = H) the hitherto unknown acyl derivatives of β-D-ribofuranosylamine would be required.

2 : 3 : 5-Tri-*O*-benzoyl-β-D-ribofuranosyl chloride [6] (III) was converted in high yield into the azide (IV) by reaction with sodium azide in methyl cyanide. The azide probably

* Part I, *J.*, 1956, 2818.

[1] Goldthwait, Peabody, and Greenberg, *J. Biol. Chem.*, 1956, **221**, 555.
[2] Peabody, Goldthwait, and Greenberg, *ibid.*, p. 1071.
[3] Hartman, Levenberg, and (J. M.) Buchanan, *ibid.*, p. 1057.
[4] Baddiley, Buchanan, Handschumacher, and Prescott, *J.*, 1956, 2818.
[5] Baddiley, Buchanan, Hodges, and Prescott, *Proc. Chem. Soc.*, 1957, 148.
[6] Kissman, Pidacks, and Baker, *J. Amer. Chem. Soc.*, 1955, **77**, 18.

possesses the β-configuration, since acylribofuranosyl halides normally give β-glycosides. A proof of the β-configuration of this compound was obtained by debenzoylation with sodium methoxide in methanol to β-D-ribofuranosyl azide (V), which was oxidised with sodium periodate to the dialdehyde (VI). Although this product was not isolated it had $[\alpha]_D^{20}$ −216°, in close agreement with the values found for this compound prepared in a similar manner from β-D-glucopyranosyl azide (VII). The structure of the glucopyranosyl azide is undisputed, both α- and β-forms being known.[7,8] The pronounced negative rotations of the azide (V) and its tribenzoyl derivative (IV) are also consistent with the β-D-ribofuranosyl structures.



Catalytic hydrogenation of 2 : 3 : 5-tri-*O*-benzoyl-β-D-ribofuranosyl azide (IV) yielded the amino-sugar (VIII), characterised as a crystalline hydrochloride. The specific rotation of the hydrochloride in ethanol (+51·7°) did not alter significantly at room temperature during 24 hours. Experiments discussed below suggest that the β-compound mutarotates very readily and we consider that the positive specific rotation observed supports the view that the hydrochloride, even when freshly prepared, is an equilibrium mixture of α- and β-forms. In this respect it differs from the corresponding compound in the glucose series, 2 : 3 : 4 : 6-tetra-*O*-acetyl-β-D-glucopyranosylamine, which, although it mutarotates under certain conditions,[9] is moderately stable. The relative instability of the ribose derivative is probably associated with the presence in it of a furanose ring. Attempts to crystallise the amino-sugar (VIII) were unsuccessful and resulted in the formation of a substance which was no longer basic. Analysis indicated that this was isomeric with the amino-sugar and was probably represented by (IX). In the α-form of the amino-sugar (VIII) the benzoyl residue at position 2 is in a sterically favourable position for migration to the amino-group. The migration should be complete as the β-amino-compound assumes the α-structure. The ready migration of a 2-benzoyl residue to the 1-position has been observed with 2 : 3 : 5-tri-*O*-benzoylribofuranose.[10] A potassium bromide disc of the neutral compound (IX) showed infrared absorption maxima at 3328, 1652, and 1526 cm.$^{-1}$, characteristic of a secondary amide. A hydroxyl band at 3425 cm.$^{-1}$ and an ester-carbonyl band at 1723 cm.$^{-1}$ were also present. In the hydrochloride of (VIII) the hydroxyl and amide absorptions were absent and there was an appropriate increase in the band at 1723 cm.$^{-1}$ together with a complex series of bands from 3300 to 2400 cm.$^{-1}$, characteristic of the $^{+}NH_3$ group.[11]

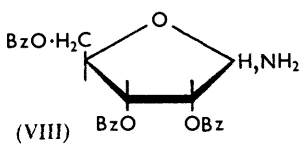
Freshly prepared 2 : 3 : 5-tri-*O*-benzoyl-D-ribofuranosylamine (VIII) reacted readily with benzyloxycarbonylglycyl chloride or benzyloxycarbonylglycyl ethyl carbonate, giving the glycine derivative (X) in 67% yield. In neither case did the product crystallise even after chromatography, but analysis indicated that it was reasonably pure. The gum had

[7] Bertho and Aures, *Annalen*, 1955, **592**, 54.
[8] Bertho, *Ber.*, 1930, **63**, 836.
[9] Bertho and Maier, *Annalen*, 1932, **498**, 50.
[10] Ness and Fletcher, *J. Amer. Chem. Soc.*, 1956, **78**, 4710.
[11] Bellamy, " The Infrared Spectra of Complex Molecules," Methuen, London, 1954.

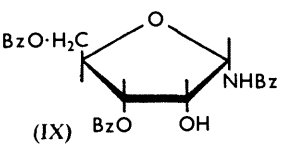
a low positive specific rotation, which suggested that it was a mixture of anomers. Removal of benzoyl groups from this with ammonia in methanol proceeded slowly, but sodium methoxide in methanol effected rapid debenzoylation. Crystallisation of the mixture from methanol gave the pure *N*-(benzyloxycarbonylglycyl)-α-D-ribofuranosylamine (XI), and the β-anomer was obtained from the mother-liquors as a monohydrate by crystallisation from water. The combined yield was excellent.

The structures of the benzyloxycarbonyl compounds (XI and its anomer) follow from their specific rotations (+76·6° and −34·4° respectively) and from their behaviour towards periodate. They each consumed one mol. of periodate without the formation of formic acid, and consequently must be furanosides. The specific rotation of the dialdehyde obtained from the isomer with $[\alpha]_D$ −34·4° agreed very closely with that derived from *N*-(benzyloxycarbonylglycyl)-β-D-glucopyranosylamine, whose configuration is firmly established.[4] It was necessary to carry out the periodate oxidations under slightly acidic conditions. This was particularly important with the ribofuranosyl derivatives where no formic acid is produced and consequently acidity does not develop. Under neutral conditions the dialdehydes formed were unstable and the optical activity of the products slowly disappeared.

It should be noted that whereas the ribofuranosylamine (VIII) mutarotates with great ease its glycyl derivatives (XI and the β-anomer) are stable, at least under moderate conditions of pH and temperature. A similar greatly increased stability of glycyl derivatives was observed in the glucose series.[4] The stability of the furanose ring in the *N*-glycyl-



(VIII)



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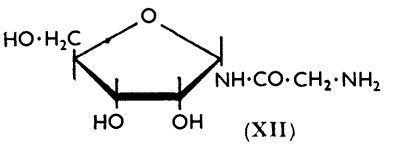
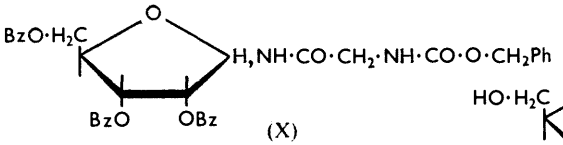
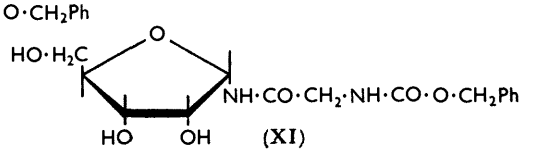


(XII)



(X)



(XI)

ribofuranosylamines is noteworthy and recalls the behaviour of *N*-acetyl-D-glucofuranosylamine.[12] We conclude that the anomerisation which had occurred in the above synthesis of the *N*-(benzyloxycarbonylglycyl) compounds (XI and its anomer) took place immediately after hydrogenolysis of the azide to the amine (VIII), and not at a later stage. Even when the azide was hydrogenated in the presence of acetic anhydride a mixture of anomeric *N*-acetylribofuranosylamines was formed.

Hydrogenolysis of the benzyloxycarbonyl derivatives (XI and its anomer) gave the corresponding *N*-glycyl-α- and -β-D-ribofuranosylamines (XII and its anomer). Each compound was isolated as its hydrogen oxalate by adsorption on Amberlite IRC-50 resin and elution with oxalic acid solution. The hydrogen oxalate of the α-compound (XII) was crystalline. Each consumed one mol. of periodate and the dialdehyde from the β-compound had the same specific rotation as that obtained by similar oxidation of *N*-glycyl-β-D-glucopyranosylamine.[4]

The relation of the glycylribofuranosylamines (XII and its anomer) to natural nucleotide precursors must await further experiment. This may be achieved either by enzymic dephosphorylation of " glycineamide ribotide " or by chemical phosphorylation of the two synthetic ribosides at position 5.

[12] Hockett and Chandler, *J. Amer. Chem. Soc.*, 1944, **66**, 957.

Extensive use has been made during this work of paper chromatography. Glycosylamines and their *N*-substituted derivatives on paper chromatograms were readily detected by the periodate–Schiff method. As this method depends on the presence in the molecule of a 1 : 2-glycol system it could not be applied directly to the acetylated and benzoylated derivatives. Acetylated sugars have been detected on paper by spraying with hydroxylamine solution, followed by ferric chloride.[13] This method, which depends upon the formation of acylhydroxamic acids, is unsatisfactory with benzoylated sugars. We have found that both acetylated and benzoylated sugar derivatives can be readily detected by exposing the paper to the vapour from saturated methanolic ammonia in a chromatography tank for 12 hours, followed by spraying with the periodate–Schiff reagents.

This chromatographic method enabled the course of debenzoylation of tri-*O*-benzoylribofuranosyl derivatives with ammonia to be studied. It was found that benzoyl groups at positions 2 and 3 were removed much more readily than that at position 5. Conditions were found where debenzoylation at positions 2 and 3 was complete but little attack at the 5-position had occurred. Thus, a compound believed to be 5-*O*-benzoyl-β-D-ribofuranosyl azide was detected as a major product of the action of ammonia on 2 : 3 : 5-tri-*O*-benzoyl-β-D-ribofuranosyl azide. Also, the main product from 2 : 3 : 5-tri-*O*-benzoyl-*N*-(benzyloxycarbonylglycyl)-D-ribofuranosylamine (X) was probably the 5-*O*-benzoyl derivative.

Experimental

2 : 3 : 5-*Tri*-O-*benzoyl*-β-D-*ribofuranosyl Azide*.—1-*O*-Acetyl-2 : 3 : 5-tri-*O*-benzoyl-β-D-ribofuranose (5·12 g., 1 mol.) was suspended in ether, saturated with hydrogen chloride at 0°, and kept at −14° for 10 days. Ether and hydrogen chloride were removed under reduced pressure at <5°. The residual gum was treated twice with benzene and once with toluene, followed by evaporation. There was finally no odour of acetic acid. The clear gum was dissolved in methyl cyanide (150 c.c.), finely ground sodium azide (5·1 g.; 7·7 mol.) was added, and the mixture stirred under reflux for 90 min. The solid was removed and washed with hot methyl cyanide. The combined filtrate and washings were evaporated to a gum, which was thrice dissolved in methanol and recovered by evaporation. Crystallised from methanol the *azide* (4·65 g., 94%) had m. p. 62—63°. Recrystallised from methanol, it had m. p. 66·5—67°, $[\alpha]_D^{22}$ −41·2° (*c* 2·97 in $CHCl_3$) (Found: C, 63·6; H, 4·7; N, 8·8. $C_{26}H_{21}O_7N_3$ requires C, 64·0; H, 4·3; N, 8·6%). The compound exists in two crystalline forms: large prisms, m. p. 62—63°, and fine needles, m. p. 66·5—67°. A mixture of the two forms has m. p. 63—64°.

β-D-*Ribofuranosyl Azide*.—The tribenzoate (1·0 g., 1 mol.) was suspended in dry methanol (10 c.c.), a solution of sodium (0·01 g., 0·2 mol.) in dry methanol (5 c.c.) added, and the mixture left overnight at room temperature. Excess of alkali was removed with Amberlite IRC-50 (H^+ form; methanol-washed) resin, and the solution was evaporated to a gum. This was dissolved in water (10 c.c.), extracted twice with ether (5 c.c.) to remove methyl benzoate, and evaporated to constant weight (0·3 g., 83%), $[\alpha]_D^{20}$ −193° (*c* 1·77 in H_2O). The product did not crystallise but was chromatographically pure. The dialdehyde produced by periodate oxidation had $[\alpha]_D^{20}$ −216° (*c* 1·41 in H_2O). β-D-Glucopyranosyl azide, $[\alpha]_D^{21}$ −28·9° (*c* 1·28 in H_2O), gave a dialdehyde with $[\alpha]_D^{20}$ −212° (*c* 0·86 in H_2O).

2 : 3 : 5-*Tri*-O-*benzoyl*-β-D-*ribofuranosylamine Hydrochloride*.—The tri-*O*-benzoyl-β-D-ribofuranosyl azide (1·0 g.) was dissolved in ethyl acetate (25 c.c.), Adams catalyst (0·1 g.) added, and the mixture hydrogenated at room temperature and pressure for 90 min. There was no change in gas volume. Magnesium sulphate (anhydrous) was added and after 10 min. the solids were filtered off and washed with ethyl acetate. Ether (16 c.c.) saturated with hydrogen chloride was added to the filtrate and washings. The resulting colourless *hydrochloride* (0·78 g., 76%), m. p. 124—127° (decomp.), was filtered off and washed with ether. Recrystallised from ethanol–ether it (0·28 g.) had m. p. 142—143·5°, $[\alpha]_D^{20}$ +51·7° (*c* 0·92 in EtOH) (Found: C, 63·4; H, 5·2; N, 2·9. $C_{26}H_{24}O_7NCl$ requires C, 62·7; H, 4·9; N, 2·8%). The specific rotation did not change significantly during 24 hr. at room temperature.

3 : 5-*Di*-O-*benzoyl*-N-*benzoyl*-α-D-*ribofuranosylamine*.—Tri-*O*-benzoyl-β-D-ribofuranosyl azide (0·5 g.) was hydrogenated as before for 4¼ hr. After removal of catalyst the solvent was

[13] Abdel-Akher and Smith, *J. Amer. Chem. Soc.*, 1951, **73**, 5859.

evaporated to a gum which slowly crystallised from dry methanol. The *product* (0·19 g., 40%) had m. p. 138—143°. Recrystallised from dry methanol it had m. p. 160—164°, $[\alpha]_D^{22}$ +60·8° (*c* 1·92 in $CHCl_3$) (Found: C, 67·7; H, 6·1; N, 3·1. $C_{26}H_{23}O_7N$ requires C, 67·7; H, 5·6; N, 3·1%).

2 : 3 : 5-*Tri*-O-*benzoyl*-N-(*benzyloxycarbonylglycyl*)-α,β-D-*ribofuranosylamine*.—Tri-*O*-benzoyl-β-D-ribofuranosyl azide was reduced in ethyl acetate (25 c.c. per g. of azide) with Adams catalyst (10%) at room temperature and pressure for 90 min., treated with anhydrous magnesium sulphate, and filtered. The resulting solution was used immediately.

(a) *Acid chloride method.* Benzyloxycarbonylglycyl chloride (from 3·07 g. of acid, 3 mol.) in chloroform (5 c.c.) was mixed at −5° with the amine solution (from 2·38 g. of azide, 1 mol.). After 5 min., pyridine (2·5 c.c., 6 mol.) was added, and the solution kept at −5° for 20 min. and at room temperature for 2 hr. The mixture was diluted with chloroform (180 c.c.) and washed with 2N-hydrochloric acid (twice), water, saturated sodium hydrogen carbonate solution, and water (150 c.c. of each). The chloroform layer was dried (Na_2SO_4) and evaporated to a gum. The gum was dissolved in benzene–light petroleum (b. p. 60—80°) (3 : 1) and chromatographed on neutral alumina (300 g.). After the column had been washed with benzene–chloroform mixtures the product was eluted with pure chloroform—in about 500 c.c. of solution. Evaporation left a gummy amide (2·13 g., 67% based on azide), $[\alpha]_D^{20}$ +6·2° (*c* 3·0 in $CHCl_3$) (Found: C, 65·3; H, 5·3; N, 4·4. Calc. for $C_{36}H_{32}O_{10}N_2$: C, 66·3; H,4·9; N, 4·3%).

(b) *Carbonic anhydride method.* Ethyl chloroformate (2·33 c.c., 3 mol.) was added dropwise to a solution of benzyloxycarbonylglycine (5·16 g., 3 mol.) and triethylamine (3·22 c.c., 3 mol.) in dry ethyl acetate (75 c.c.) cooled to −20°. After 10 min. the amine solution [from azide (4·0 g., 1 mol.)] was added at −5° and the mixture kept at this temperature for 10 min., then allowed to warm to room temperature overnight. The solution was washed with 2N-hydrochloric acid (twice), water, saturated sodium hydrogen carbonate solution, and water. Evaporation of the dried ($MgSO_4$) solution to small volume gave crystals of benzyloxycarbonylglycine anhydride (1·74 g.), m. p. 117—121°, raised to m. p. 120·5—124° by recrystallisation from ethyl acetate. The mother-liquors were evaporated to dryness and chromatographed on neutral alumina as before, to give a gum (3·48 g., 68% based on azide), $[\alpha]_D^{21}$ +11·4° (in $CHCl_3$). Careful rechromatography on neutral alumina failed to yield crystalline material.

N-(*Benzyloxycarbonylglycyl*)-α- *and* -β-D-*ribofuranosylyamine*.—The foregoing tribenzoate (3·48 g., 1 mol.) was dissolved in a little dry methanol, and sodium methoxide (from 0·012 g. of sodium; 0·1 mol.) in methanol (5 c.c.) added at room temperature. After 12 hr. crystals of the α-form (0·65 g.), m. p. 163—164°, were filtered off. The filtrate was treated with Amberlite IRC-50 (H^+; methanol-washed) resin until neutral. The solution was evaporated to a gum which yielded the α-form (0·27 g.), m. p. 158—163°, on trituration with methanol. The filtrate was evaporated and the residue was dissolved in water, washed with ether (twice), evaporated to small volume, and inoculated with the β-form. A fraction (0·14 g.), m. p. 87—140° (containing α,β-forms), separated, followed by another (0·44 g.), m. p. 80—86° (mainly β-form). The total yield of crystals was 1·50 g. (83%).

The α-containing fractions were combined and recrystallised from methanol. The pure α-*compound* had m. p. 169—170·5°, $[\alpha]_D^{20}$ +76·6° (*c* 1·06 in H_2O), $[\alpha]_D^{18}$ +63·6° (*c* 0·98 in pyridine) (Found: C, 53·0; H, 5·4; N, 8·0. $C_{15}H_{20}O_7N_2$ requires C, 52·9; H, 5·9; N, 8·2%).

The pure β-*compound* crystallised from water, with m. p. 98—101°, $[\alpha]_D^{20}$ −34·4° (*c* 1·96 in H_2O), $[\alpha]_D^{20}$ −31·9° (*c* 0·88 in pyridine) (Found: C, 50·7; H, 6·3; N, 7·2. $C_{15}H_{20}O_7N_2,H_2O$ requires C, 50·4; H, 6·2; N, 7·5%). Seed crystals of the β-form were initially obtained from β-enriched mother-liquors by countercurrent distribution. In a butan-1-ol–water system, 50 transfers effected separation from a small amount of β-D-ribofuranosyl azide, $[\alpha]_D^{20}$ −193°, and the main peak yielded crystalline material.

Periodate Oxidations.—The α-compound consumed 0·97 mol. of sodium metaperiodate, giving a dialdehyde of $[\alpha]_D^{20}$ +35·7° (*c* 0·79 in H_2O). The β-compound consumed 1·00 mol., the dialdehyde having $[\alpha]_D^{20}$ −72·4° (*c* 0·94 in H_2O). *N*-Benzyloxycarbonylglycyl-β-D-glucopyranosylamine gave a dialdehyde with $[\alpha]_D^{20}$ −69·7° (*c* 1·69 in H_2O).

N-*Glycyl*-α-D-*ribofuranosylamine Hydrogen Oxalate*.—*N*-Benzyloxycarbonylglycyl-α-D-ribofuranosylamine (0·65 g., 1 mol.) was hydrogenolysed in 50% aqueous ethanol in the presence of palladium. The evolved carbon dioxide was absorbed by concentrated sodium hydroxide in a side-arm to the reaction vessel and hydrogenation was complete in 70 min. The solution was filtered from the catalyst, which was washed with aqueous ethanol. The combined filtrate

and washings were evaporated to about half-volume and adsorbed on a column of Amberlite IRC-50 resin (H^+ form; 1·5 × 12·0 cm.). The column was washed with water (100 c.c.) and the product was eluted with 0·1M-oxalic acid, 10 c.c. fractions being collected. A drop of each fraction was examined on paper by using the ninhydrin reaction. Fractions 2—7 were combined and evaporated to a semicrystalline residue. This was dissolved in water (10 c.c.) and ethanol was added gradually until there was no further precipitation. The *oxalate* (0·37 g.), m. p. 131—134° (decomp.), was collected. Recrystallisation from water–ethanol gave a product (0·30 g., 53%) with m. p. 148—151° (decomp. with evolution of gas), $[\alpha]_D^{23}$ +88·9° (*c* 0·73 in H_2O) (Found: C, 36·7; H, 5·4; N, 9·0. $C_9H_{16}O_9N_2$ requires C, 36·5; H, 5·4; N, 9·5%). On periodate oxidation, 0·96 mol. of oxidant was consumed. The resulting dialdehyde had $[\alpha]_D^{20}$ +36·4° (*c* 0·47 in H_2O).

N-*Glycyl*-β-D-*ribofuranosylamine Hydrogen Oxalate*.—This was prepared from the β-benzyloxycarbonyl compound (0·38 g.) in a manner similar to that described above for the α-compound. After adsorption and elution from an ion-exchange resin the ninhydrin-positive fractions were evaporated to a gum. This was reprecipitated from water (1 c.c.) by addition of ethanol (24 c.c.). Solvents were decanted and the residue of *oxalate* was evaporated to a foam (0·14 g., 48%), $[\alpha]_D^{18}$ −49·7° (*c* 1·13 in H_2O) (Found: C, 36·6; H, 6·8; N, 9·8%). On oxidation 0·98 mol. of sodium periodate was consumed and the resulting dialdehyde had $[\alpha]_D^{18}$ −92·7° (*c* 0·54 in H_2O). The dialdehyde obtained by oxidation of *N*-glycyl-β-D-glucopyranosylamine had $[\alpha]_D^{18}$ −91·9° (*c* 0·71 in H_2O).

Paper Chromatography.—The general methods were similar to those used in Part I. *O*-Acyl derivatives were detected in the following manner: The air-dried papers were hung in a chromatography tank above saturated methanolic ammonia for 12 hr. at room temperature. Excess of ammonia was allowed to diffuse from the papers during 2 hr. and the paper was sprayed with the periodate–Schiff reagents.

R_F Values.

Compound	Ninhydrin	IO_4^-/ Schiff	BuOH–AcOH	PrOH–NH_3
Tri-*O*-benzoyl-β-D-ribofuranosyl azide	—	+ *	0·98	
5-*O*-Benzoyl-β-D-ribofuranosyl azide	—	+	0·91	
β-D-Ribofuranosyl azide	—	+	0·63	
Tri-*O*-benzoyl-*N*-(benzyloxycarbonylglycyl)-D-ribofuranosylamine	—	+ *	0·97	
5-*O*-Benzoyl-*N*-(benzyloxycarbonylglycyl)-D-ribofuranosylamine	—	+	0·91	
N-(Benzyloxycarbonylglycyl)-α- and -β-D-ribofuranosylamines	—	+	0·67	0·89
N-Glycyl-α- and -β-D-ribofuranosylamines	+ (Yellow)	+	0·16	0·66
Glycine	+ (Purple)	—	0·18	0·51
Ribose	—	+	0·28	0·62

* After ammonia treatment.

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