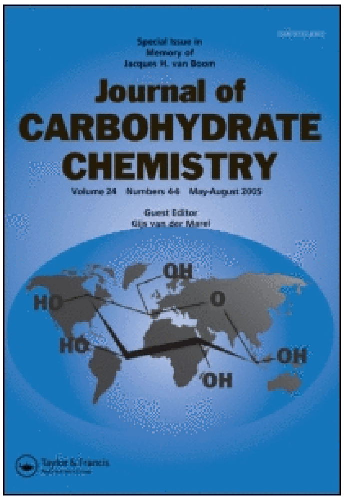


Journal of Carbohydrate Chemistry
Publication details, including instructions for authors and subscription information:
http://www.informaworld.com/smpp/title~content=t713617200

SYNTHESIS OF IMINO-*C*-DISACCHARIDES RELATED TO SUCROSE[1]

Barbara La Ferla[a]; Laura Cipolla[a]; Francesco Peri[a]; Francesco Nicotra[a]
[a] Department of Biotechnology and Biosciences, University of Milano-Bicocca, Milano, Italy

Online publication date: 30 November 2001

To cite this Article La Ferla, Barbara , Cipolla, Laura , Peri, Francesco and Nicotra, Francesco(2001) 'SYNTHESIS OF IMINO-*C*-DISACCHARIDES RELATED TO SUCROSE[1]', Journal of Carbohydrate Chemistry, 20: 7, 667 — 680
To link to this Article: DOI: 10.1081/CAR-100108281
URL: http://dx.doi.org/10.1081/CAR-100108281

J. CARBOHYDRATE CHEMISTRY, 20(7&8), 667–680 (2001)

SYNTHESIS OF IMINO-*C*-DISACCHARIDES RELATED TO SUCROSE[1]

Barbara La Ferla, Laura Cipolla, Francesco Peri, and Francesco Nicotra*

Department of Biotechnology and Biosciences, University of Milano-Bicocca, Piazza della Scienza 2–I-20126 Milano, Italy

ABSTRACT

Stabilised ylides **1** and **10**, prepared from perbenzylated and peracetylated allyl *C*-glucopyranosides, respectively, were reacted with differently protected D-serinal; osmylation of the obtained α,β-unsaturated ketones **3** and **12**, followed by intramolecular reductive amination, afforded different imino-*C*-disaccharides **14**, **15**, **18**, and **19** related to sucrose.

INTRODUCTION

The significant role that carbohydrates play in a variety of biological processes of pharmaceutical relevance has stimulated the interest in compounds that could interfere in carbohydrate metabolism and in carbohydrate-based recognition phenomena. In this context, great efforts have been devoted recently to the synthesis of glycomimetics,[2,3] such as iminosugars and *C*-glycosides, that can act as inhibitors of carbohydrate processing enzymes and/or as stable analogues of glycidic entities.

The synthesis of sucrose mimetics is particularly attractive, due to the serious and widespread sucrose metabolism disorders, such as diabete mellitus. Furthermore, from a synthetic point of view, stable analogues of sucrose, in which a carbon atom substitutes the interglycosidic oxygen, are challenging synthetic targets, both the anomeric centres of the disaccharide being involved in the *C*-glycosidic linkage.

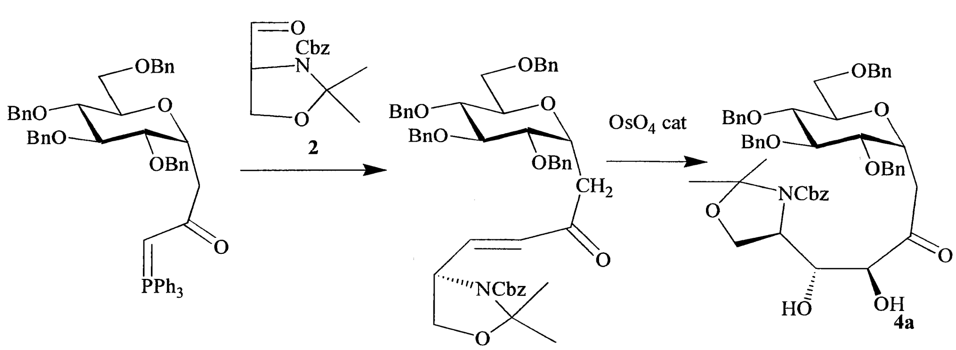
The synthesis of *C*-glycosidic analogues of sucrose has already been reported by Kishi[4,5] and our group;[6,7] our analogues showed no inhibition of invertase and very weak inhibition of α-glucosidase from yeast. These results prompted us to synthesize imino-*C*-glycosides related to sucrose, taking advantage of the well known property of iminosugars to inhibit glycosidases, as mimics of the oxonium ion transition state of the enzymatic reaction.[8]

To our knowledge, no examples of synthesis of imino-*C*-disaccharides related to sucrose have been reported. We decided to perform the synthesis of mimetics in which the nitrogen atom is part of the fructosidic moiety of the disaccharide. Towards this aim we exploited the synthetic strategy already optimised for the *C*-disaccharide,[6,7] using protected D-serinal (Scheme 1) in place of protected D-glyceraldehyde.

RESULTS AND DISCUSSION

The α-*C*-glucosidic stabilised ylide **1** (Scheme 1), synthesised as already reported,[6,7] was reacted with *N*-benzyloxycarbonyl-*N,O*-isopropylidene-D-serinal **2**. The reaction afforded **3** in 83% yield, whose *E*-double[9] bond was submitted to catalytic osmylation in order to introduce the two hydroxyl groups with a relative *syn* stereochemistry. In terms of absolute stereochemistry, the reaction was expected to afford the (3*S*,4*R*)-product **4a** preferentially. Indeed it is well established that electrophiles attack double bonds with allylic heteroatom from the less hindered face, in a conformation where the heteroatom lies in the same plane of the double bond.[10] The reaction afforded, however, the desired product **4a** with a very low stereoselection (1.6:1).

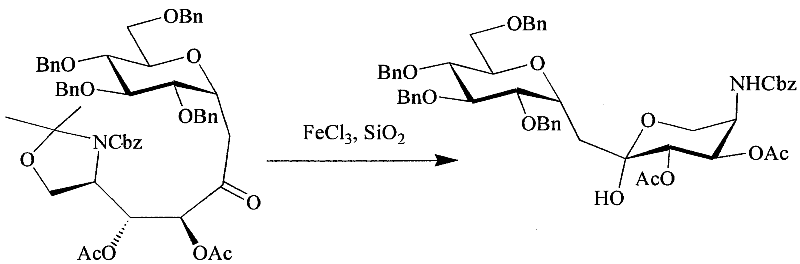
The stereochemistry of the new stereocentres of compound **4a** was determined after acetylation to compound **5** and cleavage of the isopropylidene protecting group with $FeCl_3$-SiO_2,[11] which resulted in the formation of the pyranosidic structure **6** (Scheme 2). The ^{1}H NMR coupling constants of **6** allow the determination of the relative orientation of the hydrogen atoms in the cycle (see experi-



1 3 and diastereoisomer **4b** (1.6:1)

Scheme 1.

MARCEL DEKKER, INC.
270 Madison Avenue, New York, New York 10016



5 6

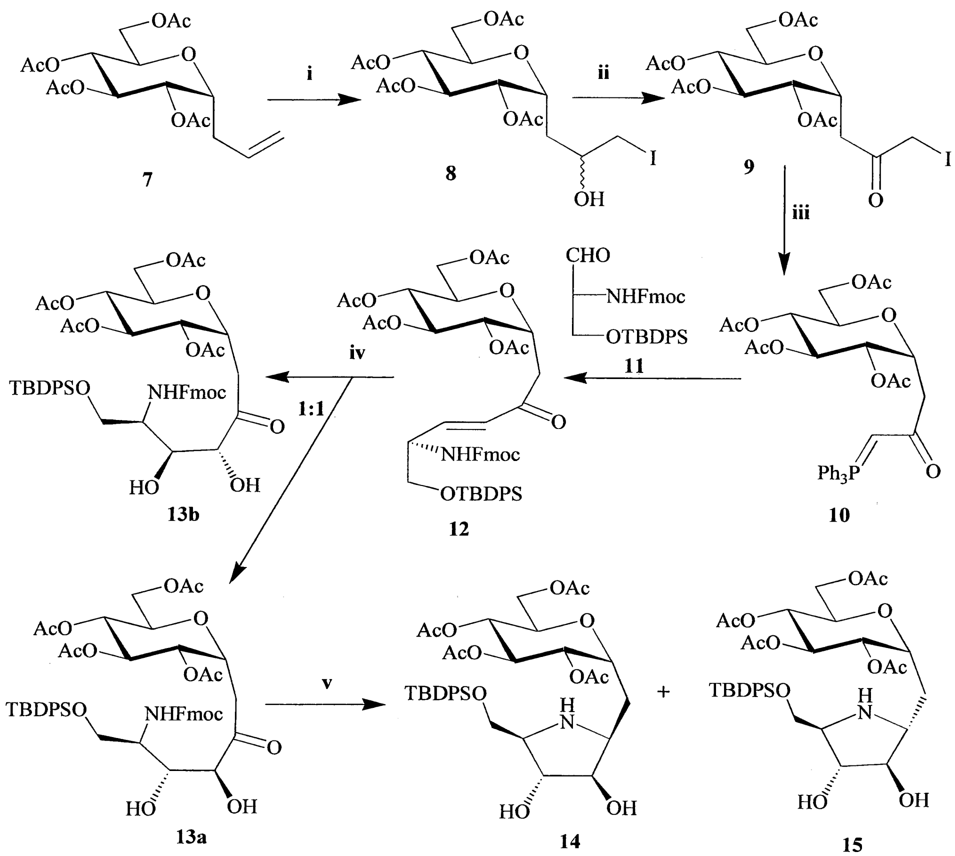
Scheme 2.

mental). In order to enhance the stereoselection, stoichiometric osmylation in the presence of chiral auxiliaries such as quinuclidine[12] or the Sharpless ligand (DHQD)2-PHAL (AD-mix-β)[13] was performed. However, in the first case the stereochemical outcome of the reaction was surprisingly reversed, the 3*R*,4*S* product being preferentially obtained (75% d.e.), whereas in the second case no stereoselection was observed. The synthesis was then performed with the mixture of diastereoisomers obtained by catalytic osmylation.

We studied the possibility of performing the reductive aminocyclization without affecting the protecting groups of the glucose moiety. However, any attempt to effect an acidic hydrolysis of the carbobenzyloxy protecting groups of **5** resulted in the degradation of the product. To overcome this problem, the protecting groups of both the *C*-glucopyranosyl ylide and D-serinal were modified. Starting from polyacetylated allyl *C*-glucopyranoside **7**[14] (Scheme 3), ylide **10** was synthesised and reacted with *O*-diphenyl-*tert*-butyl-silyl-*N*-Fmoc-D-serinal **11**, affording compound **12** in 87 % yield (no traces of the *Z* isomer were detected). The catalytic osmylation of **12** proceeded without stereoselection, giving a 1:1 mixture of **13a** and **13b** (Scheme 3) which could be separated by flash chromatography (the stereochemistry was attributed only after cyclization).

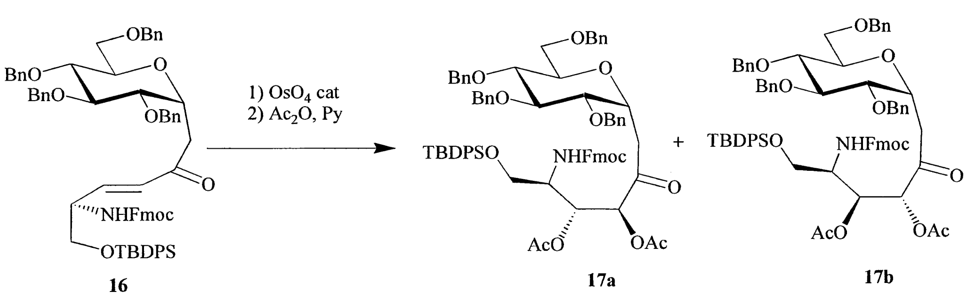
The amino group of **13a** was deprotected with piperidine, and the obtained labile hemiaminal was reduced. Different reduction conditions were investigated (catalytic hydrogenation with Pd/C or PtO_2, $NaBH_3CN$), and the best results were obtained using 3 equivalents of $NaBH(OAc)_3$, dry $MgSO_4$, and acetic acid (6 equivalents) in 1,2-dichloroethane as solvent. Under these conditions compound **13a** (the isomer with the correct stereochemistry) afforded a 25:75 mixture of the imino-*C*-disaccharides **14** and **15,** in 65% overall yield. These compounds show complex NMR spectra due to the equilibrium between two conformers of the pyrrolidine ring, nevertheless the stereochemistry of C-2,3,4 of **14** and **15** was determined by NOE experiments. The stereochemical outcome of the reduction suggests coordination of the 3-OH group with the boron atom of the reducing agent, inducing the hydride attack preferentially from the β-face of the intermediate imine.

In a parallel approach, *O*-diphenyl-*tert*-butyl-silyl-*N*-Fmoc-D-serinal **11** reacted with compound **1** affording compound **16** in 87% yield (Scheme 4). Catalytic



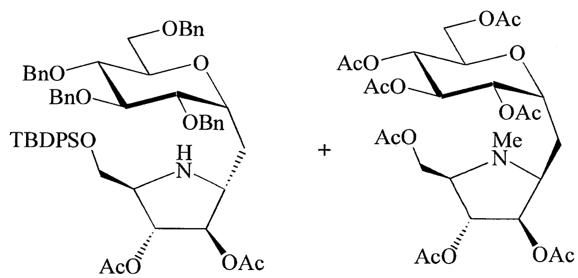
Scheme 3. i: NIS, DMSO-H_2O; ii: PCC, CH_2Cl_2; iii: PPh_3, Et_3N, MeCN, then $NaHCO_3$; iv: OsO_4, *N*-methylmorpholine-*N*-oxide, acetone-H_2O; v, piperidine, DMF, then $NaBH(OAc)_3$, AcOH.

osmylation of **16** gave a 1:1 mixture of inseparable diastereoisomers which were acetylated affording compounds **17a** and **17b**, easily separated by flash chromatography. Acetylation was also effected to prevent the coordination by $NaBH(OAc)_3$ to the 3-OH group.



Scheme 4.

Marcel Dekker, Inc.
270 Madison Avenue, New York, New York 10016



18

19

Figure 1.

Deprotection of the amino group of **17a** with piperidine afforded a labile hemiaminal which was directly submitted to reduction with $NaHB(OAc)_3$. Under these conditions, the diastereoisomer **17a** afforded only compound **18** (40% yield) (Figure 1). The stereochemistry of C-2,3,4 of **18** was attributed by NOE experiments. Once more, the reduction occurred stereoselectively from the β-face of the "pseudo-furanosidic" pyrrolidine ring, affording an imino-*C*-disaccharide epimer at C-2 of sucrose.

Finally, the mixture of diastereomers **4** was submitted to catalytic hydrogenation under slightly acidic conditions, in order to perform complete deprotection, formation of the cyclic hemiaminal, and reductive amination at once. This sequence of reactions afforded directly the desired deprotected imino-*C*- disaccharides. The catalytic hydrogenation was performed under different experimental conditions, the best results being finally obtained with Pd/C, THF/MeOH/AcOH. In these conditions compound **19** was isolated in 17% overall yield after acetylation and chromatographic purification of the crude that allowed the separation of **19** from the undesired diastereomer. It is noteworthy that the nitrogen of **19** is methylated, a result that could be explained with the hypothesis that formaldehyde formed during the reaction undergoes a reductive amination.

In conclusion, starting from differently protected allyl-*C*-glucopyranosides it is possible to synthesise various imino-*C*-disaccharides related to sucrose, exploiting an approach in which the furanosidic moiety of the molecule is built up on the allylic appendage by conversion into a stabilised ylide and condensation with a properly protected D-serinal. Depending on the reagents employed in the osmylation of the double bond and in the intramolecular reductive amination, different diastereoisomeric imino-*C*-disaccharides have been obtained.

EXPERIMENTAL

General Methods. Optical rotations were measured with a Perkin Elmer 241 digital polarimeter. NMR spectra were recorded on a Varian XL200 (200 MHz for ^{1}H and 50.29 MHz for ^{13}C) and on a Bruker AC300 (300 MHz for ^{1}H and 75.47

MHz for ^{13}C). Chemical shifts are expressed in parts per million downfield from TMS. Melting points were determined on a Büchi 510 apparatus. Mass spectra were recorded on a VG 70-70 EQ, using FAB (Na^+) ionization. Reactions were followed on TLC on silica gel $60F_{254}$ (E. Merck); flash column chromatography was performed on silica gel 60 (0.040–0.063 mm, E. Merck).

(3*E*)-5-Amino-1-*C*-(2,3,4,6-tetra-*O*-benzyl-α-D-glucopyranosyl)-5-*N*-benzyloxycarbonyl-1,3,4,5-tetradeoxy-5,6-*N*,*O*-isopropylidene-D-*glycero*-hex-3-eno-2-ulose (3). To a solution of compound **1** (2.50 g, 2.97 mmol, 1.3 equiv) in dry MeCN (10 mL) under an inert atmosphere, compound **2** was added (0.61 g, 2.3 mmol, 1 equiv) dissolved in dry MeCN (7 mL). After 5 days the solvent was removed under reduced pressure; chromatographic purification (petroleum ether/acetone 8:2 v/v) afforded compound **3** (1.67 g, 2.02 mmol, 88% yield, only *E* isomer): oil, *m/z*: 849 $(M+23)^+$; 826 $(M)^+$; $[\alpha]_D$ +55.0° (*c* 0.96, $CHCl_3$); ^1H NMR (300 MHz, $CDCl_3$) δ 1.54, 1.66 (2s, 6H, CH_3 *i*Pr), 2.72 (dd, 1H, $J_{1a,1b}$ = 15.8 Hz, $J_{1a,1'}$ = 8.1 Hz, H-1a), 2.90 (dd, 1H, $J_{1b,1a}$ = 15.8 Hz, $J_{1b,1'}$ = 5.0 Hz, H-1b), 3.57–3.78 (m, 7H, H-2′, 3′, 4′, 5′, 6′a, 6′b, 6a), 4.03 (dd, 1H, J = 9.3, J = 6.5 Hz, H-6b), 4.38–4.45 (m, 1H, H-5), 4.44 (d, 1H, J = 11.4 Hz, C*H*Ph), 4.48 (d, 1H, J = 10.3 Hz, C*H*Ph), 4.53–4.63 (m, 3H, 3C*H*Ph), 4.69–4.78 (m, 1H, H-1′), 4.78 (d, 1H, J = 11.0 Hz, C*H*Ph), 4.80 (d, 1H, J = 10.7 Hz, C*H*Ph), 4.89 (d, 1H, J = 11.0 Hz, C*H*Ph), 5.03 (bs, 2H, CH_2Ph), 6.03 (d, 1H, $J_{3,4}$ = 15.8 Hz, H-3), 6.60 (dd, 1H, $J_{4,3}$ = 15.8, $J_{4,5}$ = 7.0 Hz, H-4), 7.05–7.35 (m, H_{Ph}); ^{13}C NMR (75.47 MHz, C_6D_6, 60°C) δ 21.55, 24.63 (2q, CH_3 *i*Pr), 36.57 (q, C-1), 56.10 (d, C-5), 64.97,65.54, 67.81, 71.19, 71.61, 73.01, 73.23 (7t, C-6′, 6, 5CH_2Ph), 69.26, 71.32, 76.50, 78.02, 80.52 (5d, C-1′, 2′, 3′, 4′, 5′), 92.98 (s, Cq *i*Pr), 128.01–129.00 (CH_{Ph}), 128.69, 141.52 (2d, C-3, 4), 134.91–137.50 (*C*q Ph), 194.47 (s, C-2).

Anal. Calcd for $C_{51}H_{55}NO_9$: C, 74.16; H, 6.71; N, 1.70. Found: C, 74.09; H, 6.77; N, 1.69.

3,4-Di-*O*-acetyl-5-amino-1-*C*-(2,3,4,6-tetra-*O*-benzyl-(α-D-glucopyranosyl)-5-*N*-benzyloxycarbonyl-1,5-dideoxy-5,6-*N*,*O*-isopropyliden-D-*arabino*-hex-2-ulose (5). Compound **3** (1g, 1.16 mmol) was dissolved in 8 mL of H_2O/acetone 1/8; *N*-methylmorpholine-*N*-oxide (317 mg, 2.32 mmol, 2 equiv) and OsO_4 (3 mL of a 5 mg/mL solution in *t*BuOH, 0.05 equiv) were added. After 4 h the reaction was quenched with aqueous $Na_2S_2O_3$. After 30 min, the reaction mixture was extracted with AcOEt, the organic layer was dried over Na_2SO_4, filtered and the solvent was removed under reduced pressure. Chromatographic purification (petroleum ether/AcOEt 65:35 v/v) afforded compounds **4a** and **4b** in 75% yield (748 g, 0.87 mmol) as a mixture of inseparable diastereomers, which was directly acetylated for characterisation. The mixture of compounds **4a** and **4b** (748 g, 0.87 mmol) was dissolved in 9 mL of dry Py and 0.32 mL of Ac_2O and a catalytic amount of DMAP was added. After 90 min the solvent was removed under reduced pressure and chromatographic purification (petroleum ether/AcOEt 7:3 v/v) afforded pure compound **5** (455 mg, 0.482 mmol, 55% yield) and the other diastereomer (284 mg, 0.301 mmol, 35% yield). Compound **5:** *m/z*: 967 $(M + 23)^+$;

944 $(M)^+$; ^{1}H NMR (300 MHz, $CDCl_3$) two conformers δ 1.48–1.39 (m, 6H, 2CH_3 iPr), 1.60 (s, 3H CH_3 Ac), 1.98 (s, 3H, CH_3 Ac), 2.65–3.00 (m, 2H, H-1a,1b), 4.25–3.50 (m, 9H, H-2′, 3′, 4′, 5′, 6′a, 6′b, 5, 6a, 6b), 4.44 (d, 1H, J = 12.2 Hz, C*H*Ph), 4.50 (d, 1H, J = 11.0 Hz, C*H*Ph), 4.50–4.58 (m, 3H, 3C*H*Ph), 4.62–4.73 (m, 1H, H-1′), 4.74 (d, 1H, J = 11.4 Hz, C*H*Ph), 4.78 (d, 1H, J = 11.0 Hz, C*H*Ph), 4.86 (d, 1H, J = 11.4 Hz, C*H*Ph), 5.10–5.30 (bs, 3H, C*H*-OAc, CH_2Ph), 5.89 (bs, 1H, C*H*-OAc), 7.10–7.41 (m, H_{Ph}); ^{13}C NMR (50.29 MHz, $CDCl_3$) two conformers δ 20.49 (*C*H_3 Ac), 22.90, 24.33, 25.37, 27.05 (4q, *C*H_3 iPr), 35.76 (d, C-1), 57.89, 58.65 69.50, 72.47, 77.55, 77.94, 78.80, 81.74 (8d, C-1′, 2′, 3′, 4′, 5′, 3, 4, 5), 63.52, 67.46, 69.03, 72.95, 73.46, 74.84, 75.16 (7t, C-6′, 6, 5*C*H_2Ph), 93.32, 93.38 (2s, Cq-*i*Pr), 127.93–128.26 (*C*H_{Ph}) 136.10–139.63 (CqPh), 169.41, 169.93 (2s, *C*O), 200.44 (s, C-2).

Anal. Calcd for $C_{55}H_{61}NO_{13}$: C, 69.97; H, 6.51; N, 1.48. Found: C, 70.02; H, 6.56; N, 1.47.

3,4-Di-*O*-acetyl-2-amino-7,11-anhydro-8,9,10,12-tetra-*O*-benzyl-2-*N*-benzyloxycarbonyl-2,6-dideoxy-D-*glycero*-D-*ido*-D-*manno*-dodec-5-ulopyranose (6). Compound **5** (91 mg, 0.096 mmol) was mixed with $FeCl_3$-SiO_2[11] (270 mg) and vigorously stirred for 16 h. Then the mixture was filtered on florisil eluting with Et_2O, then with EtOAc. Chromatographic purification (petroleum ether/AcOEt 7:3 v/v) afforded 62 mg of pure compound **6** (76% yield). Compound **6**: white amorphous solid; *m/z*: 927 $(M + 23)^+$, 904 $(M)^+$; $[\alpha]_D = -15.7°$ (*c* 0.9, $CHCl_3$); ^{1}H NMR (300 MHz, C_6D_6) δ 1.67 (s, 3H, CH_3 Ac), 1.81 (s, 3H, CH_3 Ac), 1.95 (bd, 1H, $J_{6a,6b}$ = 14.7 Hz, H-6a), 2.51 (dd, 1H, $J_{6b,6a}$ = 14.7, $J_{6b,7}$ = 12.0 Hz, H-6b), 3.38 (dd, 1H, $J_{10,11}$ = 9.4, $J_{10,9}$ = 7.4 Hz, H-10), 3.46 (dd, 1H, $J_{12a,12b}$ = 10.0, $J_{12a,11}$ = 6.4 Hz, H-12a), 3.53–3.59 (m, 2H, H-8, 12b), 3.78 (t, 1H, $J_{9,8}$ = $J_{9,10}$ = 7.4 Hz, H-9), 4.12 (dt, 1H, $J_{11,10}$ = 9.4, $J_{11,12a}$ = 6.4, $J_{11,12b} < 1$ Hz, H-11), 4.28 (d, 1H, J = 12.4 Hz, C*H*Ph), 4.32 (d, 2H, J = 11.2 Hz, 2C*H*Ph), 4.36 (d, 1H, J = 11.2 Hz, C*H*Ph), 4.45–4.48 (m, 1H, H-2), 4.48 (d, 1H, J = 11.4 Hz, C*H*Ph), 4.54 (d, 1H, J = 11.5 Hz, C*H*Ph), 4.68 (d, 1H, J = 11.2 Hz, C*H*Ph), 4.71 (d, 1H, J = 11.5 Hz, *CH*Ph), 4.82 (m, 1H, H-7), 5.00 (d, 1H, J = 11.3 Hz, C*H*Ph), 5.04 (dd, 1H, $J_{1a,1b}$ = 12.1, $J_{1a,2} \leq 1$ Hz, H-1a), 5.10 (d, 1H, J = 11.3 Hz, C*H*Ph), 5.30 (bs, 1H, NH), 5.34 (dd, 1H, $J_{1b,1a}$ = 12.1, $J_{1b,2}$ = 4.9 Hz, H-1b), 5.39 (bd, 1H, $J_{4,3}$ = 10.3 Hz, H-4), 5.71 (dd, 1H, $J_{3,4}$ = 10.3, $J_{3,2}$ = 3.2 Hz, H-3), 7.10–7.33 (m, H_{Ph}); ^{13}C NMR (50.29 MHz, $CDCl_3$) δ 20.63, 20.93, (2q, *C*H_3 Ac), 31.37 (t, C-6), 50.09 (d, C-2), 61.63, 66.88, 68.79, 72.95, 73.36, 74.54, 74.62 (7t, C-1, 12, 5*C*H_2Ph), 69.06, 69.42, 71.34, 72.03, 76.81, 78.32, 80.06 (7d, C-3, 4, 7, 8, 9, 10, 11), 97.91 (d, C-5), 127.74–128.40 (*C*H_{Ph}), 135.60–138.27 (CqPh), 170.11, 170.40 (2s, *C*O).

Anal. Calcd for $C_{52}H_{57}NO_{13}$: C, 69.09; H, 6.36; N, 1.55. Found: C, 69.11; H, 6.41; N, 1.60.

1-*C*-(2,3,4,6-Tetra-*O*-acetyl-(α-D-glucopyranosyl)-3-iodopropan-2-ol (8). Compound **7**[14] (4.7 g, 12.6 mmol, 1 equiv) was dissolved in DMSO (60 mL) then H_2O (680 μL, 3 equiv) and NIS (6.4 g, 28.5 mmol, 2.3 equiv) were added. After

24 h an aqueous solution of $Na_2S_2O_3$ was added until the reaction became colourless. The reaction mixture was then extracted with Et_2O, the organic layer dried over Na_2SO_4 and concentrated to dryness. Chromatographic purification (petroleum ether/AcOEt 1/1, v/v) afforded 5.6 g of pure compound **8** as a mixture of diastereomers (86% yield). Compound **8**: ^{1}H NMR (200 MHz, $CDCl_3$) δ 1.60–1.90 (m, 2H, H-1a, 1b), 2.10 (m, 12H, 4CH_3 Ac), 2.55 (s, 1H, OH), 2.85 (s, 1H, OH), 3.25–3.40 (m, 2H, H-3a, 3b), 3.60–4.50 (m, 6H, H-1′, 5′, 6′a, 6′b, 2), 4.90–5.00 (m, 1H, H-4′), 5.00–5.15 (m, 1H, H-2′), 5.20–5.40 (m, 1H, H-3′); ^{13}C NMR (50.29 MHz, $CDCl_3$) δ 13.80, 14.10 (2t, C-1), 22.02 (*C*H_3 Ac), 32.41 (t, C-3), 62.44 (t, C-6′), 67.46, 68.22, 68.84, 69.63, 69.89, 70.13, 71.05 (7d, C-1′, 2′, 3′, 4′, 5′, 2), 169.43, 169.70, 170.51, 170.73 (4s, *C*O).

Anal. Calcd for $C_{17}H_{25}IO_{10}$: C, 39.55; H, 4.88. Found: C, 39.58; H, 4.91.

1-C-(2,3,4,6-Tetra-*O*-acetyl-(α-D-glucopyranosyl)-3-(triphenyl-λ^5-phosphanyliden)-propan-2-one (10). A solution of compound **8** (3.7 g, 7.16 mmol) in dry CH_2Cl_2 (40 mL), was added, under an inert atmosphere, to a mixture of PCC (2.3 g, 10.8 mmol, 1.5 equiv) and 4Å powdered molecular sieves. After 18 h the mixture was filtered first on a celite pad and then on silica gel (petroleum ether/AcOEt 1/1, v/v, +1% Et_3N). Compound **9** (3.37 g, 92% yield) was immediately used for the next step. PPh_3 (1.89 g, 7.20 mmol) and Et_3N (170 μL, 1.22 mmol) were dissolved in dry MeCN (44 mL), then compound **9** (3.3 g, 6.4 mmol) dissolved in dry MeCN (40 mL) was added. After 3.5 h the solvent was removed under reduced pressure, the crude was dissolved in AcOEt and washed sequentially with a saturated solution of $NaHCO_3$ and H_2O, dried over Na_2SO_4, filtered and the solvent removed. Purification by flash chromatography (AcOEt) afforded 2.8 g (67% yield) of pure compound **10**. Yellow solid, mp 125–128°C; $[\alpha]_D = +5.6°$ (*c* 1, $CHCl_3$); ^{1}H NMR (200 MHz, $CDCl_3$) δ 1.90–2.00 (m, 12H, 4CH_3 Ac), 2.54 (dd, 1H, $J_{1a,1b} = 14.3$, $J_{1a,1'} = 4.2$ Hz, H-1a), 2.78 (m, 1H, H-1b), 4.05–4.25 (m, 3H, H-5′, 6′a, 6′b), 4.72–4.82 (m, 1H, H-1′), 5.05 (t, 1H, $J_{4',3'} = J_{4',5'} = 8.0$ Hz, H-4′), 5.15 (dd, 1H, $J_{2',3'} = 8.8$, $J_{2',1'} = 5.6$ Hz, H-2′), 5.28 (bt, 1H, H-3′), 7.40–7.80 (m, 15H, H_{Ph}). ^{13}C NMR (50.29 MHz, $CDCl_3$) δ 20.50 (*C*H_3 Ac), 29.50 (t, C-1), 37.96 (d, C-3), 62.39 (t, C-6′), 68.91, 69.17, 70.03, 70.78, 71.52 (5d, C-1′, 2′, 3′, 4′, 5′), 128.00–133.00 (CH_{Ph}), 169.45, 170.01, 170.13, 170.64 (4s, *C*O), 187.40 (s, C-2).

Anal. Calcd for $C_{35}H_{37}O_{10}P$: C, 64.81; H, 5.75. Found: C, 64.79; H, 5.77.

(3*E*)-1-*C*-(2,3,4,6-Tetra-*O*-acetyl-(α-D-glucopyranosyl)-5-amino-1,3,4,5-tetradeoxy-5-*N*-fluorenylmethoxycarbonyl-6-*O*-diphenyl-*tert*-butylsilyl-D-*glycero*-hex-3-eno-2-ulose (12). Compound **10** (286 mg, 0.44 mmol), dissolved in dry MeCN (5 mL), was added to a solution of **11** (302 mg, 0.55 mmol, 1.25 equiv) in dry MeCN (10 mL). After 48 h the solvent was removed under reduced pressure and chromatographic purification (petroleum ether/AcOEt 6/4, v/v) afforded 353 mg of pure compound **12** (87% yield). Compound **12**: amorphous solid; $[\alpha]_D = +17.2°$ (*c* 1, $CHCl_3$); ^{1}H NMR (200 MHz, $CDCl_3$) δ 1.10 (s, 9H, *t*Bu), 1.90–2.00 (m, 12H, 4CH_3 Ac), 2.90 (m, 2H, H-1a, 1b), 3.70–3.90 (m, 3H, H-5′, 6a, 6b), 4.00–4.14 (m, 3H, H-6′a, 6′b, C*H*Fmoc), 4.40–4.55 (m, 3H, H-5, CH_2Fmoc), 4.81 (m, 1H, H-1′), 5.00 (t, 1H, $J_{4',3'} = J_{4',5'} = 8.5$ Hz, H-4′), 5.15 (dd, 1H, $J_{2',3'} = 8.5$, $J_{2',1'} = 5.3$ Hz, H-2′), 5.27 (t, 1H, $J_{3',2'} = J_{3',4'} = 8.5$ Hz, H-3′), 6.25 (d, 1H, $J_{3,4} = 15.8$ Hz, H-3), 6.80 (dd, 1H, $J_{4,3} = 15.8$, $J_{4,5} = 4.9$ Hz, H-4), 7.30–7.70 (m, 19H, H_{Ph}, NH).

Anal. Calcd for $C_{51}H_{57}NO_{13}Si$: C, 66.58; H, 6.24; N, 1.52. Found: C, 66.60; H, 6.31; N, 1.57.

1-*C*-(2,3,4,6-Tetra-*O*-acetyl-(α-D-glucopyranosyl)-5-amino-1,5-dideoxy-5-*N*-fluorenylmethoxycarbonyl-6-*O*-diphenyl-*tert*-butylsilyl-D-*arabino*-hex-2-ulose (13a) and 1-*C*-(2,3,4,6-tetra-*O*-acetyl-α-D-glucopyranosyl)-5-amino-1,5-dideoxy-5-*N*-fluorenylmethoxycarbonyl-6-*O*-diphenyl-*tert*-butylsilyl-D-*xylo*-hex-2-ulose (13b). Compound **12** (229 mg, 0.325 mmol) was dissolved in 2 mL of H_2O/acetone 1/8; then *N*-methylmorpholine-*N*-oxide (88 mg, 0.65 mmol) and OsO_4 (0.8 mL of a solution 5 mg/mL in *t*BuOH, 0.05 equiv) was added. After 6 h the reaction was quenched with aqueous $Na_2S_2O_3$. After stirring 30 min the reaction mixture was extracted with AcOEt, the organic layer was dried over Na_2SO_4, filtered and the solvent removed under reduced pressure. Chromatographic purification (petroleum ether/AcOEt 6:4 v/v) afforded 57 mg of compound **13a,** 111 mg of **13b** and 119 mg of the mixture of the two which was separated by medium pressure chromatography (petroleum ether/AcOEt 65:35 v/v). The total yield of the reaction was 92% and the ratio of the two diastereomers 1/1. Compound **13a**: oil; *m/z* 978 $(M+23)^+$, 955 $(M)^+$; ^{1}H NMR (300 MHz, $CDCl_3$) δ 1.10 (s, 9H, *t*Bu), 1.90–2.15 (m, 12H, 4CH_3 Ac), 2.92 (dd, 1H, $J_{1a,1b} = 15.9$, $J_{1a,1'} = 9.7$ Hz, H-1a), 3.00–3.05 (m, 1H, H-1b), 3.60–4.50 (m, 10H, H-5′, 6′a, 6′b, 4, 5, 6a, 6b, C*H*Fmoc, CH_2Fmoc), 4.80–4.82 (m, 1H, H-1′), 4.98 (t, 1H, $J_{4',3'} = J_{4',5'} = 8.7$ Hz, H-4′), 5.18 (dd, 1H, $J_{2',3'} = 9.1$, $J_{2',1'} = 5.5$ Hz, H-2′), 5.26 (bt, 1H, H-3′), 5.27–5.35 (m, 1H, H-3), 7.30–7.70 (m, 19H, H_{Ph}, NH); ^{13}C NMR (75.47 MHz, $CDCl_3$) δ 20.62 (CH_3 Ac), 26.91 (CH_3 *t*Bu), 37.15 (t, C-1), 47.18 (d, *C*HFmoc), 54.00 (d, C-5), 62.03, 64.40, 67.21 (3t, C-6′, 6, *C*H_2Fmoc), 68.35, 68.64, 69.33, 69.97, 70.12, 70.31, 71.98 (7d, C-1′, 2′, 3′, 4′, 5′, 3, 4), 119.99–135.51 (CH_{Ph}), 132.45–143.88 (CqPh), 156.99, 169.42, 169.42, 169.92, 170.69 (5s, *C*O), 206.79 (s, C-2).

Anal. Calcd for $C_{51}H_{59}NO_{15}Si$: C, 64.20; H, 6.23; N, 1.47. Found: C, 64.25; H, 6.19; N, 1.51.

Compound **13b**: mp 102–104°C; *m/z* 978 $(M+23)^+$; $[\alpha]_D = +15.4°$ (*c* 1, $CHCl_3$); ^{1}H NMR (200 MHz, $CDCl_3$) δ 1.10 (s, 9H, *t*Bu), 2.00 (m, 12H, 4CH_3 Ac), 2.30–2.40 (m, 2H, OH), 2.92 (dd, 1H, $J_{1a,1b} = 16.7$, $J_{1a,1'} = 5.1$ Hz, H-1a), 3.25 (dd, 1H, $J_{1b,1a} = 16.7$, $J_{1b,1'} = 9.0$ Hz, H-1b), 3.65–4.50 (m, 10H, H-5′, 6′a, 6′b, 4, 5, 6a, 6b, C*H*Fmoc, CH_2Fmoc), 4.81 (m, 1H, H-1′), 5.00 (t, 1H, $J_{4',3'} = J_{4',5'} = 8.5$ Hz, H-4′), 5.15 (dd, 1H, $J_{2',3'} = 8.7$, $J_{2',1'} = 5.5$ Hz, H-2′), 5.25 (dd, 1H, $J_{3',4'} = 8.5$, $J_{3',2'} = 8.7$ Hz, H-3′), 5.36 (d, 1H, $J_{3,4} = 8.4$ Hz, H-3), 7.30–7.70 (m, 19H, H_{Ph}, NH). ^{13}C NMR (50.29 MHz, $CDCl_3$) δ 20.59 (CH_3 Ac), 26.98 (CH_3 *t*Bu), 29.60 (t, C-1), 47.11 (d, *C*HFmoc), 53.23 (d, C-5), 62.00, 64.41, 67.24 (2t, C-6′, 6, *C*H_2Fmoc), 68.47, 68.47, 69.26, 69.26, 70.00, 70.11, 71.97 (7d, C-1′, 2′, 3′, 4′, 5′, 3, 4), 120.00–135.41 (CH_{Ar}), 141.20, 143.42 (2s, Cq Ph) 169.40–170.60 (*C*O), 207.20 (s, C-2).

Anal. Calcd for $C_{51}H_{59}NO_{15}Si$: C, 64.20; H, 6.23; N, 1.47. Found: C, 64.18; H, 6.25; N, 1.50.

1-*C*-(2,3,4,6-tetra-*O*-acetyl-(α-D-glucopyranosyl)-1,2,5-trideoxy-2,5-imino-6-*O*-diphenyl-*tert*-butylsilyl-D-*gluco*-hexitol (14) and 1-*C*-(2,3,4,6-tetra-*O*-acetyl-α-D-glucopyranosyl)-1,2,5-trideoxy-2,5-imino-6-*O*-diphenyl-*tert*-butylsilyl-D-*manno*-hexitol (15): Compound **13a** (198 mg, 0.207 mmol) was dissolved in dry DMF (4 mL) under an inert atmosphere, and piperidine (27 μL, 0.27 mmol, 1.3 equiv) was added. After 30 min the solvent was removed under reduced pressure. The crude was dissolved in dry 1,2-dichloroethane (6 mL) and anhydrous $MgSO_4$ (411 mg, 3.41 mmol) was added; after 5 min AcOH (79 μL, 6.7 equiv) was added and the reaction was allowed to stir for 10 min, then $NaBH(OAc)_3$ (162 mg, 0.77 mmol) was added. After 4 h the reaction was neutralised with a saturated aqueous solution of $NaHCO_3$ and extracted with CH_2Cl_2, the organic layer was dried over Na_2SO_4, filtered and the solvent removed under reduced pressure. Chromatographic purification (petroleum ether/acetone 1:1→0:1 v/v) afforded 59 mg (41% yield) of pure compound **15** and 20 mg (13% yield) of pure compound **14**. Compound **14**: two conformers, *m/z* 716 $(M+1)^+$; ^1H NMR (200 MHz, $CDCl_3$) δ 1.10 (s, 9H, *t*Bu), 1.62–1.90 (m, 2H, H-1a, 1b), 1.98–2.13 (m, 12H, 4CH_3 Ac), 3.39–3.59 (m, 2H, H-2, 5), 3.84–4.42 (m, 8H, H-1′, 5′, 6′a, 6′b, 3, 4, 6a, 6b), 4.85–5.09 (m, 2H, H-2′, 4′), 5.27, 5.30 (2t, 1H, J = 8.9, J = 8.0 Hz, H-3′), 7.35–7.70 (m, 10H, H_{Ph}); ^{13}C NMR (50.29 MHz, C_6D_6) δ 19.91 (CH_3 Ac), 25.20, 25.67 (2t, C-1), 26.69 (CH_3 *t*Bu), 56.60, 57.49, 60.13, 69.02, 69.35, 70.23, 70.59, 70.70, 71.56, 78.00, 78.55, 79.15 (12d, C-1′, 2′, 3′, 4′, 5′, 2, 3, 4, 5), 62.20, 63.99 (2t, C-6′, 6), 128.00–135.66 (CH_{Ph}), 169.01, 169.35, 169.52, 169.98 (4s, *C*O);

Anal. Calcd for $C_{36}H_{49}NO_{12}Si$: C, 60.40; H, 6.90; N, 1.96. Found: C, 60.42; H, 6.88; N, 2.00.

Compound **15**: two conformers, *m/z* 716 $(M+1)^+$; $[\alpha]_D = +31.2°$ (*c* 0.9, $CHCl_3$); ^1H NMR (300 MHz, $CDCl_3$, 50°C) δ 1.10 (s, 9H, *t*Bu), 1.69 (ddd, 1H, $J_{1a,1b}$ = 14.6, J = 7.1, J = 2.7 Hz, H-1a), 1.84 (ddd, 1H, $J_{1b,1a}$ = 14.6, J = 4.9, J = 3.4 Hz, H-1b), 1.94–2.13 (m, 12H, 4CH_3 Ac), 2.90–3.05 (m, 1H, H-5), 3.38 (m, 1H, H-2), 3.74–4.25 (m, 7H, H-5′, 6′a, 6′b, 3, 4, 6a, 6b), 4.33 (m, 1H, H-1′), 4.93 (t, 1H, $J_{4',3'} = J_{4',5'}$ = 8.6 Hz, H-4′), 5.05 (m, 1H, H-2′), 5.26, 5.28 (2t, 1H, $J_{3',2'} = J_{3',4'}$ = 8.6 Hz, H-3′), 7.35–7.80 (m, 10H, H_{Ph}); ^{13}C NMR (75.47 MHz, C_6D_6, 60°C) δ 19.87 (CH_3 Ac), 26.85 (CH_3 *t*Bu), 30.21, 30.57 (2t, C-1), 62.00, 64.41 (2t, C-6′, 6), 60.53, 69.04, 69.21, 70.01, 70.42, 70.63, 70.63, 72.13, 78.69, 79.14, 82.44, 83.02 (12d, C-1′, 2′, 3′, 4′, 5′, 2, 3, 4, 5), 127.840–135.70 (CH_{Ph}), 133.40 (Cq Ph), 168.87, 169.27, 169.80, 169.95 (4s, *C*O).

Anal. Calcd for $C_{36}H_{49}NO_{12}Si$: C, 60.40; H, 6.90; N, 1.96. Found: C, 60.39; H, 6.91; N, 1.98.

(3*E*)-1-*C*-(2,3,4,6-Tetra-*O*-benzyl-(α-D-glucopyranosyl)-5-amino-1,3,4,5-tetradeoxy-5-*N*-fluorenylmethoxycarbonyl-6-*O*-diphenyl-*tert*-butylsilyl-D-*glycero*-hex-3-eno-2-ulose (16). To a solution of compound **1** (1.64 g, 1.94

mmol, 1 equiv) in dry MeCN (8 mL) under an inert atmosphere, compound **11** (1.64 g, 2.98 mmol, 1.53 equiv), dissolved in dry MeCN (8 mL), was added. After 20 h the solvent was removed under reduced pressure; chromatographic purification (petroleum ether/AcOEt 75:25 v/v) afforded 1.86 g of compound **16** (86% yield, only *E* isomer). Oil, $[\alpha]_D = +6.4°$ (*c* 1, $CHCl_3$); ^1H NMR (300 MHz, $CDCl_3$) δ 1.10 (s, 9H, *t*Bu), 2.83 (dd, 1H, $J_{1a,1b} = 15.8$, $J_{1a,1'} = 7.3$ Hz, H-1a), 2.97 (dd, 1H, $J_{1a,1b} = 15.8$, $J_{1b,1'} = 4.8$ Hz, H-1b), 3.57–4.90 (m, 21H, H-1′, 2′, 3′, 4′, 5′, 6′a, 6′b, 5, 6a, 6b, C*H*Fmoc, CH_2Fmoc, 8C*H*Ph), 6.19 (d, 1H, $J_{3,4} = 15.8$ Hz; H-3), 6.69 (dd, 1H, $J_{3,4} = 15.8$, $J_{4,5} = 4.9$ Hz, H-4), 7.10–7.80 (m, 19H, H_{Ph}, NH); ^{13}C NMR (75.47 MHz, $CDCl_3$) δ 26.69 (s, *C*q *t*Bu), 26.81 (*C*H_3 *t*Bu), 37.94 (t, C-1), 47.24 (d, *C*HFmoc), 50.43 (d, C-5), 61.98, 65.22, 68.97, 73.25, 73.49, 74.91, 75.28 (7t, C-6′, 6, 4*C*H_2Ph, *C*H_2Fmoc), 70.53, 72.71, 77.75, 79.31, 82.09 (5d, C-1′, 2′, 3′, 4′, 5′), 120.00–138.10 (C-3, 4, CH_{Ar}), 138.29–144.41 (CqAr), 198.30 (s, C-2).

Anal. Calcd for $C_{71}H_{73}NO_9Si$: C, 76.66; H, 6.61; N, 1.26. Found: C, 76.70; H, 6.63; N, 1.30.

1-*C*-(2,3,4,6-Tetra-*O*-benzyl-(α-D-glucopyranosyl)-3,4-di-*O*-acetyl-5-amino-1,5-dideoxy-5-*N*-fluorenylmethoxycarbonyl-6-*O*-diphenyl-*tert*-butylsilyl-D-*arabino*-hex-2-ulose (17a) and 1-*C*-(2,3,4,6-tetra-*O*-benzyl-(-D-glucopyranosyl)-3,4-di-*O*-acetyl-5-amino-1,5-dideoxy-5-*N*-fluorenylmethoxycarbony l-6-*O*-diphenyl-*tert*-butylsilyl-D-*xylo*-hex-2-ulose (17b). Compound **16** (1.78 g, 1.59 mmol) was dissolved in 10 mL of H_2O/acetone 1/8; then *N*-methylmorpholine-*N*-oxide (540 mg, 3.99 mmol) and OsO_4 (4 mL of a 5 mg/mL solution in *t*BuOH, 0.05 equiv) were added. After 4 h the reaction was heated to 40°C; after 2 h the reaction was quenched with aqueous $Na_2S_2O_3$ and allowed to stir for 30 min. The reaction mixture was then extracted with AcOEt, the organic layer was dried over Na_2SO_4, filtered and the solvent removed under reduced pressure. Chromatographic purification (petroleum ether/AcOEt 65:35 v/v) afforded 1.56 g (85% yield) of a 1/1 mixture of the two inseparable diastereomers. 82 mg of the mixture (0.07 mmol) was dissolved in 90 mL of CH_2Cl_2 then Ac_2O (0.07 mL, 100 equiv) and DMAP (8.7 mg, 1 equiv) were added. After 5 min the reaction was quenched with MeOH; then the solvent was removed under reduced pressure and medium pressure chromatographic purification (toluene/AcOEt 9:1 v/v) afforded compounds **17a** (39 mg, 46% yield) and compound **17b** (35 mg, 44% yield).

Compound **17a**: oil, $[\alpha]_D = +15.0°$ (*c* 1, $CHCl_3$); ^1H NMR (300MHz, $CDCl_3$) δ 1.05 (s, 9H, CH_3 *t*Bu), 1.82 (s, 3H, C*H_3* Ac), 1.95 (s, 3H, C*H_3* Ac), 2.15 (m, 1H, H-1a), 2.97 (m, 1H, H-1b), 3.53–3.83 (m, 8H, H-2′, 3′, 4′, 5′, 6′a, 6′b, 6a, 6b), 4.16–4.87 (m, 13H, H-1′, 5, C*H_2*Fmoc, C*H*Fmoc, 8C*H*Ph), 5.30–5.50 (m, 2H, H-3, 4), 7.07–7.80 (m, 19H, H_{Ph}, HN); ^{13}C NMR (50.29 MHz, $CDCl_3$)δ: 20.35, 20.50 (*C*H_3 Ac), 26.86 (*C*H_3 *t*Bu), 29.64 (s, Cq *t*Bu), 35.03 (t, C-1), 47.04 (d, *C*HFmoc), 51.57 (d, C-5), 62.50, 67.19, 69.03, 72.70, 73.29, 74.80, 75.12 (7t, C-6′, 6, 4*C*H_2Ph, *C*H_2Fmoc), 68.88, 69.66, 72.44, 76.01, 77.40, 78.67, 81.51 (7d, C-1′, 2′, 3′, 4′, 5′, 3, 4), 119.90–135.50 (CH_{Ar}), 132.50, 132.60, (2s, Cq Si-Ph), 132.80, 132.90, 138.10, 138.60 (4s, Cq Ph), 143.60, 141.30 (2s, C_{quat} Fmoc), 169.50, 170.00 (2s, *C*O), 201.80 (s, C-2).

Anal. Calcd for $C_{75}H_{79}NO_{13}Si$: C, 73.21; H, 6.47; N, 1.14. Found: C, 73.14; H, 6.43; N, 1.10.

Compound **17b**: oil, $[\alpha]_D = +9.5°$ (*c* 1, $CHCl_3$); ^{13}C NMR (75.47 MHz, $CDCl_3$) δ 20.45, 20.45 (*C*H_3 Ac), 26.92 (*C*H_3 *t*Bu), 29.68 (s, Cq *t*Bu), 36.28 (t, C-1), 47.14 (d, *C*HFmoc), 53.01 (d, C-5), 62.96, 66.95, 68.91, 73.07, 73.42, 74.80, 75.27 (7t, C-6′, 6, 4*C*H_2Ph, *C*H_2Fmoc), 69.09, 69.65, 72.38, 76.43, 77.64, 78.59, 82.25 (7d, C-1′, 2′, 3′, 4′, 5′, 3, 4), 119.90–135.50 (*C*H_{Ar}), 132.60, 132.60 (Cq Si-Ph), 137.80, 138.00, 138.30, 138.60 (4s, Cq Ph), 143.80, 141.30 (s, Cq Fmoc), 169.80, 170.40 (2s, *C*O), 200.80 (s, C-2).

Anal. Calcd for $C_{75}H_{79}NO_{13}Si$: C, 73.21; H, 6.47; N, 1.14. Found: C, 73.12; H, 6.43; N, 1.10.

1-*C*-(2,3,4,6-Tetra-*O*-benzyl-(α-D-glucopyranosyl)-3,4-di-*O*-acetyl-1,2,5-trideoxy-2,5-imino-6-*O*-diphenyl-*tert*-butylsilyl-D-*manno*-hexitol (18). Compound **17a** (90 mg, 0.073 mmol) was dissolved in dry DMF (0.7 mL) under an inert atmosphere, and piperidine (7 μL) was added. After 30 min the solvent was removed under reduced pressure. The crude was dissolved in dry 1,2-dichloroethane (1.5 mL) and Na_2SO_4 (420 mg, 2.94 mmol) was added. After 5 min AcOH (42 μL, 10 equiv) was added and the reaction was allowed to stir for 10 min, then $NaBH(OAc)_3$ (63 mg, 0.29 mmol) was added. After 4 h the reaction was neutralised with a saturated aqueous solution of $NaHCO_3$ and extracted with CH_2Cl_2; the organic layer was dried over Na_2SO_4, filtered and the solvent removed under reduced pressure. Chromatographic purification (petroleum ether/AcOEt 83:17 →75:25 v/v) afforded 30 mg (41% yield) of compound **18**. Compound **18**: oil, *m/z* 992 $(M)^+$; ^{1}H NMR (300 MHz, $CDCl_3$) δ 1.30 (s, 9H, CH_3 *t*Bu), 1.90 (s, 3H, C*H_3* Ac), 2.00 (s, 3H, C*H_3* Ac), 1.20–2.10 (m, 2H, H-1a, 1b), 3.05 (m, 1H, H-5), 3.33–3.41 (m, 1H, H-2), 3.52–3.88 (m, 8H, H-2′, 3′, 4′, 5′, 6′a, 6′b, 6a, 6b), 4.12–4.20 (m, 1H, H-1′), 4.37 (d, 1H, J = 12.0 Hz, C*H*Ph), 4.45 (d, 1H, J = 11.1 Hz, C*H*Ph), 4.52 (d, 1H, J = 12.0 Hz, C*H*Ph), 4.59 (d, 1H, J = 11.7 Hz, C*H*Ph), 4.66 (d, 1H, J = 11.7 Hz, C*H*Ph), 4.77 (d, 1H, J = 11.1 Hz, C*H*Ph), 4.79 (d, 1H, J = 10.9 Hz, C*H*Ph), 4.89 (d, 1H, J = 10.9 Hz, C*H*Ph), 5.04 (d, 1H, $J_{4,5}$ = 4.6 Hz, H-4), 5.23 (d, 1H, $J_{3,2}$ = 4.0 Hz, H-3), 7.10–7.70 (m, 19H, H_{Ph}, HN); ^{13}C NMR (75.47 MHz, $CDCl_3$) δ 20.77 (CH_3 Ac), (s, Cq *t*Bu), 26.88 (*C*H_3 *t*Bu), 24.10, 29.66 (t, C-1, Cq *t*Bu), 58.69, 65.61, 71.56, 72.67, 78.31, 79.07, 79.81, 80.31, 82.25 (9d, C-1′, 2′, 3′, 4′, 5′, 2, 3, 4, 5), 63.89, 69.27, 73.00, 73.42, 74.80, 75.33 (6t, C-6′, 6, 4*C*H_2Ph), 127.50–135.60 (*C*H_{Ph}), 133.20 (Cq Si-Ph), 138.20, 138.40, 138.70 (Cq Ph), 169.70, 169.85 (*C*O).

Anal. Calcd for $C_{57}H_{69}NO_9Si$: C, 68.99; H, 7.01; N, 1.41. Found C, 68.90; H, 7.03; N, 1.43.

1-*C*-(2,3,4,6-Tetra-*O*-acetyl-(α-D-glucopyranosyl)-3,4,6-tri-*O*-acetyl-1,2,5-trideoxy-2,5-imino-*N*-methyl-D-*gluco*-hexitol (19). The mixture of diastereomers **4a and 4b** (228 mg, 0.26 mmol) was dissolved in THF/MeOH and hydrogenated using Pd/C as catalyst. After 4 days AcOH was added and the reaction was prolonged for 4 more days. The catalyst was filtered over a celite pad, and the

Marcel Dekker, Inc.
270 Madison Avenue, New York, New York 10016

solvent was removed under reduced pressure. The crude was then dissolved in Py and Ac_2O and a catalytic amount of DMAP were added. After 6 h the solvent was removed. Chromatographic purification (petroleum ether/AcOEt 6/4, 1/1, v/v) afforded 28 mg of pure compound **7** (17% yield). Compound **7**: oil, *m/z* 618 $(M)^+$; $[\alpha]_D = +26.2°$ (*c* 1, $CHCl_3$); ^1H NMR (300 MHz, $CDCl_3$) δ 1.71 (bdd, 1H, $J_{1a,1b} = 15.5$, $J_{1a,2} = 6.5$ Hz, H-1b), 1.90–2.11 (m, 21H, 7CH_3 Ac), 2.22 (ddd, 1H, $J_{1b,1a} = 15.5$, $J_{1b,1'} = 10.3$, $J_{1a,2} = 2.6$ Hz, H-1a), 2.30 (s, 3H, N-CH_3), 2.45–2.53 (m, 1H, H-2), 2.95–4.20 (m, 5H, H-5′, 6′a, 6′b, 6a, 6b), 4.50 (bdd, 1H, $J_{1',1a} = 10.3$, $J_{1',2'} = 5.8$ Hz, H-1′), 4.95 (t, 1H, $J_{4',3'} = J_{4',5'} = 9.4$ Hz, H-4′), 5.00–5.15 (m, 3H, H-2′, 3, 4), 5.22 (t, 1H, $J_{3',2'} = J_{3',4'} = 9.4$ Hz, H-3′); ^{13}C NMR (75.47 MHz, $CDCl_3$) δ 20.63 (q, *C*H_3 Ac), 24.56 (t, C-1), 39.29 (q, *C*H_3-N), 61.74, 62.44 (2t, C-6′, 6), 64.95, 68.84, 68.97, 69.40, 69.55, 69.88, 70.43, 75.91, 78.63 (9d, C-1′, 2′, 3′, 4′, 5′, 2, 3, 4, 5), 169.00–170.60 (*C*O).

Anal. Calcd for $C_{27}H_{39}NO_{15}$: C, 52.51; H, 6.36; N, 2.27. Found C, 52.49; H, 6.38; N, 2.29.

ACKNOWLEDGMENTS

We thank MURST (COFIN 2000, MM03155477) for the financial support and Dr. Enrico Caneva for the NMR spectra.

REFERENCES

1. Dedicated to Prof. Joachim Thiem on the occasion of his 60th birthday.
2. Chapleur, Y. Ed; *Carbohydrate Mimics - Concepts and Methods*, Wiley-VCH Verlag GmbH, D-69469: Weinheim, 1998.
3. Nicotra, F. Modified Carbohydrates and Carbohydrate Analogues. In *Carbohydrate Chemistry*, Boons, G.-J. Ed.; Blackie Academic & Professional: London, 1998; 384.
4. Dyer, U. C.; Kishi, Y. Synthesis of *C*-Sucrose. J. Org. Chem. **1988**, *53* (14), 3383–3384.
5. O'Leary, D. J.; Kishi, Y. Preferred Conformation of C-Glycosides. 11. C-Sucrose: New Practical Synthesis, Structural Reassignment, and SoliD-State and Solution Conformation of Its Octaacetate. J. Org. Chem. **1993**, *58* (2), 304–306.
6. Carcano, M; Nicotra, F.; Panza, L.; Russo, G. Synthesis of 1-(α-D-Glucopyranosyl)-1-deoxy-D-fructose a Non-metabolisable Analogue of Sucrose. J. Chem. Soc., Chem. Commun. **1989**, *10*, 642–643.
7. Lay, L.; Nicotra, F.; Pangrazio, C.; Panza, L.; Russo, G. Synthesis of Antimetabolites of Sucrose. J. Chem. Soc. Perkin Trans. 1 **1994**, *3*, 333–338.
8. Stütz, A. Ed. *Iminosugars as Glycosidase Inhibitors - Nojirimicin and Beyond*, Wiley-VCH Verlag GmbH, D-69469: Weinheim, 1999.
9. As expected, the Wittig reaction afforded selectively the product with *E* stereochemistry, no *Z* isomer was detected by NMR.
10. Cha, J. K.; Christ, W. J.; Kishi, Y. On Stereochemistry of Osmium Tetraoxide Oxidation of Allylic Alcohol Systems. Empirical Rule. Tetrahedron **1984**, *40* (12), 2247–2256.

MARCEL DEKKER, INC.
270 Madison Avenue, New York, New York 10016

11. Fadel, A.; Yefsah, R.; Salaün, J. Anhydrous Iron(III) Chloride Dispersed on Silica Gel; III. A Convenient and Mild Reagent for Deacetalization in Dry Medium. Synthesis **1987**, 37–40.
12. Annunziata, R.; Cinquini, M.; Cozzi, F.; Raimondi, L. Double Asymmetric Induction in the Osmylation of γ-Alkoxy α,β-Unsaturated Esters. Tetrahedron **1988**, *44* (22), 6897–6902.
13. Sharpless, K. B.; Amberg, W.; Bennani, Y. L.; Crispino, G. A.; Hartung, J.; Jeong, K-S.; Kwong, H-L.; Morikawa, K.; Wang, Z-M.; Xu, D.; Zhang, X-L. The Osmium-Catalyzed Asymmetric Dihydroxylation: A New Ligand Class and a Process Improvement. J. Org. Chem. **1992**, *57* (10), 2768–2771.
14. Giannis, A.; Sandhoff, K. Stereoselective Synthesis of α-*C*-Allyl-Glycopyranosides. Tetrahedron Lett. **1985**, *26* (12), 1479–1482.

Received March 7, 2001
Accepted September 7, 2001