ous ethanol gave clusters of rosettes, mp 291–293° dec, identical with **15** prepared above.

**Periodate Uptake.**—Periodate uptake was determined spectrophotometrically at 300 mμ by the procedure developed for nucleosides by Rammler and Rabinowitz.[28]

**Polarimetric Studies.**—The procedure used here was similar to that used previously for the determination of anomeric configuration of a number of hexopyranosyl nucleosides,[29] except that the rotations of the dialdehydes and the dialcohols were determined in separate experiments.

**Dialdehydes.**—Between 10 and 13 mg of each nucleoside was weighed into a 2-ml volumetric flask and dissolved in 0.75 ml of water (heated, if necessary), and 0.5 ml of 0.25 *M* sodium metaperiodate was added at room temperature. The reaction was allowed to proceed in the dark for 3 days, the volume was adjusted to 2 ml with water, and the rotations were determined. The results are shown in Table III.

**Dialcohols.**—The exact same procedure was used here as described above except that after the 3 days, 60 mg of sodium borohydride was added, and the reaction was allowed to proceed for 45 min. The excess borohydride was destroyed by careful addition of 0.4 ml of 20% acetic acid. When effervescence ceased (1–2 hr), the volume was adjusted to 2 ml and the rotation was determined.

(28) D. H. Rammler and J. C. Rabinowitz, *Anal. Biochem.*, **4**, 116 (1962).
(29) L. M. Lerner and P. Kohn, *J. Med. Chem.*, **7**, 655 (1964).

**Registry No.**—**7**, 36807-77-9; **8**, 36807-78-0; **8** picrate, 36807-79-1; **9**, 36807-80-4; **11**, 36807-81-5; **12**, 36807-82-6; **13**, 35867-45-9; **14**, 36807-84-8; **15**, 36807-85-9.

# Branched-Chain Glycosyl α-Amino Acids. I. Stereospecific Synthesis of 2-L-(3-Deoxy-1,2-*O*-isopropylidene-α-D-allofuranos-3-yl)glycine, an Analog of the Polyoxin Sugar Moiety

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Stereospecific hydroxylation of the hitherto described 3-*C*-*trans*-(methoxycarbonylmethylene)-3-deoxy-1,2:5,6-di-*O*-isopropylidene-α-D-*ribo*-hexofuranose (**2**) with osmium tetroxide or potassium permanganate in pyridine yielded 3-*C*-[*S*-hydroxy(methoxycarbonyl)methyl]-1,2:5,6-di-*O*-isopropylidene-α-D-glucofuranose (**6**) in high yield. Selective acetylation of **6** using acetic anhydride and pyridine gave 3-*C*-[*S*-acetoxy(methoxycarbonyl)methyl]-1,2:5,6-di-*O*-isopropylidene-α-D-glucofuranose (**7**) in 73% yield which was stereoselectively dehydrated with thionyl chloride in pyridine to afford 3-*C*-*trans*-1′-*O*-acetyl-1′-methoxycarbonylmethylene-3-deoxy-1,2:5,6-di-*O*-isopropylidene-α-D-ribofuranose (**8**). Stereospecific catalytic reduction of **8** afforded 3-*C*-[*R*-acetoxy(methoxycarbonyl)methyl]-3-deoxy-1,2:5,6-di-*O*-isopropylidene-α-D-allofuranose (**10**). Tosylation of deacetylated **10** yielded the tosylate **12**, which was then transformed into an azide. Reduction of the latter compound afforded methyl 2-L-(3-deoxy-1,2:5,6-di-*O*-isopropylidene-α-D-allofuranos-3-yl)glycinate (**13**). Basic hydrolysis of **13** yielded 2-L-(3-deoxy-1,2:5,6-di-*O*-isopropylidene-α-D-allofuranos-3-yl)glycine (**15**). Selective hydrolysis of **15** afforded 2-L-(3-deoxy-1,2-*O*-isopropylidene-α-D-allofuranos-3-yl)glycine (**16**). The ORD spectra of the branched-chain α-amino and α-hydroxy acid sugars are described.

The structurally novel amino acid sugar 5-amino-5-deoxy-D-allofuranuronic acid is a component of the polyoxin complex of antifungal agents.[1] The elucidation of structures of the polyoxins has been recently described.[1] Subsequently, the sugar component[2] and the nucleoside moiety of the polyoxins have been synthesized.[3,4] The sugar moiety of the polyoxins might be regarded as being composed of a two-carbon α-L-amino acid moiety attached to C-4 of the sugar. We report herein a stereospecific synthesis of an analog of the sugar moiety of the polyoxins in which the two-carbon α-L-amino acid moiety is attached to C-3 of a hexofuranose having essentially the same stereochemistry as the sugar of the polyoxin. In essence, the objective of the research described herein was to replace stereospecifically with inversion the C-3 hydroxyl of D-glucofuranose by a two-carbon α-L (*S*)[5] amino acid to yield a branched-chain sugar having the allo configuration. Such a sugar could then be readily degraded by periodate oxidation followed by sodium borohydride reduction to afford a branched-chain sugar possessing the D-ribo constitution.

The key intermediate in the synthesis of the branched-chain sugar was 3-*C*-*trans*-(methoxycarbonylmethylene)-3-deoxy-1,2:5,6-di-*O*-isopropylidene-α-D-*ribo*-hexofuranose (**2**), previously described[6] but not obtained in crystalline form. Compound **2** was prepared from the readily available 1,2:5,6-di-*O*-isopropylidene-α-D-*ribo*-hexofuranos-3-ulose (**1**).[7] When the condensation of the ketose **1** and phosphonoacetic acid trimethyl ester in the presence of potassium *tert*-butoxide was allowed to take place at room temperature, the major component of the reaction products was a mixture of trans- and cis-unsaturated ribo sugars **2** and **3**. A minor component (about 6%) consisted of a mixture of trans- and cis-unsaturated sugars **4** which was tentatively believed to have the xylo configuration. The ribo-unsaturated sugars **2** and **3** were readily separated from the epimeric mixture of unsaturated sugars **4** by column chromatography on silica gel. Fractional crystallization of the mixture of trans- and cis-unsaturated sugars **2** and **3** from hexane afforded pure crystalline ribo trans-unsaturated sugar **2** in about 40% yield. Although the mixture of xylo

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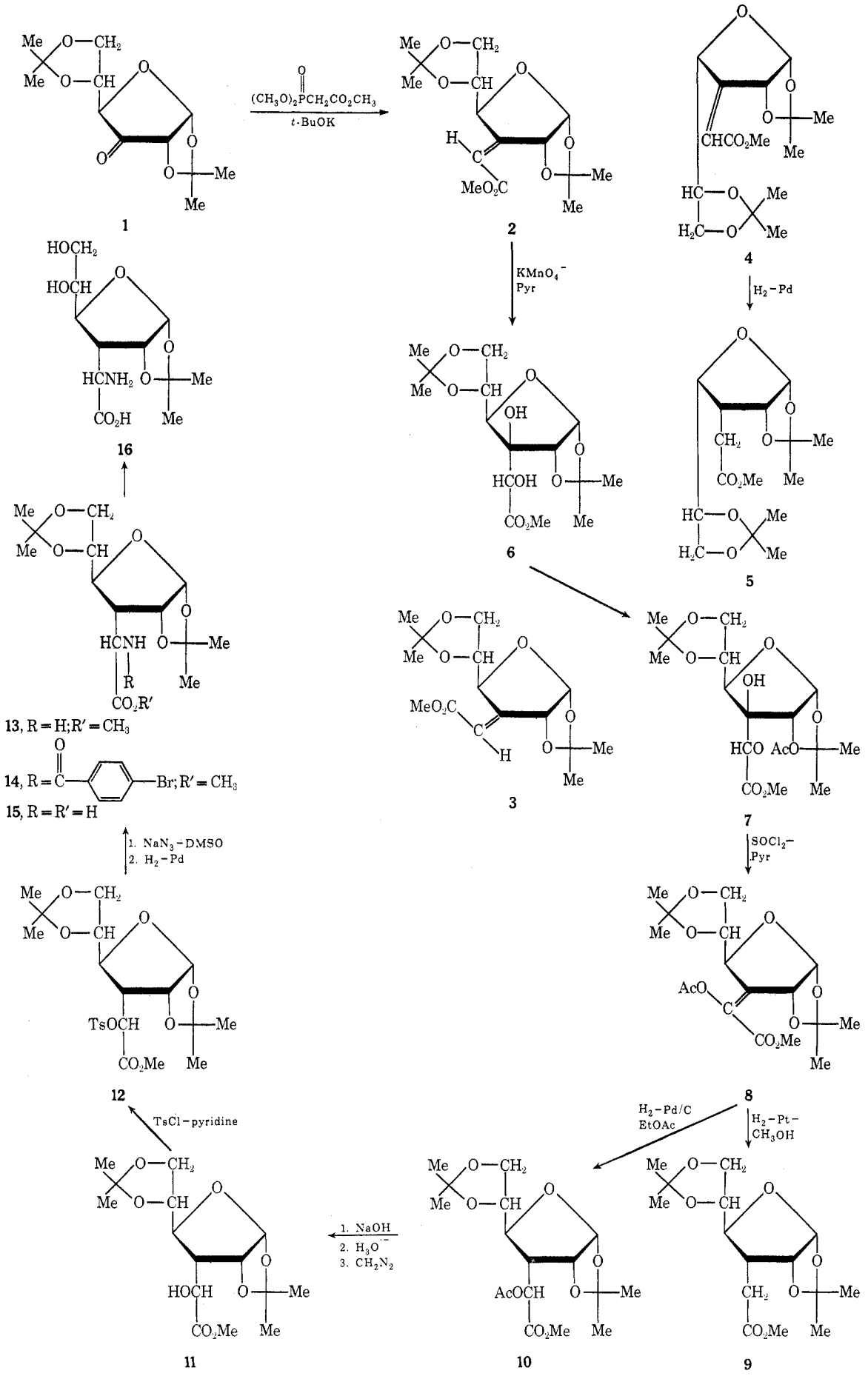
(6) A. Rosenthal and L. Nguyen, *J. Org. Chem.*, **34**, 1029 (1969).
(7) (a) P. J. Beynon, P. M. Collins, and W. G. Overend, *Proc. Chem. Soc.*, 342 (1964); (b) K. Onodera, S. Hirano, and N. Kashimura, *J. Amer. Chem. Soc.*, **87**, 4651 (1965); (c) K. Onodera, S. Hirano, and N. Kashimura, *Carbohyd. Res.*, **6**, 276 (1968).


(CH3O)2PCH2CO2CH3
t-BuOK
KMnO4-
Pyr
H2-Pd
1. NaN3-DMSO
2. H2-Pd
SOCl2-
Pyr
TsCl-pyridine
1. NaOH
2. H3O+
3. CH2N2
H2-Pd/C
EtOAc
H2-Pt-
CH3OH
13, R = H; R' = CH3
14, R = C(=O)-C6H4-Br; R' = CH3
15, R = R' = H

trans- and cis-unsaturated sugars **4** could not be separated by preparative tlc, hydrogenation of this mixture in the presence of palladium on charcoal gave a new homogeneous crystalline branched-chain sugar **5**. The configuration of C-3 of **5** was readily ascertained from its nmr spectrum. The H-2 signal of **5** appears as a triplet at $\tau$ 5.27, showing that H-2 is coupled to H-3 and to H-1. On the other hand, in the glucofuranose series[8] there is no coupling between H-2 and H-3, thus leading to a doublet for H-2. Therefore H-1, H-2, and H-3 of **5** are all in the cis orientation. Because of overlapping signals an analysis of H-4 of **5** could not be made and therefore the configuration of C-4 of **5** is not known. Probably C-4 of **1** was epimerized under the basic conditions of the Wittig reaction and compound **4** might be expected to have the xylo configuration. Reduction of **4** might then give the gulo branched-chain sugar **5**.

Hydroxylation of the trans-unsaturated sugar **2** with osmium tetroxide in pyridine gave essentially pure *cis*-diol **6** in almost quantitative yield. When a combination of osmium tetroxide and 30% hydrogen peroxide was used as oxidant, the reaction on a macro scale proved hard to control, leading to side reactions. Conversion of **2** into **6** was most efficiently carried out (70% yield) by use of potassium permanganate in pyridine as oxidant. Although the yield of diol **6** was considerably lower in the latter hydroxylation reaction, the mixture of products was readily separated by silica gel column chromatography. Reaction conditions must be carefully controlled to reduce the side reactions.

The stereochemical assignment of structure of the diol **6** was based upon the well-known fact that hindered olefins are attacked from the less hindered face of the molecule to afford stereospecifically the *cis*-diol.[9] Thus, it was surmised that **6** was probably 3-*C*-[*S*-hydroxy(methoxycarbonyl)methyl]-1,2:5,6-di-*O*-isopropylidene-α-D-glucofuranose. Confirmation of the structural assignment to **6** was provided by the fact that its optical rotatory dispersion (ORD) spectrum (see **6**, Figure 1) was similar to that of L-lactic acid.[10]

Selective acetylation of the diol **6** with acetic anhydride in pyridine afforded the monoacetate **7** in 73% yield. Stereoselective dehydration of the tertiary alcohol **7** was achieved using thionyl chloride in pyridine to afford, after silica gel column chromatography, the enol acetate **8** in over 60% yield. Because dehydrations of carbocyclic systems containing a tertiary hydroxyl group are known to proceed stereoselectively *via* a trans elimination of hydrogen and the hydroxyl group,[11] it was surmised that the enol acetate **8** must be the trans isomer. Although catalytic hydrogenation of the latter in ethyl acetate over palladium on charcoal proceeded stereoselectively to

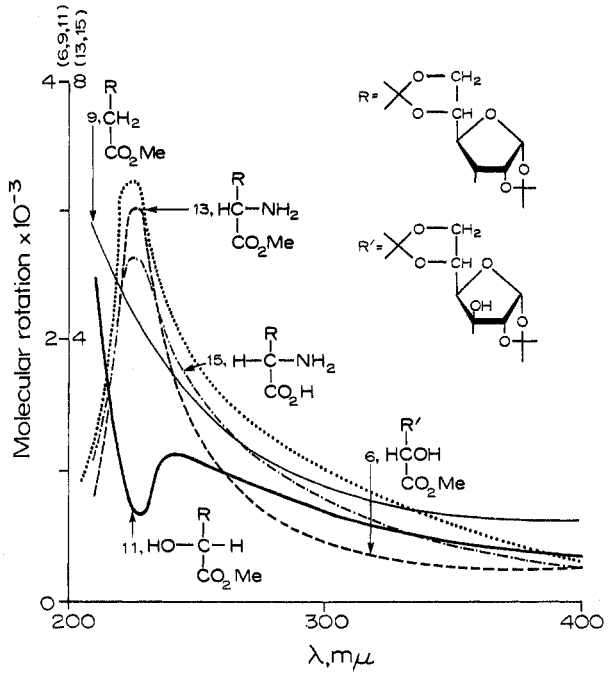



Figure 1.—Rotatory dispersion curves of branched-chain sugar **9**, branched-chain α-hydroxy ester sugars **6** and **11**, and L-(3-deoxyglycos-3-yl)amino acid ester **13** and amino acid **15**.

afford after column chromatography 3-*C*-[*R*-acetoxy(methoxycarbonyl)methyl]-3-deoxy-1,2:5,6-di-*O*-isopropylidene-α-D-allofuranose (**10**) in 65% yield, the product was contaminated with a minor product **9** in which the acetate group had undergone hydrogenolysis. Utilization of methanol as solvent led to an increase of the yield of the by-product **9**. Compound **9** was identical with the product obtained by direct reduction of either the trans- or cis-unsaturated sugar **2** or **3** and is therefore 3-*C*-methoxycarbonylmethyl-3-deoxy-1,2:5,6-di-*O*-isopropylidene-α-D-allofuranose.[6] Treatment of the α-acetate ester **10** with aqueous methanolic sodium hydroxide deacetylated and deesterified the product to afford an α-hydroxy acid which was immediately reesterified with diazomethane to yield after column chromatography the α-hydroxy ester **11** in an overall yield of 74% based on **10**. Compound **11** exhibited a negative Cotton effect in contrast to the positive Cotton effect exhibited by **6** (see **6** and **11**, Figure 1), thus establishing that an inversion of configuration of the asymmetric carbon in the branched chain of **6** had occurred during the dehydration and reduction steps to afford 3-*C*-[*R*-hydroxy(methoxycarbonyl)methyl]-3-deoxy-1,2:5,6-di-*O*-isopropylidene-α-D-allofuranose (**11**). Tosylation of the latter compound with *p*-toluenesulfonyl chloride in pyridine yielded the tosylate **12** in 78% yield. Conversion of the latter compound into an α-amino acid ester **13** was achieved by treatment of **12** with sodium azide in dimethyl sulfoxide at 55–60° for 40 hr followed by immediate hydrogenation of the azide over palladium on charcoal. The α-amino ester **13**, isolated after chromatography in 34% yield based on **12**, exhibited a positive Cotton effect (see **13** in Figure 1), which indicated, as expected, that a second inversion of configuration of the branched-chain asymmetric carbon had taken place when the tosylate was displaced by the azide group. The α-amino ester **13** gave

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a positive ninhydrin test and was characterized as its crystalline *p*-bromobenzamido derivative **14**. Treatment of the α-amino ester **13** with aqueous methanolic sodium hydroxide afforded the crystalline glycosyl α-amino acid **15** in 89% yield. Because compounds **13** and **15** exhibited positive ORD spectra (see curves **13** and **15** in Figure 1) which were similar to that of L-alanine,[12] compound **15** is therefore 2-L-(3-deoxy-1,2:5,6-di-*O*-isopropylidene-α-D-allofuranos-3-yl)-glycine. Selective hydrolysis of the 5,6-*O*-isopropylidene group of compound **15** with 50% aqueous acetic acid afforded, in 69% yield, the crystalline glycosyl amino acid 2-L-(3-deoxy-1,2-*O*-isopropylidene-α-D-allofuranos-3-yl)glycine (**16**), which also exhibited a positive Cotton effect.

## Experimental Section

**General Considerations.**—Pmr spectra were obtained in deuteriochloroform solution (unless otherwise stated) with tetramethylsilane as the internal standard (set at $\tau$ 10) using a Varian A-60 or Varian HA-100 spectrometer. The ORD measurements were performed on a JASCO Model ORD/UV-5 spectropolarimeter at room temperature. The infrared spectra were performed on a Perkin-Elmer Model 337 spectrometer. For column chromatography, silica gel "Davison" grade (60–200 mesh), and, for tlc, silica gel G (Mondray) were used. Optical rotations were measured at room temperature (22°) with a Perkin-Elmer automatic polarimeter Model 141. All melting points (micro hot stage) are corrected. Elemental analyses were performed by Mr. P. Borda, Microanalytical Laboratory, University of British Columbia, Vancouver.

**Wittig Reaction of 1,2:5,6-Di-*O*-isopropylidene-α-D-*ribo*-hexofuranos-3-ulose (1) to Yield 3-*C*-*trans*- and -*cis*-methoxycarbonylmethylene-3-deoxy-1,2:5,6-di-*O*-isopropylidene-α-D-*ribo*-hexofuranose (2 and 3) and 3-*C*-*trans*- and -*cis*-methoxycarbonyl-3-deoxy-1,2:5,6-di-*O*-isopropylidene-α-D-*xylo*-furanose (4).**—An amount of 7.5 g of anhydrous ketose **1** was allowed to react with phosphonoacetic acid trimethyl ester according to a procedure already published[6] except that the temperature was kept at about 20°. The product (6.5 g), worked up as described previously, showed by tlc on silica gel using 4:1 benzene–ethyl acetate as developer two spots having $R_f$'s of 0.45 and 0.40. The faster moving zone consisted of a mixture of trans- and cis-unsaturated branched-chain sugars **2** and **3** identical with the compounds described previously and a mixture of two new unsaturated compounds **4**. Gradient elution chromatography on silica gel (60 × 7.5 cm) of the product mixture using 6:1 chloroform–ethyl acetate followed by 3:1 chloroform–ethyl acetate as developer yielded one main fraction (faster mobility) and a slower moving zone. The faster moving zone was recrystallized from hexane to afford crystalline trans-unsaturated sugar **2** (3.3 g, 36.5%): mp 68–69°; $[\alpha]^{22}D$ +119° (*c* 2, chloroform); $\tau^{CDCl_3}$ 3.65 (q, H-1′), 4.15 (d, $J_{1,2}$ = 4.0 Hz, H-1), 4.23 (m, H-2), 5.32 (m, H-4), 6.0 (m, H-6 and H-5), 6.30 (s, $COCH_3$).

*Anal.* Calcd for $C_{15}H_{22}O_7$: C, 57.32; H, 7.05. Found: C, 57.09; H, 6.83.

The mother liquor from the recrystallization of compound **2** was evaporated to dryness to yield 1.1 g (12%) of an almost equal mixture of the trans- and cis-unsaturated sugars **2** and **3** (as evidenced by nmr). The slower moving zone (1.2 g, 13%) obtained from the column chromatography was purified by preparative tlc to afford about 0.6 g of a mixture of **2** and **3** and a new pair of unsaturated sugars **4** (about 0.6 g, 6%): $\tau^{CDCl_3}$ of **4**, 3.82–4.0 (m, C-1′ H), 4.20 (t, possibly H-1), 4.38 (two doublets), 4.60 (two doublets), 5.18 (d, $J$ = 4 Hz), 5.1–5.75 (m), 6.26 and 6.28 (s, $COCH_3$).

**Reduction of 2 and 4 to Yield 3-*C*-(Methoxycarbonylmethyl)-3-deoxy-1,2:5,6-di-*O*-isopropylidene-α-D-allofuranose (9) and 3-*C*-(Methoxycarbonylmethyl)-3-deoxy-1,2:5,6-di-*O*-isopropylidene-α-D-gulofuranose (5).**—Compound **2** was hydrogenated in the presence of 10% palladium on charcoal according to a previous procedure[6] to yield pure **9**: mp 57–59°; ORD (*c* 0.09, ethanol) $[\Phi]_{220}$ + 2400°, $[\Phi]_{225}$ + 2140°, $[\Phi]_{250}$ + 1565°.

Reduction of the trans and cis mixture of unsaturated sugars **4** gave in quantitative yield pure **5** (as evidenced by tlc). Compound **5** was sublimed under high vacuum to afford crystalline 3-*C*-(methoxycarbonylmethyl)-3-deoxy-1,2:5,6-di-*O*-isopropylidene-α-D-gulofuranose: mp 109–110°; $[\alpha]^{22}D$ −6° (*c* 1.6, chloroform); $\tau^{CDCl_3}$ 4.18 (d, $J_{1,2}$ = 4 Hz, H-1), 5.27 (t, $J_{1,2}$ = 4, $J_{2,3}$ = 4 Hz, H-2), 5.38–6.1 (overlapping signals), 6.35 (s, $CO_2CH_3$), 6.42–6.70 (m), 7.2–7.7 (overlapping peaks, H-3, H-1′), 8.45, 8.6, 8.65, 8.7 (four s, $CH_3$).

*Anal.* Calcd for $C_{15}H_{24}O_7$: C, 56.95; H, 7.65. Found: C, 56.85; H, 7.73.

**Hydroxylation of 2 to Yield 3-*C*-[*S*-Hydroxy(methoxycarbonyl)-methyl]-1,2:5,6-di-*O*-isopropylidene-α-D-glucofuranose (6). A. Using Osmium Tetroxide.**—To a solution of the unsaturated trans sugar **2** (0.105 g) in 3 ml of anhydrous pyridine was added osmium tetroxide (0.098 g) and the mixture was allowed to stand at room temperature for 3 hr. After addition of 4 ml of 3% aqueous sodium hydrogen sulfite the mixture was shaken for 10 min and then extracted twice with methylene chloride. The combined methylene chloride extracts were washed with water, dried over sodium sulfate, filtered, and evaporated to yield 0.120 g of an oil which was homogeneous by tlc.

**B. Using Osmium Tetroxide and Hydrogen Peroxide.**—To the unsaturated sugar **2** (0.100 g) in 2 ml of pyridine was added osmium tetroxide (0.005 g) followed by dropwise addition of 30% hydrogen peroxide (1.0 ml) over a period of 30 min. The reaction mixture was let stand at room temperature for an additional 0.5 hr. After addition of water the reaction mixture was extracted with chloroform. The chloroform extract was washed with water, dried, and evaporated to yield 0.120 g of oil which was darker in appearance than that obtained by procedure A above. The product was mainly **6**. Repetition of the reaction on a larger scale gave a mixture of products, possibly owing to poor control of the temperature during the addition of hydrogen peroxide.

**C. Using Potassium Permanganate in Pyridine.**—To a cold solution (kept at −10°) of the unsaturated sugar **2** (1.66 g) in 10 ml of water and 20 ml of pyridine was added dropwise with vigorous stirring a solution of potassium permanganate (0.90 g) in 20 ml of water over a period of 10 min. The reaction was very rapid. After addition of 50 ml of water and a few milliliters of alcohol (to prevent emulsification) the reaction mixture was extracted with chloroform (3 × 100 ml). The combined chloroform extracts were washed with water, dried over sodium sulfate, and evaporated to yield an oil (1.4 g, 76%) having a purity greater than 95% (evidenced by tlc and nmr). An analytical sample of **6** was prepared by preparative tlc on silica gel using 3:1 benzene–ethyl acetate as developer: $[\alpha]^{22}D$ +54° (*c* 1.5, chloroform); ORD (*c* 0.07, ethanol) $[\Phi]_{215}$ +1930°, $[\Phi]_{220}$ +2710°, $[\Phi]_{225}$ +3055°, $[\Phi]_{250}$ +1578°; $\tau^{CDCl_3}$ 4.15 (d, $J_{1,2}$ = 3.8 Hz, H-1), 5.42 (s, H-1′), 5.55 (d, $J_{2,1}$ = 3.8 Hz, H-2), 5.62–5.95 (overlapping peaks), 6.08 (s, OH, disappears on addition of $D_2O$), 6.20 (s, $CO_2CH_3$).

*Anal.* Calcd for $C_{15}H_{24}O_9$: C, 51.72; H, 6.94. Found: C, 51.57; H, 7.12.

Similar oxidation of **2** (8.1 g) but on a larger scale gave the diol **6** (68% yield) and a minor by-product (0.25 g). These substances were separated by silica gel column chromatography using 1:2 ethyl acetate–benzene as developer.

**3-*C*-[*S*-Acetoxy(methoxycarbonyl)methyl]-1,2:5,6-di-*O*-isopropylidene-α-D-glucofuranose (7).**—The diol **6** (0.110 g) was acetylated with a mixture of 1 ml of acetic anhydride and 2 ml of pyridine at room temperature for 3 hr. After removal of the acetylating mixture by evaporation under vacuum the monoacetate **7** was purified by preparative tlc on silica gel using 1:3 ethyl acetate–benzene as developer to yield 0.100 g (73%) of an oil which was distilled at 110° (0.1 mm): $[\alpha]^{22}D$ +35° (*c* 1.5, chloroform); $\tau^{CDCl_3}$ 4.10 (d, $J_{1,2}$ = 3.0 Hz, H-1), 4.26 (s, H-1′), 6.74 (OH), 7.81 (OAc).

*Anal.* Calcd for $C_{17}H_{26}O_{10}$: C, 52.30; H, 6.71. Found: C, 52.43; H, 6.71.

**Dehydration of 7 to Yield 3-*C*-*trans*-1′-*O*-Acetyl-1′-methoxycarbonylmethylene-3-deoxy-1,2:5,6-di-*O*-isopropylidene-α-D-*ribo*-hexofuranose (8).**—To the monoacetate **7** (0.800 g) in anhydrous pyridine (10 ml) kept at 0° was added freshly distilled thionyl chloride (3 ml). After the mixture was allowed to stand at room temperature for 20 hr in the dark, ice was added. The reaction mixture was then extracted with dichloromethane (3 × 200 ml). The combined dichloromethane extracts were washed with water, dried over sodium sulfate, and evaporated under reduced pressure to yield a dark brown oil. This oil was chromatographed on 70 ml of silica using 3:1 benzene–ethyl acetate as developer to

(12) J. C. Craig and S. K. Roy, *Tetrahedron*, **21**, 391 (1965).

afford 0.476 g (62%) of enol acetate **8** and 0.084 g (11%) of impure sample. An analytical sample of **8** was prepared by preparative tlc using 3:1 benzene–ethyl acetate as developer followed by molecular distillation of the product at 110° (0.1 mm). The product was unstable at room temperature and had $[\alpha]^{22}D$ +57° (*c* 0.8, chloroform); $\tau^{CDCl_3}$ 4.12 (d, $J_{1,2}$ = 4 Hz, H-1), 4.38 (two d, $J_{2,1}$ = 4, $J$ = 2 Hz), 5.0 (two d, $J_{4,5}$ = 5, $J$ = 2 Hz), 5.78–6.3 (m), 6.24 (s, $CO_2CH_3$), 7.88 (OAc).

*Anal.* Calcd for $C_{17}H_{24}O_9$: C, 54.83; H, 6.50. Found: C, 55.03; H, 6.70.

**Reduction of 8 to Yield 3-*C*-[*R*-Acetoxy(methoxycarbonyl)methyl]-3-deoxy-1,2:5,6-di-*O*-isopropylidene-α-D-allofuranose (10).**—The enol acetate **8** (0.600 g) in 60 ml of purified ethyl acetate was hydrogenated at room temperature under 1 atm pressure in the presence of 5% palladium on carbon (0.300 g). The product was separated by silica gel column chromatography using 1:3 ethyl acetate–benzene as developer to afford 0.360 g (65%) of the acetate **10** and a mixture of the ester **9** and **10** (0.070 g, 13%). An analytical sample of **10** was prepared by preparative tlc followed by molecular distillation at 110° (0.1 mm) to yield an oil: $[\alpha]^{22}D$ +69° (*c* 0.4, chloroform); $\tau^{CDCl_3}$ 4.2 (d, $J_{1,2}$ = 4 Hz, H-1), 4.50 (d, $J_{1',3}$ = 7.5 Hz, H-1′), 5.3 (q, $J_{1,2}$ = 4, $J_{2,3}$ = 5 Hz, H-2), 5.7–6.1 (m), 6.20 (s, $COCH_3$), 7.35–7.7 (m, $J_{1',3}$ = 7.5, $J_{3,4}$ = 9.0, $J_{2,3}$ = 5 Hz, H-3), 7.90 (s, OAc), 8.48, 8.66, 8.70 (s, four $CH_3$).

*Anal.* Calcd for $C_{17}H_{26}O_9$: C, 54.54; H, 7.00. Found: C, 54.49; H, 7.07.

When the enol acetate **8** was reduced in the presence of platinum, palladium, or rhodium in methanol the ester **9** was produced as a major compound. The ester **9** had the same nmr and ir as the product obtained by catalytic hydrogenation of **2** or **3**.[6]

**3-*C*-[*R*-Hydroxy(methoxycarbonyl)methyl]-3-deoxy-1,2:5,6-di-*O*-isopropylidene-α-D-allofuranose (11).**—The acetate **10** (0.360 g) was deacetylated at room temperature for 3 hr using 5 ml of methanol and 5 ml of 10% aqueous sodium hydroxide. The solution was then neutralized with hydrochloric acid with external cooling. The slightly acidic solution was saturated with sodium chloride and extracted with ethyl acetate (5 × 10 ml). The combined ethyl acetate extracts were dried over sodium sulfate and then evaporated to yield 0.293 g (96%) of an oil which was esterified in methanol with an ether solution of diazomethane. After evaporation of the solvent the hydroxy ester **11** was purified by silica gel column chromatography using 1:3 ethyl acetate–benzene as developer to afford 0.235 g (74%) of **11**. An analytical sample was prepared by preparative tlc followed by molecular distillation at 115° (0.1 mm) to yield an oil: $[\alpha]^{22}D$ +57° (*c* 3.8, chloroform); ORD (*c* 0.09, ethanol) $[\Phi]_{220}$ +1110°, $[\Phi]_{225}$ +658° (trough), $[\Phi]_{240}$ +1110°, $[\Phi]_{250}$ +1073°; $\tau^{CDCl_3}$ 4.25 (d, $J_{1,2}$ = 4 Hz, H-1), 5.22 (d, $J_{2,1}$ = 4 Hz, H-2), 5.25–5.9 (overlapping peaks), 5.92 (d, 2 hydrogens, $J$ = 2.5 Hz), 6.2 (s, $CO_2CH_3$), 7.42–7.75 (m, H-3), 8.45, 8.53, 8.68, 8.72 (4 s, $CH_3$).

*Anal.* Calcd for $C_{15}H_{24}O_8$: C, 54.21; H, 7.28. Found: C, 54.60; H, 7.58.

**3-*C*-[(*R*)-*p*-Toluenesulfonyloxy(methoxycarbonyl)methyl]-3-deoxy-1,2:5,6-di-*O*-isopropylidene-α-D-allofuranose (12).**—The hydroxy ester **11** (0.050 g) in 2 ml of anhydrous pyridine was tosylated with *p*-toluenesulfonyl chloride (0.100 g) (all reagents must be pure and anhydrous) in the usual way to afford 0.055 g (78%) of the tosylate **12**, which was distilled at 125° (0.1 mm): $[\alpha]^{22}D$ +79° (*c* 1, chloroform); $\tau^{CDCl_3}$ 2.15 and 2.65 (two d, $C_6H_4$), 4.27 (d, $J_{1,2}$ = 4 Hz, H-1), 4.90 (d, $J_{1,3}$ = 9.0 Hz, H-1′), 5.40 (*t*, $J_{1,2}$ = 4, $J_{2,3}$ = 4 Hz, H-2), 5.85–6.2 (m), 6.30 (s, $CO_2CH_3$), 7.58 (s, $CH_3$), 7.5 (m, H-3), 8.62, 8.66, 8.73, 8.82 (four s, $CH_3$). Irradiation at $\tau$ 7.5 changed the doublet at $\tau$ 4.90 to a singlet and the triplet at $\tau$ 5.40 to a doublet.

*Anal.* Calcd for $C_{22}H_{30}O_{10}S$: C, 54.32; H, 6.13. Found: C, 54.35; H, 6.28.

**Methyl 2-L-(3-Deoxy-1,2:5,6-di-*O*-isopropylidene-α-D-allofuranos-3-yl)glycinate (13).**—The tosylate **12** (0.200 g) and sodium azide (0.200 g) were heated for 40 hr at 55–60° in anhydrous dimethyl sulfoxide (3 ml). After the solvent was removed under high vaccuum at 50°, water (1 ml) and the dichloromethane (5 ml) were added. The organic extract was evaporated and the crude residue was dissolved in methanol (50 ml) and immediately hydrogenated over palladium on charcoal (0.100 g) at 1 atm pressure for 3 hr. The catalyst was then removed by filtration and the filtrate was evaporated under reduced pressure. The residue was extracted with dichloromethane and the solution was then evaporated to dryness to yield 0.120 g of a syrup which was purified by multiple ascending preparative tlc (nine plates of 20 × 20 cm) using ethyl acetate as developer. The principal zone ($R_f$ 0.1), detected with iodine or ninhydrin, was extracted with 3:1 ethyl acetate–methanol. This extract was washed with aqueous sodium thiosulfate. Evaporation of the solvent afforded **13**, yield 0.050 g (34% based on the tosylate). A minor very diffuse zone of ninhydrin-positive material was not extracted. The crude sugar azide could not be purified by preparative tlc on silica gel.

The α-amino ester **13** was twice distilled at 90° (0.1 mm) to give a substance homogeneous by tlc: $[\alpha]^{22}D$ +60° (*c* 0.6, chloroform); ORD (*c* 0.12, ethanol $[\Phi]_{220}$ +5960°, $[\Phi]_{225}$ +6450° (peak), $[\Phi]_{250}$ +3970°; ir (film) 1735, ($CO_2CH_3$), 3350 $cm^{-1}$ (NH); $\tau^{CDCl_3}$ 4.22 (d, $J_{1,2}$ = 4 Hz, H-1), 5.23 (t, $J_{1,2}$ = $J_{2,3}$ = 4 Hz), 5.6–6.14 (overlapping peaks), 6.26 (s, $CO_2CH_3$), 7.52–7.76 (m, H-1′, clearly visible after addition of $D_2O$), 7.7–8.1 ($NH_2$, disappears on addition of $D_2O$), 8.62–8.78 (four s, $CH_3$).

*Anal.* Calcd for $C_{15}H_{25}O_7N$: C, 54.37; H, 7.60; N, 4.23. Found: C, 54.06; H, 7.37; N, 4.01.

**Methyl 2-L-(3-Deoxy-1,2:5,6-di-*O*-isopropylidene-α-D-allofuranos-3-yl)-*N*-*p*-bromobenzoylglycinate (14).**—The amino ester **13** (0.005 g) was dissolved in dry pyridine (0.1 ml), and *p*-bromobenzoyl chloride (0.020 g) was added. After standing at room temperature for 3 hr water was added and the product was extracted with dichloromethane. The extracted solid product was purified by tlc on silica gel using 1:3 ethyl acetate–benzene as developer to remove *p*-bromobenzoic acid. The benzamido derivative **14** was recrystallized from ethanol–hexane: mp 108–109°; $[\alpha]^{22}D$ +46° (*c* 0.2, chloroform); $\tau^{CDCl_3}$ 2.55 (NH), 4.21 (d, $J_{1,2}$ = 4 Hz, H-1), 4.80 (t, $J$ = 6.5 Hz, H-1′), 5.24 (t, $J_{1,2}$ = $J_{1,3}$ = 4 Hz, H-2), 7.3 (m, H-3). Irradiation of the signal at $\tau$ 2.55 collapsed the triplet at $\tau$ 4.8 to a doublet, $J_{1',3}$ = 6.5 Hz. Irradiation at $\tau$ 7.3 collapsed the triplet at $\tau$ 5.24 to a doublet having $J_{1,2}$ = 4 Hz.

*Anal.* Calcd for $C_{22}H_{28}NO_8Br$: C, 51.37; H, 5.49; N, 2.72. Found: C, 51.79; H, 5.65; N, 2.30.

**2-L-(3-Deoxy-1,2:5,6-di-*O*-isopropylidene-α-D-allofuranos-3-yl)-glycine (15).**—The amino ester **13** (0.045 g) in 2.5% aqueous methanolic sodium hydroxide (2.5 ml of 1:1 solution) was kept at room temperature for 1 hr. The solution was then passed through 10 ml of Rexyn RG 51(H) (polystyrene carboxylic acid type resin) which was prewashed with 1% acetic acid and then water. Fractions which gave a positive ninhydrin test were collected and evaporated under reduced pressure to give 0.039 g (89%) of crystalline amino acid sugar **15**. This compound was recrystallized from methanol and water: mp 180–181°; $R_f$ 0.35 on Whatman 20.1 paper using 5:2:1:1 ethyl acetate–*tert*-butyl alcohol–water–pyridine as developer: $[\alpha]^{22}D$ +25° (*c* 0.5, water); ORD (*c* 0.05, 0.5 *N* HCl in 95% ethanol) $[\Phi]_{220}$ +4560°, $[\Phi]_{225}$ +5200° (peak), $[\Phi]_{250}$ +3040° [the ORD was taken within 10 min (about 5% hydrolysis of the 5,6-*O*-isopropylidene group took place during a period of 30 min)]; $\tau^{D_2O}$ (external TMS) 4.06 (d, $J_{1,2}$ = 4 Hz, H-1), 5.01 (t, $J_{1,2}$ = $J_{2,3}$ = 4 Hz, H-2), 7.50 (m, H-3).

*Anal.* Calcd for $C_{14}H_{23}NO_7 \cdot {}^1/_2H_2O$: C, 51.53; H, 6.41; N, 4.29. Found: C, 51.64; H, 6.33; N, 4.07.

**2-L-(3-Deoxy-1,2-*O*-isopropylidene-α-D-allofuranos-3-yl)glycine (16).**—Compound **15** (0.030 g) in 50% aqueous acetic acid (2 ml) was kept at room temperature for 80 hr (the reaction was monitored by paper chromatography using the same solvent as in the identification of compound **15**). After the solvent was evaporated the amino acid **16** was crystallized from ethanol–water: yield 0.018 g (69%); mp 213–215°; $[\alpha]^{22}D$ +60° (*c* 0.5, water); $R_f$ 0.15; ORD (*c* 0.045, 0.5 *N* HCl in 95% ethanol) $[\Phi]_{220}$ +5720°, $[\Phi]_{225}$ +6280° (peak), $[\Phi]_{250}$ +3690°; $\tau^{D_2O}$ (external TMS) 4.07 (d, $J$ = 4 Hz, H-1), 5.0 (t, $J_{1,2}$ = $J_{2,3}$ = 4 Hz, H-2), 5.9 (d, $J$ = 6 Hz, H-1′), 7.4 (m, H-3), 8.4 and 8.6 (two $CH_3$).

*Anal.* Calcd for $C_{11}H_{19}O_7N$: C, 47.65; H, 6.91; N, 5.05. Found: C, 47.79; H, 7.09; N, 4.70.

**Registry No.**—**2**, 18427-17-3; **5**, 36807-87-1; **6**, 36807-88-2; **7**, 36807-89-3; **8**, 36807-90-6; **9**, 18427-18-4; **10**, 36807-92-8; **11**, 36807-93-9; **12**, 36870-63-0; **13**, 36807-94-0; **14**, 36807-95-1; **15**, 36807-96-2; **16**, 36807-97-3.

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