43. Synthesis of a Phosphonic Acid Analogue of *N*-Acetyl-2,3-didehydro-2-deoxyneuraminic Acid, an Inhibitor of *Vibrio cholerae* Sialidase

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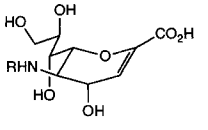
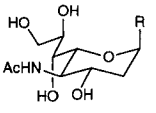
The synthesis of the phospha analogue **10** of DANA (**2**) is described. Bromo-hydroxylation of the known **11** (→**12** and **13**) followed by treatment of the major bromohydrin **13** with 1,8-diazabicyclo[5.4.0]undec-7-ene (DBU) gave the oxirane **14** (*Scheme 1*). Depending on the solvent, $TiBr_4$ transformed **14** into **16** or into a **15/16** mixture. Reductive debromination of **16** (→**17**), followed by benzylation provided **18**. Oxidative decarboxylation ($Pb(OAc)_4$) of the acid, obtained by saponification of **18**, yielded the anomeric acetates **19** and **20**. While **19** was inert under the conditions of phosphonoylation, the more reactive imidate **22**, obtained together with **23** from **19/20** *via* **21** (*Scheme 2*), gave a mixture of the phosphonates **24/25** and the bicyclic acetal **26**. Debenzylation of **24/25** and acetylation led to the acetoxyphosphonates **27/28**. Since β-elimination of AcOH from **27/28** proved difficult, the bromide **34** was prepared from **27/28** by photobromination and subjected to reductive elimination with Zn/Cu (→**35**; *Scheme 3*). This two-step sequence was first investigated using the model compounds **30** and **31**. Transesterification of **35**, followed by deacetylation gave **10**, which is a strong inhibitor of the *Vibrio Cholerae* sialidase.

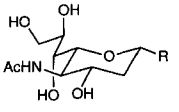
Introduction. – FANA (2,6-anhydro-3,5-dideoxy-5-(trifluoroacetamido)-D-*glycero*-D-*galacto*-non-2-enonic acid; **1**) and DANA [1] (5-acetamido-2,6-anhydro-3,5-dideoxy-D-*glycero*-D-*galacto*-non-2-enonic acid; **2**) are among the strongest inhibitors of *N*-acetylneuraminidases of different origin. We have described the three phosphonates **3**, **5**, and **7** which are all stronger inhibitors of *Vibrio cholerae* neuraminidase than the corresponding carboxylates **4**, **6**, and **8** [2][3]. The K_i values of **3** and **5** are $2.3 \cdot 10^{-4}$ M and $7.5 \cdot 10^{-5}$ M, respectively, as compared to $2.6 \cdot 10^{-3}$ M for **6**, while **4** is inactive. We were, therefore, interested in the inhibitory effect of the phospha analogues **9** and **10** of FANA (**1**) and DANA (**2**).



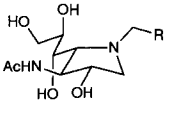
1 R=$COCF_3$
2 R=$COCH_3$



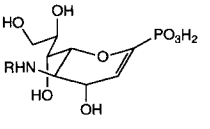
3 R=PO_3H_2
4 R=CO_2H



5 R=PO_3H_2
6 R=CO_2H



7 R=PO_3H_2
8 R=CO_2H



9 R=$COCH_3$
10 R=$COCF_3$

As we had prepared **2** by β-elimination of a suitably protected β-acetoxy ester [4][5], we investigated an analogous route to **10** which should also be feasable for the preparation of **9**. The preparation of **10** then involves introduction of a leaving group at C(3), decarboxylation, and phosphonoylation. As phosphonoylation [6] is expected to proceed better in the presence of *O*-alkyl instead of *O*-acyl protective groups [7], we planned to first prepare the benzylated acetates **19/20** (*Scheme 1*). For this, we thought to use the previously developed halogenohydroxylation [4][8] of Neu2en5Ac derivatives such as **11** to refunctionalize C(3) and a decarboxylation by $Pb(OAc)_4$ [2]. Syntheses of 1-alkenyl phosphonates by β-elimination are known [9].

Results and Discussion. – Bromohydroxylation of **11**[1]) with *N*-bromosuccinimide (NBS) and H_2O in MeCN at 70° [10] gave the bromohydrins **12** and **13** (98%; **12/13** 1:2.8, *Scheme 1*)[2]). Treatment of **13** with 1,8-diazabicyclo[5.4.0]undec-7-ene (DBU) [8] gave the epoxide **14** (85%). Br–C(3) is axial in **13** (J(3,4) = 3.5 Hz) and equatorial in **12** (J(3,4) = 9.7 Hz). The long-range W-coupling ^4J(3,OH–C(2)) = 1.2 Hz observed in the ^{1}H-NMR spectrum of **12** also proves the axial orientation of OH–C(2), since the requirements for such a coupling are not fulfilled by an equatorial OH–C(2) [11]. The ^{1}H-NMR spectrum of **14** shows a *s* for H–C(3) at 3.64 ppm (for similar examples, see [8]), indicating a dihedral angle between H–C(3) and H–C(4) of *ca.* 90° and thus a $^5H_4$ or a ^6S conformation of the pyranose ring.

The reaction of the epoxide **14** with $TiBr_4$ gave a mixture of the desired bromohydrin **16** and of the bicyclic acetal **15** (95%; **16/15** 1.8:1), when the reaction was carried out in 1,2-dichloroethane at –78°, but exclusively the desired **16** in THF at –40° (96%). The 2,7-anhydro derivative **15** must be formed by interception of the (incipient) intermediate carboxonium ion by the BnO–C(7) group[3]). The suppression of this side reaction in THF may be due to an intermolecular solvation of the carboxonium ion by THF competing successfully with BnO–C(7). Reductive debromination of **16** with tributyltin hydride (Bu_3SnH) gave the alcohol **17** (91%).

The IR spectrum of **15** shows an OH band at 3460 cm^{-1}, and the ^{13}C- and ^{1}H-NMR spectra show the presence of only 3 BnO groups. A downfield shift of 1–2 ppm for the N*H* signal (as compared to **12–14** and **16–18**) evidences the presence of an H-bond NH···O–C(3). The small vicinal coupling constants for the pyranose-ring protons (< 2 Hz) and the long-range couplings J(3,5) and J(4,6) (1.6 and 1.4 Hz, resp.) indicate a $^5C_2$ conformation, compatible with a 6,8-dioxa[3.2.1]bicyclooctane structure. In the ^{1}H-NMR spectra of **17**, H–C(2) resonates at 3.63 ppm, with J(2,3) = 9.6 Hz proving its axial orientation. The exclusive axial attack of Bu_3SnH is in agreement with our previous results [13][4].

Benzylation of **17** ($PhCH_2Br$, NaH, DMF) yielded the penta-*O*-benzyl derivative **18** (63%) together with unreacted **17** (26%). Hydrolysis of **18** gave the corresponding acid which was oxidatively decarboxylated with $Pb(OAc)_4$ [14] in toluene and in the presence of pyridine[4]) to a mixture of the anomeric acetates **19** and **20** (*Scheme 1*; 74%; **19/20**

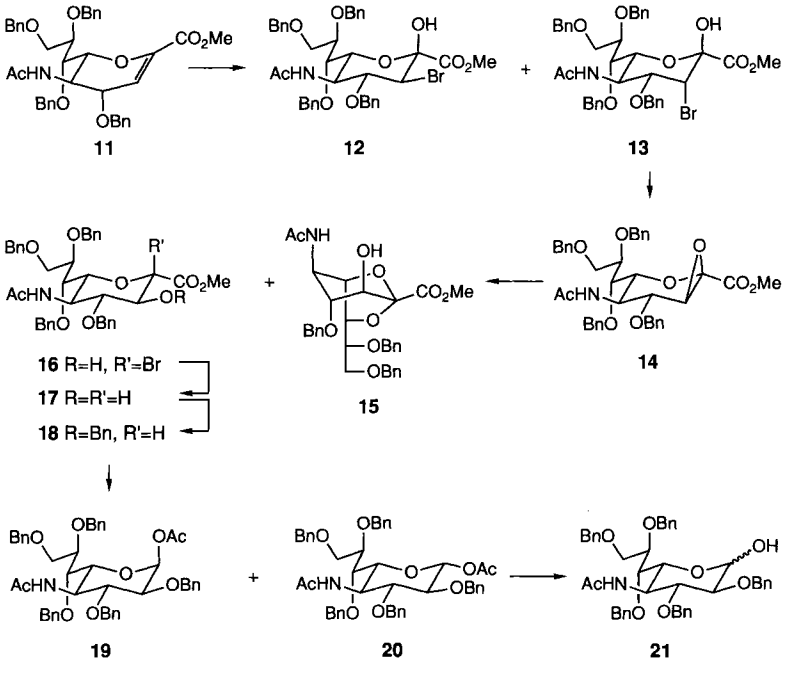
[1]) Obtained in five steps from *N*-acetylneuraminic acid (Neu5Ac) according to known procedures [3].

[2]) *Ito* and *Ogawa* indicate a ratio **12/13** of 1:4.1 [10].

[3]) Such a neighbouring group participation [12] and particularly the formation of 6,8-dioxa[3.2.1]bicyclooctane structures similar to **15** have been described in some detail; see [5] and refs. cit. therein.

[4]) Almost no reaction occurred in the absence of pyridine.

Scheme1



3.3:1). The anomeric configuration of **19** and **20** is deduced from the chemical shifts of H–C(1) and ^3J(1,2) (**19**: 6.33 ppm, J = 3.5 Hz; **20**: 5.57 ppm, J = 8.2 Hz; *Table 1*). The specific rotations of **19** and **20** confirm this assignment (**19**: $[\alpha]_D = -27.4$, and **20**: $[\alpha]_D = -3.4$). The acetate **19** proved inert to trimethyl phosphite ($P(OMe)_3$) in the presence of trimethylsilyl triflate (Me_3SiOTf) [2][15].

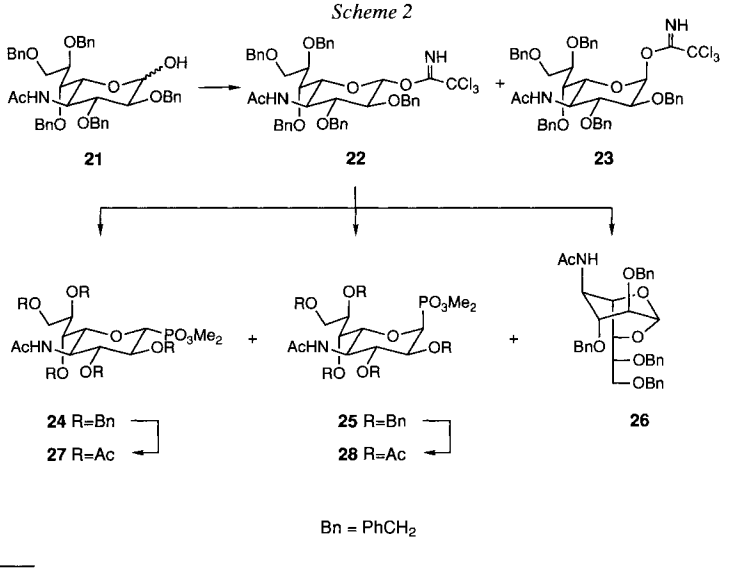
Table 1. *Selected Data of the Carboxylates* **17** *and* **18**, *the Acetates* **19** *and* **20**, *and the Imidates* **22** *and* **23**

	H_a [a])	J(a,b)	$[M]_D^{25}$	Anomeric configuration
17	3.63	9.6	–65.0	
18	3.80	[b])	–49.5	
19	6.33	3.5	–212.1	β-D
20	5.57	8.2	–26.3	α-D
22	5.78	8.3	–47.3	α-D
23	6.51	3.2	–191.0	β-D

[a]) H_a corresponds to H–C(1) in **19**, **20**, **22**, and **23** and to H–C(2) in **17** and **18**. [b]) Could not be determined.

Trichloroacetimidates are more reactive starting materials for the preparation of glycosylphosphonates than the corresponding acetates [7]. We, therefore, deacetylated the mixture **19/20** (NaOMe/MeOH) to obtain **21** (100%) as a 1:1.9 mixture of the α- and the β-D-anomers[5]). Reaction of **21** with trichloracetonitrile and K_2CO_3 in MeCN [17] gave the stable imidates **22** and **23** (70%; **22/23** 2.4:1; *Scheme 2*) and unreacted **21** (14%). The IR spectra of **22** and **23** show the amide N–H bands at 3430 and the typical imide N–H bands at 3340 (**22**) and 3350 cm^{-1} (**23**). Similarly as for **19** and **20**, the anomeric configuration of **22** and **23** was deduced from a comparison of the H–C(1) resonances (**22**: 5.78 ppm, $J = 8.3$ Hz; and **23**: 6.51 ppm, $J = 3.2$ Hz; *Table 1*), and from their specific rotations (**22**: $[\alpha]_D = -5.4$; **23**: $[\alpha]_D = -21.8$). Treating the imidate **22**[6]) with $P(OMe)_3$ and Me_3SiOTf [15] under rigorously anhydrous conditions gave a mixture of the anomeric phosphonates **24** and **25** (44%; **24/25** *ca.* 1:1) and of the bicyclic derivative **26** (41%), formed in a similar way as **15**. Debenzylation of the mixture **24/25** followed by acetylation gave the pentaacetates **27** and **28** (97%). The equatorial 1,2-*trans*-phosphonate **24** was obtained in a surprisingly high proportion, considering both the results of *Meuwly* and *Vasella* [15] who found that mild reaction conditions lead mainly to the 1,2-*cis*-phosphonate and those of *Vaghefi et al.* [16] and of *Briner* and *Vasella* [6][7] who found that harsher conditions lead mostly to axial phosphonates. The results of *Meuwly* and *Vasella* [15] have been rationalized on the basis of a stabilizing coordination between the P-centre in the phosphonium-salt intermediate and a *cis*-oriented neighbouring BnO group [15], and this rationalization can also be applied to the present case. Formation of a six-membered ring by coordination between the P-centre and BnO–C(6) in the phosphonium-salt intermediate may indeed compete with the formation of a four-membered ring by coordination with BnO–C(2), and this may lead to a mixture **24/25**.

Scheme 2

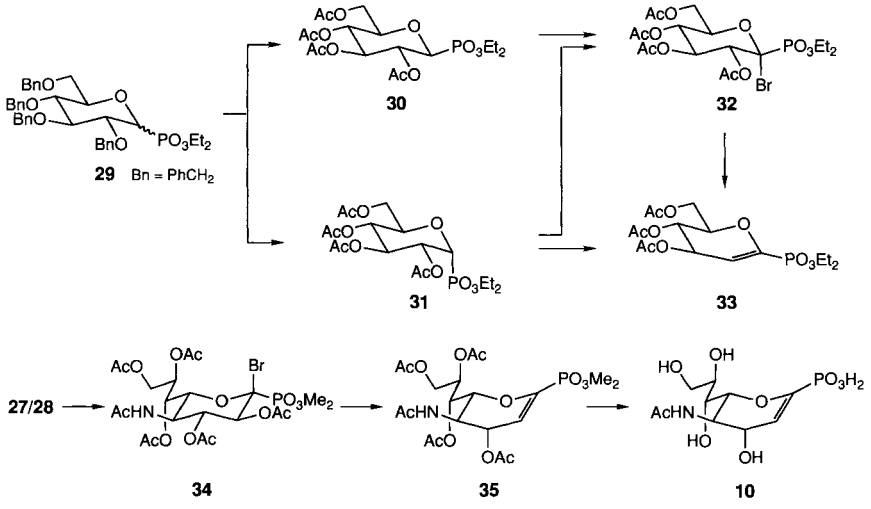


[5]) The ratio of the anomers was determined by ^{1}H-NMR spectroscopy.

[6]) Under similar conditions, the imidate **23** did not react.

Preliminary experiments showed that β-elimination from **27/28** was not straightforward. We, therefore, examined the β-elimination from the model compound **31**, which was obtained in excellent yields by debenzylation and acetylation of **29** [15], together with a small amount of **30** (*Scheme 3*). As several conditions led to the elimination of AcOH, but not to completion of the reaction, we investigated an alternative reaction sequence. Photobromination according to a procedure by *Ferrier* and coworkers [18] (Br_2 or NBS in CCl_4) gave exclusively the bromide **32** from either **30** or **31** (50–65%). Best results (76% of **33**) for the reductive elimination from **32** were obtained with Zn/Cu in EtOH[7]) [19]. Similarly, photobromination of **27/28** yielded the bromide **34** (45%) together with unreacted **27/28** (15%). The acetoxy bromide **34** was converted into the vinylphosphonate **35** by treatment with activated Zn/Cu in EtOH (72%).

Scheme 3



Similarly to **15**, the presence of an H-bond between N*H* and O–C(2) of **26** is deduced from the downfield shift of the N*H* signal (5.85 ppm as compared to 4.3–4.6 ppm for **19–24**). The presence of the dimethoxyphosphono group in **24**, **25**, **27**, and in **28** is evidenced by the presence of 2 *d* for the MeO groups at 3.65–3.85 ppm (^2J(C,P) = 10.6–10.9 Hz) in the ^{1}H-NMR spectra. The ^{31}P-NMR signals (see *Table 2*) show the presence of the phosphonate group for **24**, **25**, **27**, **28**, and **30** and **31**. Comparison of the ^{31}P-NMR shifts, the H–C(1) shifts, ^3J(H–C(2),P) and of ^1J(C(1),P) (*Table 2*) of **24/25**, **27/28**, and **30/31** allow the assignment of their anomeric configuration. As shown for the specific rotations of **27** ($[\alpha]_D = -36.8$) and **28** ($[\alpha]_D = +9.7$), *Hudson*'s rule [22] is followed.

On the basis of the low value of ^3J(H–C(2),P) (6.2 and 6.5 Hz, *Table 2*), we assume that the newly introduced Br-atom in **32** and **34** is axial. The presence of a Br-substituent at C(1) is evidenced by two peaks of equal intensity for $[M + 1]^+$ at *m/z* 549 and 547 for **32** and at *m/z* 664 and 662 for **34** and by the absence of the H–C(1) signal in the ^{1}H-NMR spectrum. As photobromination proceeds by a radical mechanism, it is not surprising that only the axial bromide is found, regardless of the anomeric configuration of the starting material [18]. Photobromination occurred selectively at C(1), in keeping with the directing effect of the phosphonoyl group, whereas *Ferrier* and coworkers [18] observed mainly bromination at C(5) of β- and to a lesser extent also of α-D-hexosides. The double bond of **33** and **35** was evidenced by the resonance of the H–C(2) signal at 5.80 and 5.79 ppm, respectively, and by the chemical shift of the C(1) (147.28 and 146.81 ppm) and C(2) signals (113.56 and 110.78 ppm).

[7]) Zn/Cu in $AcOH/H_2O$ gave **33** together with **30** and **31** [20][21].

Table 2. *Selected NMR Data of the Phosphonates* **24**, **25**, **27**, **28**, **30–35**, *and* **10**[a])

	δ(H–C(1))	^2J(H–C(1),P)	^3J(H–C(2),P)	^1J(C(1),P)	δ(^{31}P)
24	< 3.90	b)	b)	c)	22.60
25	4.51	12.0	23.1	c)	23.99
27	3.75	10.4	9.2	173.2	18.60
28	4.74	10.2	30.8	152.4	21.56
30	3.83	10.2	10.3	172.7	16.18
31	4.66	11.4	29.6	154.0	19.74
32	–	–	6.2	195.6	8.06
33	–	–	10.5	225.2	6.70
34	–	–	6.5	195.5	9.46
35	–	–	10.6	228.5	9.25
10[d])	–	–	9.7	212.6	3.55

a) All data were obtained in $CDCl_3$. b) Could not be determined. c) Not measured. d) In D_2O.

Table 3. $^1H,^1H$*-Coupling Constants* (Hz) *of Neu5Ac, DANA* (**2**), *and* **10** a)

	J(3,4)	J(4,5)	J(5,6)	J(6,7)	J(7,8)	J(8,9)	J(8,9')	J(9,9')
Neu5Ac	11.8/5.0	10.4	10.7	1.2	9.4	2.8	6.4	–12.4
DANA (**2**)	2.5	8.9	10.9	1.2	9.3	2.7	6.0	–11.9
	J(2,3)	J(3,4)	J(4,5)	J(5,6)	J(6,7)	J(7,8)	J(7,8')	J(8,8')
10	2.2	8.9	10.7	–	9.8	2.6	6.5	–12.3

a) Spectra recorded in D_2O.

The phosphonate **35** was deprotected by transesterification with Me_3SiBr [23], hydrolysis of the silyl ester, and deacetylation with NaOMe/MeOH to yield 54% of **10**. Comparison of the coupling constants found in the ^{1}H-NMR spectra of **1**, **2**, and **10** indicates that these compounds possess identical conformations of the trihydroxypropyl side chain and of the dihydropyran ring (**10** and **2**; *Table 3*). The relatively low δ (^{31}P) values, and the relatively high ^1J(C(1),P) values of the phosphonates **34** and **35** and of the phosphonic acid **10** (*Table 2*) are in agreement with earlier observations. Thus, alkyl, alkenyl, and alkynyl phosphonates on the one hand, and alkyl, 1-oxyalkyl, and (1-bromo-1-oxyalkyl) phosphonates on the other hand show decreasing values in this order for their ^{31}P-NMR shifts and increasing values for ^1J(C(1),P) [24].

Inhibition of the Vibrio cholerae *Sialidase by the Vinylphosphonic Acid* **10**. The phosphonic acid **10** was found to be a strong inhibitor of the *Vibrio cholerae* sialidase. The

activity of the sialidase was reduced by 45, 62, and 80% at inhibitor concentrations of 0.1, 0.2, and 0.5 mM, respectively. The K_i value of **10** ($7.2 \cdot 10^{-5}$ M) was found to be slightly lower than for the anomeric phosphonates **3** and **5**. The expected strong increase of the inhibitory power of the phosphonic acid **10** as compared to the corresponding carboxylic acid **2** was, however, not observed.

We thank the *Swiss National Science Foundation* and *F. Hoffmann-La-Roche AG*, Basle, for generous support.

Experimental Part

General. See [25]. Methods for the sialidase experiments, see [5].

*Methyl 5-Acetamido-4,7,8,9-tetra-*O*-benzyl-3-bromo-3,5-dideoxy-β-*D*-*erythro*-*L*-gluco-2-nonulopyranosonate* (**12**) *and Methyl 5-Acetamido-4,7,8,9-tetra-*O*-benzyl-3-bromo-3,5-dideoxy-β-*D*-*erythro*-*L*-manno-2-nonulopyranosonate* (**13**). A soln. of **11** (11.5 g, 17.27 mmol) in MeCN (400 ml) and H_2O (140 ml) was heated to 70°, and NBS (3.69 g, 20.76 mmol, 1.2 equiv.) was added. After stirring for 20 min., the soln. was cooled and evaporated. The residue was purified by chromatography (SiO_2, AcOEt/hexane 1:4 to 2:1): **12** (3.373 g, 26%) and **13** (9.532 g, 72%).

Data of **12**. M.p. 153–154° (from Et_2O/hexane) ([10]: 148–150°). R_f (AcOEt/hexane 1:1) 0.54. $[\alpha]_D^{25} = -54.3$ (c = 1.11, $CHCl_3$). IR ($CHCl_3$): 3510*m*, 3440*m*, 3000*m*, 2960*m*, 2870*m*, 1750*s*, 1690*s*, 1510*m*, 1500*m*, 1455*m*, 1370*m*, 1280*m*, 1160*s*, 1120*s*, 1095*s*, 1050*s*, 1030*s*. ^{1}H-NMR (400 MHz, $CDCl_3$): 7.4–7.2 (*m*, 20 arom. H); 4.88 (*d*, J = 10.8, PhC*H*); 4.81 (*d*, J = 9.0, NH); 4.65 (*d*, J = 10.9, PhC*H*); 4.64 (*d*, J = 11.4, PhC*H*); 4.60–4.40 (*m*, 3 H, PhC*H*); 4.50 (*m*, H–C(6)); 4.50 (*d*, J = 10.9, PhC*H*); 4.46 (*d*, J = 11.3, PhC*H*); 4.35 (br. *d*, J = 9.7, H–C(3)); 4.18 (*d*, J = 1.2, OH); 4.10 (*m*, H–C(4), H–C(5)); 3.86 (*s*, COOMe); 3.79 (*dd*, J = 10.5, 2.1, 1 H–C(9)); 3.77 (*dd*, J = 8.4, 1.3, H–C(7)); 3.71 (*dt*, J = 8.6, 2.6, H–C(8)); 3.66 (*dd*, J = 10.1, 2.8, 1 H–C(9)); 1.73 (*s*, AcN). ^{13}C-NMR (50 MHz, $CDCl_3$): 169.82 (*s*); 168.56 (*s*); 138.12 (*s*); 137.99 (*s*); 137.86 (*s*); 137.77 (*s*); 128.7–127.6 (*m*, 20 *d*); 95.47 (*s*); 79.64 (*d*); 76.80 (*d*); 74.44 (*d*); 74.27 (*t*); 73.98 (*t*); 73.32 (*t*); 72.31 (*t*); 70.47 (*d*); 67.97 (*t*); 53.93 (*q*); 52.35 (*d*); 51.89 (*d*); 23.46 (*q*). CI-MS: 682 (100, $[M + 1 - Br]^+$). Anal. calc. for $C_{40}H_{44}BrNO_9$ (762.70): C 62.99, H 5.81, Br 10.48, N 1.84; found: C 63.09, H 5.83, Br 10.28, N 1.78.

Data of **13**. R_f (AcOEt/hexane 1:1) 0.44. $[\alpha]_D^{25} = +11.9$ (c = 0.9, $CHCl_3$) ([10]: $[\alpha]_D$ = 15.4 (c = 1, $CHCl_3$)). IR ($CHCl_3$): 3500*m*, 3430*m*, 3000*m*, 2960*m*, 2880*m*, 1725*s*, 1680*s*, 1560*m*, 1550*m*, 1450*m*, 1370*m*, 1290*m*, 1240*m*, 1160*s*, 1130*s*, 1095*s*, 1050*s*, 1030*s*. ^{1}H-NMR (400 MHz, $CDCl_3$): 7.4–7.2 (*m*, 20 arom. H); 4.73 (*d*, J = 11.8, PhC*H*); 4.68 (*d*, J = 11.5, PhC*H*); 4.65–4.55 (*m*, 4 H, PhC*H*); 4.61 (*d*, J = 3.5, H–C(3)); 4.54 (*d*, J = 12.0, PhC*H*); 4.52 (*dd*, J = 10.9, 1.7, H–C(6)); 4.51 (*d*, J = 8.2, NH); 4.45 (*dd*, J = 10.1, 3.5, H–C(4)); 4.35 (*d*, J = 11.8, PhC*H*); 4.05–3.95 (*m*, 2 H, H–C(8), 1 H–C(9)); 3.83 (*dt*, J = 8.2, 10.3, H–C(5)); 3.80 (*dd*, J = 6.8, 1.7, H–C(7)); 3.78 (*s*, COOMe); 3.75 (*dd*, 11.6, 5.0, 1 H–C(9)); 3.51 (*s*, OH); 1.66 (*s*, AcN). ^{13}C-NMR (50 MHz, $CDCl_3$): 170.77 (*s*); 168.20 (*s*); 138.67 (*s*); 138.34 (*s*); 138.07 (*s*); 137.71 (*s*); 129.1–127.5 (*m*, 20*d*); 96.16 (*s*); 78.38 (*d*); 74.25 (*d*); 73.36 (*t*); 72.64 (*t*); 72.41 (*t*); 72.26 (*d*); 70.60 (*t*); 70.26 (*d*); 69.64 (*t*); 53.16 (*d*); 52.76 (*q*); 49.46 (*d*); 23.43 (*q*). CI-MS: 682 (100, $[M + 1 - Br]^+$). Anal. calc. for $C_{40}H_{44}BrNO_9$ (762.70) C 62.99, H 5.81, Br 10.48, N 1.84; found: C 62.84, H 5.56, Br 10.73, N 2.01.

*Methyl 5-Acetamido-2,3-anhydro-4,7,8,9-tetra-*O*-benzyl-5-deoxy-β-*D*-*erythro*-*L*-gluco-2-nonulopyranosonate* (**14**). DBU (0.77 ml, 5.17 mmol, 1.2 equiv.) was added to a soln. of **13** (3.30 g, 4.33 mmol) in abs. MeCN (25 ml). After stirring at r.t. for 10 min., the soln. was evaporated and the residue purified by chromatography (SiO_2, AcOEt/hexane 1:1) to give **14** (2.507 g, 85%). Foam. R_f (AcOEt/hexane 1:1) 0.32. $[\alpha]_D^{25} = -19.6$ (c = 1.1, $CHCl_3$). IR ($CHCl_3$): 3430*m*, 3000*m*, 2960*m*, 2870*m*, 1755*s*, 1680*s*, 1500*m*, 1450*m*, 1370*m*, 1310*m*, 1250*m*, 1170*m*, 1095*s*, 1070*s*, 1030*m*, 990*w*, 910*w*. ^{1}H-NMR (400 MHz, $CDCl_3$): 7.5–7.3 (*m*, 20 arom. H); 5.10 (*d*, J = 8.2, NH); 4.75 (*d*, J = 12.0, PhC*H*); 4.64 (*d*, J = 11.5, PhC*H*); 4.55–4.63 (*m*, 6 H, PhC*H*); 4.28 (*m*, H–C(5)); 3.98–4.03 (*m*, H–C(6), H–C(7)); 3.94 (*ddd*, J = 6.2, 4.4, 3.4, H–C(8)); 3.87–3.83 (*m*, H–C(4)); 3.87 (*dd*, J = 10.8, 3.4, 1 H–C(9)); 3.70 (*dd*, J = 10.5, 4.4, 1 H–C(9)); 3.70 (*s*, COOMe); 3.64 (*s*, H–C(3)); 1.74 (*s*, AcN). ^{13}C-NMR (50 MHz, $CDCl_3$): 169.35 (*s*); 165.60 (*s*); 138.45 (*s*); 138.25 (*s*); 138.11 (*s*); 137.04 (*s*); 128.5–127.5 (*m*, 20 *d*); 79.51 (*s*); 77.88 (*d*); 75.98 (*d*); 73.90 (*d*); 73.52 (*t*); 73.32 (*t*); 72.45 (*t*); 72.12 (*t*); 71.96 (*d*); 68.85 (*t*); 57.35 (*d*); 52.89 (*q*); 47.96 (*d*); 23.33 (*q*). CI-MS: 682 (100, $[M+1]^+$), 610 (15), 592 (25). Anal. calc. for $C_{40}H_{43}NO_9$ (681.79) C 70.47, H 6.36, N 2.05; found: C 70.32, H 6.51, N 1.88.

*Methyl 5-Acetamido-2,7-anhydro-4,8,9-tri-*O*-benzyl-5-deoxy-β-*D*-erythro*-l-gluco-2-nonulopyranosonate (**15**) *and Methyl 5-Acetamido-4,7,8,9-tetra-*O*-benzyl-2-bromo-2,5-dideoxy-β-*D*-erythro*-*L*-gluco-2-nonulopyranosonate* (**16**). a) A soln. of freshly distilled $TiBr_4$ (1.78 g, 4.84 mmol, 1.1 equiv.) in abs. 1,2-

dichloroethane (20 ml) was added dropwise to a soln. of **14** (3.0 g, 4.4 mmol) in abs. 1,2-dichloroethane (50 ml) at –40°. After stirring at –40° for 5 min, the soln. was poured into a sat. Na_2SO_4 soln. (50 ml), and AcOEt (150 ml) was added. The org. layer was treated with a 5% $NaHCO_3$ soln. (50 ml) and brine (20 ml), dried ($MgSO_4$), and evaporated. Chromatography of the residue (SiO_2, AcOEt/hexane 1:1, AcOEt after the elution of the first product) gave **16** (2.05 g, 61%) and **15** (0.91 g, 34%) as foams.

b) A soln. of freshly distilled $TiBr_4$ (1.426 g, 3.87 mmol, 1.1 equiv.) in abs. THF (30 ml) was added dropwise to a soln. of **14** (2.40 g, 3.52 mmol) in abs. THF (80 ml) at –70°. After stirring at –70° for 10 min, the soln. was directly poured on a silica-gel column. Elution with AcOEt/hexane 1:1 gave **16** (2.57 g, 96%) as a foam.

Data of **15:** R_f (AcOEt) 0.38. $[\alpha]_D^{25} = -4.0$ (c = 1.1, $CHCl_3$). IR ($CHCl_3$): 3460 (br.), 3430*m*, 3000*m*, 2960*m*, 2860*m*, 1750*s*, 1670*s*, 1500*m*, 1450*m*, 1370*m*, 1310*w*, 1110*s*, 1090*s*, 1070*s*, 1030*s*, 950*w*, 910*w*. ^{1}H-NMR (400 MHz, $CDCl_3$): 7.35–7.25 (*m*, 15 arom. H); 6.37 (*d*, J = 9.1, NH); 4.75 (*d*, J = 11.8, 2 H, PhC*H*); 4.65–4.50 (*m*, 6 H, PhC*H*, H–C(6), H–C(7)); 4.28 (*dq*, J = 9.2, 1.6, H–C(5)); 4.06 (br. *d*, J = 4.4, H–C(3)); 3.81 (*s*, COOMe); 3.78 (*dd*, J = 10.4, 2.3, H–C(9)); 3.61 (*dd*, J = 10.4, 5.0, H–C(9)); 3.56 (*ddd*, J = 7.7, 5.0, 2.6, H–C(8)); 3.53 (*q*, J = 1.4, H–C(4)); 2.89 (*d*, J = 4.5, OH); 1.99 (*s*, AcN). ^{13}C-NMR (50 MHz, $CDCl_3$): 169.43 (*s*); 167.55 (*s*); 138.16 (*s*); 138.03 (*s*); 137.47 (*s*); 128.83–127.52 (*m*, 15 *d*); 103.66 (*s*); 79.06 (*d*); 78.93 (*d*); 78.07 (*d*); 76.60 (*d*); 73.30 (*t*); 72.48 (*t*); 71.61 (*t*); 69.10 (*t*); 68.84 (*d*); 52.97 (*q*); 47.17 (*d*); 23.12 (*q*). CI-MS: 592 (100, $[M + 1]^+$). Anal. calc. for $C_{33}H_{37}NO_9$ (591.66): C 66.99, H 6.30, N 2.37; found: C 67.08, H 6.36, N 2.22.

Data of **16:** R_f (AcOEt/hexane 1:1) 0.39. $[\alpha]_D^{25} = -53.6$ (c = 0.94, $CHCl_3$). IR ($CHCl_3$): 3550*w*, 3430*m*, 3000*m*, 2960*m*, 2860*m*, 1730*s*, 1680*s*, 1500*m*, 1450*m*, 1440*m*, 1370*m*, 1310*m*, 1280*m*, 1100*s*, 1040 (sh), 1025*m*, 910*w*, 890*w*. ^{1}H-NMR (400 MHz, $CDCl_3$): 7.40–7.25 (*m*, 20 arom. H); 4.95 (*d*, J = 11.9, PhC*H*); 4.7–4.6 (*m*, 5 H, NH, PhC*H*); 4.59 (*d*, J = 12.1, PhC*H*); 4.56 (*d*, J = 12.1, PhC*H*); 4.51 (*d*, J = 10.6, PhC*H*); 4.49 (br. *d*, J = 10.6, H–C(6)); 4.11 (*dt*, J = 10.7, 9.5, H–C(5)); 3.94 (*dd*, J = 9.7, 8.1, H–C(4)); 3.86 (*s*, COOMe); 3.82–3.74 (*m*, H–C(3), H–C(7), H–C(8), 1 H–C(9), OH); 3.67 (br. *d*, J = 11.0, 1 H–C(9)); 1.73 (*s*, AcN). ^{13}C-NMR (50 MHz, $CDCl_3$): 169.90 (*s*); 167.64 (*s*); 138.31 (*s*); 138.21 (*s*); 137.85 (2 *s*); 127.50–128.87 (*m*, 20 *d*); 99.81 (*s*); 78.86 (*d*); 77.00 (*d*); 75.20 (*d*); 74.74 (*d*); 74.44 (*d*); 74.19 (*t*); 74.05 (*t*); 73.26 (*t*); 72.65 (*t*); 68.13 (*t*); 53.56 (*q*); 49.09 (*d*); 23.47 (*q*). CI-MS: 682 (17, $[M + 1 - Br]^+$), 592(39), 576(23), 502(19), 486(27), 91(100). Anal. calc. for $C_{40}H_{44}BrNO_9$ (762.70) C 62.99, H 5.81, Br 10.48, N 1.84; found: C 62.81, H 5.68, Br 10.36, N 1.67.

*Methyl 5-Acetamido-2,6-anhydro-4,7,8,9-tetra-*O*-benzyl-5-deoxy-*D-arabino-L-gulo-*2-nononate* (**17**). A mixture of **16** (4.31 g, 5.65 mmol), 2,2'-dimethyl-2,2'-azobis[propanenitrile] (AIBN; 460 mg, 2.8 mmol, 0.5 equiv.), Bu_3SnH (2.1 ml, 7.92 mmol, 1.4 equiv.) and dry benzene (150 ml) was heated to 60° for 30 min. Evaporation and chromatography of the residue (SiO_2, AcOEt/hexane 1:4 to 2:1) gave **17** (3.529 g, 91%) as a foam. R_f (AcOEt/hexane 1:1) 0.25. $[\alpha]_D^{25} = -9.5$ (c = 0.94, $CHCl_3$). IR ($CHCl_3$): 3550*m* (br.), 3430*m*, 3060*w*, 3000*m*, 2960*m*, 2870*m*, 1730*s*, 1675*s*, 1510*m*, 1500*m*, 1450*m*, 1440*m*, 1370*m*, 1320*w*, 1270*s*, 1200*s* (br.), 1100*s*, 1050*s*, 910*w*, 890*w*. ^{1}H-NMR (400 MHz, $CDCl_3$): 7.40–7.25 (*m*, 20 arom. H); 4.88 (*d*, J = 11.8, PhC*H*); 4.70 (*d*, J = 11.6, PhC*H*); 4.63–4.53 (*m*, 6 H, PhC*H*); 4.31 (*d*, J = 8.2, NH); 4.09 (*dd*, J = 10.4, 1.4, H–C(6)); 3.94 (*dd*, J = 9.8, 8.7, H–C(4)); 3.92–3.84 (*m*, H–C(8), 1 H–C(9)); 3.85 (*dt*, J = 2.1, 9.1, H–C(3)); 3.74 (*s*, COOMe); 3.72 (*dd*, J = 5.7, 1.5, H–C(7)); 3.71 (*dd*, J = 10.8, 3.8, 1 H–C(9)); 3.63 (*d*, J = 9.6, H–C(2)); 3.47 (*dt*, J = 8.2, 10.1, H–C(5)); 3.26 (*d*, J = 2.2, OH); 1.58 (*s*, AcN). ^{13}C-NMR (50 MHz, $CDCl_3$): 170.32 (*s*); 169.98 (*s*); 138.71 (*s*); 138.33 (*s*); 138.11 (*s*); 138.08 (*s*); 129.35–127.53 (*m*, 20 *d*); 81.01 (*d*); 77.90 (*d*); 77.45 (*d*); 76.45 (*d*); 74.39 (*t*); 73.94 (*d*); 73.36 (*t*); 73.17 (*t*); 72.75 (*d*); 72.59 (*t*); 68.94 (*t*); 52.35 (*q*); 51.99 (*d*); 23.51 (*q*). CI-MS: 684 (100, $[M + 1]^+$), 592 (20), 501 (16). Anal. calc. for $C_{40}H_{45}NO_9 \cdot {}^1/_2H_2O$ (692.81): C 69.35, H 6.69, N 2.02; found: C 69.50, H 6.81, N 2.02

*Methyl 5-Acetamido-2,6-anhydro-3,4,7,8,9-penta-*O*-benzyl-5-deoxy-*D-arabino-L-gulo-*2-nononate* (**18**). A mixture of **17** (3.5 g, 5.12 mmol), NaH (300 mg, 12.5 mmol), and abs. DMF (130 ml) was stirred at r.t. for 1 h. Benzyl bromide (850 µl, 7.14 mmol) was then added and stirring continued for 16 h. After addition of *Dowex 50 WX4* (H^+ form), the partly hydrolyzed methyl ester was regenerated by treating the soln. with an Et_2O soln. of diazomethane. The soln. was then poured into H_2SO_4 (0.2M, 100 ml) and extracted with CH_2Cl_2 (4 × 100 ml). The org. layer was dried ($MgSO_4$) and evaporated and the residue purified by chromatography (SiO_2, AcOEt/hexane 1:1) to give **18** (2.5 g, 63%) and **17** (923 mg, 26%). R_f (AcOEt/hexane 1:1) 0.38. $[\alpha]_D^{25} = -6.4$ (c = 1.31, $CHCl_3$). IR ($CHCl_3$): 3430*m*, 3090*w*, 3070*w*, 3000*w*, 2960*m*, 2870*m*, 1750*s*, 1680*s*, 1650*m*, 1500*m*, 1450*m*, 1440*m*, 1365*m*, 1250*s* (br.), 1095*s*, 1030*s*, 910*m*. ^{1}H-NMR (400 MHz, $CDCl_3$): 7.40–7.25 (*m*, 25 arom. H); 4.83 (*d*, J = 11.5, PhC*H*); 4.78 (*d*, J = 10.8, PhC*H*); 4.67 (*d*, J = 10.9, PhC*H*); 4.66 (*d*, J = 11.4, PhC*H*); 4.60–4.55 (*m*, 5 H, PhC*H*); 4.52 (*d*, J = 8.3, NH); 4.51 (*d*, J = 11.4, PhC*H*); 4.01 (*dd*, J = 10.5, 1.4, H–C(6)); 3.97 (*ddd*, J = 9.1, 6.9, 2.2, H–C(8)); 3.90–3.75 (*m*, H–C(2), H–C(3), H–C(4), H–C(5), 1 H–C(9)); 3.71 (*dd*, J = 8.9, 1.4, H–C(7)); 3.70 (*s*, COOMe); 3.69 (*dd*, J = 10.5, 3.5, H–C(9)); 1.60 (*s*, AcN). ^{13}C-NMR (50 MHz, $CDCl_3$): 170.00 (*s*); 168.88 (*s*); 138.32 (*s*); 138.17 (*s*); 138.11 (*s*); 138.02 (*s*); 137.87 (*s*); 129.09–127.66 (*m*, 25 *d*); 82.23 (*d*); 80.05 (*d*); 78.11 (*d*);

77.45 (*d*); 76.51 (*d*); 74.73 (2 *t*); 74.21 (*d*); 73.39 (*t*); 73.33 (*t*); 72.60 (*t*); 68.54 (*t*); 52.15 (*q*); 51.95 (*d*); 23.50 (*q*). CI-MS: 774 (100, $[M + 1]^+$). Anal calc. for $C_{47}H_{51}NO_9$ (773.93): C 72.94, H 6.64, N 1.81; found: C 72.94, H 6.45, N 1.55.

4-Acetamido-2,3,6,7,8-penta-O-*benzyl-4-deoxy-β*-D-erythro-L-gluco-*octopyranosyl Acetate* (**19**) *and 4-Acetamido-2,3,6,7,8-penta*-O-*benzyl-4-deoxy-α*-D-erythro-L-gluco-*octopyranosyl Acetate* (**20**). A soln. of **18** (1.55 g, 2.00 mmol) in MeOH (20 ml) and 1M aq. NaOH (3 ml, 3.00 mmol) was stirred at r.t for 2.5 h. Filtration of the soln. through a short *Dowex 50 WX4* (H^+ form) column (6 ml of resin) and evaporation of the solvents gave the free acid (1.49 g, 98%) which was used without further purification. A mixture of the free acid (1.60 g, 2.1 mmol), abs. toluene (15 ml), pyridine (1.5 ml), and $Pb(OAc)_4$ (2.80 g, 6.32 mmol, 3equiv.) was heated under N_2 at 60° for 2 h. Evaporation of the solvents at 0.01 Torr and chromatography of the residue (SiO_2, AcOEt/hexane 1:1) gave **19/20**[8]) (1.20 g, 74%). A sample of this mixture was separated by chromatography (SiO_2, AcOEt/hexane 1:2).

Data of **19:** R_f (AcOEt/hexane 1:1) 0.47. $[\alpha]_D^{25} = -27.4$ (*c* = 1.05, $CHCl_3$). IR ($CHCl_3$): 3430*m*, 3060*w*, 3000*w*, 2940*m*, 2870*m*, 1745*s*, 1680*s*, 1500*m*, 1450*m*, 1370*m*, 1270*m*, 1230*s* (br.), 1145*m*, 1095*s*, 1025*s*, 1010*s*, 930*m*. ^{1}H-NMR (400 MHz, $CDCl_3$): 7.37–7.27 (*m*, 25 arom. H); 6.33 (*d*, *J* = 3.5, H–C(1)); 4.89 (*d*, *J* = 11.7; PhC*H*); 4.70–4.50 (*m*, 8 H, NH, 7 PhC*H*); 4.52 (*d*, *J* = 10.8, PhC*H*); 4.46 (*d*, *J* = 11.7, PhC*H*); 4.34 (br. *d*, *J* = 10.7, H–C(5)); 4.04 (*t*, *J* = 9.6, H–C(3)); 3.90 (*dt*, *J* = 10.4, 9.6, H–C(4)); 3.80–3.70 (*m*, H–C(6), H–C(7), H–C(8)); 3.69 (*dd*, *J* = 9.2, 3.5, H–C(2)); 3.67 (*m*, H–C(8)); 1.89 (*s*, AcO); 1.72 (*s*, AcN). ^{13}C-NMR (50 MHz, $CDCl_3$): 169.89 (*s*); 169.36 (*s*); 138.65 (*s*); 138.48 (*s*); 137.94 (2*s*); 137.61 (*s*); 129.50–127.23 (*m*, 25 *d*); 90.11 (*d*); 79.22 (*d*); 77.95 (*d*); 77.38 (*d*); 74.92 (*t*); 74.02 (*t*); 73.97 (*t*); 73.33 (*t*); 73.06 (*t*); 72.11 (*t*); 70.32 (*d*); 67.84 (*t*); 51.23 (*d*); 23.69 (*q*); 20.73 (*q*). CI-MS: 774 (5, $[M + 1]^+$), 714 (100), 624 (30). Anal. calc. for $C_{47}H_{51}NO_9$ (773.93): C 72.94, H 6.64, N 1.81; found: C 72.91, H 6.47, N 1.75.

Data of **20:** R_f (AcOEt/hexane 1:1) 0.51. $[\alpha]_D^{25} = -3.4$ (*c* = 1.1, $CHCl_3$). IR ($CHCl_3$): 3430*m*, 3090*w*, 3030*w*, 3000*w*, 2920*m*, 2870*m*, 1755*s*, 1680*s*, 1510*m*, 1500*m*, 1450*m*, 1370*m*, 1325*w*, 1220*m*, 1090*s*, 1050*s*, 1030*s*, 910*w*, 890*w*. ^{1}H-NMR (400 MHz, $CDCl_3$): 7.4–7.2 (*m*, 25 arom. H); 5.57 (*d*, *J* = 8.2, H–C(1)); 4.39 (*d*, *J* = 8.0, NH); 4.85–4.50 (*m*, 10 H, PhC*H*); 4.06 (br. *d*, *J* = 9.7, H–C(5)); 3.90–3.84 (*m*, H–C(3), H–C(4)); 3.80 (*ddd*, *J* = 8.9, 3.3, 2.2, H–C(7)); 3.75 (*dd*, *J* = 10.7, 2.2, 1 H–C(8)); 3.70 (*dd*, *J* = 8.9, 1.0, H–C(6)); 3.67 (*dd*, *J* = 10.7, 3.3, 1 H–C(8)); 3.62 (*t*, *J* = 8.5, H–C(2)); 2.03 (*s*, AcO); 1.55 (*s*, AcN). ^{13}C-NMR (50 MHz, $CDCl_3$): 169.77 (*s*); 169.01 (*s*); 138.34 (*s*); 138.22 (*s*); 138.00 (*s*); 137.96 (*s*); 137.93 (*s*); 129.39–127.51(*m*, 25 *d*); 94.09 (*d*); 81.38 (*d*); 80.98 (*d*); 77.34 (*d*); 74.92 (*t*); 74.82 (*t*); 73.72 (*t*); 73.65 (*d*); 73.23 (*t*); 72.82 (*t*); 72.58 (*d*); 68.02 (*t*); 51.35 (*d*); 23.51 (*q*); 20.89 (*q*). CI-MS: 774 (8, $[M + 1]^+$), 714 (100), 624 (15), 594 (9), 534 (8). Anal. calc. for $C_{47}H_{51}NO_9$ (773.93): C 72.94, H 6.64, N 1.81; found: C 72.73, H 6.65, N 1.90.

4-Acetamido-2,3,6,7,8-penta-O-*benzyl-4-deoxy*-D-erythro-L-gluco-*octopyranose* (**21**). A soln. of **19/20** (1,10 g, 1.42 mmol), abs. MeOH (40 ml), and 0.5M NaOMe in MeOH (1 ml; 0.5 mmol) was stirred at r.t. for 2.5 h. Filtration through a *Dowex 50 WX4* (H^+ form) column and evaporation gave **21** (100%). *α*-D/*β*-D 1:1.9. R_f (AcOEt/hexane 1:1) 0.32. ^{1}H-NMR (400 MHz, $CDCl_3$): 7.4–7.2 (*m*, 25 arom. H); 5.06 (*t*, *J* = 2.9, 0.65 H, H–C(1)); 4.9–4.4 (*m*, 10 H, PhC*H*); 4.74 (*d*, *J* = 9.6, 0.65 H, NH); 4.41 (*d*, *J* = 8.5, 0.35 H, NH); 4.35 (*dd*, *J* = 7.3, 6.0, 0.35 H, H–C(1)); 4.18 (br. *d*, *J* = 10.7, 0.65 H, H–C(5)); 4.09 (*q*, *J* = 9.8, 0.65 H, H–C(4)); 3.84 (0.35 H, H–C(5)); 3.83 (*t*, *J* = 9.1, 0.65 H, H–C(3)); 3.80 (*t*, *J* = 8.8, 0.35 H, H–C(3)); 3.70 (br. *d*, *J* = 7.8, 0.65 H, H–C(6)); 3.68 (*q*, *J* = 9.4, 0.35 H, H–C(4)); 3.58 (*dd*, *J* = 9.1, 3.5, 0.65 H, H–C(2)); 3.29 (*dd*, *J* = 8.6, 7.4, 0.35 H, H–C(2)); 3.66–3.73, 3.77–3.93 (2 *m*, all missing signals); 2.58 (*d*, *J* = 6.0, 0.35 H, OH); 2.42 (*d*, *J* = 2.7, 0.65 H, OH); 1.74 (*s*, 1.95 H, AcN); 1.62 (*s*, 1.05 H, AcN). CI-MS: 732 (42, $[M + 1]^+$), 714 (56), 624 (29), 516 (18), 91 (100).

O-*[4-Acetamido-2,3,6,7,8-penta*-O-*benzyl-4-deoxy-α*-D-erythro-L-gluco-*octopyranosyl] Trichloroacetimidate* (**22**) *and* O-*[4-Acetamido-2,3,6,7,8-penta*-O-*benzyl-4-deoxy-β*-D-erythro-L-gluco-*octopyranosyl] Trichloroacetimidate* (**23**). A mixture of **21** (500 mg, 0.683 mmol), K_2CO_3 (450 mg, 3.261 mmol, 4.8 equiv.), trichloroacetonitrile (344 µl, 3.414 mmol, 5 equiv.), and abs. CH_2Cl_2 (20 ml) was stirred at r.t. After 48 h, a second portion of trichloroacetonitrile (344 µl) was added. After stirring for another 48 h, the soln. was poured onto a silica-gel column. Elution (AcOEt/hexane 1:2) gave **22** (295 mg, 49.3%), **23** (123 mg, 20.5%), and **21** (70 mg, 14 %).

Data of **22:** R_f (AcOEt/hexane 1:1) 0.38. $[\alpha]_D^{25} = -5.4$ (*c* = 0.8, $CHCl_3$). IR ($CHCl_3$): 3430*m*, 3340*m*, 3090*w*, 3060*w*, 3000*m*, 2920*m*, 2860*m*, 1670*s*, 1090*s*, 1030*m*, 830*m*. ^{1}H-NMR (400 MHz, $CDCl_3$): 8.63 (*s*, NH); 7.4–7.2 (*m*, 25 arom. H); 5.78 (*d*, *J* = 8.3, H–C(1)); 4.97 (*d*, *J* = 10.8, PhC*H*); 4.83 (*d*, *J* = 11.7, PhC*H*); 4.76 (*d*, *J* = 11.0, PhC*H*); 4.64–4.64 (*m*, 7 H, PhC*H*); 4.38 (*d*, *J* = 8.7, NH); 4.15 (*dd*, *J* = 10.5, 1.3, H–C(5)); 4.00 (*t*, *J* = 9.4,

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[8]) The **19/20** ratio was determined by integration of the H–C(1) signals of **19** and **20** in the ^{1}H-NMR spectra of the crude product.

H–C(3)); 3.89 (*ddd*, *J* = 7.8, 3.8, 2.0, H–C(7)); 3.83 (*dd*, *J* = 10.8, 2.3, 1 H–C(8)); 3.80–3.67 (*m*, H–C(2), H–C(4), H–C(6), 1 H–C(8)); 1.56 (*s*, AcN). ^{13}C-NMR (50 MHz, $CDCl_3$): 169.88 (*s*); 161.35 (*s*); 138.58 (*s*); 138.44 (*s*); 138.18 (2*s*); 137.98 (*s*); 129.33–127.58 (*m*, 25*d*); 98.61 (*d*); 90.90 (*s*); 81.45 (*d*); 80.48 (*d*); 78.21 (*d*); 74.97 (*t*); 74.88 (*t*); 74.07 (*d*); 73.35 (2t); 73.01 (*d*); 72.89 (*t*); 68.89 (*t*); 51.99 (*d*); 23.56 (*q*). CI-MS: 714 (42), 624 (50), 606 (37), 91 (100). Anal. calc. for $C_{47}H_{49}Cl_3N_2O_8$ (876.28): C 64.42, H 5.64, Cl 12.14, N 3.20; found: C 64.60, H 5.37, Cl 12.29, N 3.40.

Data of **23:** R_f (AcOEt/hexane 1:1) 0.41. $[\alpha]_D^{25} = -21.8$ (*c* = 0.97, $CHCl_3$). IR ($CHCl_3$): 3430*m*, 3350*m*, 3090*w*, 3060*w*, 3000*m*, 2930*m*, 2870*m*, 1670*s*, 1510*m*, 1500*m*, 1455*m*, 1370*m*, 1295*m*, 1115*s*, 1090*s*, 1070*s*, 1030*s*, 970*m*, 910*w*, 895*w*, 880*w*, 830*w*. ^{1}H-NMR (400 MHz, $CDCl_3$): 8.53 (*s*, NH); 7.4–7.2 (*m*, 25 arom. H); 6.51 (*d*, *J* = 3.2, H–C(1)); 4.87 (*d*, *J* = 11.7, PhC*H*); 4.73–4.45 (*m*, 10 H, NH, PhC*H*); 4.27 (br. *d*, *J* = 10.2, H–C(5)); 4.11 (*q*, *J* = 9.8, H–C(4)); 4.06 (*t*, *J* = 9.8, H–C(3)); 3.79 (*dd*, *J* = 9.0, 3.2, H–C(2)); 3.65 (br. *s*, H–C(6), H–C(7)); 3.65 (br. *s*, 2 H–C(8)); 1.76 (*s*, AcN). ^{13}C-NMR (50 MHz, $CDCl_3$): 169.85 (*s*); 160.97 (*s*); 138.35 (*s*); 138.26 (*s*); 137.89 (2*s*); 137.80 (*s*); 129.00–127.49 (*m*, 25 *d*); 94.60 (*d*); 91.15 (*s*); 79.64 (*d*); 77.42 (*d*); 76.89 (*d*); 74.52 (*t*); 74.40 (*d*); 74.14 (*t*); 73.14 (*t*); 72.69 (*t*); 72.16 (*t*); 71.43 (*d*); 68.26 (*t*); 50.43 (*d*); 23.58 (*q*). CI-MS: 714 (5), 624 (43), 534 (28), 516 (31), 444 (10), 426 (21) 107 (100), 91 (74). Anal. calc. for $C_{47}H_{49}Cl_3N_2O_8$ (876.28): C 64.42, H 5.64, Cl 12.14, N 3.20; found: C 64.27, H 5.84, Cl 12.35, N 3.12.

*Dimethyl (4-Acetamido-2,3,6,7,8-penta-*O*-benzyl-4-deoxy-α-*D*-erythro-*L*-gluco-octopyranosyl)-phosphonate* (**24**), *Dimethyl (4-Acetamido-2,3,6,7,8-penta-*O*-benzyl-4-deoxy-β-*D*-erythro-*L*-gluco-octopyranosyl)phosphonate* (**25**), *and 4-Acetamido-1,6-anhydro-2,3,7,8-tetra-*O*-benzyl-4-deoxy-α-*D*-erythro-*L*-gluco-octopyranose* (**26**). A mixture of **22** (277 mg, 0.316 mmol), $P(MeO)_3$ (250 µl, 2.12 mmol, 6.7 equiv.), molecular sieves (4Å, 2.8 g) and abs. CH_2Cl_2 (5 ml) was stirred at r.t. Me_3SiOTf (58 µl, 0.32 mmol, 1.01 equiv.) was added at 0° and stirring was continued for 24 h at 5°. The soln. was filtered through *Celite* and the filtrate evaporated. Chromatography of the residue (SiO_2, AcOEt/hexane 1:1) gave **24/25** (113 mg, 44%) and **26** (80 mg, 41%). Enriched fractions of **24** and **25** were collected and their ^{1}H-NMR spectra measured.

Data of **24:** R_f (AcOEt/hexane 3:1) 0.39. ^{1}H-NMR (400 MHz, $CDCl_3$): 7.4–7.2 (*m*, 25 arom. H); 4.90 (*d*, *J* = 10.3, PhC*H*); 4.84 (*d*, *J* = 11.6, PhC*H*); 4.83 (*d*, *J* = 10.3, PhC*H*); 4.68 (*d*, *J* = 11.2, PhC*H*); 4.62–4.50 (*m*, 7 H, PhC*H*, NH); 3.9–3.8 (*m*, 6 H); 3.76 (*d*, *J*(H,P) = 10.6, 3H, $P(OMe)_2$); 3.72–3.63 (*m*, 3 H); 3.68 (*d*, *J*(H,P) = 10.7, 3 H, $P(OMe)_2$); 1.62 (*s*, AcN). ^{31}P-NMR (81 MHz, $CDCl_3$): 22.60.

Data of **25:** R_f (AcOEt/hexane 3:1) 0.36. ^{1}H-NMR (400 MHz, $CDCl_3$): 7.4–7.2 (*m*, 25 arom. H); 5.85 (*d*, *J* = 9.6, NH); 4.76 (*d*, *J* = 11.7, PhC*H*); 4.71 (*d*, *J* = 11.3, PhC*H*); 4.71 (*d*, *J* = 11.3, PhC*H*); 4.68 (*d*, *J* = 11.6, PhC*H*); 4.66 (*d*, *J* = 11.2, PhC*H*); 4.62 (*d*, *J* = 10.0, PhC*H*); 4.59 (*d*, *J* = 11.2, PhC*H*); 4.58 (*d*, *J* = 10.0, PhC*H*); 4.55 (*d*, *J* = 12.0, PhC*H*); 4.51 (*dd*, *J*(H,P) = 12.0, *J* = 5.5, H–C(1)); 4.49 (*d*, *J* = 12.1, PhC*H*); 4.34 (*q*, *J* = 8.5, H–C(4)); 4.17 (*ddd*, *J* = 8.4, 3.1, 1.2, H–C(5)); 4.06 (*dt*, *J* = 1.1, 7.2, H–C(3)); 3.93 (*ddd*, *J*(H,P) = 23.1, *J* = 7.4, 5.5, H–C(2)); 3.90–3.84 (*m*, H–C(6), H–C(7), 1 H–C(8)); 3.71 (*dd*, *J* = 10.6, 5.0, 1 H–C(8)); 3.67 (*d*, *J*(H,P) = 10.8, 3 H, $P(OMe)_2$); 3.65 (*d*, *J*(H,P) = 10.7, 3 H, $P(OMe)_2$); 1.76 (*s*, AcN). ^{31}P-NMR (81 MHz, $CDCl_3$): 23.99.

Data of **26:** R_f (AcOEt/hexane 1:1) 0.36. ^{1}H-NMR (400 MHz, $CDCl_3$): 7.4–7.2 (*m*, 20 arom. H); 6.25 (*d*, *J* = 9.4, NH); 5.40 (br. *s*, H–C(1)); 4.75 (*d*, *J* = 11.7, PhC*H*); 4.73 (*d*, *J* = 12.3, PhC*H*); 4.60–4.50 (*m*, 4 H, PhC*H*); 4.51 (br. *d*, *J* = 7.7, H–C(6)); 4.36 (br. *s*, H–C(5)); 4.33 (*d*, *J* = 11.9, PhC*H*); 4.30 (*d*, *J* = 11.9, PhC*H*); 4.23 (*d*, fine struct., *J* = 9.1, H–C(4)); 3.76 (*dd*, *J* = 10.4, 2.7, 1 H–C(8)); 3.60 (*dd*, *J* = 10.5, 5.3, 1 H–C(8)); 3.46 (*ddd*, *J* = 7.7, 5.3, 2.7, H–C(7)); 3.44 (br. *s*, H–C(2) or H–C(3)); 3.32 (br. *s*, H–C(2) or H–C(3)); 1.93 (*s*, AcN). ^{13}C-NMR (50 MHz, $CDCl_3$): 169.06 (*s*); 138.23 (*s*); 138.18 (*s*); 137.63 (*s*); 137.25 (*s*); 128.51–127.50 (*m*, 20 *d*); 100.84 (*d*); 78.30 (*s*); 76.29 (*s*); 75.27 (*s*); 74.81 (*d*); 74.73 (*d*); 73.42 (*t*); 72.55 (*t*); 71.77 (*t*); 71.41 (*t*); 69.78 (*t*); 47.50 (*d*); 23.22 (*q*). CI-MS: 624 (100, $[M + 1]^+$).

*Dimethyl (4-Acetamido-2,3,6,7,8-penta-*O*-acetyl-4-deoxy-α-*D*-erythro-*L*-gluco-octopyranosyl)-phosphonate* (**27**) *and Dimethyl (4-Acetamido-2,3,6,7,8-penta-*O*-acetyl-4-deoxy-β-*D*-erythro-*L*-gluco-octopyranosyl)phosphonate* (**28**). A mixture **24/25** (100 mg, 0.121 mmol), 10% Pd/C (50 mg), and MeOH (15 ml) was hydrogenated at r.t./8 atm for 19 h. The soln. was then filtered through *Celite* and evaporated. TLC: single spot. ^{1}H-NMR: no arom. signals. The residue was acetylated overnight in Ac_2O/pyridine 1:2 (3 ml) to give, after evaporation and chromatography (SiO_2, AcOEt/MeOH 95:5), **27** (20 mg, 28%), **28** (22 mg, 31%), and **27/28** (27.0 mg, 38%).

Data of **27:** R_f (AcOEt/MeOH 9:1) 0.36. $[\alpha]_D^{25} = -36.8$ (*c* = 0.75, $CHCl_3$). IR ($CHCl_3$): 3430*m*, 3000*m*, 2960*m*, 2860*w*, 1740*s*, 1685*s*, 1655 (sh), 1510*w*, 1370*s*, 1290*s*, 1240*s* (br.), 1080 (sh), 1040*s*, 940*w*, 905*w*, 835*m*. ^{1}H-NMR (400 MHz, $CDCl_3$): 5.36 (*dt*, *J*(H,P) = 9.2, *J* = 10.5, H–C(2)); 5.35 (*d*, *J* = 9.6, NH); 5.32 (*ddd*, *J* = 6.5, 2.1, 0.7, H–C(6)); 5.21 (*dt*, *J* = 2.6, 6.4, H–C(7)); 5.15 (*dt*, *J* = 0.7, 10.2, H–C(3)); 4.42 (*dd*, *J* = 12.5, 2.6, 1 H–C(8)); 4.13 (*q*, *J* = 10.3, H–C(4)); 4.11 (*dd*, *J* = 12.5, 6.3, 1 H–C(8)); 3.85 (*d*, *J*(H,P) = 10.7, $P(OMe)_2$); 3.79 (*d*, *J*(H,P) = 10.9, 3 H, $P(OMe)_2$); 3.76 (*dd*, *J* = 10.3, 2.1, H–C(5)); 3.75 (*t*, *J*(H,P) = 10.4, *J* = 10.4, H–C(1)); 2.13, 2.08, 2.05, 2.04,

2.03 (5 *s*, 5 AcO); 1.90 (*s*, AcN). ^{13}C-NMR (50 MHz, $CDCl_3$): 171.07 (*s*); 170.54 (*s*); 170.28 (*s*); 170.22 (*s*); 170.12 (*s*); 169.26 (*s*); 78.38 (*dd*, *J*(C,P) = 16.2); 74.12 (*dd*, *J*(C,P) = 18.6); 72.82 (*dd*, *J*(C,P) = 173.2); 70.70 (*d*); 67.63 (*d*); 67.44 (*d*); 62.13 (*t*); 54.20 (*dq*, *J*(C,P) = 6.9); 53.15 (*dq*, *J*(C,P) = 6.6); 49.18 (*d*); 22.95 (*q*); 20.78 (*q*); 20.67 (2*q*); 20.62 (*q*); 20.60 (*q*). ^{31}P-NMR (81 MHz, $CDCl_3$): 18.60. CI-MS: 584 (100, $[M + 1]^+$).

Data of **28:** R_f (AcOEt/MeOH 9:1) 0.40. $[\alpha]_D^{25} = +9.7$ (*c* = 0.82, $CHCl_3$). IR ($CHCl_3$): 3430*m*, 3000*m*, 2960*m*, 2860*m*, 1745*s*, 1690*s*, 1510*m*, 1370*s*, 1290*m*, 1240*s* (br.), 1080 (sh), 1035*s*, 950*w*, 905*w*, 860*m*, 830*m*. ^{1}H-NMR (400 MHz, $CDCl_3$): 5.67 (*t*, *J* = 10.0, H–C(3)); 5.64 (d; *J* = 10.3; NH); 5.33 (*dd*, *J* = 7.5, 2.1, H–C(6)); 5.16 (*ddd*, *J* = 7.5, 5.2, 2.9, H–C(7)); 5.16 (*ddd*, *J*(H,P) = 30.8, *J* = 9.9, 7.3, H–C(2)); 4.74 (*dd*, *J*(H,P) = 10.2, *J* = 7.4, H–C(1)); 4.38 (*dd*, *J* = 12.6, 2.9, 1 H–C(8)); 4.36 (*dt*, *J* = 10.3, 1.7, H–C(5)); 4.22 (*q*, *J* = 10.2, H–C(4)); 4.11 (*dd*, *J* = 12.4, 5.2, 1 H–C(8)); 3.78 (*d*, *J*(H,P) = 10.7, 3 H, $P(OMe)_2$); 3.77 (*d*, *J*(H,P) = 10.9, 3 H, $P(OMe)_2$); 2.13, 2.11, 2.09, 2.05, 2.04 (5 *s*, 5 AcO); 1.90 (*s*, AcN). ^{13}C-NMR (50 MHz, $CDCl_3$): 170.80 (*s*); 170.53 (*s*); 170.19 (*s*); 170.08 (*s*); 169.83 (*s*); 169.70 (*s*); 74.02 (*d*); 70.60 (*d*); 69.86 (*d*); 69.07 (*d*); 67.91 (*dd*, *J*(C,P) = 152.4); 67.28 (*d*); 61.76 (*t*); 53.74 (*dq*, *J*(C,P) = 7.4); 52.75 (*dq*, *J*(C,P) = 6.9); 48.69 (*d*); 23.00 (*q*); 21.03 (*q*); 20.78 (*q*); 20.67 (3 *q*). ^{31}P-NMR (81 MHz, $CDCl_3$): 21.56. CI-MS: 584 (100, $[M + 1]^+$).

*Diethyl (2,3,4,6-Tetra-*O*-acetyl-β-*D*-glucopyranosyl)phosphonate* (**30**) *and Diethyl (2,3,4,6-Tetra-*O*-acetyl-α-*D*-glucopyranosyl)phosphonate* (**31**). A mixture of crude **29** [15] (2.0 g, 3.03 mmol), 10% Pd/C (200 mg), and MeOH (50 ml) was hydrogenated at r.t./8 atm for 16 h. The soln. was then filtered through *Celite* and evaporated. The residue was acetylated overnight in Ac_2O/Pyridine 1:2 (10 ml) to give, after evaporation and chromatography (SiO_2, AcOEt), **30** (58 mg, 4%) and **31** (1.304 g, 92%) as colorless oils.

Data of **30:** R_f (AcOEt) 0.30. ^{1}H-NMR (400 MHz, $CDCl_3$): 5.34 (*dt*, *J*(H,P) = 10.3, *J* = 9.1, 10.3, H–C(2)); 5.20 (*dt*, *J*(H,P) = 0.6, *J* = 9.3, H–C(3)); 5.08 (*t*, *J* = 9.7, H–C(4)); 4.30–4.10 (*m*, 6 H, 2 H–C(6), $P(OCH_2CH_3)_2$); 3.83 (*t*, *J*(H,P) = 10.2, *J* = 10.2, H–C(1)); 3.67 (*ddd*, *J* = 9.9, 4.9, 2.3, H–C(5)); 2.06, 2.04, 2.03, 2.01 (4 *s*, 3 H, AcO); 1.34 (*t*, *J*(H,P) = 7.1, 3 H, $P(OCH_2CH_3)_2$); 1.34 (*t*, *J*(H,P) = 7.1, 3 H, $P(OCH_2CH_3)_2$). ^{13}C-NMR (50 MHz, $CDCl_3$): 170.40 (*s*); 170.15 (*s*); 169.28 (*s*); 169.03 (*s*); 77.44 (*dd*, *J*(C,P) = 17.2); 74.14 (*dd*, *J*(C,P) = 17.9); 73.15 (*dd*, *J*(C,P) = 172.7); 67.90 (2 *d*); 63.42 (*dt*, *J*(C,P) = 7.3); 63.28 (*dt*, *J*(C,P) = 7.0); 61.97 (*t*); 20.61 (*q*); 20.56 (*q*); 20.50 (*q*); 20.46 (*q*); 16.35 (2*dq*, *J*(C,P) = 5.6). ^{31}P-NMR (81 MHz, $CDCl_3$): 16.18.

Data of **31**: R_f (AcOEt) 0.39. ^{1}H-NMR (400 MHz, $CDCl_3$): 5.81 (*t*, *J* = 9.4, H–C(3)); 5.14 (*ddd*, *J*(H,P) = 29.6, *J* = 9.8, 7.4, H–C(2)); 5.02 (*t*, *J* = 9.4, H–C(4)); 4.66 (*dd*, *J*(H,P) = 11.4, *J* = 4.1, H–C(1)); 4.30–4.10 (*m*, H–C(5), 2 H–C(6), $P(OCH_2CH_3)_2$); 2.09, 2.08, 2.03, 2.03 (4 *s*, 4 AcO); 1.41 (*t*, *J*(H,P) = 7.1, 3 H, $P(OCH_2CH_3)_2$); 1.36 (*t*, *J*(H,P) = 7.0, 3 H, $P(OCH_2CH_3)_2$). ^{13}C-NMR (50 MHz, $CDCl_3$): 170.47 (*s*); 169.96 (*s*); 169.77 (*s*); 169.55 (*s*); 72.27 (*d*); 70.18 (*d*); 69.45 (*dd*, *J*(C,P) = 154); 69.04 (*d*); 68.16 (*d*); 63.45 (*dt*, *J*(C,P) = 7.0); 62.45 (*dt*, *J*(C,P) = 6.9); 62.07 (*t*); 20.58 (3 *q*); 20.51 (*q*); 16.41 (*dq*, *J*(C,P) = 5.2); 16.31 (*dq*, *J*(C,P) = 4.9). ^{31}P-NMR (81 MHz, $CDCl_3$): 19.74. CI-MS: 469 (100, $[M + 1]^+$), 427 (41), 385 (11), 157 (49).

*Diethyl (2,3,4,6-Tetra-*O*-acetyl-1-*C*-bromo-α-*D*-glucopyranosyl)phosphonate* (**32**). a) *From* **30**: A mixture of **30** (100 mg, 0.213 mmol), NBS (90 mg, 0.506 mmol, 2.4 equiv.), K_2CO_3 (60 mg, 0.434 mmol, 2.0 equiv.), and CCl_4 (7 ml) was heated to reflux and irradiated with a 100-W lamp for 2 h. After cooling, the soln. was filtered and evaporated and the residue purified by chromatography (SiO_2, AcOEt): 105 mg of crude product. CCl_4 (1.5 ml) was added, the suspension cooled to 0°, and the precipitated succinimide (30 mg) was filtered off. Evaporation of the solvent gave **32** (75 mg, 64%).

b) *From* **31**: As described under *a*), a mixture of **31** (55 mg, 0.117 mmol), NBS (50 mg, 0.28 mmol, 2.4 equiv.), K_2CO_3 (33 mg, 0.24 mmol, 2.0 equiv.), and CCl_4 (4 ml) gave **32** (34 mg, 53%). R_f (AcOEt) 0.45. ^{1}H-NMR (400 MHz, $CDCl_3$): 5.47 (*t*, *J* = 9.5, H–C(3)); 5.38 (*dd*, *J*(H,P) = 6.2, *J* = 9.5, H–C(2)); 5.21 (*t*, *J* = 9.7, H–C(4)); 4.40–4.20 (*m*, H–C(5), H–C(6), $P(OCH_2CH_3)_2$); 4.14 (*dd*, *J* = 12.4, 1.7, H–C(6)); 2.06, 2.05, 2.03, 1.98 (4 *s*, 4 AcO); 1.36 (*t*, *J*(H,P) = 6.9, 3 H, $P(OCH_2CH_3)_2$); 1.35 (*t*, *J*(H,P) = 7.1, 3 H, $P(OCH_2CH_3)_2$). ^{13}C-NMR (50 MHz, $CDCl_3$): 170.20 (*s*); 169.70 (*s*); 169.18 (*s*); 168.68 (*s*); 97.58 (*d*, *J*(C,P) = 195.6); 73.60 (*dd*, *J*(C,P) = 12.5); 71.49 (*dd*, *J*(C,P) = 12.3); 68.83 (*dd*, *J*(C,P) = 2.9); 66.60 (*d*); 65.71 (*dt*, *J*(C,P) = 7.2); 65.25 (*dt*, *J*(C,P) = 7.3); 60.69 (*t*); 20.55 (*q*); 20.48 (*q*); 20.42 (*q*); 20.34 (*q*); 16.26 (*dq*, *J*(C,P) = 5.3); 16.21 (*dq*, *J*(C,P) = 5.8). ^{31}P-NMR (81 MHz, $CDCl_3$): 8.06. CI-MS: 549 (100, $[M + 1]^+$), 547 (100, $[M + 1]^+$), 507 (22), 505 (20), 467 (20), 409 (15), 365 (45), 263 (28).

*Diethyl (3,4,6-Tri-*O*-acetyl-2-deoxy-*D*-*arabino*-hex-1-enopyranosyl)phosphonate* (**33**). a) *From* **32**: A mixture of **32** (25 mg, 46 μmol), EtOH (0.5 ml), and a Zn/Cu slurry (0.1 ml) was stirred at r.t for 30 min. The soln. was filtered and evaporated. Pyridine (2 ml) and Ac_2O (1 ml) were added, and the soln. was stirred at r.t. for 2 h. Evaporation and chromatography (SiO_2, AcOEt) afforded **33** (14.2 mg, 76%). R_f (AcOEt) 0.38. ^{1}H-NMR (400 MHz, $CDCl_3$): 5.80 (*dd*, *J*(H,P) = 10.5, *J* = 3.3, H–C(2)); 5.43 (*dddd*, *J*(H,P) = 2.2, *J* = 5.9, 3.3, 0.6, H–C(3)); 5.25 (*dd*, *J* = 7.5, 6.2, H–C(4)); 4.40 (*ddd*, *J* = 11.8, 5.2, 0.5, H–C(6)); 4.35 (*dddd*, *J* = 7.8, 5.4, 2.7, 0.5, H–C(5)); 4.23 (*dd*, *J* = 11.8, 2.8, H–C(6)); 4.40–4.20 (*m*, 4 H, $P(OCH_2CH_3)_2$); 2.06, 2.05, 2.05 (3 *s*, 3 AcO); 1.35 (*t*,

J(H,P) = 7.1, 3 H, P(OCH$_2$CH_3)$_2$); 1.34 (t, J(H,P) = 7.0, 3 H, P(OCH$_2$CH_3)$_2$). ^{13}C-NMR (100 MHz, $CDCl_3$): 169.90 (s); 169.56 (s); 168.96 (s); 147.28 (d, J(C,P) = 225.2, C(1)); 110.78 (dd, J(C,P) = 22.7, C(2)); 74.66 (dd, J(C,P) = 9.1, C(5)); 66.37 (dd, J(C,P) = 14.6, C(3)); 66.02 (d, C(4)); 62.83 (m, 2 C, 2 POC); 60.47 (t, C(6)); 20.28 (q); 20.18 (q); 20.09 (q); 15.75 (2dq, J(C,P) = 5.8). ^{31}P-NMR (81 MHz, $CDCl_3$): 6.70.

b) *From* **31**: A soln. of **31** (100 mg, 0.213 mmol) was heated to reflux under the following conditions: *i*) with 7-methyl-1,5,7-triazabicyclo[4.4.0]dec-5-ene (MTBD; 51.3 µl, 0.416 mmol, 2 equiv. in toluene (3 ml) for 7h, *ii*) with 2-[(*tert*-butyl)imino]-2-(diethylamino)-perhydro-1,3-dimethyl-1,3,2-diazaphosphorine [26] (BEMP; 123 µl, 0.416 mmol, 2 equiv.) in MeCN (3 ml) for 8 h; *iii*) with $Bu_4NF \cdot 3H_2O$ (202 mg, 0.64 mmol, 3 equiv.) in THF (3 ml) for 2 h. Evaporation and chromatography (SiO_2, AcOEt) gave unseparable **31/33** mixtures (*i*)72 mg, 73% (9:1); *ii*) 34 mg, 36% (58:42); *iii*) 22 mg, 22% (95:5)).

Dimethyl (4-Acetamido-2,3,6,7,8-penta-O-*acetyl-1-bromo-4-deoxy*-D-erythro-*β*-L-gluco-*octopyranosyl)-phosphonate* (**34**). A mixture of **27/28** (60 mg, 0.103 mmol), NBS (55 mg, 0.310 mmol, 3 equiv.), K_2CO_3 (28 mg, 2 equiv.), and abs. CCl_4 (3.5 ml) was irradiated with a 100-W lamp under reflux for 3 h. Evaporation and chromatography (SiO_2, AcOEt/MeOH 95:5 to 90:10) gave **34** (31 mg, 45%) and starting material (9 mg, 15%). R_f (AcOEt/MeOH 9:1) 0.48. $[\alpha]_D^{25}$ = –50.1 (c = 0.79, $CHCl_3$). IR ($CHCl_3$): 3430w, 3000w, 2960w, 2860w, 1750s, 1690s, 1505m, 1430w, 1370s, 1200–1250s (br.), 1140w, 990s, 950m, 890w, 865w, 840w. ^{1}H-NMR (400 MHz, $CDCl_3$): 5.44 (dd, J(H,P) = 6.5, 9.5, H–C(2)); 5.42 (ddd, J = 8.5, 2.1, 1.2, H–C(6)); 5.41 (d, J = 10.2, NH); 5.34 (ddd, J = 10.4, 9.4, 0.9, H–C(3)); 5.14 (ddd, J = 8.5, 5.1, 2.7, H–C(7)); 4.39 (q, J = 10.5, H–C(4)); 4.33 (ddd, J = 11.0, 2.1, 1.6, H–C(5)); 4.31 (dd, J = 12.7, 2.8, H–C(8)); 4.04 (dd, J = 12.6, 5.1, H–C(8)); 3.97 (d, J(H,P) = 10.6, 3 H, P(OMe)$_2$); 3.91 (d, J(H,P) = 10.8, 3 H, P(OMe)$_2$); 2.14, 2.12, 2.10, 2.05, 2.02 (5 s, 5 AcO); 1.92 (s, AcN). ^{13}C-NMR (50 MHz, $CDCl_3$): 170.97 (s); 170.55 (s); 170.17 (s); 179.76 (s); 169.31 (s); 168.90 (s); 96.94 (d, J(C,P) = 195.5); 74.71 (dd, J(C,P) = 11.3); 71.72 (dd, J(C,P) = 12.9); 68.93 (d); 68.74 (dd, J(C,P) = 3.3); 66.22 (d); 61.72 (t); 56.32 (dq, J(C,P) = 7.0); 55.38 (dq, J(C,P) = 7.5); 47.86 (d); 22.94 (q); 21.04 (q); 20.67 (2q); 20.59 (q); 20.50 (q). ^{31}P-NMR (81 MHz, $CDCl_3$): 9.46. CI-MS: 664 (14, $[M + 1]^+$), 662 (14, $[M + 1]^+$), 464 (100).

Dimethyl (4-Acetamido-3,6,7,8-tetra-O-*acetyl-2,4-dideoxy*-D-glycero-D-galacto-*oct-1-enopyranosyl)-phosphonate* (**35**). To a soln. of **34** (29 mg, 0.044 mmol) and EtOH (99.5%, 1 ml), activated Zn/Cu slurry (200 µl; see preparation of **33**) was added under vigourous stirring. After 30 min, the Zn/Cu was filtered off and the filtrate evaporated. The residue was then dissolved in Ac_2O (250 µl) and pyridine (500 µl) and stirred for 3 h at r.t. Evaporation and chromatography (SiO_2, AcOEt/MeOH 92.5:7.5) gave **35** (16.5 mg, 72%). R_f (AcOEt/MeOH 9:1) 0.38. $[\alpha]_D^{25}$ = +36.7 (c = 0.83, $CHCl_3$). IR ($CHCl_3$): 3430w, 3040w, 3000m, 2960m, 2860w, 1745s, 1690s, 1650w, 1540 (sh), 1505m, 1430w, 1370s, 1200–1250s (br.), 1145s, 1100s, 1040s, 950m, 910w, 860m. ^{1}H-NMR (400 MHz, $CDCl_3$): 5.79 (dd, J(H,P) = 10.6, J = 2.7, H–C(2)); 5.56 (d, J = 9.8, NH); 5.55 (dt, J = 8.2, 2.4, H–C(3)); 5.46 (ddd, J = 6.6, 2.8, 1.4, H–C(6)); 5.30 (dt, J = 3.0, 6.3, H–C(7)); 4.40 (dd, J = 12.5, 3.0, 1 H–C(8)); 4.39 (dd, J = 9.8, 3.0, H–C(5)); 4.35 (q, fine struct., J = 8.9, H–C(4)); 4.13 (dd, J = 12.4, 6.1, 1 H–C(8)); 3.82 (d, J(H,P) = 11.3, 3 H, P(OMe)$_2$); 3.78 (d, J(H,P) = 11.2, 3 H, P(OMe)$_2$); 2.13, 21.08, 2.07, 2.05 (4 s, 4 AcO); 1.94 (s, AcN). ^{13}C-NMR (50 MHz, $CDCl_3$): 170.83 (s); 170.53 (s); 170.34 (s); 170.02 (s); 169.71 (s); 146.81 (d, J(C,P) = 228.5); 113.56 (dd, J(C,P) = 23.1); 76.55 (dd, J(C,P) = 7.6); 69.72 (d); 68.22 (dd, J(C,P) = 15.5); 67.19 (d); 61.84 (t); 53.67 (dq, J(C,P) = 6.0); 53.33 (dq, J(C,P) = 5.8); 46.63 (d); 23.09 (q); 20.82 (q); 20.72 (2q); 20.66 (q). ^{31}P-NMR (81 MHz, $CDCl_3$): 9.25. CI-MS: 524 (3, $[M + 1]^+$), 464 (100).

4-Acetamido-2,4-dideoxy-D-glycero-D-galacto-*oct-1-enopyranosyl)phosphonic Acid* (**10**). A soln. of **35** (11.0 mg, 21 µmol) and CH_2Cl_2 (1 ml) was cooled to 0°, and Me_3SiBr (15 µl, 116 µmol, 5.5 equiv.) was added. After stirring for 24 h at 0°, MeOH (5 ml) was added and the soln. evaporated. The residue was dissolved in MeOH (1 ml) and 0.5M NaOMe/MeOH (168 µl, 4 equiv.) added. After stirring for 1 h at r.t., the soln. was filtered through *Dowex 50WX4* (H^+ form) and loaded on a *Dowex 1 × 8* column ($HCOO^-$ form, 10 ml). Elution with a HCOOH gradient (0→1.0M, 200 ml) gave, after freeze-drying, **10** (4.1 mg, 54%). R_f ($PrOH/H_2O$ 7:3) 0.28. ^{1}H-NMR (400 MHz, D_2O): 5.51 (dd, J(H,P) = 9.7, J = 2.2, H–C(2)); 4.46 (dt, J = 8.7, 2.2, H–C(3)); 4.23 (br. d, J = 10.7, H–C(5)); 4.10 (dd, J = 10.7, 9.1, H–C(4)); 3.95 (ddd, J = 9.8, 6.4, 2.6, H–C(7)); 3.92 (dd, J = 12.4, 2.5, H–C(8)); 3.68 (dd, J = 12.1, 6.6, H–C(8)); 3.63 (br. d, J = 9.8, H–C(6)); 2.10 (s, AcN). ^{13}C-NMR (100 MHz, D_2O): 175.08 (s); 151.62 (d, J(C,P) = 212.6, C(1)); 110.65 (dd, J(C,P) = 22.4, C(2)); 76.12 (dd, J(C,P) = 9.2, C(5)); 70.12 (d); 68.61 (d); 67.84 (dd, J(C,P) = 13.5, C(3)); 63.52 (t, C(8)); 50.38 (d, C(4)); 22.37 (q). ^{31}P-NMR (162 MHz, D_2O): 3.55.

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