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Synthesis of the methyl 3-amino-3-deoxy-α- and β-D-allopyranosides and -allofuranosides

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ABSTRACT

Methyl 3-amino-3-deoxy-α-D-allopyranoside was synthesized from methyl 2-*O*-benzoyl-4,6-*O*-benzylidene-α-D-glucopyranoside in a 5-step sequence involving trifluoromethylsulfonylation, azide displacement, deprotection, and catalytic hydrogenation. On displacement with tetramethylguanidinium azide, 1,2:5,6-di-*O*-isopropylidene-α-D-glucofuranose 3-triflate afforded the corresponding 3-azido-3-deoxy-α-D-allofuranose diacetal, which was converted into the 3-amino and 3-acetamido products. Acid-catalyzed methanolysis of the azido diacetal gave methyl 3-azido-3-deoxy-β- and -α-D-allopyranosides and the corresponding β-D-allofuranoside, with a 3:1 pyranoside to furanoside ratio; the two amino β-glycosides were then obtained by catalytic hydrogenation. Methanolysis of the 3-acetamido-3-deoxy-α-D-allofuranose diacetal produced a glycoside mixture composed mainly of methyl 3-amino-3-deoxy-β- and -α-D-allofuranosides in a 2:1 ratio, together with only small proportions of the pyranosidic isomers.

INTRODUCTION

Concurrent work[1] on the cycloaddition of nitromethane to the dialdehyde obtainable by periodate oxidation of methyl 4,6-*O*-benzylidene-α-D-glucopyranoside has provided six new, stereoisomeric methyl 3-deoxy-3-nitro-α-D-heptoseptanosides, which were converted into the corresponding 3-acetamido-3-deoxy derivatives. Because of the conformational flexibility of septanose rings it would have been precarious to base configurational assignments for these glycosides on their n.m.r. parameters alone. Therefore, the acetamido heptoseptanosides were isomerized to heptopyranosides and thence converted, by chain shortening at the non-reducing terminal, into 3-amino-3-deoxy-D-hexose derivatives whose identities could be ascertained more readily by spectroscopy and by reference to the literature. For seven of the eight possible methyl 3-amino-3-deoxy-α-D-hexopyranosides (or for acetylated derivatives thereof) that could arise from the degradative transformations mentioned, reference samples or reliable literature data for comparison were at hand, but this was not the case for the α-D-*allo* isomer. Although its per-*N*,*O*-acetyl derivative has been described[2,3], no n.m.r. data were recorded and the reported syntheses were lengthy and inconvenient. We therefore undertook an alternative, shorter synthesis of this glycoside; at the same time, a new synthesis of its β anomer was developed and hitherto unknown, furanosidic isomers were characterized.

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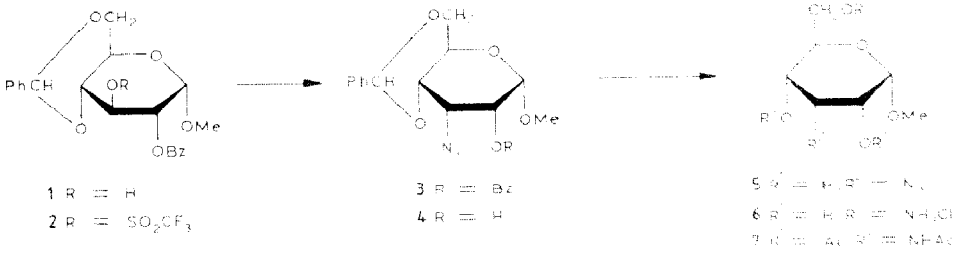
RESULTS AND DISCUSSION

Methyl 2-*O*-benzoyl-4,6-*O*-benzylidene-α-D-glucopyranoside (**1**), conveniently obtainable[4] by monobenzoylation of the (commercial) parent 2,3-diol, was first converted into the 3-triflate **2**, and this underwent displacement with lithium azide in dimethyl sulfoxide (1.5 h at 100°) to furnish crystalline methyl 3-azido-2-*O*-benzoyl-4,6-*O*-benzylidene-3-deoxy-α-D-allopyranoside (**3**) in 54% yield. Sequential *O*-debenzoylation (Zemplén) and *O*-debenzylidenation (70% acetic acid) then provided quantitatively the crystalline azido compounds **4** and **5**. The unprotected azide **5** was reduced by catalytic transfer hydrogenation to give hygroscopic methyl 3-amino-3-deoxy-α-D-allopyranoside hydrochloride (**6**), which readily afforded the crystalline *N*-acetyl 2,4,6-triacetate **7**.



Another simple approach to **6** was investigated. It was considered that acid-catalyzed methanolysis of 3-amino-3-deoxy-1,2:5,6-di-*O*-isopropylidene-α-D-allofuranose (**11**) or its *N*-acetyl derivative **12** might yield the desired methyl α-pyranoside, presumably together with isomers. The amine **11** can be obtained[5-7] by hydrazinolysis of 1,2:5,6-di-*O*-isopropylidene-3-*O*-tosyl-α-D-glucofuranose (**8**), followed by hydrogenolysis of the resulting hydrazino sugar. It appeared desirable to replace this somewhat inconvenient procedure by one involving azide displacement, but early attempts to displace the tosyl group in **8** by azide ion had failed completely, even under forcing conditions[8]. However, we found the displacement to occur readily in the corresponding triflate **9**, which has since become available[9], using tetramethylguanidinium azide in *N*,*N*-dimethylformamide (6 h at 25°) to give the 3-azido-3-deoxy-α-D-allofuranose diacetal **10** in 61% yield*. Reduction of **10** with lithium aluminum hydride and *N*-acetylation afforded **11**, then **12**.

When **10** was boiled with 2% hydrogen chloride in methanol, deacetalation occurred and a mixture of methyl glycosides was generated. Thin-layer chromatography showed two product-spots, with the faster-moving one predominating at early stages, and the slower one at the end of a 32-h period, when isomeric equilibrium appeared established. Column chromatography of the products furnished the pure,

* Yields of 56–58% were achieved by use of lithium or sodium azide (24 h at 25°). Under all reaction conditions tried, considerable proportions of 3-deoxy-3-enofuranose diacetal arose as a by-product. It is known that **9** is prone to suffer base-induced elimination even at room temperature[10].

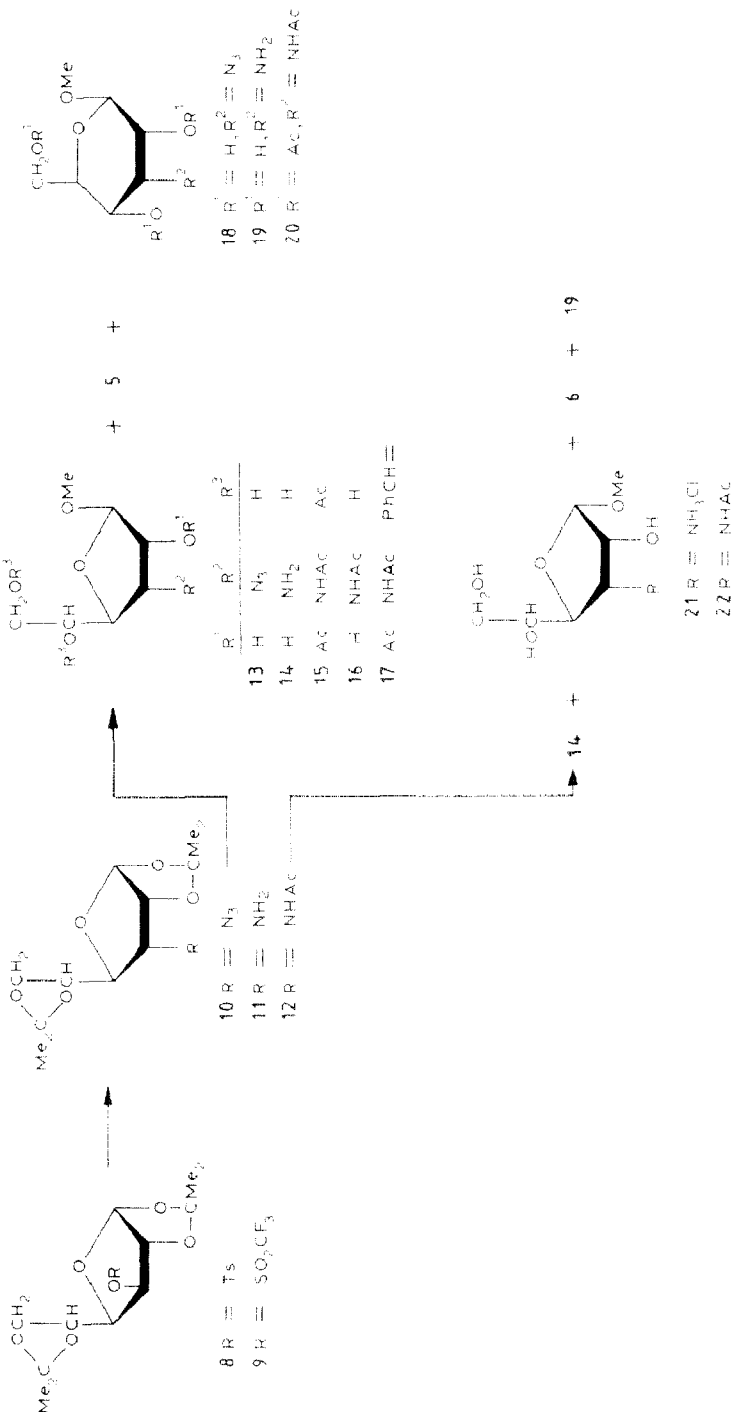
faster-moving component (23%), which proved to be methyl 3-azido-3-deoxy-β-D-allofuranoside (**13**), and crystalline mixtures (67%) of the α-pyranoside **5** and its β anomer **18**, emerging in 1 : 2.5 ratio. Part of the **18** was obtained pure after recrystallization, and its structure was confirmed by hydrogenation to give known[11] methyl 3-amino-3-deoxy-β-D-allopyranoside (**19**), characterized additionally as the tetraacetyl derivative **20**. The more-soluble **5** was difficult to obtain free from anomer, and it is obvious that for its preparation the aforedescribed route from **1** is superior. However, the formation of **13** afforded an opportunity to prepare the hitherto unknown amino furanoside **14**, by catalytic hydrogenation, and subsequently, the derivatives **15** and **16** by conventional acetylation.

Similar, acid-catalyzed methanolyses of the acetamido diacetal **12** led to mixtures of methyl aminoglycosides. Reactions for 7, 16, and 42 h gave similar results, with the β-furanoside **14** being the major product in every case, and with varying proportions of isomers being formed as minor components. This was deduced from the ^{1}H- and ^{13}C-n.m.r. spectra of the reaction mixtures themselves and of mixtures obtained after *N*-acetylation and per-*O*-acetylation. Thus, for example, after a 42-h methanolysis the characteristic H-1 singlet (δ 5.0) of **14** hydrochloride was the strongest signal in the region of anomeric proton resonances; it was accompanied by a small doublet at δ 4.9 (*J* 3.5 Hz) for the α-pyranoside hydrochloride **6** and one at δ 4.65 (*J* 7.8 Hz) for the β-pyranoside (**19** hydrochloride), and, furthermore, by a doublet of intermediate intensity at δ 5.1 (*J* 4.0 Hz), which was attributed to the α-furanoside hydrochloride **21**, not previously encountered. The intensity ratios of the four isomers were approximately 4:1:1:2. In accord herewith, the ^{13}C-n.m.r. spectrum showed a set of seven strong signals for **14** hydrochloride, which included the characteristic, low-field signals for C-1 and C-4 at 111.1 and 82.8 p.p.m., respectively, and a set of seven signals second in strength that included furanosidic C-1 and C-4 signals (105.1 and 83.9 p.p.m.) and was therefore attributable to **21**. Minor signals present in addition were assignable to the pyranosides **6** and **19** hydrochloride by comparison with spectra of the pure compounds previously obtained. The chemical-shift relations for C-1 and C-4 in **14** and **21** were typical for methyl hexofuranosides; compare the values reported[12,13] for methyl β-D-allofuranoside (109.0 and 83.4 p.p.m.) and its α anomer (103.8 and 85.9 p.p.m.).

In methanolyses of shorter duration (7–16 h) the proportions of pyranosides were very small to negligible. Pure **14** was isolated as the crystalline hydrochloride from such an experiment. When processing included treatment of the methanolyzate with excess basic ion-exchange resin for removal of hydrochloric acid, the resultant free amines reacted with methyl acetate present in the medium to form *N*-acetyl derivatives (**16** and isomers). In two experiments, small amounts of the *N*-acetylated α-furanoside **22** fortuitously crystallized from such mixtures. Although the compound was not characterized by physical and analytical data, it gave excellent ^{1}H- and ^{13}C-n.m.r. spectra that proved its structure.

Acetalation of **14** hydrochloride with α,α-dimethoxytoluene, followed by acetylation, gave the crystalline 5,6-*O*-benzylidene derivative **17**.

It is noteworthy that methanolysis of the azido sugar **10** during 1–2 days afforded


8 R = Ts
9 R = SO2CF3
10 R = N3
11 R = NH2
12 R = NHAc
13 R1 = H, R2 = N3, R3 = H
14 R1 = H, R2 = NH2, R3 = H
15 R1 = Ac, R2 = NHAc, R3 = Ac
16 R1 = H, R2 = NHAc, R3 = H
17 R1 = Ac, R2 = NHAc, R3 = PhCH=
18 R1 = H, R2 = N3
19 R1 = H, R2 = NH2
20 R1 = Ac, R2 = NHAc
21 R = NH2Cl
22 R = NHAc

pyranosides and furanoside in a 3:1 ratio (which probably was close to thermodynamic equilibrium), whereas the ratio observed after 42 h in the similar methanolysis of the acetamido analog **12** was reversed. This may be explained by the occurrence of *N*-deacetylation at an early stage of the process, with protonation of the resulting amines retarding acid-catalyzed isomerization of the kinetically favored furanosides.

In summary, methyl 3-amino-3-deoxy-α-D-allopyranoside was synthesized in a convenient 6-step sequence from commercial methyl 4,6-*O*-benzylidene-α-D-glucopyranoside, and its β anomer as well as the hitherto unknown furanoid isomers were prepared in 4 or 5 facile steps from commercial 1,2:5,6-di-*O*-isopropylidene-α-D-glucofuranose.

EXPERIMENTAL

Methyl 2-O-benzoyl-4,6-O-benzylidene-3-O-(trifluoromethylsulfonyl)-α-D-glucopyranoside (**2**). — A solution of triflic anhydride (1.5 mL) in dry CH_2Cl_2 (7.5 mL) was added dropwise, at 0°, to a solution of compound[4] **1** (900 mg) in dry CH_2Cl_2 (20 mL) and pyridine (3 mL). After 10 min the conversion of **1** (R_F 0.25) into **2** (R_F 0.4) was complete (t.l.c., 1:4 EtOAc–hexane). The mixture was shaken with ice–water (2 × 30 mL), the aqueous layer extracted once with CH_2Cl_2, and the combined organic phase was sequentially washed with cold (0°), saturated aq. $NaHCO_3$ and twice with water, dried (Na_2SO_4), and evaporated with additions of toluene, to give a light-brown, spontaneously crystallizing syrup. Processing of the material by trituration and recrystallization with ether and hexane (including decolorization of the mother liquors with activated charcoal) gave **2** (845 mg, 70%) in several crops, all having m.p. 119–121° (dec.), unchanged on recrystallization from 95% EtOH–ether–hexane; $[\alpha]_D$ +116° (*c* 1, $CHCl_3$); ν_{max}^{Nujol} 1725, 1220, 1200, and 1145 cm^{-1}; ^{1}H-n.m.r. (200 MHz, $CDCl_3$): δ 8.12, 7.65–7.35 (2 m, 2 and 8 H, arom.), 5.62 (s, PhC*H*), 5.46 (t, $J_{2,3} = J_{3,4} = 9.3$ Hz, H-3), 5.22 (dd, $J_{1,2}$ 3.7, $J_{2,3}$ 9.3 Hz, H-2), 5.17 (d, $J_{1,2}$ 3.7 Hz, H-1), 4.38 (dd, $J_{5,6eq}$ 3.5, $J_{6ax,6eq}$ 9.5 Hz, H-6*eq*), 3.99–3.79 (m, 3 H, H-4,5,6*ax*), 3.39 (s, 3 H, OCH_3); ^{13}C-n.m.r. (75.43 MHz, $CDCl_3$): δ 165.6 (Ph*C*O), 136.3–125.9 (multiple peaks, C_6H_5CH and C_6H_5CO), 118.3 (q, $J_{C,F}$ 319.7 Hz, *C*F_3), 101.5 (Ph*C*H), 97.8 (C-1), 82.4 (C-3), 78.2 (C-4), 71.2 (C-2), 68.5 (C-6), 62.3 (C-5), and 55.6 (O*C*H_3).

Anal. Calc. for $C_{22}H_{21}F_3O_9S$ (518.5): C, 50.96; H, 4.08; F, 10.99; S, 6.18. Found: C, 51.07; H, 4.27; F, 10.81; S, 6.15.

Methyl 3-azido-2-O-benzoyl-4,6-O-benzylidene-3-deoxy-α-D-allopyranoside (**3**). — A solution of LiN_3 (900 mg, 18.4 mmol) in warm Me_2SO (10 mL) was allowed to cool (25°), triflate **2** (729 mg, 1.39 mmol) was introduced, and the mixture was heated for 1.5 h in an oil bath (100 ± 3°), cooled, diluted with CH_2Cl_2 (50 mL), and extracted with water (3 × 30 mL) and brine. The combined aqueous extracts were shaken once with CH_2Cl_2, and the combined organic phases were washed once more with brine, dried ($MgSO_4$), treated with charcoal, and evaporated to a pale yellow, partly crystalline mass. Trituration with small amounts of MeOH, ether, and hexane, and processing of the mother liquor residue by crystallization from aqueous MeOH–EtOH, gave **3** (307

mg, 54%), R_f 0.5 (almost indistinguishable from **2**; t.l.c. with 1:2 EtOAc–hexane). Column chromatography of the brown, noncrystallizable residues from the mother liquors on SiO_2 with 1:4 EtOAc–hexane gave mainly faster- and slower-moving byproducts, and little additional **3**. Pure **3** showed m.p. 132–133°, $[\alpha]_D$ +108.7° (*c* 1, $CDCl_3$); ν_{max}^{Nujol} 2120 (N_3), 1730, and 1725 (doublet) cm^{-1}, without strong bands in the 1220–1145 cm^{-1} region; ^1H-n.m.r. (300 MHz, $CDCl_3$): δ 8.1, 7.6–7.4 (2 m, 2 and 8 H, arom.), 5.59 (s, PhC*H*), 5.18 (~t, $J_{1,2}$ 4.1, $J_{2,3}$ 3.9 Hz, H-2), 4.96 (d, $J_{1,2}$ 4.1 Hz, H-1), 4.46 (~t, $J_{2,3}$ 3.9, $J_{3,4}$ 3.2 Hz, H-3), 4.36 (dd, $J_{5,6eq}$ 5.1, $J_{6ax,6eq}$ 10.25 Hz, H-6*eq*), 4.25 (sx, H-5), 3.81 (dd, $J_{3,4}$ 3.2, $J_{4,5}$ 9.4 Hz, H-4), 3.76 (t, $J_{5,6ax} = J_{6ax,6eq}$ 10.25 Hz, H-6*ax*), 3.45 (s, 3 H, OC*H*$_3$); ^{13}C-n.m.r. (50.29 MHz, $CDCl_3$): δ 165.5 (CO), 136.8 126.3 (multiple peaks, C_6H_5CH and C_6H_5CO), 102.0 (PhCH), 97.4 (C-1), 77.4 (C-4), 69.1, 69.0 (C-2,6), 59.0, 58.1 (C-3,5), and 56.2 (OCH$_3$).

Anal. Calc. for $C_{21}H_{21}N_3O_6$ (411.4): C, 61.31; H, 5.15; N, 10.21. Found: C, 61.17; H, 5.28; N, 10.24.

Methyl 3-azido-4,6-O-benzylidene-3-deoxy-α-D-allopyranoside (**4**). — To a solution of **3** (270 mg) in MeOH (8 mL) and $CHCl_3$ (8 mL) was added 10 drops of M methanolic NaOMe, at room temperature. The conversion of **3** (R_f 0.6) into **4** (R_f 0.3) was complete after 30 min (t.l.c., 1:2 EtOAc–hexane). Deionization with Amberlite IR-120(H^+) resin and evaporation gave **4** as a white, crystalline mass that was washed with ether and petroleum ether. The residue from the evaporated washings was freed from BzOMe by repeated coevaporation of added water, to yield an additional, small amount of **4**, for a total of 198 mg (98%); m.p. 186–187° (dec.), $[\alpha]_D$ −46.8° (*c* 1.1, $CDCl_3$); ν_{max}^{Nujol} 3300 (br.), 2120 (strong), and 2157 (weak) cm^{-1}; ^1H-n.m.r. (200 MHz, $CDCl_3$): δ 7.5–7.3 (m, 5 H, arom.), 5.55 (s, PhC*H*), 4.66 (d, $J_{1,2}$ 4.4 Hz, H-1), 4.33 (dd, $J_{5,6eq}$ 5.0, $J_{6ax,6eq}$ 10.3 Hz, H-6*eq*), 4.25 (~t, splitting 3.75 Hz, H-3), 4.11 (sx, $J_{5,6ax}$ 5.0, $J_{4,5} \approx J_{5,6eq} \approx$ 10 Hz, H-5), 3.78 (dt, collapsing to t on D_2O exchange, $J_{1,2} = J_{2,3} =$ 4.4 Hz, $J_{2,OH}$ 12 Hz, H-2), 3.70 (t for H-6*ax* superposed on dd for H-4; $J_{5,6ax} = J_{6ax,6eq} =$ 10.2, $J_{3,4}$ 3.1, $J_{4,5}$ 9.4 Hz), 3.45 (s, 3 H, OC*H*$_3$), and 2.72 (d, $J_{2,OH}$ 12 Hz, O*H*-2).

Anal. Calc. for $C_{14}H_{17}N_3O_5$ (307.3): C, 54.72; H, 5.58; N, 13.67. Found: C, 54.90; H, 5.85; N, 13.72.

Methyl 3-azido-3-deoxy-α-D-allopyranoside (**5**). — The acetal **4** (170 mg) was heated for 30 min in 7:3 AcOH–water (10 mL) on a steam bath, after which t.l.c. (1:2 EtOAc–hexane) revealed complete conversion of **4** (R_f 0.3) into immobile **5**. The solution was evaporated with several added portions of water and, eventually, some EtOH, to give **5** as a dry crystalline solid (125 mg, theoretical yield 121 mg) that apparently contained a trace of BzOH (minor i.r. band at 1730 cm^{-1}), removable by repeated trituration of the material with ether. Compound **5** showed m.p. 160° (dec., with gradual browning from 150°), $[\alpha]_D$ +152.5° (*c* 1, D_2O); ν_{max}^{Nujol} 3400 (br.) and 2120 (with shoulder at 2143 and satellite band at 2157) cm^{-1}; ^1H-n.m.r. (200 MHz, D_2O): δ 4.75 (d, $J_{1,2}$ 4.2 Hz, H-1), 4.19 (dd, $J_{3,4}$ 3.0, $J_{2,3}$ 4.2 Hz, H-3), 3.96 (t, $J_{1,2} = J_{2,3} =$ 4.2 Hz, H-2), 3.9–3.7 (m, 4 H, H-4,5,6,6'), and 3.41 (s, 3 H, OC*H*$_3$); ^{13}C-n.m.r. (50.29 MHz, D_2O): δ 101.6 (C-1), 70.0, 69.9, 68.6, 67.6 (C-2,3,4,5), 63.2 (C-6), and 58.5 (OCH$_3$).

Anal. Calc. for $C_7H_{13}N_3O_5$ (219.2): C, 38.35; H, 5.98; N, 19.17. Found: C, 38.35; H, 6.06; N, 19.24.

*Methyl 3-amino-3-deoxy-α-*D*-allopyranoside hydrochloride* (**6**). — A mixture of **5** (100 mg), water (1 mL), MeOH (10 mL), cyclohexene (0.8 mL), and 10% Pd–C (150 mg) was placed under N_2 and sonicated for 4 h in an ultrasonic bath, the temperature of which slowly rose from 23 to 37°. The gradual replacement of **5** (R_F 0.85) by an amine (R_F 0.7, ninhydrin-positive) was monitored by t.l.c. (12:5:3 MeOH–$CHCl_3$–conc. aq. NH_3). The catalyst was filtered off and washed exhaustively with MeOH, and the filtrate evaporated to give the amino sugar as a colorless syrup (75 mg, vacuum-dried). The hydrochloride **6** was obtained as a dry foam (85 mg, 81%) by treatment of the syrup with a 20:5:0.1 mixture of ether, MeOH, and conc. HCl in small portions until the supernatant remained slightly acidic (indicator paper), and evaporation to dryness. (The material crystallized from a small volume of absol. EtOH–ether, but isolation of the crystals was impractical because of their extreme hygroscopicity). Compound **6** showed $[\alpha]_D$ + 103.3° (*c* 2, D_2O); ν_{max}^{film} 3300 (br.) and 1600 cm^{-1}; ^{1}H-n.m.r. (300 MHz, D_2O): δ 4.90 (d, $J_{1,2}$ 3.5 Hz, H-1), 4.06 (dd, $J_{1,2}$ 3.5, $J_{2,3}$ 4.5 Hz, H-2), 4.035 (dd, $J_{3,4}$ 4.6, $J_{4,5}$ 10.4 Hz, H-4), 3.95 (dd, $J_{5,6}$ 2.1, $J_{6,6'}$ 12 Hz, H-6), 3.86 (t, H-3), 3.82 (dd, $J_{5,6'}$ 5.0, $J_{6,6'}$ 12 Hz, H-6'), 3.76 (oct, *J* 2, 5, and 10 Hz, H-5), and 3.45 (s, 3 H, OCH_3); ^{13}C-n.m.r. (50.29 MHz, D_2O): δ 101.5 (C-1), 69.6 (C-5), 66.9, 65.0 (C-2,4), 63.2 (C-6), 58.1 (OCH_3), and 57.6 (C-3); for the *free base*, δ 102.5 (C-1), 70.2, 69.7, 68.8 (C-2,4,5), 63.8 (C-6), and 58.2 (OCH_3), and 56.4 (C-3).

It was noticed that part of the amine generated in the transfer hydrogenation tends to remain stubbornly adsorbed on the catalyst. When the used catalyst was resuspended in MeOH and treated with Ac_2O, an amorphous material (15 mg, 14%) was obtained which, according to its i.r. and n.m.r. spectra, appeared to be the *N*-acetyl derivative of **6**.

*Methyl 3-acetamido-2,4,6-tri-*O*-acetyl-3-deoxy-α-*D*-allopyranoside* (**7**). — A solution of **6** (80 mg) and a few crystals of 4-dimethylaminopyridine in dry pyridine (2 mL) and Ac_2O (2 mL) was kept for 3 h at room temperature and 1 h at 50°, then diluted with CH_2Cl_2, washed three times with water, dried (Na_2SO_4), and evaporated with additions of toluene, to give a light-brown syrup that showed a strong spot for **7** (R_F 0.3) accompanied by faster-moving trace spots (t.l.c., 3:1 EtOAc–hexane). Purified by column chromatography (16 mL of SiO_2; 3:1 EtOAc–hexane), **7** was obtained as a homogeneous, colorless syrup that crystallized slowly; m.p. 114–116°. After recrystallization from EtOAc–hexane, **7** showed a double m.p., 114–116° and 127–128°; $[\alpha]_D$ +83° (*c* 1.3, $CHCl_3$); lit.[2] m.p. 112–115° and 128–129°, $[\alpha]_D$ +85.3°; ν_{max}^{film} 3410, 1740, 1680, and 1520 cm^{-1}; ^{1}H-n.m.r. (300 MHz, $CDCl_3$): δ 6.70 (d, $J_{3,NH}$ 8 Hz, N*H*), 4.93 (dd, $J_{1,2}$ 3.6, $J_{2,3}$ 4.5 Hz, H-2), 4.87 (d, $J_{1,2}$ 3.6 Hz, H-1), 4.88–4.83 (m, 2 H, H-3,4), 4.22 (m, 2 H, B_2 of AB_2, H-6,6'), 3.99 (ddd, $J_{4,5}$ 10, $J_{5,6} = J_{5,6'}$ = 3.7 Hz, H-5), 3.46 (s, 3 H, OCH_3), 2.08, 2.07, 2.02, and 1.98 (4 s, 12 H, 4 $COCH_3$); ^{13}C-n.m.r. (75.43 MHz, $CDCl_3$): δ 170.5, 170.5, 169.4, 169.3 (4 *C*O), 97.8 (C-1), 66.5, 66.3, 63.9 (C-2,4,5), 62.3 (C-6), 56.0 (OCH_3), 47.7 (C-3), 23.4 ($NHCOCH_3$), and 20.8–20.7 ($OCOCH_3$).

*3-Azido-3-deoxy-1,2:5,6-di-*O*-isopropylidene-α-*D*-allofuranose* (**10**) — To a solution of triflate[9] **9** (8.0 g) in $HCONMe_2$ (100 mL) was added tetramethylguanidinium azide (12 g), at 0°. The temperature was allowed to rise to 25° and the mixture was stirred

for 6 h, after which **9** (R_f 0.8) was completely converted into a major (R_f 0.5) and a minor (R_f 0.7) product (t.l.c. with 1:3 EtOAc–hexane). The solvent was removed by coevaporation with toluene and the resulting yellow syrup was passed through a short column of SiO_2 by means of EtOAc. The recovered, pale yellow syrup was then chromatographed on SiO_2 (240 g, 20–45 mesh) with 1:8 EtOAc–hexane as the eluent. Eluted first was the known 3-deoxy-1,2:5,6-di-*O*-isopropylidene-α-D-*erythro*-hex-3-enofuranose. R_f 0.7, m.p. 51°; lit.[14] m.p. 51°; ν_{max}^{Nujol} 1670 cm^{-1} (enol ether); m.s. (c.i., ether): *m/z* 243 ($M^+ + 1$); the ^1H- and ^{13}C-n.m.r. spectra agreed fully with the recorded data[15]. Further elution gave syrupy **10** (3.58 g, 62%), ν_{max}^{film} 2010 cm^{-1}; ^1H-n.m.r. (200 MHz, $CDCl_3$): δ 5.76 (d, $J_{1,2}$ 3.7 Hz, H-1), 4.71 (dd, $J_{1,2}$ 3.7, $J_{2,3}$ 4.75 Hz, H-2), 4.2–3.9 (m, 4 H, H-4,5,6,6'), 3.50 (dd, $J_{2,3}$ 4.75, $J_{3,4}$ 9.0 Hz, H-3), 1.55, 1.46, 1.35, and 1.33 (4 s, 12 H, 4 C-CH_3); m.s. (c.i., ether): *m/z* (%) 286 (4, $M^+ + 1$), 270 (60), 258 (24, $M^+ + 1 - N_2$), 228 (84, $M^+ + 1 - Me_2CO$), 200 (19, $M^+ + 1 - Me_2CO - N_2$), and 185 (30).

*3-Amino-3-deoxy-1,2:5,6-di-*O*-isopropylidene-α-*D*-allofuranose* (**11**). — The azide **10** (3.46 g) and $LiAlH_4$ (1.1 g) were boiled for 1 h in anhydrous ether (120 mL) under reflux. A mixture of ether (90 mL) and EtOAc (18 mL) was then cautiously added, followed by water (1 mL), and boiling was continued for 10 min. The inorganic precipitate was filtered off and washed well with ether, and the dried ($MgSO_4$) filtrate evaporated to dryness. The residue was recrystallized from ether to give **11** (2.75 g, 88%), m.p. 91–92°; (lit.[7] m.p. 92–93°); ν_{max}^{Nujol} 3400 and 3320 (sharp), 1580, and 1500 cm^{-1}; ^1H-n.m.r. (300 MHz, $CDCl_3$, with D_2O exchange): δ 5.74 (d, $J_{1,2}$ 3.7 Hz, H-1), 4.54 (dd, $J_{1,2}$ 3.7, $J_{2,3}$ 4.7 Hz, H-2), 4.1–3.9 (m, 3 H, H-5,6,6'), 3.60 (dd, $J_{4,5}$ 6.2, $J_{3,4}$ 9.1 Hz, H-4), 3.12 (dd, $J_{2,3}$ 4.7, $J_{3,4}$ 9.1 Hz, H-3), 1.53, 1.43, 1.35, and 1.32 (4 s, 12 H, 4 C-CH_3); m.s. (c.i., ether): *m/z* (%) 260 (100, $M^+ + 1$).

*3-Acetamido-3-deoxy-1,2:5,6-di-*O*-isopropylidene-α-*D*-allofuranose* (**12**). — The amine **11** (2.13 g) in MeOH (20 mL) was treated with Ac_2O (3 mL) for 30 min. Evaporation of the solution with added toluene, and crystallization of the residue from ether, gave **12** (2.36 g, 95%), m.p. 132–133°; lit.[6] m.p. 127–128° and 130°; ν_{max}^{Nujol} 3330 (sharp), 1675, and 1530 (amide I and II) cm^{-1}; ^1H-n.m.r. (300 MHz, $CDCl_3$): δ 5.80 (d, $J_{1,2}$ 3.7 Hz, H-1), 4.58 (dd, $J_{1,2}$ 3.7, $J_{2,3}$ 4.9 Hz, H-2), 4.20 (m, 2 H, H-3,5), 4.07 (dd, $J_{5,6}$ 6.6, $J_{6,6'}$ 8.2 Hz, H-6), 3.93 (dd, $J_{5,6'}$ 6.2, $J_{6,6'}$ 8.2 Hz, H-6'), 3.86 (dd, *J* 4.3 and 9.7 Hz, H-4), 2.00 (s, 3 H, COCH_3), 1.54, 1.42, 1.30 (3 s, 3, 3, and 6 H, 4C-CH_3); ^{13}C-n.m.r. (50.29 Hz, $CDCl_3$): δ 170.0 (*C*O), 112.6, 109.6 [2 $(CH_3)_2C$], 104.1 (C-1), 78.9, 78.5, 75.4 (C-2,4,5), 65.0 (C-6), 53.0 (C-3), 26.4, 26.13, 26.08, 25.0 (4 C-CH_3), and 23.0 ($NHCOCH_3$); m.s. (c.i., ether): *m/z* (%) 302 (57, $M^+ + 1$) and 244 (78, $M^+ + 1 - Me_2CO$).

Methanolysis of azide **10**. — The azide **10** (5.0 g) was boiled with methanolic HCl, prepared by adding AcCl (2 mL) to MeOH (50 mL). After 10 h, t.l.c. (EtOAc) showed residual **10** (R_f 0.9) and two new spots, R_f 0.5 (stronger) and 0.3 (weaker). The solution was evaporated to dryness and the residue subjected again to methanolysis, under the same conditions, for 22 h during which time all of **10** disappeared and the intensities of the product-spots became reversed. The pattern was not significantly changed after a further 16 h of treatment. The solvent was removed and the residue chromatographed

on SiO_2 (120 g) with 4:1 EtOAc–hexane as the eluent, to give fractions (A–E) of crystalline methyl glycosides totalling 3.57 g (93%).

Fraction A (890 mg, 23%) was methyl 3-azido-3-deoxy-β-D-allofuranoside (**13**), m.p. 118.5–120°, $[\alpha]_D$ −46° (*c* 1, H_2O); ν_{max}^{Nujol} 3470, 3240, and 2120 cm^{-1}; ^{1}H-n.m.r. (300 MHz, D_2O): δ 4.93 (~s, H-1), 4.31 (dd, $J_{1,2}$ 0.9, $J_{2,3}$ 4.8 Hz, H-2), 4.19 (dd, $J_{2,3}$ 4.8, $J_{3,4}$ 7 Hz, H-3), 4.00 (~t, $J_{3,4} \approx J_{4,5} \approx 7$ Hz, H-4), 3.84, 3.68 (2 m, 1 and 2 H, H-5,6,6'), and 3.40 (s, 3 H, OCH_3); ^{13}C-n.m.r. (50.29 MHz, D_2O): δ 110.8 (C-1), 83.1 (C-4), 77.7 (C-2), 76.2 (C-5), 66.6 (C-3), 65.8 (C-6), and 57.8 (OCH_3); m.s. (c.i., ether): *m/z* (%) 220 (17, $M^+ + 1$), 192 (37, $M^+ + 1 - N_2$), 188 (82, $M^+ + 1 -$ MeOH).

Anal. Calc. for $C_7H_{13}N_3O_5$ (219.2): C, 38.35; H, 5.98; N, 19.17. Found: C, 38.47; H, 6.23; N, 19.48.

Fraction B (115 mg, 3%) was a mixture. Fraction C (1.44 g, 38%) was methyl 3-azido-3-deoxy-β-D-allopyranoside (**18**) containing ~10% of anomer **5** (n.m.r.), which was removed by recrystallization from EtOAc. Pure **18** had m.p. 109–110°; $[\alpha]_D$ −33.7° (*c* 0.5, H_2O); ν_{max}^{Nujol} 3420, 3320, and 2100 with satellite at 2150 cm^{-1}; ^{1}H-n.m.r. (300 MHz, D_2O): δ 4.58 (d, $J_{1,2}$ 8.1 Hz, H-1), 4.27 (t, $J_{2,3} \approx J_{3,4} \approx 3.5$ Hz, H-3), 3.92 (m, H-5), 3.85 (dd, $J_{3,4}$ 3.4, $J_{4,5}$ 9.7 Hz, H-4), 3.73 (m, 2 H, H-6,6'), 3.64 (dd, $J_{2,3}$ 3.6, $J_{1,2}$ 8.1 Hz, H-2), and 3.58 (s, 3 H, OCH_3); ^{13}C-n.m.r. (50.29 MHz, D_2O): δ 103.9 (C-1), 76.9 (C-5), 72.6, 69.3, 69.2 (C-2,3,4), 63.6 (C-6), and 60.0 (OCH_3); m.s. (c.i., ether): *m/z* (%) 220 (27, $M^+ + 1$), 192 (85, $M^+ + 1 - N_2$), 188 (100, $M^+ + 1 -$ MeOH).

Anal. Calc. for $C_7H_{13}N_3O_5$ (219.2): C, 38.35; H, 5.98; N, 19.17. Found: C, 38.55; H, 6.08; N, 19.43.

Fraction D (821 mg, 21.4%) was a ~3:2 mixture of **18** and **5**. Fraction E (300 mg, 7.8%) consisted mainly of **5** (i.r., ^{1}H- and ^{13}C-n.m.r.), with a small proportion of **18** (13% as calculated from the $[\alpha]_D$ value of E, +122°).

Methyl 3-amino-3-deoxy-β-D-allopyranoside (**19**) *and its tetraacetyl derivative* **20**. — Compound **18** (100 mg) was hydrogenated (3 h) as described for **5**, but by use of 1,4-cyclohexadiene, to give **19** (63 mg, 72%), m.p. 198–199° (from EtOH); lit.[11] m.p. 199–200°; ^{1}H-n.m.r. (300 MHz, D_2O): δ 4.70 (d, $J_{1,2}$ 7.6 Hz, H-1), 3.93 (dd, $J_{5,6}$ 2.4, $J_{6,6'}$ 11.8 Hz, H-6), 3.87 (m, H-5), 3.73 (dd, $J_{3,4}$ 3.8, $J_{4,5}$ 9.7 Hz, H-4), 3.71 (dd, $J_{5,6'}$ 5.8, $J_{6,6'}$ 12 Hz, H-6'), 3.59 (s, 3 H, OCH_3), 3.56 (t, $J_{2,3} \approx J_{3,4} \approx 4$ Hz, H-3), 3.53 (dd, $J_{1,2}$ 7.8, $J_{2,3}$ 4 Hz, H-2); acidification of the solution with CF_3CO_2H shifted the H-1 and OMe signals to δ 4.53 and 3.49, and the H-2 and H-3 signals, to δ 3.70 and 3.84, respectively. ^{13}C-N.m.r. (50.29 MHz, D_2O): δ 103.5 (C-1), 76.3 (C-5), 72.9, 69.6 (C-2,4), 64.2 (C-6), 59.8 (OCH_3), and 56.0 (C-3); after acidification with CF_3CO_2H, δ 103.5 (C-1), 77.1 (C-5), 69.3, 65.8 (C-2,4), 63.6 (C-6), 59.9 (OCH_3), and 56.9 (C-3); m.s. (c.i., ether): *m/z* (%) 194 (100, $M^+ + 1$) and 162 (15, $M^+ + 1 -$ MeOH).

Treatment of **19** with Ac_2O in pyridine (with a trace of 4-dimethylaminopyridine) for 2 h at 23° gave **20**, m.p. 179° (from butanone); $[\alpha]_D$ −41.2° (*c* 2, $CHCl_3$); lit.[11] m.p. 179–180°, $[\alpha]_D$ −43°; ^{1}H-n.m.r. (200 MHz, $CDCl_3$): δ 6.0–5.7 (variable; exchangeable d, *J* 8 Hz, N*H*), 4.96 (dd affected by virtual coupling, 4.5 and 5.5 Hz splittings, H-4), 4.84 (narrow m, 2 H, narrowed on D_2O exchange, H-2,3), 4.61 (d, $J_{1,2}$ 4.5 Hz, H-1), 4.26 (AB-qd, 2 H, H-6,6'), 3.99 (q, $J_{4,5} = J_{5,6} = J_{5,6'} = 5.5$ Hz, H-5), 3.43 (s, 3 H, OCH_3), 2.08,

2.06, 2.05, and 1.99 (4 s, 12 H, $COCH_3$); ^{13}C-n.m.r. (50.29 MHz, $CDCl_3$): δ 170.8–169.8 (*C*O), 99.45 (C-1), 72.0 (C-5); 69.1, 67.2 (C-2,4), 62.9 (C-6), 56.45 (OCH_3), 44.4 (C-3), 23.0 ($NCOCH_3$), and 20.7–20.5 ($OCOCH_3$).

Acetylation of **19** with Ac_2O and anhydrous NaOAc (5 min at 100°) gave **20**, m.p. 178.5–179°; ^{1}H- and ^{13}C-n.m.r. spectra identical with those of the previous sample.

*Methyl 3-amino-3-deoxy-β-*D*-allofuranoside* (**14**). — Azide **13** (250 mg) in MeOH (20 mL) was subjected to transfer hydrogenolysis in the presence of 10% Pd-C (200 mg) and 1,4-cyclohexadiene (1 mL), as described for **5**. After 4 h, **13** (R_f 0.5) was absent and an immobile, ninhydrin-positive spot for **14** was seen (t.l.c. with EtOAc). The catalyst was filtered off and washed well with MeOH, the solvent removed, and the solid residue recrystallized from EtOH to give **14** (200 mg, 90%), m.p. 169–170°, $[\alpha]_D$ −45.2° (*c* 1, H_2O); ^{1}H-n.m.r. (200 MHz, D_2O): δ 4.89 (s, H-1), 4.05 (d, $J_{2,3}$ 4.5 Hz, H-2), 3.85–3.60 (m, 4 H, H-4,5,6,6', with H-4 located by COSY at δ 3.80), 3.50 (dd, $J_{2,3}$ 4.5, $J_{3,4}$ 7.5 Hz, H-3), and 3.39 (s, 3 H, OCH_3); ^{13}C-n.m.r. (50.29 MHz, D_2O): δ 111.0 (C-1), 86.4 (C-4), 77.9 (C-2), 76.5 (C-5), 65.7 (C-6), 57.6 (C-3), and 57.0 (OCH_3). On acidification of the solution with CF_3CO_2H, some chemical shifts were significantly changed and the spectra were identical with those of **14** hydrochloride (see a subsequent section). M.s. (c.i., ether): *m/z* (%) 194 (100, $M^+ + 1$) and 162 (34, $M^+ + 1 - MeOH$).

Anal. Calc. for $C_7H_{15}NO_5$ (193.2): C, 43.51; H, 7.83; N, 7.25. Found: C, 43.68; H, 8.23; N, 7.05.

*Methyl 3-acetamido-2,5,6-tri-*O*-acetyl-3-deoxy-β-*D*-allofuranoside* (**15**). — A sample of **14** was treated for 5 min at 100° with Ac_2O and anhydrous NaOAc. Conventional processing by extraction with $CHCl_3$ gave **15** as a colorless syrup that crystallized on storage, m.p. 89–90°; $[\alpha]_D$ +18.4° (*c* 1.2, $CHCl_3$); ν_{max} 3260, 1745, 1635, and 1545 cm^{-1}; ^{1}H-n.m.r. (300 MHz, $CDCl_3$): δ 5.64 (br. d, exchangeable, J ~9 Hz, N*H*), 5.12 (td, $J_{5,6}$ 3.3, $J_{4,5} = J_{5,6'}$ = 6 Hz, H-5), 4.94 (m, 2 H, $W^{1/2}$ 24 Hz and, after D_2O exchange, 14.5 Hz, H-2,3), 4.80 (s, H-1), 4.43 (dd, $J_{5,6}$ 3.5, $J_{6,6'}$ 12.1 Hz, H-6), 4.13 (dd, $J_{5,6'}$ 6.1, $J_{6,6'}$ 12.1 Hz, H-6'), 4.01 (dd, $J_{4,5}$ 6.0, $J_{3,4}$ 7.7 Hz, H-4), 3.34 (s, 3 H, OCH_3), 2.12, 2.05, 2.04, and 1.99 (4 s, 12 H, 4 CH_3CO); ^{13}C-n.m.r. (50.29 MHz, $CDCl_3$): δ 170.8, 170.3, 169.7, 169.5 (4 *C*O), 106.2 (C-1), 80.0 (C-4), 76.3 (C-2), 72.3 (C-5), 62.2 (C-6), 55.3 (OCH_3), 50.2 (C-3), 22.9 ($NHCOCH_3$), and 20.7–20.6 ($OCOCH_3$); m.s. (c.i., ether) *m/z* (%) 362 (41, $M^+ + 1$) and 330 (58, $M^+ + 1 - MeOH$).

Anal. Calc. for $C_{15}H_{23}NO_9$ (361.3): C, 49.86; H, 6.42; N, 3.88. Found: C, 49.78; H, 6.35; N, 3.74.

*Methyl 3-acetamido-3-deoxy-β-*D*-allofuranoside* (**16**). — A sample of **14** (50 mg) in MeOH (5 mL) was treated at 25° with Ac_2O (0.2 mL). Evaporation of the solution after 1 h quantitatively gave solid **16**. Alternatively, a sample of **15** (100 mg) in MeOH (10 mL) was treated overnight at 25° with a catalytic amount of NaOMe. Deionization and evaporation of the solution furnished **16** (65 mg, 100%). The two preparations were identical; m.p. 102–103°; $[\alpha]_D$ −6.7° (*c* 2, water); ^{1}H-n.m.r. (200 MHz, D_2O): δ 4.94 (s, H-1), 4.52 (dd, $J_{2,3}$ 4.8, $J_{3,4}$ 8 Hz, H-3), 4.17 (d, $J_{2,3}$ 4.8 Hz, H-2), 4.00 (dd, $J_{4,5}$ 6.3, $J_{3,4}$ 8 Hz, H-4), 3.76 (m, 2 H, H-5,6), 3.59 (dd, $J_{5,6'}$ 7.8, $J_{6,6'}$ 12.5 Hz, H-6'), 3.41 (s, 3 H, OCH_3), 2.06 (s, 3 H, $COCH_3$); ^{13}C-n.m.r. (50.29 MHz, D_2O): δ 177.3 (*C*O), 111.1 (C-1), 83.2 (C-4),

76.4 and 76.3 (C-2,5), 65.5 (C-6), 57.6 (OCH_3), 55.85 (C-3), 24.6 ($NHCOCH_3$); m.s. (c.i., ether): *m/z* (%) 236 (100, $M^+ + 1$), 204 (98, $M^+ + 1 - MeOH$).

Methanolysis of acetamide **12**. — *A. Spectroscopic identification of products.* A solution of **12** (1.0 g) and AcCl (1 mL) in abs. MeOH (10 mL) was boiled under reflux for 42 h, with exclusion of atmospheric moisture. The solvent was then evaporated at 35° with several additions of toluene, and the white solid obtained by trituration of the residue with EtOH and Et_2O was dried in vacuo over KOH. The glycoside mixture (0.75 g, 98%) showed $[\alpha]_D$ +7° (*c* 2, H_2O); ν_{max}^{Nujol} 3300 (strong), 1605, 1580, and 1530 cm^{-1} (medium strong); m.s. (c.i., ether): *m/z* (%) 194 (100, $M^+ - Cl$). The ^1H-n.m.r. spectrum (200 MHz, D_2O) contained H-1 signals in intensity ratios of ~2:4:1:1 at δ 5.11 (d, *J* 4 Hz), 5.02 (s), 4.92 (d, *J* 3.5 Hz), and 4.66 (d, *J* 8 Hz) for **21**, **14** hydrochloride, **6**, and **19** hydrochloride, respectively; two singlets with an intensity ratio 3:5 representing coincident CH_3 resonances of **21** and **19** hydrochloride (δ 3.49), and of **14** hydrochloride and **6** (δ 3.43); and in the δ 4.5–4.2 region (in which the pyranosides do not resonate) well-separated signals for the furanosides (intensity ratios $\alpha:\beta$ = 1:2) at δ 4.50 (dd, $J_{1,2}$ 4, $J_{2,3}$ 7.5 Hz, H-2α), 4.35 (d, $J_{2,3}$ 5 Hz, H-2β), 4.34 (dd, *J* 3 and 4 Hz, H-4α), and 4.15 (~t, $J_{3,4} = J_{4,5}$ = 7.5 Hz, H-4β). All the remaining signals for the four isomers were ill-resolved in the δ 4.1–3.6 region.

The ^{13}C-n.m.r. spectrum (50.29 MHz, D_2O) showed the following strong and medium strong peaks for **14**·HCl and **21**, respectively: δ 111.1 and 105.1 (C-1), 82.8 and 83.9 (C-4), 76.1 and 75.8, and 74.0 and 71.9 (C-2,5), 65.7 and 65.0 (C-6), 57.7 (OCH_3, coincident), and 56.7 and 53.8 (C-3); **6** and **19**·HCl gave weaker peaks at δ 101.4 and 103.5 (C-1), 69.6 and 77.1 (C-5), 66.9 and 65.0, and 69.5 and 65.8 (C-2,4), 63.2 and 63.5 (C-6), 58.1 and 59.8 (OCH_3), and 57.5 and 56.8 (C-3).

Similar solvolyses for 7 and 16 h gave similar results, with **14** and **21** arising in ~2:1 ratio, but with negligible formation of pyranosides.

*B. Methyl 3-amino-3-deoxy-β-*D*-allofuranoside* (**14**) *hydrochloride.* A solution of **12** (2.0 g) in abs. MeOH (20 mL) containing AcCl (2 mL) was boiled under reflux for 16 h, cooled, diluted with MeOH, and neutralized to pH 5 with Amberlite IR-45 (OH^-), without prolonged exposure to the resin. The residue obtained upon evaporation of the solvent was crystallized from EtOH to give a product (0.96 g, 63%) consisting chiefly of **14** hydrochloride. Recrystallization from EtOH have the pure compound as fine needles, m.p. 209° (dec.); $[\alpha]_D$ −28° (*c* 0.6, H_2O); ^1H-n.m.r. (200 MHz, D_2O): δ 4.99 (s, H-1), 4.32 (d, $J_{2,3}$ 5 Hz, H-2), 4.12 (~t, $J_{3,4} \approx J_{4,5} \approx$ 7.5 Hz, H-4), 3.92 (dd, $J_{2,3}$ 5, $J_{3,4}$ 7.3 Hz, H-3), 3.85–3.63 (m, 3 H, H-5,6,6'), 3.37 (s, 3 H, OCH_3; value from 3 independent preparations). The reason for the discrepancy with the value given in section A is unclear. The ^{13}C-n.m.r. data were identical with those recorded in A; m.s. (c.i., ether): *m/z* (%) 194 (100, $M^+ - Cl$) and 162 (38, $M^+ - Cl - MeOH$).

Anal. Calc. for $C_7H_{16}ClNO_5$ (229.7): C, 36.60; H, 7.02; Cl, 15.44; N, 6.10. Found: C, 36.36; H, 7.10; Cl, 15.61; N, 5.97.

Passage of an aqueous solution of the hydrochloride through a Dowex 1 (OH^-) anion exchange column gave the free base **14**, identical (n.m.r.) with **14** obtained from **10**.

C. Methyl 3-acetamido-3-deoxy-α-D-allofuranoside (**22**). After methanolysis of **12** performed as described in **B**, the acidic solution was stirred with a large amount of anion exchange resin for 1–2 h. The product (60%, crystallized from EtOH) was a 2:1 mixture of anomeric acetamides **16** and **22** (^{1}H- and ^{13}C-n.m.r.). Stored at 0°, the ethanolic mother liquors slowly deposited stout crystals of pure **22** in amounts sufficient only for spectroscopy. (This occurred on 2 occasions). ^{1}H-N.m.r. (200 MHz, D_2O): δ 4.99 (d, $J_{1,2}$ 4 Hz, H-1), 4.45 (dd, $J_{3,4}$ 4, $J_{2,3}$ 7.7 Hz, H-3), 4.21 (dd, $J_{1,2}$ 4.1, $J_{2,3}$ 7.7 Hz, H-2), 4.04 (t, $J_{3,4} = J_{4,5} = 4$ Hz, H-4), 3.96 (dt, $J_{4,5} = J_{5,6} = 4$, $J_{5,6}$ 7 Hz, H-5), 3.57 (center of AB-qd, 2 H, $J_{6,6'}$ 12 Hz, H-6,6'), 3.44 (s, 3 H, OCH_3), and 2.03 (s, 3 H, $NCOCH_3$); ^{13}C-n.m.r. (50.29 MHz, D_2O): δ 177.0 (*C*O), 105.5 (C-1), 85.5 (C-4), 74.6, 73.2 (C-2,5), 65.0 (C-6), 57.8 (OCH_3), 51.9 (C-3), and 24.7 ($NHCOCH_3$).

Methyl 3-acetamido-2-O-acetyl-5,6-O-benzylidene-3-deoxy-β-D-allofuranoside (**17**). — A mixture of **14** hydrochloride (500 mg), dry MeCN (20 mL), α,α-dimethoxytoluene (0.3 mL), and a catalytic amount of *p*-toluenesulfonic acid was stirred for 30 min at room temperature and then concentrated at 35° to a volume of 10 mL, neutralized with Et_3N, and evaporated to dryness. The residue was treated overnight with Ac_2O (5 mL) and pyridine (10 mL), and the mixture processed by dilution with methanol followed by coevaporation of the solvents with added toluene. The light-brown residue was purified by column chromatography (30 g of SiO_2, 1:1 EtOAc–hexane), affording **17** (435 mg, 55%, after recrystallization from EtOAc–petroleum ether); m.p. 139–140°, ν_{max}^{Nujol} 3260, 1750, 1655, and 1565 cm^{-1}; ^{1}H-n.m.r. (300 MHz, $CDCl_3$): δ 7.49, 7.36 (2m, 5H, arom.), 5.76 (s, PhC*H*), 5.45 (d, exchangeable, $J_{3,NH} \sim 9$ Hz, N*H*), 4.99 (d, $J_{2,3}$ 4.8 Hz, H-2), 4.84 (s, H-1), 4.74 (td, $J_{2,3}$ 4.8, $J_{3,4} = J_{3,NH} = 8.8$ Hz, H-3), 4.27, 4.13 (2 m, 2 and 1 H, H-5,6,6'), 3.97 (dd, $J_{4,5}$ 5.5, $J_{3,4}$ 8.8 Hz, H-4), 3.38 (s, 3 H, OCH_3), 2.11, 1.87 (2 s, 6 H, 2 $COCH_3$); m.s. (c.i., ether): *m/z* (%) 366 (54, $M^+ + 1$) and 334 (100, $M^+ + 1 - MeOH$).

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REFERENCES

1 J. Defaye, A. Gadelle, F. Movilliat, R. Nardin, and H. H. Baer, *Carbohydr. Res.*
2 B. R. Baker and S. Schaub, *J. Org. Chem.*, 19 (1954) 646–660.
3 S. Koto, N. Kawakatsu, and S. Zen, *Bull. Chem. Soc. Jpn.*, 46 (1973) 876–880.
4 R. W. Jeanloz and D. A. Jeanloz, *J. Am. Chem. Soc.*, 79 (1957) 2579–2583; F. A. Carey and K. O. Hodgson, *Carbohydr. Res.*, 12 (1970) 463–465.
5 K. Freudenberg and F. Brauns, *Ber. Dtsch. Chem. Ges.*, 55 (1922) 3233–3238.
6 R. U. Lemieux and P. Chu, *J. Am. Chem. Soc.*, 80 (1958) 4745.
7 B. Coxon and L. Hough, *J. Chem. Soc.*, (1961) 1643–1649.
8 M. L. Wolfrom, J. Bernsmann, and D. Horton, *J. Org. Chem.*, 27 (1962) 4505–4509; A. K. Chatterjee, D. Horton, and J. S. Jewell, *Carbohydr. Res.*, 7 (1968) 212–217.
9 L. D. Hall and D. C. Miller, *Carbohydr. Res.*, 47 (1976) 299–305; R. W. Binkley and D. G. Hehemann, *J. Org. Chem.*, 43 (1978) 3244–3245; R. W. Binkley, M. G. Ambrose, and D. G. Hehemann, *ibid.*, 45 (1980) 4387–4391.

10 T. W. Flechtner, *Carbohydr. Res.*, 77 (1979) 262–266.
11 B. Lindberg and O. Theander, *Acta Chem. Scand.*, 13 (1959) 1226–1230.
12 R. G. S. Ritchie, N. Cyr, B. Korsch, H. J. Koch, and A. S. Perlin, *Can. J. Chem.*, 53 (1975) 1424–1433.
13 K. Bock and C. Pedersen, *Adv. Carbohydr. Chem. Biochem.*, 41 (1983) 27–66.
14 F. Weygand and H. Wolz, *Chem. Ber.*, 85 (1952) 256–260.
15 A. Fürstner and H. Weidmann, *J. Org. Chem.*, 54 (1989) 2307–2311.