complex of mercury was filtered off, and the filtrate was lyophilized. The solid was repeatedly dissolved in methanol, the solvent was evaporated, and the white powder resulting was finally recrystallized from methanol–acetone–ether to afford 107 mg (66%) of white needles, mp 180–182° dec, $[\alpha]^{27}D$ +8.4° (*c* 0.74, water, final) [lit.[19] mp 184–187° dec, $[\alpha]^{29}D$ +8° (*c* 1, water, final) for unlabeled compound]. This material was identical in several tlc systems with an authentic sample of *N*-acetyl-α-D-xylosamine provided by the late Professor Wolfrom. It was recrystallized to a constant specific activity of 3.10×10^6 dpm/mg (0.29 mCi/mmol).

Enzymic Synthesis of Oligosaccharides Containing Xylosamine.—In a typical experiment, 17 mg (0.020 mmol) of the β(1→4)-linked tetramer of 2-acetamido-2-deoxy-D-glucose (**12**) and 17 mg (0.085 mmol) of 5-^3H-2-acetamido-2-deoxy-α-D-xylopyranose (**10**, 3.10×10^6 dpm/mg) were incubated with 2 mg of lysozyme (Worthington LYSF, three times recrystallized salt free) in 2 ml of 0.1 *M* sodium acetate–acetic acid buffer, pH 5.2, at 39.5° for 25 hr, and the mixture was applied to a 1 × 30 cm charcoal–Celite column. The column was eluted with a gradient from water to 40% ethanol over 2 l. Fractions of 10 ml were collected at a rate of 1.5 ml/min and analyzed (Figure 3). Fractions 37–50 (A) were pooled and lyophilized to yield 4.5 mg of material which was rechromatographed on a 1 × 30 cm column with a 2-l. 0–20% ethanol gradient. The major peak was collected and lyophilized to yield pure *O*-2-acetamido-2-deoxy-β-D-glucopyranosyl-(1→4)-5-^3H-2-acetamido-2-deoxy-D-xylopyranose (**1**). This material was shown to be identical with that produced synthetically, by tlc (systems I, II, III) and cochromatography on a 1 × 30 cm charcoal–Celite column with a 2-l. 0–15% ethanol gradient.

Fractions 67–78 from the initial chromatography (B, Figure 3) contained *O*-2-acetamido-2-deoxy-β-D-glucopyranosyl-(1→4)-*O*-2-acetamido-2-deoxy-β-D-glucopyranosyl-(1→4)-5-^3H-2-acetamido-2-deoxy-D-xylopyranose (**7**), together with the β(1→4)-linked trimer of 2-acetamido-2-deoxy-D-glucose (**6**), and fractions 87–97 (C) contained *O*-2-acetamido-2-deoxy-β-D-glucopyranosyl-(1→4)-*O*-2-acetamido-2-deoxy-β-D-glucopyranosyl-(1→4)-*O*-2-acetamido-2-deoxy-β-D-glucopyranosyl-(1→4)-5-^3H-2-acetamido-2-deoxyxylopyranose (**9**), together with the β(1→4) tetramer of 2-acetamido-2-deoxy-D-glucose (**12**). Each of these peaks was pooled and rechromatographed twice, with the front of the peak being collected each time. Analysis of known weights of the final products for ^3H content revealed that the trisaccharide mixture contained 22 mol % of the xylosamine-containing compound **7** and that the tetrasaccharide mixture contained 16 mole % of the xylosamine-containing compound **9**.

Registry No.—**1**, 38864-17-4; **2**, 35061-50-8; **3**, 38864-18-5; **4**, 38864-19-6; **5**, 38864-20-9; **6**, 38864-21-0; **8**, 38864-22-1; **10**, 38864-23-2; **11**, 38864-24-3; **13**, 38864-25-4; **14**, 38859-04-0; **15**, 7115-40-4.

C-Glycosyl Nucleosides. II.[1] A Facile Synthesis of Derivatives of 2,5-Anhydro-D-allose

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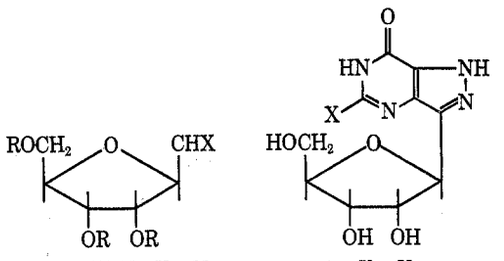
A very facile synthetic route to 3,4,6-substituted derivatives of 2,5-anhydro-D-allose is described. Reductive hydrolysis of 2,3,5-tri-*O*-benzoyl-β-D-ribofuranosyl cyanide (**3**) with Raney nickel and sodium hypophosphite in aqueous pyridine–acetic acid is accompanied by extensive elimination of benzoate to give furfural derivatives. In the presence of *N*,*N*′-diphenylethylenediamine (**6**), however, the initial aldehyde is trapped as a crystalline 1,3-diphenylimidazolidine derivative (**7**) which is obtained in 74% yield. In a similar way 5-*O*-benzoyl-2,3-*O*-isopropylidene-β-D-ribofuranosyl cyanide is converted into the corresponding imidazolidine derivative (**12**). Alkaline hydrolysis of (**7**) gives 1,3-diphenyl-2-(β-D-ribofuranosyl)imidazolidine (**8**) which can be converted into the tri-*O*-benzyl ether **9a** or the tri-*O*-acetate **9b**. Regeneration of the free 3,4,6-trisubstituted 2,5-anhydro-D-alloses from the imidazolidine derivatives can be achieved by mild acidic treatment.

In recent years a considerable number of *C*-glycosyl nucleosides have been isolated from natural sources.[2] The frequently interesting biological properties of these substances have made them interesting targets for chemical synthesis, but as yet this has proved to be a more formidable task than the preparation of conventional *N*-glycosyl nucleosides. Thus, while the preparation of 5-(β-D-ribofuranosyl)uracil (pseudouridine) has been achieved through carbon–carbon bond formation between a 5-lithiopyrimidine and a suitable derivative of ribose,[1,3] and this method has also been extended to other 5-glycosyluracils,[4] this route has not yet been readily adapted for use with other heterocycles.

A more versatile route would appear to involve the preparation of an appropriately C_1-functionalized derivative of 2,5-anhydro-D-allose or 2,5-anhydro-D-allitol (**1**), a compound already containing the desired elusive carbon–carbon bond, from which C_1 can be elaborated into a variety of heterocycles. One such derivative is the diazo compound **1a** which has been



1a, R = CH_2Ph; X = N_2
b, R = CH_2Ph; X = O
c, R = Bz; X = O

2a, X = H
b, X = OH

ingeniously converted into formycin B (**2a**)[5] and oxoformycin (**2b**)[6] *via* initial cycloaddition to dimethyl acetylenedicarboxylate.

In a related way the furanosyl keto ester (**1**, R = Ac; CHX = $COCO_2Me$) has been transformed into the

(1) For part I, see U. Lerch, M. G. Burdon, and J. G. Moffatt, *J. Org. Chem.*, **36**, 1507 (1971).

(2) For reviews, see (a) K. Gerzon, D. C. de Long, and J. C. Cline, *Pure Appl. Chem.*, **28**, 489 (1971); (b) R. J. Suhadolnik, "Nucleoside Antibiotics," Wiley-Interscience, New York, N. Y., 1970.

(3) D. M. Brown, M. G. Burdon, and R. P. Slatcher, *J. Chem. Soc.*, 1051 (1968).

(4) W. A. Asbun and S. B. Binkley, *J. Org. Chem.*, **31**, 3315 (1966); **33**, 140 (1968).

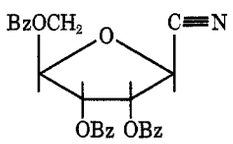
(5) E. M. Acton, K. J. Ryan, D. W. Henry, and L. Goodman, *Chem. Commun.*, 986 (1971).

(6) (a) M. Bobek, J. Farkaš, and F. Šorm, *Tetrahedron Lett.*, 4611 (1970); (b) J. Farkaš and F. Šorm, *Coll. Czech. Chem. Commun.*, **37**, 2798 (1972).

nucleoside antibiotic showdomycin,[7] and both the carboxylic acid (1, R = Bz; CHX = COOH)[8] and the thioformimidate [1, R = Bz; CHX = C(=NH)-SCH_2Ph][9] have been incorporated into derivatives of 8-β-D-ribofuranosyladenine. Finally, the recently described synthesis of a β-D-ribofuranosylethyne (R = CH_2Ph; CHX = C≡CH) paves the way to certain 4-ribosyltriazoles.[10]

A recent brief communication by Ogawa, *et al.*,[11] has described a multistep process by which glucose may be converted into 2,5-anhydro-3,4,6-tri-*O*-benzyl-D-allose (**1b**) which was subsequently transformed into intermediates leading to the diazo compound **1a**. The free aldehyde group of **1b** is also, however, an attractive functional group for elaboration of *C*-glycosyl heterocycles, and in this paper we describe a facile route for the preparation of variously substituted derivatives of 2,5-anhydro-D-allose.[12]

The key intermediate in our synthesis is 2,3,5-tri-*O*-benzoyl-β-D-ribofuranosyl cyanide (**3**), a crystalline compound which is readily prepared in 70–80% yields from 2,3,5-tri-*O*-benzoyl-D-ribofuranosyl bromide and mercuric cyanide according to the procedure of Bobek and Farkaš.[8] This substance has been both hydrolyzed to the corresponding allonic acid[8] and reduced to 1-amino-2,5-anhydro-1-deoxyallitol[13] during previous work, but the most direct route to the desired compound would appear to be reductive hydrolysis of the cyano function to the aldehyde **1c**. Such procedures have been reviewed[14] and a convenient modification would appear to be that developed by Backeberg and Staskun.[15] Indeed, the reaction of **3** with an excess of Raney nickel and sodium hypophosphite in a mixture of pyridine, acetic acid and water at 45° for 1 hr led to quite rapid conversion into a material giving a positive test for aldehydes using acidic dinitrophenylhydrazine as a spray on thin layer plates. The colored spot was,



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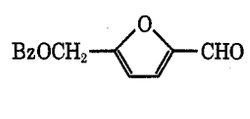

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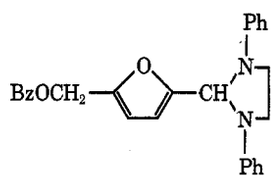


5

(7) L. Kalvoda, J. Farkaš, and F. Šorm, *Tetrahedron Lett.*, 2297 (1970).

(8) M. Bobek and J. Farkaš, *Collect. Czech. Chem. Commun.*, **34**, 247 (1968).

(9) J. Igolen and T. H. Dink, *Chem. Commun.*, 1267 (1971).

(10) J. G. Buchanan, A. R. Edgar, and M. J. Power, *J. Chem. Soc. D*, 346 (1972).

(11) T. Ogawa, Y. Kikuchi, M. Matsui, H. Ohrui, H. Kuzuhara, and S. Emoto, *Agr. Biol. Chem.*, **35**, 1825 (1971).

(12) For a general review on 2,5-anhydro sugars, see J. Defaye, *Advan. Carbohyd. Chem. Biochem.*, **25**, 181 (1970). Routes similar to that of ref 11 have subsequently been developed by Emoto, *et al.*, for the preparation of the dimethyl acetals of other 2,5-anhydrohexose derivatives: personal communication from Drs. H. Ohrui and S. Emoto.

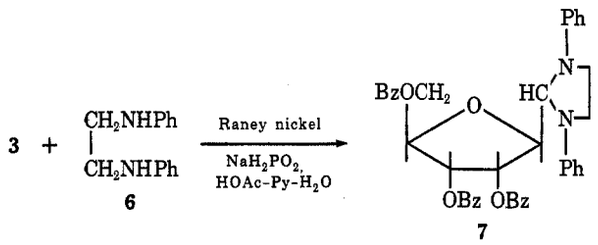
(13) M. Bobek and J. Farkaš, *Collect. Czech. Chem. Commun.*, **34**, 1684 (1969).

(14) (a) E. Mosettig, *Org. React.*, **8**, 218 (1954). (b) Houben-Weyl, "Methoden der organischen Chemie," 4th ed, Vol. VII, part I, Thieme Verlag, Stuttgart, 1954, p 299.

(15) O. G. Backeberg and B. Staskun, *J. Chem. Soc.*, 3961 (1962).

however, orange rather than yellow and suggested the presence of an unsaturated aldehyde. Indeed, this substance was isolated as a crystalline derivative (**5**) and shown to be the furan **4** resulting from elimination of benzoate from the desired aldehyde **1c**. It could be readily shown by tlc that this elimination took place during the reductive hydrolysis rather than during preparation of the derivative **5**. Thus regeneration of the aldehyde **4** from **5** (see later) gave a substance identical with the direct product of the reductive hydrolysis and clearly different from **1c**.

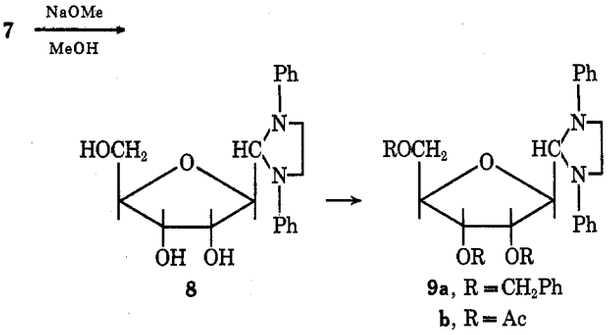
This very facile elimination reaction was finally avoided by conducting the reductive hydrolysis reaction in the presence of *N,N'*-diphenylethylenediamine (**6**). The latter reagent has been developed



6 7

by Wanzlick and Löchel[16] for the selective conversion of aldehydes[17] into 1,3-diphenylimidazolidine derivatives and has previously been used to trap aldehydes formed by hydrogenation of nitriles[18] or desulfurization of thio esters.[19] In the presence of **6** the reaction of **3** with sodium hypophosphite and Raney nickel in aqueous pyridine–acetic acid was rapid at room temperature and gave crystalline 1,3-diphenyl-2-(2,3,5-tri-*O*-benzoyl-β-D-ribofuranosyl)imidazolidine (**7**) in 74% yield.

While, as will be seen later, the imidazolidine ring is very readily hydrolyzed under acidic conditions, it is very stable toward base. Thus treatment of **7** with



8 9a, R = CH_2Ph; b, R = Ac

methanolic sodium methoxide led to smooth cleavage of the benzoyl groups, giving crystalline 1,3-diphenyl-2-(β-D-ribofuranosyl)imidazolidine (**8**) in a yield of 73%. Subsequent benzylation of **8** using benzyl chloride and sodium hydride in dimethyl sulfoxide gave the crystalline tri-*O*-benzyl ether **9a** in 80% yield. Alternatively, simple acetylation of the triol **8** gave the tri-*O*-acetyl

(16) H. W. Wanzlick and W. Löchel, *Chem. Ber.*, **86**, 1463 (1953).

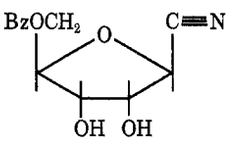
(17) This reagent has also been widely exploited in this laboratory by Dr. G. H. Jones, *et al.*, for the isolation of nucleoside 5'-aldehydes. See, *e.g.*, N. P. Damodaran, G. H. Jones, and J. G. Moffatt, *J. Amer. Chem. Soc.*, **93**, 3812 (1971). We are particularly grateful to Dr. Jones for his advice in this matter.

(18) H. Plieninger and B. Kiefer, *Chem. Ber.*, **90**, 617 (1957).

(19) (a) H. J. Bestmann and H. Schulz, *Chem. Ber.*, **92**, 530 (1959); (b) W. J. Gottstein, G. E. Bocian, L. B. Crast, K. Dadabo, J. M. Essery, J. C. Godfrey, and L. C. Cheney, *J. Org. Chem.*, **31**, 1922 (1966).

derivative **9b** in 96% yield. Clearly, other types of protecting groups could also be introduced under basic conditions if so desired.

The above methods make derivatives of 2,5-anhydro-D-allose containing protecting groups that can be subsequently removed under alkaline or reductive conditions readily available. Protection of the vicinal diol by a noneliminatable, acid-labile substituent such as an isopropylidene group was also desirable. To this end the nitrile **3** was treated with methanolic ammonia at 0° which selectively removed the secondary benzoyl groups, giving 5-*O*-benzoyl-β-D-ribofuranosyl cyanide (**10**) in 83% yield. This reaction has previously been described by Montgomery and Hewson,[20] but under the present conditions the yield of crystalline product was more than doubled without the necessity of chromatography. Subsequent treatment of **10** with acetone



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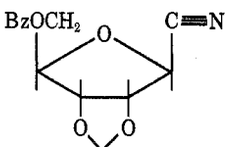

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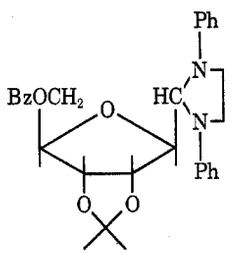
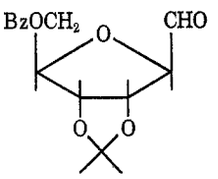


12



13

and 2,2-dimethoxypropane in the presence of perchloric acid gave a 95% yield of the crystalline isopropylidene derivative **11** which was previously described as a syrup.[20] Reductive hydrolysis of **11** in the presence of *N*,*N*′-diphenylethylenediamine gave, as above, the crystalline imidazolidine derivative **12** in 78% yield.

Regeneration of the free aldehyde function from 1,3-diphenylimidazolidine derivatives has usually been achieved by treatment with a heterogeneous mixture of ether and 3–6 *N* hydrochloric acid.[18,19a] The aldehydes can, however, be liberated under much milder conditions by treatment with 2.5–3 molar equiv of *p*-toluenesulfonic acid monohydrate in a mixture of acetone and methylene chloride at 0–20°.[21] Such treatment of **7**, **9a**, and **12** leads to the rapid precipitation of the *p*-toluenesulfonate salt of *N*,*N*′-diphenylethylenediamine which can be removed by filtration and aqueous extraction. The residual products so obtained in high yields are the 3,4,6-substituted 2,5-anhydro-D-allose derivatives (**1c**, **1b**, and **13**, respectively) which are sufficiently pure for direct use in subsequent reactions to be described in forthcoming papers.[22] It is interesting to note that, even though tlc examination of the crude reaction mixtures shows complete disappearance of the imidazolidine derivatives, small amounts (perhaps 5%) of unreacted material are usually found in the worked up products. This could be due to the precipitation of traces of the *p*-toluenesulfonate salt of the starting material which does not become solubilized until work-up. For the preparation of analytical samples these minor impurities can be removed by rapid chromatography on a column of silicic acid. By this means chromatographically and analytically pure samples of **1c**, **1b**, and **13** were obtained. Our previous experience in the chemistry of nucleoside 5′-aldehydes has made us acutely aware of the perils of elimination and epimerization reactions which attend chromatography of molecules of this sort.[23] The derivatives of 2,5-anhydro-D-allose are also potentially subject to these reactions, and, accordingly, we do not recommend chromatography as a preparative procedure. We do not have any evidence, however, for such side reactions prior to, or during, acidic removal of the imidazolidine groups. Certainly the chromatographic purity of the crude aldehydes (**1b**, **1c**, and **13**) precludes elimination reactions which are always much more prevalent than epimerization.[23] The lack of side reactions accompanying the liberation of nucleoside 5′-aldehydes from their imidazolidine derivatives under comparable conditions has been previously demonstrated.[17]

The free aldehydes are rather unstable compounds in solution and it is recommended that they be generated only immediately prior to use. For example, the tribenzoyl aldehyde **1c** can be shown by tlc to undergo extensive decomposition upon storage in chloroform at room temperature for 2 hr. It can, however, be stored as a syrup at −20° for many days. The benzyl and isopropylidene derivatives (**1b** and **13**) were, expectedly, more stable.

As an alternative procedure for the hydrolysis of the imidazolidine derivatives, we have sometimes used treatment with Dowex-50 (H^+) resin in aqueous tetrahydrofuran. This procedure is convenient since all traces of basic hydrolysis products are bound by the resin and can be removed by simple filtration. This procedure, however, requires treatment at 50–60° for several hours to complete the hydrolysis, but the reaction can be taken to completion giving chromatographically homogeneous aldehydes. By this method, the tribenzyl ether **1b** can be obtained in very high yield as described in the accompanying paper.[24]

The derivatives of 2,5-anhydro-D-allose described in this paper provide very useful starting materials for the synthesis of a wide range of *C*-glycosyl nucleosides. Such syntheses will be described in forthcoming papers in this series.[22,24]

Experimental Section

General Methods.—The general analytical methods were similar to those described previously.[1]

Nmr Data.—These are given in Tables I and II.

2,3,5-Tri-*O*-benzoyl-β-D-ribofuranosyl Cyanide (3).—This compound was prepared in 78% yield according to Bobek and Farkaš[8] with mp 77.5–79° (lit.[8] mp 78.5–80°); $[\alpha]^{23}D$ 24.2° (*c* 0.98, $CHCl_3$); λ_{max}^{MeOH} 230 nm (ε 35,000), 274 (2800), 288 (2400).

(20) J. A. Montgomery and K. Hewson, *J. Heterocycl. Chem.*, **7**, 443 (1970).

(21) *p*-Toluenesulfonic acid has previously been used by Gottstein, *et al.*,[19b] for the liberation of penicillinaldehydes from their imidazolidine derivatives.

(22) Unpublished studies by H. P. Albrecht, D. B. Repke, and J. G. Moffatt.

(23) See, *e.g.*, G. H. Jones and J. G. Moffatt, Abstracts, 158th National Meeting of the American Chemical Society, New York, 1969, CARB 16.

(24) G. Trummlitz and J. G. Moffatt, *J. Org. Chem.*, **38**, 1841 (1973).

TABLE I

CHEMICAL SHIFTS (PARTS PER MILLION) AT 100 MHz[a]

Compd	Solvent[b]	C_1H	C_2H	C_3H	C_4H	C_5H	C_6H	Other
3	C		4.96 (d)	5.98 (dd)	5.82 (dd)	4.65 (m)	4.65 (m)	7.2–8.2 (m, 15, Ar)
5	C	6.14 (s)		6.26 (s)	6.26 (s)		5.15 (s)	3.75 (m, 4, NCH_2), 6.7–8.0 (m, 15, Ar)
7	C	5.86 (br s)	4.79 (d)	5.70 (dd)	5.50 (m)	4.45 (m)	4.45 (m)	3.7 (m, 4, NCH_2), 6.8 (m, 4, Ar), 7.3 (m, 15, Ar), 7.9 (m, 6, Ar)
8	P (D_2O)	5.97 (br s)	4.87 (br d)	4.52 (dd)	4.4 (m)	4.4 (m)	3.91 (s)	3.56 and 3.84 (m, 2, NCH_2), 7.0 (m, 10, Ar)
9a	C	5.52 (d)	4.52 (dd)	3.78 (dd)[c]	4.14 (dd)	3.2–3.6 (m)	3.2–3.6 (m)	3.5 (m, 4, NCH_2), 4.28, 4.38, and 4.42 (s, 2, OCH_2Ar), 6.69 (m, 4, Ar), 7.25 (m, 21, Ar)
9b	C	5.65 (d)	4.46 (dd)	5.24 (dd)	4.92 (dd)	4.08 (m)	4.08 (m)	3.7 (m, 4, NCH_2), 1.86, 1.96, and 2.00 (s, 3, OAc), 6.6–7.3 (m, 10, Ar)
10	P		5.14 (d)	4.94 (m)	4.24 (m)	4.24 (m)	4.24 (m)	7.35 (m, 3, Ar), 8.18 (dd, 2, Ar)
11	C		4.73 (d)	5.09 (dd)	4.85 (d)	4.48 (s)	4.50 (s)	1.33 and 1.50 (s, 3, CMe_2), 7.3–8.2 (m, 5, Ar)
12	B	5.62 (d)	4.51 (dd)	4.69 (dd)	4.2 (m)	4.06 (m)	4.2 (m)	1.06 and 1.27 (s, 3, CMe_2), 3.08 and 3.38 (m, 2, NCH_2), 6.6–8.1 (m, 15, Ar)

[a] The compounds are all numbered as though they were derivatives of 2,5-anhydro-D-allose. [b] The solvents used are designated as follows: B, benzene-d_6; C, $CDCl_3$; D, DMSO-d_6; P, pyridine-d_5. [c] The usual position of C_3H upfield of C_4H is confirmed by decoupling studies.

TABLE II

COUPLING CONSTANTS (HERTZ)

Compd	$J_{1,2}$	$J_{2,3}$	$J_{3,4}$	$J_{4,5}$	$J_{5,6}$
3		4	5	5	*a*
5			0		
7	1	6	6	*a*	*a*
8	1	6	6	*a*	0
9a	1	5	5	5	*a*
9b	1	5.5	5.5	5.5	*a*
10		4	*a*	*a*	*a*
11		2	6	0	0
12	1.5	6	6	*a*	*a*

[a] Not resolved.

1,3-Diphenyl-2-(2,3,5-tri-*O*-benzoyl-β-D-ribofuranosyl)imidazolidine (7).—Solid **3** (25 g, 53 mmol) was added to a vigorously stirred suspension of Raney nickel[25] (75 g) in a solution of monosodium hypophosphite (50 g), and *N*,*N*′-diphenylethylenediamine (21.2 g, 100 mmol) in a mixture of pyridine (375 ml), acetic acid (185 ml), and water (185 ml). The mixture was stirred at room temperature for 1.25 hr and then filtered. The precipitate was washed thoroughly with chloroform (3 × 200 ml), and the combined filtrates were diluted to a volume of 2.5 l. with chloroform and then washed three times with 200-ml portions of water. The chloroform solution was dried ($MgSO_4$) and evaporated, leaving a syrup that crystallized upon addition of methanol giving 26 g (74%) of **7** with mp 154–155°. An analytical sample from chloroform–hexane had mp 155–155.5°; λ_{max} 232 nm (ε 47,900), 252 (34,600), 282 (5900); $[\alpha]^{23}D$ 11.2° (*c* 0.1, $CHCl_3$).

Anal. Calcd for $C_{41}H_{36}N_2O_7$ (668.72): C, 73.63; H, 5.43; N, 4.19. Found: C, 73.74; H, 5.40; N, 4.05.

2-(1,3-Diphenylimidazolidin-2-yl)-5-benzoyloxymethylfuran (5).—A mixture of **3** (9.25 g, 19.6 mmol), Raney nickel (18.5 g), sodium hypophosphite (18.5 g), pyridine (140 ml), acetic acid (70 ml), and water (70 ml) was stirred at 45° for 2 hr. The mixture was then filtered and the filtrate evaporated *in vacuo*. The residue was partitioned between ethyl acetate and water, and the filtered organic phase was evaporated to dryness. The residue was dissolved in methanol (100 ml) containing **6** (5.3 g) and glacial acetic acid (2 ml) was added. After 16 hr at 23° the solution was evaporated, and the residue was chromatographed on a column of silicic acid using hexane–ether (5:2). Evaporation of the main peak followed by crystallization from methanol gave 1.4 g (18%) of **5** with mp 111.5–113°; λ_{max}^{MeOH} 231 nm (sh, ε 31,400), 251 (38,000), 281 (4800), 290 (sh, 4500); λ_{max} (KBr) 1725, 1600 cm^{-1}.

Anal. Calcd for $C_{27}H_{24}N_2O_3$ (424.48): C, 76.39; H, 5.70; N, 6.60. Found: C, 76.15; H, 5.68; N, 6.45.

1,3-Diphenyl-2-(β-D-ribofuranosyl)imidazolidine (8).—A solution of **7** (19.8 g, 29.6 mmol) in chloroform (200 ml) was added to methanolic sodium methoxide (200 ml of 0.075 *M*), and the mixture was stirred at room temperature for 2.5 hr. The solution was then neutralized by addition of Dowex 50 (H^+) resin, filtered, and evaporated to dryness leaving a residue that was freed from methyl benzoate by rapid chromatography on a column of silicic acid (1 kg) using chloroform–ethyl acetate (1:1) and then ethyl acetate. The product was then crystallized from aqueous methanol giving 7.5 g (73%) of **8** with mp 169–170°; λ_{max}^{MeOH} 250 nm (ε 36,700), 295 (5400); $[\alpha]^{23}D$ 5.3° (*c* 0.2, MeOH).

Anal. Calcd for $C_{20}H_{24}N_2O_4$ (356.4): C, 67.39; H, 6.79; N, 7.86. Found: C, 67.35; H, 7.01; N, 7.79.

1,3-Diphenyl-2-(2,3,5-tri-*O*-benzyl-β-D-ribofuranosyl)imidazolidine (9a).—Carefully dried **8** (7.5 g, 21 mmol) was added to a stirred suspension of sodium hydride (9.6 g, 400 mmol) in DMSO (300 ml) and kept under argon at room temperature for 30 min. Benzyl chloride (70 ml, 600 mmol) was then added dropwise, and the mixture was heated at 60° for 2 hr. After storage overnight at room temperature the mixture was diluted with chloroform (1 l.) and washed once with 200 ml of 2 *N* acetic acid and then with saturated aqueous sodium bicarbonate and water. The organic phase was dried and evaporated, leaving a syrup that was chromatographed on a column of silicic acid using hexane–ether (4:1) and giving 10.5 g (80%) of **9a** with mp 92–94° from ether–hexane; λ_{max}^{MeOH} 254 nm (ε 33,000), 294 (4300); $[\alpha]^{23}D$ 2.6° (*c* 0.6, $CHCl_3$).

(25) No. 28 Raney nickel under water obtained from W. R. Grace and Co.

Anal. Calcd for $C_{41}H_{42}N_2O_4$ (626.76): C, 78.56; H, 6.75; N, 4.47. Found: C, 78.94; H, 6.83; N, 4.62.

1,3-Diphenyl-2-(2,3,5-tri-*O*-acetyl-β-D-ribofuranosyl)imidazolidine (9b).—A solution of **8** (760 mg, 2 mmol) in pyridine (6 ml) and acetic anhydride (3 ml) was kept for 16 hr at room temperature. Methanol (15 ml) was added, and after 1 hr the solution was evaporated to dryness. The residue was dissolved in chloroform, washed with water, dried, and evaporated giving 950 mg (96%) of crystalline **9b** with mp 109–110° unchanged upon recrystallization from ether–hexane; $[\alpha]^{28}D$ −22° (*c* 0.1, $CHCl_3$).

Anal. Calcd for $C_{26}H_{30}N_2O_7$ (482.52): C, 64.71; H, 6.27; N, 5.81. Found: C, 64.99; H, 6.38; N, 5.87.

5-*O*-Benzoyl-β-D-ribofuranosyl Cyanide (10).—A solution of **3** (61 g) in chloroform (600 ml) was added with stirring to ice-cooled, saturated methanolic ammonia (900 ml) and kept at 0° for 4.5 hr. The solvent was then evaporated *in vacuo*, and the residue was dissolved in ethyl acetate, washed with a small volume of saturated aqueous sodium bicarbonate and then water, dried, and evaporated. The residual syrup was crystallized from benzene–hexane giving 28 g (83%) of **10** with mp 117–117.5° (lit.[20] mp 118°).

5-*O*-Benzoyl-2,3-*O*-isopropylidene-β-D-ribofuranosyl Cyanide (11).—Solid **10** (42 g) was added to a solution of 72% perchloric acid (6 ml) in 2,2-dimethoxypropane (50 ml) and acetone (300 ml), and the resulting mixture was stirred at room temperature for 2 hr. The solution was neutralized with ammonium hydroxide and evaporated to dryness, leaving a residue that was dissolved in chloroform and washed twice with water. The organic phase was dried and evaporated and the residue crystallized from ether–hexane giving 46 g (95%) of **11** with mp 57–60° (lit.[20] as a syrup). An analytical sample had mp 60–61°.

1,3-Diphenyl-2-(5-*O*-benzoyl-2,3-*O*-isopropylidene-β-D-ribofuranosyl)imidazolidine (12).—Nitrile **11** (5.0 g, 17.2 mmol) was added to a suspension of Raney nickel (20 g), **6** (5.0 g), and sodium hypophosphite (10 g) in 40 ml of a mixture of pyridine, acetic acid, and water (2:1:1) and vigorously stirred at room temperature for 1 hr. The mixture was filtered, and the solid material was washed well with chloroform. The filtrate was diluted to a volume of 1 l. with chloroform and washed with water. The organic phase was dried and evaporated leaving a syrup that crystallized upon addition of methanol giving 6.6 g (78%) of **12** with mp 144–145° unchanged upon recrystallization from chloroform–hexane; λ_{max}^{MeOH} 253 nm (ε 34,700), 283 (4300), 292 (4400); $[\alpha]^{23}D$ −36.2° (*c* 0.1, $CHCl_3$); ν_{max} (KBr) 1715, 1600 cm^{-1}.

Anal. Calcd for $C_{30}H_{32}N_2O_5$ (500.57): C, 71.98; H, 6.44; N, 5.60. Found: C, 72.10; H, 6.38; N, 5.47.

2,5-Anhydro-3,4,6-tri-*O*-benzoyl-D-allose (1c).—A solution of *p*-toluenesulfonic acid monohydrate (355 mg, 1.87 mmol) in acetone (10 ml) was added with stirring to an ice-cooled solution of **3** (500 mg, 0.75 mmol) in methylene chloride (25 ml). After 5 min at 0° the mixture was allowed to come to room temperature over 40 min. Since tlc (ether–hexane, 2:1) showed some residual **3**, an additional 50 mg of *p*-toluenesulfonic acid in acetone (5 ml) was added. After 15 min, tlc showed completion of the reaction, and the mixture was filtered. The precipitate was washed with methylene chloride, and the combined filtrates were evaporated *in vacuo* without heating. The residue was dissolved in methylene chloride, washed three times with cold water, dried ($MgSO_4$), and evaporated. The resulting syrup was shown by tlc to contain a small amount of unreacted **3**, which was removed by rapid chromatography on a column containing 15 g of silicic acid using ether–hexane (2:1). In this way **1c** (240 mg, 68%)[26] was obtained as a chromatographically homogeneous syrup: $[\alpha]^{23}D$ 44.7° (*c* 0.33, $CHCl_3$); nmr ($CDCl_3$) δ 9.77 ppm (d, $J_{1,2}$ = 1.5 Hz, CHO).[27]

Anal. Calcd for $C_{27}H_{22}O_8$ (474.45): C, 68.34; H, 4.67. Found: C, 68.22; H, 4.64.

Upon reaction with *tert*-butyl carbazate in ethanol containing glacial acetic acid, **1c** formed a *tert*-butylcarbazone with mp 172–176° from chloroform–hexane.

Anal. Calcd for $C_{32}H_{32}N_2O_9$ (588.59): C, 65.30; H, 5.48; N, 4.76. Found: C, 65.05; H, 5.36; N, 4.70.

2,5-Anhydro-3,4,6-tri-*O*-benzyl-D-allose (1b).—The imidazolidine derivative (**9a**, 500 mg, 0.8 mmol) was treated with *p*-toluenesulfonic acid monohydrate (350 mg) in a mixture of acetone and methylene chloride as during the preparation of **1c**. The crude product once again contained a little unreacted **9a** which was removed by rapid chromatography through a column of silicic acid using ether–hexane (2:1). The pure fractions were evaporated leaving 180 mg (52%) of **1b** as a chromatographically homogeneous, clear syrup: $[\alpha]^{23}D$ 62.5° (*c* 0.28, $CHCl_3$); nmr ($CDCl_3$) δ 9.64 ppm (d, $J_{1,2}$ = 1.5 Hz, CHO);[27] λ_{max}^{MeOH} 229 nm (ε 4800).

Anal. Calcd for $C_{27}H_{28}O_5$ (432.49): C, 74.98; H, 6.53. Found: C, 74.92; H, 6.54.

2,5-Anhydro-6-*O*-benzoyl-3,4-*O*-isopropylidene-D-allose (13).—The imidazolidine derivative (**12**) was treated with *p*-toluenesulfonic acid monohydrate exactly as above to give, following rapid chromatography on silicic acid, the chromatographically homogeneous aldehyde **13** as a clear syrup: $[\alpha]^{23}D$ 11.9° (*c* 0.5, $CHCl_3$); nmr ($CDCl_3$) δ 9.65 ppm (s, CHO).[27]

Anal. Calcd for $C_{16}H_{18}O_6 \cdot 0.5H_2O$ (315.31): C, 60.94: H, 6.07. Found: C, 60.65; H, 6.22.

Treatment of the crude aldehyde in ethanol with *tert*-butyl carbazate in the presence of acetic acid for 1 hr at room temperature gave the crystalline *tert*-butylcarbazone with mp 118–120° from chloroform–hexane in 57% yield.

Anal. Calcd for $C_{21}H_{28}N_2O_7$ (420.45): C, 59.99; H, 6.71; N, 6.66. Found: C, 60.29; H, 6.71; N, 6.58.

Registry No.—**1** (R = H; X = O), 39037-97-3; **1b**, 37699-02-8; **1c**, 39037-99-5; **1c** *tert*-butylcarbazone, 39038-00-1; **3**, 23316-67-8; **5**, 39050-05-0; **6**, 150-61-8; **7**, 39038-02-3; **8**, 39038-03-4; **9a**, 38821-04-4; **9b**, 39037-09-7; **10**, 30002-87-0; **11**, 29868-36-8; **12**, 39037-12-2; **13**, 39037-13-3; **13** *tert*-butylcarbazone, 39037-14-4; 2,2-dimethoxypropane, 77-76-9; *p*-toluenesulfonic acid, 104-15-4.

(26) The yield of unchromatographed product, which is better than 90% pure, is almost quantitative. This material generally is used in subsequent reactions.

(27) The free aldehydes (**1c**, **1b**, and **13**) do not give well-resolved nmr spectra. Since the aldehyde protons inevitably integrate for less than one proton, this is probably due to the ease with which these compounds form aldehyde hydrates. Similar facile hydration of sugar aldehydes has been frequently encountered. See, *e.g.*, D. Horton and J. D. Wander, *Carbohyd. Res.*, **16**, 477 (1971).