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# SYNTHESIS OF 2-ACETAMIDO-2-DEOXY-3- AND -6-*O*-β-D-GLUCOPYRANOSYL-D-GLUCOPYRANOSE*†

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ABSTRACT

As a route for forming spacers of differing functionality for linking oligosaccharides to carrier molecules, the allyl glycosides of β-D-Glc→β-D-GlcNAc disaccharides having β-D-(1→3) and β-D-(1→6) linkages were prepared. The aglycon could be removed directly to yield the corresponding free disaccharides. Condensation of 2,3,4,6-tetra-*O*-acetyl-α-D-glucopyranosyl bromide (**1**) with the known allyl 2-acetamido-4,6-*O*-benzylidene-2-deoxy-β-D-glucopyranoside (**2**) under Koenigs–Knorr conditions gave the protected β-D-(1→3)-linked disaccharide in excellent (86%) yield. Removal of all protecting groups afforded the previously unreported 2-acetamido-2-deoxy-3-*O*-β-D-glucopyranosyl-D-glucopyranose (**6**). Condensation of allyl 2-acetamido-3,4-di-*O*-acetyl-2-deoxy-β-D-glucopyranoside (**9**) with **1** under the same conditions gave an acceptable yield (64%) of the acetylated β-D-(1→6)-linked disaccharide **11**. Zemplén deacetylation of the resulting disaccharide derivative **11** followed by palladium-assisted hydrolysis of the allyl group afforded the previously unreported 2-acetamido-2-deoxy-6-*O*-β-D-glucopyranosyl-D-glucopyranose (**13**).

## INTRODUCTION

In our studies[1–3] of the structure–specificity relationships involved in the immunological properties of the capsular polysaccharides of Group B *Streptococcus*, we needed synthetic oligosaccharides in forms suitable for use as water-soluble models for n.m.r. studies, for attachment to soluble protein-carriers to form immunogens, and for attachment to insoluble carriers for affinity chromatography. Although various functional groups have been successfully used as aglycons for the preparation of neoglycoproteins and immunoadsorbents[4–6], we oriented our approach to provide a group amenable to multifunctional transformations. We selected the allyl glycosides because they are water-soluble, readily cleaved to release the reducing oligosaccharide, and the alkenic bond can be readily transformed into a number of different functional

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groups capable of forming glycoconjugates or immunoadsorbents under a wide range of already-described conditions[4,5].

Hall *et al.*[5] demonstrated that ozonolysis of the allyl glycoside generates a terminal aldehydic function that may be linked to protein by reductive amination. Several possibilities exist for terminal functionalization. Oxidative ozonolysis or Lemieux–Von Rudloff[7] oxidative cleavage may be used to generate the corresponding carboxylic acid. Epoxides[8-10] may also be introduced and these have been used as enzyme inhibitors[9,10]. Free-radical addition of thiols to unsaturated compounds[11] has also been used by Lee *et al.*[12] to prepare 3-(2-aminoethylthio)propyl glycosides. We are also studying the addition of thioglycolic acid in the presence of a radical initiator to form a larger spacer-arm, containing terminal carboxyl group. It is also possible to couple the alkene directly with thiol-agarose by γ-irradiation[13].

In addition to the foregoing features, allyl groups also have considerable synthetic utility in that they may be used as t.l.c. tracers[14] as they are selectively detected by the potassium permanganate spray, they are readily removed[15,16], and they can be used in routes to oligosaccharide extension by direct oxazoline formation[17].

The disaccharide β-D-Glc-(1→3)-β-D-GlcNAc is part of the repeating unit of the capsular polysaccharide of type 27 *Streptococcus pneumoniae*[18] and is also present in the lipopolysaccharide[19] from *Proteus mirabilis* strain D-52. The β-D-(1→6) counterpart is a part of the repeating unit of the capsular polysaccharides of type-III Group B *Streptococcus*[1-3] and type 14 *S. pneumoniae*[20] and forms an integral part of the backbone determinant of the former[2]. It has also been recently discovered as part of a component of the antibiotic moenomycin[21].

## RESULTS AND DISCUSSION

The well known[12,22] allyl 2-acetamido-2-deoxy-β-D-glucopyranoside, used as a common intermediate for preparation of the two glycosyl acceptors **2** and **9** was prepared by glycosidation of 2-acetamido-3,4,6-tri-*O*-acetyl-2-deoxy-α-D-glucopyranosyl chloride with allyl alcohol in the presence of mercuric cyanide[12]. The chloride was formed by a modification[22] of Horton's procedure[23]. Synthon **2** was prepared in reproducible, quantitative yield by the method of Jeanloz *et al.*[24] using benzaldehyde and anhydrous zinc chloride. The intermediate **8** was prepared by acetylation (92%) of allyl 2-acetamido-2-deoxy-6-*O*-trityl-β-D-glucopyranoside[24] (**7**) or, more conveniently, in a one-flask reaction by tritylation of allyl 2-acetamido-2-deoxy-β-D-glucopyranoside in the presence of 4-dimethylaminopyridine[25,26] followed by the addition of acetic anhydride (74%). Removal of the trityl group from **8** to form the glycosyl acceptor **9** had to be performed under controlled conditions as it is known that acid-catalyzed hydrolysis of the trityl group may result in O-4→O-6 acetyl migration. Utilization of hydrogen bromide in cold acetic acid failed to give **9** in high yield: allyl 2-acetamido-3,6-di-*O*-acetyl-2-deoxy-β-D-glucopyranoside (**10**) was invariably the major product. The two isomers could be differentiated by means

of $^1$H-n.m.r. spectroscopy (C-6 protons) and by the resistance of one of them (**10**) to tritylation. The recently described detritylation procedure using anhydrous cupric sulfate in benzene[27] also failed to give any hydrolyzed product. Detritylation was eventually accomplished by careful hydrolysis with aqueous acetic acid at room temperature and afforded pure **9** in quantitative yield. Prolonged reaction times or heating during hydrolysis invariably promoted acetyl migration.

Koenigs–Knorr condensation of the glycosyl acceptor **2** with 2,3,4,6-tetra-*O*-acetyl-α-D-glucopyranosyl bromide (**1**), following the procedure of Flowers and Jeanloz[28] using mercuric cyanide in 1 : 1 benzene–nitromethane at 70°, afforded **3** as an amorphous powder in 86% yield after chromatography. Treatment of **3** with 50% aqueous acetic acid for 30 min at 100°, and evaporation of the residual acid by distillation of toluene left a glassy residue (**4**), exhibiting no aromatic signals in its $^1$H-n.m.r. spectrum; it was used without further characterization for the next step. Zemplén deacetylation then liberated **5** in 67% net yield for the two steps. The structure of allyl 2-acetamido-2-deoxy-3-*O*-β-D-glucopyranosyl-β-D-glucopyranoside (**5**) was ascertained by $^1$H- and $^{13}$C-n.m.r. spectroscopy. The two anomeric protons gave signals at 4.42 ($J_{1',2'}$ = 7 Hz, H-1') and 4.54 p.p.m. ($J_{1,2}$ = 8 Hz, H-1), whereas the anomeric carbon atoms resonated at 104.3 and 101.0 p.p.m., respectively, thus confirming the β-D-orientation of the anomeric residues[29]. Furthermore, the signal for C-3 of the 2-amino-2-deoxyglucose moiety had undergone a significant downfield displacement of 9.0 p.p.m. (Table I) relative to that of the parent allyl 2-acetamido-2-deoxy-β-D-glucopyranoside, whereas the C-2 and C-4 signals underwent smaller upfield displacements (1.0 and 1.3 p.p.m. respectively), due to shielding effects. These results are in good agreement with those found for the corresponding 6-aminohexyl[30]

TABLE I

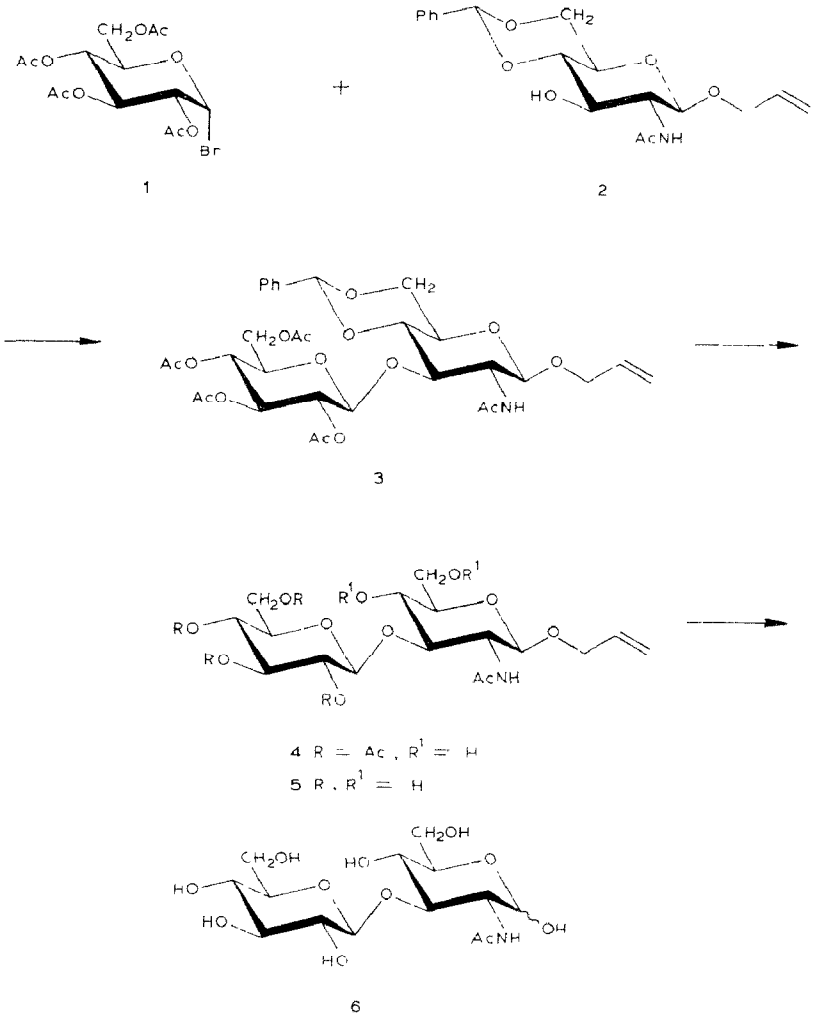
$^{13}$C-N.M.R. CHEMICAL SHIFTS OF GLYCOSYL RESIDUES IN $D_2O$ RELATIVE TO EXTERNAL TETRAMETHYLSILANE (P.P.M.)

| *Compound* | *D-GlcNAc residue* | | | | | | *β-D-Glc group* | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | *C-1* | *C-2* | *C-3* | *C-4* | *C-5* | *C-6* | *C-1'* | *C-2'* | *C-3'* | *C-4'* | *C-5'* | *C-6'* |
| [a] | 101.3 | 56.7 | 75.0 | 71.1 | 77.0 | 61.9 | | | | | | |
| **5**[b,c] | 101.0 | 55.7 | 84.0 | 69.8 | 76.6 | 61.8 | 104.3 | 74.1 | 77.1 | 70.6 | 76.6 | 61.8 |
| **6α**[b] | 92.2 | 54.0 | 81.7 | 69.8 | 72.4 | 61.8 | | | | | | |
| | | | | | | | 104.1 | 74.1 | 77.1 | 70.6 | 76.6 | 61.8 |
| **6β**[b] | 95.9 | 56.8 | 84.1 | 69.8 | 76.7 | 61.8 | | | | | | |
| **12**[b,c] | 101.4 | 56.7 | 74.9 | 70.8 | 76.1 | 69.7 | 104.0 | 74.2 | 77.1 | 70.8 | 76.8 | 61.9 |
| **13α**[b] | 92.1 | 55.2 | 71.8 | 71.1 | 71.8 | 69.9 | | | | | | |
| | | | | | | | 103.9 | 74.3 | 77.1 | 70.8 | 76.8 | 61.9 |
| **13β**[b] | 96.2 | 57.8 | 75.0 | 70.8 | 76.1 | 69.9 | | | | | | |

[a]Allyl 2-acetamido-2-deoxy-β-D-glucopyranoside. [b]C=O at 175.8 and $CH_3$ at 23.4. [c]Allyl group: $OCH_2$, 71.6; CH=, 134.5; $=CH_2$, 119.3.

and ω-carboxyoctyl[31] glycosides of the β-D-(1→3)-galactosylated disaccharide analogs.

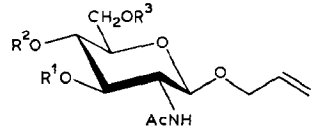
In addition, the free disaccharide **6** could be liberated directly, as it was recognized that the prototropic rearrangement[32] of the allyl ether to the enol ether, as catalyzed by transition-metal reagents[33], could be performed under conditions promoting hydrolysis of the enol ether[15]. Thus, treatment of **5** with 10% palladium-on-charcoal in boiling aqueous acetic acid[16] for 24 h resulted in complete hydrolysis and gave 2-acetamido-2-deoxy-3-*O*-β-D-glucopyranosyl-D-glucopyranose (**6**) in 91% yield. More recently, Ogawa and Nakabayashi[16] reported even milder conditions for this transformation using palladium chloride-sodium acetate as the catalyst. The $^1$H- and $^{13}$C-n.m.r. spectra were consistent with the proposed structure for **6** (Table I).



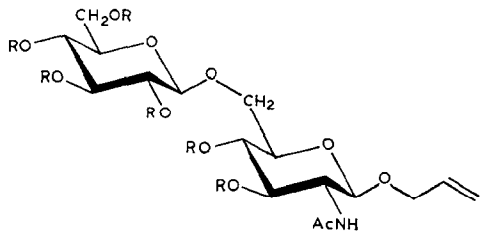
Preliminary attempts to apply directly the procedure of Flowers and Jeanloz[28] to synthesis of the β-D-(1→6)-linked isomer indicated that appreciable O-4→O-6 acetyl migration had occurred in **9**.

Glycosylation of **9** was therefore effected by the same procedure as for **3** except that the temperature was lowered to room temperature and dichloromethane was used as co-solvent with nitromethane. The acetylated disaccharide **11** was obtained in 64% yield after careful column chromatography of the mixture. The physical data were in agreement with the proposed structure for **11**, but the integrity of the anomeric center could not be ascertained from its $^1$H-n.m.r. spectrum because of overlapping signals. Zemplén deacetylation furnished allyl 2-acetamido-2-deoxy-6-*O*-β-D-glucopyranosyl-β-D-glucopyranoside (**12**) in 77% yield. The $^1$H-n.m.r. spectrum of the disaccharide was then clarified and showed two resolved anomeric-proton signals as doublets at δ 4.49 ($J_{1',2'}$ = 7.1 Hz, H-1′) and 4.55 p.p.m. ($J_{1,2}$ = 7.8 Hz, H-1). The anomeric carbon resonances appeared at 104.0 p.p.m. for the β-D-Glc residue and at 101.4 p.p.m. for the β-D-GlcNAc residue, again confirming the β-D orientation of the anomeric aglycons[29,31]. Furthermore, the C-6 signal of this (1→6)-linked disaccharide **12** showed a downfield shift of 7.8 p.p.m., consistent with a linkage carbon, whereas the C-5 signal had also undergone a characteristic[30] upfield shift of 0.9 p.p.m. Having thus confirmed the stereochemistry of **12**, the same direct procedure used previously for formation of **6** was then used to remove the allyl protecting-group, affording free 2-acetamido-2-deoxy-6-*O*-β-D-glucopyranosyl-D-glucopyranose (**13**) in excellent yield (95%).

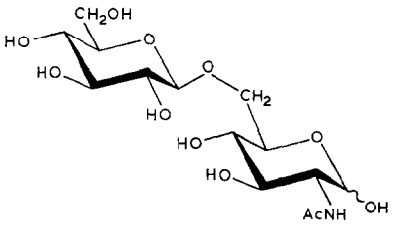
The β-D-(1→6)-linked disaccharide **13** is a constituent of the backbone re-



7 $R^1$ = $R^2$ = H, $R^3$ = Tr
8 $R^1$ = $R^2$ = Ac, $R^3$ = Tr
9 $R^1$ = $R^2$ = Ac, $R^3$ = H
10 $R^1$ = Ac, $R^2$ = H, $R^3$ = Ac



11 R = Ac
12 R = H



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peating-unit of the capsular polysaccharide of type-III Group B *Streptococcus*, and its $^{13}$C-n.m.r. parameters (Table I) were used in correlating some of the assignments made in the $^{13}$C-n.m.r. spectrum of this polysaccharide[1-3].

## EXPERIMENTAL

*General methods.* — Melting points were determined using a Fisher–Johns apparatus and are uncorrected. Solutions were evaporated under diminished pressure. Optical rotations were determined with a Perkin–Elmer Model 141 polarimeter. I.r. spectra were recorded with a Perkin–Elmer Model 237B spectrophotometer. $^1$H-N.m.r. spectra were recorded with a Varian CFT20 spectrometer and chemical shifts are expressed in p.p.m. downfield from the tetramethylsilane used as the internal standard for solutions in $CDCl_3$. $^{13}$C-N.m.r. spectra were also recorded with a Varian CFT20 spectrometer, using $D_2O$ solutions at room temperature with external tetramethylsilane as the standard. Column chromatography was performed on silica gel 60 (70–230 mesh; E. Merck, Darmstadt, Germany). Thin-layer chromatography was performed on 0.25-mm precoated plates of Silica Gel 60 $F_{254}$ (E. Merck, Darmstadt, Germany). The spray reagent was ammonium molybdate (25 g) and ceric sulfate (10 g) in sulfuric acid (100 mL) and water (900 mL)[34] and the plates were heated to 110°; spots were blue on a white background. Unsaturation was detected specifically after spraying with a 1% neutral, aqueous solution of potassium permanganate. The use of base (sodium carbonate) in this spray was also used to detect free-anomeric by-products arising from the glycosylation reactions.

*Allyl 2-acetamido-4,6-O-benzylidene-2-deoxy-3-O-(2,3,4,6-tetra-O-acetyl-β-D-glucopyranosyl)-β-D-glucopyranoside* (**3**). — Allyl 2-acetamido-4,6-*O*-benzylidene-2-deoxy-β-D-glucopyranoside (**2**, 1.05 g, 3.0 mmol)[24,35] was dissolved in 1:1 anhydrous nitromethane–benzene (150 mL). To ensure dryness, the solution was concentrated by distillation at atmospheric pressure until 50 mL of distillate had been collected in a Dean–Stark trap. Mercuric cyanide (700 mg, 2.77 mmol) was added and the temperature of the mixture was adjusted to 70°. While maintaining this temperature under argon, a solution of tetra-*O*-acetyl-α-D-glucopyranosyl bromide (**1**, 1.44 g, 3.5 mmol) in 1:1 nitromethane–benzene (10 mL) was added dropwise during 30 min. The mixture was stirred for 4 h at 70°, allowed to cool to room temperature, and diluted with benzene (200 mL). The solution was then successively washed with 10% aqueous potassium iodide, saturated aqueous sodium hydrogencarbonate, water, and then dried (sodium sulfate). The organic layer was evaporated to afford an oil that was chromatographed on a column of silica gel with 3:2 hexane–acetone as eluant. The homogeneous fractions were combined and evaporated to give **3** as an amorphous powder which was dried over phosphorus pentaoxide, yield 1.75 g (86%), m.p. 216–217°, $[\alpha]_D^{24}$ −17.8° (*c* 0.41, chloroform); $\nu_{max}^{CHCl_3}$ 3300 (NH), 1750 (OAc), 1650 (allyl and Amide I), 1550 (Amide II), and 1450, 750, 690 cm$^{-1}$ (Ph); $^1$H-n.m.r. ($CDCl_3$): δ 1.91 (s, 3 H, NHAc), 1.96, 1.99, 2.00 (3s, 12 H, OAc), 5.21 (d, 1 H, $J_{1,2}$ 8 Hz, H-1), 5.50–5.90 (m, 1 H, -CH=), and 7.38 (m, 5 H, Ph).

*Anal.* Calc. for $C_{32}H_{41}NO_{15}$: C, 56.55; H, 6.08; N, 2.06. Found: C, 56.72; H, 6.17; N, 2.06.

*Allyl 2-acetamido-2-deoxy-3-O-β-D-glucopyranosyl-β-D-glucopyranoside* (**5**). — Treatment of **3** (1.70 g, 2.50 mmol) with 50% aqueous acetic acid (5 mL) for 30 min at 100° and evaporation of the solvent left a glassy residue that was used directly in the next step. The $^1$H-n.m.r. spectrum in $CDCl_3$ was consistent with the de-*O*-benzylidenated structure **4**.

The foregoing residue was dissolved in aqueous methanol (1:1, 50 mL) to which was added 0.5 mL of ~M sodium methoxide. The mixture was stirred for 30 min at room temperature, treated with Rexyn 101 ($H^+$) ion-exchange resin, filtered, evaporated, and methanol was evaporated a few times from the residue. The resulting residue (1.05 g, quantitative) was recrystallized from abs. ethanol to give **5** as fine needles (710 mg, 67%), m.p. 259–260° (dec), $[\alpha]_D^{23}$ −47.1° (*c* 0.35, water); $^1$H-n.m.r. ($D_2O$): δ 1.96 (s, 3 H, NHAc), 4.12–4.37 (m, 2 H, -$OCH_2CH$=), 4.42 (d, 1 H, $J_{1',2'}$ 7 Hz, H-1'), 4.54 (d, 1 H, $J_{1,2}$ 8 Hz, H-1), 5.11–5.37 (m, 2 H, $CH_2$=), and 5.63–5.84 (m, 1 H, =CH-); $^{13}$C-n.m.r. ($D_2O$): δ 23.4 (NHAc), 55.7 (C-2), 61.8 (C-6, C-6'), 69.8 (C-4), 70.6 (C-4'), 71.6 ($OCH_2$-CH=), 74.1 (C-2'), 76.6 (C-5, C-5'), 77.1 (C-3'), 84.0 (C-3), 101.0 (C-1), 104.3 (C-1'), 119.4 (=$CH_2$), 134.5 (-CH=), and 175.8 (C=O).

*Anal.* Calc. for $C_{17}H_{29}NO_{11}$: C, 48.22; H, 6.90; N, 3.31. Found: C, 48.50; H, 7.02; N, 3.51.

*2-Acetamido-2-deoxy-3-O-β-D-glucopyranosyl-D-glucopyranose* (**6**). — A solution of compound **5** (200 mg, 0.47 mmol) and 10% palladium-on-charcoal (50 mg) in 2:1:1 (v/v) ethanol–water–acetic acid (8 mL) was boiled under reflux for 20 h. The cooled mixture was filtered through a bed of Celite and the filtrate and aqueous washings were evaporated. Evaporation of 2-propanol from the residue and precipitation from 2-propanol–ether liberated **6** as a white powder (166 mg, 91%) slightly contaminated with a trace of a faster-moving spot ($R_F$ 0.48 in 3:3:2 ethyl acetate–2-propanol–water); the starting allyl glycoside **5** had $R_F$ 0.62 in the same system. Recrystallization from abs. ethanol afforded pure **6** as needles, m.p. 155–156°, $[\alpha]_D^{24}$ +8.2 (5 min)→−5.1° (24 h) (*c* 1.71, water); $^1$H ($D_2O$): δ 2.00 (s, 3 H, NAc), 4.44 (d, 1 H, *J* 7.1 Hz, H-1β), 4.48 (d, 1 H, *J* 7.3 Hz, H-1'), and 5.14 (d, 1 H, *J* 2.8 Hz, H-1α); $^{13}$C-n.m.r. ($D_2O$): δ 23.0 (NHAcα), 23.4 (NHAcβ), 5.40 (C-2α), 56.8 (C-2β), 61.8 (C-6α,β and C-6'), 69.8 (C-4), 70.6 (C-4'), 72.4 (C-5α), 74.1 (C-2'), 76.7 (C-5β and C-5'), 77.1 (C-3'), 81.7 (C-3α), 84.1 (C-3β), 92.2 (C-1α), 95.9 (C-1β), and 104.1 (C-1').

*Anal.* Calc. for $C_{14}H_{25}NO_{11}$: C, 43.86; H, 6.57; N, 3.65. Found: C, 43.63; H, 6.75; N, 3.57.

*Allyl 2-acetamido-3,4-di-O-acetyl-2-deoxy-6-O-trityl-β-D-glucopyranoside* (**8**). — Allyl 2-acetamido-2-deoxy-6-*O*-trityl-β-D-glucopyranoside[24] (**7**, 5.76 g, 11.5 mmol) in pyridine (50 mL) containing acetic anhydride (10 mL) was stirred overnight at room temperature. The excess reagents were removed by successive codistillations from methanol and then from toluene. The residue was recrystallized from dichloro-

methanol–ether to afford **8** as needles (6.2 g, 92%), m.p. 214.5–215.5°, $[\alpha]_D^{21}$ +22.9 (*c* 1.03, chloroform); $\nu_{max}^{CHCl_3}$ 3440 (NH), 1750 (OAc), 1680 (allyl and Amide I), and 1520 $cm^{-1}$ (Amide II); $^1$H-n.m.r. ($CDCl_3$): $\delta$ 1.71, 1.95, and 2.01 (3s, 9 H, NAc, OAc), 4.67 (d, 1 H, $J_{1,2}$ 8.3 Hz, H-1), 5.10–5.55 (m, 2 H, $CH_2=$), 5.60–6.10 (m, 1 H, =CH-), and 7.37 (m, 15 H, Ph).

*Anal.* Calc. for $C_{34}H_{37}NO_8$: C, 69.49; H, 6.35; N, 2.38. Found: C, 69.37; H, 6.46; N, 2.49.

This compound has also been obtained directly in a one-flask reaction from the known[12,22] allyl 2-acetamido-2-deoxy-β-D-glucopyranoside by the following procedure. A suspension of the glycoside (1.50 g, 5.74 mmol) and chlorotriphenylmethane (1.76 g, 6.32 mmol) was shaken in dry pyridine (10 mL) at room temperature in the presence of 4-dimethylaminopyridine (100 mg, Aldrich). After 2 days, acetic anhydride (2 mL) was added to the clear solution which was stirred for a further 24 h. The mixture was then poured into ice–water (150 mL) from which compound **8** precipitated. Filtration of the dried **8** over silica gel with a gradient of benzene–ethyl acetate (0–100%) afforded pure **8** (2.50 g, 74%) identical in all respects with the compound prepared by the foregoing procedure.

*Allyl 2-acetamido-3,4-di-*O*-acetyl-2-deoxy-β-*D*-glucopyranoside* (**9**). – A solution of **8** (588 mg, 1 mmol) in 80% aqueous acetic acid (20 mL) was stirred for 48 h at room temperature, whereupon some triphenylmethanol started to precipitate. The mixture was then filtered and the solid washed with a little 80% acetic acid (5 mL). The filtrate and washings were evaporated, the last traces of acetic acid being removed by repeated evaporation of toluene from the residue. The residue thus obtained was chromatographed on silica gel with 19:1 chloroform–ethanol to yield a foam (345 mg) that crystallized from ethanol–ether. Compound **9** had m.p. 187–188°, $[\alpha]_D^{23}$ –18.5° (*c* 1.35, chloroform); $\nu_{max}^{CH_2Cl_2}$ 3400 (NH, OH), 1745 (OAc), 1675 (allyl and Amide I), and 1530 $cm^{-1}$ (Amide II); $^1$H-n.m.r. ($CDCl_3$): $\delta$ 1.94 (s, 3 H, NHAc), 2.03 (s, 6 H, OAc), 4.72 (d, 1 H, $J_{1,2}$ 8 Hz, H-1), 4.88–5.43 (m, 2 H, $CH_2=$) 5.50–6.00 (m, 1 H, -CH=), and 5.80 (d, 1 H, *J* 9 Hz, NH).

*Anal.* Calc. for $C_{15}H_{23}NO_8$: C, 52.17; H, 6.71; N, 4.05. Found: C, 51.86; H, 6.90; N, 4.01.

*Allyl 2-acetamido-3,4-di-*O*-acetyl-2-deoxy-6-*O*-(2,3,4,6-tetra-*O*-acetyl-β-*D*-glucopyranosyl)-β-*D*-glucopyranoside* (**11**). – 2,3,4,6-Tetra-*O*-acetyl-α-D-glucopyranosyl bromide (**1**, 617 mg, 1.5 mmol) in dichloromethane (10 mL) was added dropwise to a solution of compound **9** (345 mg, 1 mmol) in anhydrous nitromethane (10 mL) containing mercuric cyanide (506 mg, 2 mmol). After 24 h at room temperature, the mixture was evaporated and the residue dissolved in chloroform. The solution was successively washed with 10% aqueous potassium iodide, 10% sodium thiosulfate, saturated sodium hydrogencarbonate, and water, dried (sodium sulfate) and evaporated. The crude syrup was chromatographed with 3:7 acetone–ether to afford pure **11** (430 mg, 64%), which crystallized on standing. Trituration with ether gave needles of **11**, m.p. 183.5–184.5°, $[\alpha]_D^{23}$ –20.0° (*c* 0.36, chloroform); $\nu_{max}^{CH_2Cl_2}$ 1745 (OAc),

1675 (Amide I and allyl), and 1530 $cm^{-1}$ (Amide II); $^1$H-n.m.r. ($CDCl_3$): $\delta$ 1.92 (NAc), 1.97, 2.00, and 2.07 (3s, 18 H, OAc).

*Anal.* Calc. for $C_{29}H_{41}NO_{17}$: C, 51.55; H, 6.12; N, 2.07. Found: C, 51.72; H, 6.32; N, 2.11.

*Allyl 2-acetamido-2-deoxy-6-O-β-D-glucopyranosyl-β-D-glucopyranoside* (**12**). — A solution of the protected allyl disaccharide **11** (930 mg, 1.34 mmol) in 25 mL of methanol containing 0.5 mL of ~M sodium methoxide in methanol was stirred for 30 min at room temperature. The mixture was then made neutral with Rexyn 101 ($H^+$) ion-exchange resin and the solution was filtered and evaporated. Trituration of the white solid, obtained after evaporation of ethanol from the residue, with acetone gave virtually pure **12** (450 mg, 77%). One recrystallization from abs. ethanol afforded **12** as fine needles; m.p. 218–219° (dec), $[\alpha]_D^{23}$ −34.3° (*c* 0.37, water); $^1$H-n.m.r. ($D_2O$): $\delta$ 2.01 (s, 3 H, NAc), 4.14–4.29 (m, 2 H, -OC$H_2$CH=), 4.49 (d, 1 H, *J* 7.1 Hz, H-1′), 4.55 (d, 1 H, *J* 7.8 Hz, H-1), 5.20–5.40 (m, 2 H, $CH_2$=), and 5.60–6.00 (m, 1 H, -CH=); $^{13}$C-n.m.r. ($D_2O$): $\delta$ 23.3 (NAc), 56.7 (C-2), 61.9 (C-6′), 69.7 (C-6), 70.8 (C-4 and C-4′), 71.8 (O$CH_2$-CH=), 74.2 (C-2′), 74.9 (C-3), 76.1 (C-5), 76.8 (C-5′), 77.1 (C-3′), 101.4 (C-1), 104.0 (C-1′), 119.3 ($CH_2$=), 134.6 (-CH=), and 175.8 (C=O).

*Anal.* Calc. for $C_{17}H_{29}NO_{11}$: C, 48.22; H, 6.90; N, 3.31. Found: C, 47.94; H, 6.97; N, 3.47.

*2-Acetamido-2-deoxy-6-O-β-D-glucopyranosyl-D-glucopyranose* (**13**). — A solution of the allyl disaccharide **12** (200 mg, 0.47 mmol), and 10% palladium-on-charcoal (50 mg) in 12 mL of 2:1:1 (v/v) ethanol–water–acetic acid was boiled overnight under reflux. The flask was cooled to room temperature and the mixture filtered through a bed of Celite. The filtrate and washings (methanol, 10 mL) were evaporated. Water was removed azeotropically by evaporation of methanol. Precipitation from the resulting concentrated solution by 2-propanol afforded pure, free disaccharide **13** (171 mg, 95%); $R_F$ 0.31 in 3:3:2 ethyl acetate–2-propanol–water; m.p. 153–154° (dec), $[\alpha]_D^{24}$ +21.1 (5 min)→+19.2° (24 h) (*c* 0.76, water); $^1$H-n.m.r. ($D_2O$): $\delta$ 2.02 (s, 3 H, NAc), 4.48 (d, ½ H, *J* 7.2 Hz, H-1β), 4.50 (d, 1 H, *J* 7.1 Hz, H-1′), and 5.17 (d, ½ H, *J* 3.0 Hz, H-1α); $^{13}$C-n.m.r. ($D_2O$) $\delta$: 23.4 (NHAc), 55.2 (C-2α), 57.8 (C-2β), 61.9 (C-6′), 69.9 (C-6), 70.8 (C-4β and C-4′), 71.1 (C-4α), 71.8 (C-3α, C-5α), 74.3 (C-2′), 75.0 (C-3β), 76.1 (C-5β), 76.8 (C-5′), 77.1 (C-3′), 92.1 (C-1α), 96.2 (C-1β), 103.9 (C-1′), and 175.6 (C=O).

*Anal.* Calc. for $C_{14}H_{25}NO_{11}$: C, 43.86; H, 6.57; N, 3.65. Found: C, 43.83; H, 6.80; N, 3.45.

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