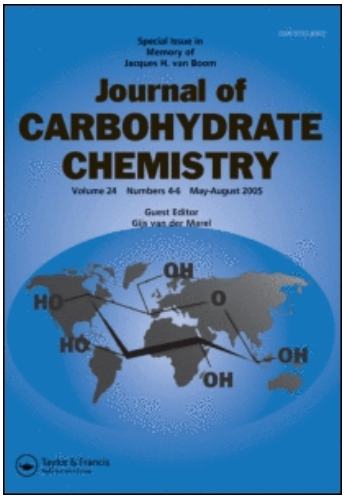

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SYNTHESIS OF SOME NEW 6,7-UNSATURATED OCTURONATES FROM 5-*O*-tert-BUTYLDIMETHYLSILYL-1,2-*O*-ISOPROPYLIDENE-α-D-GLUCO- AND β-L-IDO-HEXODIALDOSE AND THEIR TRANSFORMATION INTO OCTOSES AND OCTITOLS *VIA* OSMYLATION

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ABSTRACT

Carbon chain extensions of 5-*O*-*tert*-butyldimethylsilyl-1,2-*O*-isopropylidene-α-D-*gluco*- and β-L-*ido*-hexodialdose with ethoxycarbonylmethylenetriphenylphosphorane or triethyl phosphonoacetate gave the corresponding α,β-unsaturated octuronic esters, the *(E)/(Z)*-ratios of which strongly depending on the reagent used as well as the starting material. After conventional reduction of the ester moieties the corresponding *O*-acetyl protected allylic alcohols were subjected to osmylation leading to the respective 1,2-*O*-isopropylidene protected octoses, which were subsequently converted to some previously unreported octitols. Unambiguous structure proofs, demonstrating the validity of Kishi's empirical rule for the stereochemical outcome of the osmylation reactions reported, were obtained from the NMR spectroscopic features of these products as well as regiospecific chemical degradations to corresponding known heptitols.

INTRODUCTION

Higher carbon sugars (monosaccharides with seven, eight or more consecutive carbon atoms) have been attracting widespread interest[1] in the past years as such molecules have been found as sub-units or partial structures in a large variety of natural products of biological significance, for example the antibacterial lincomycins,[2] the antifungal ezomycins,[3] the antihelmintic hikizimycin,[4] tunicamycins,[5] KDO (3-deoxy-D-*manno*-2-octulosonic acid),[6] a component of membrane strucures of Gram-negative bacteria, and sialic acids,[7] just to

mention a few. Chain extended monosaccharides have been used as intermediates in the syntheses of many natural products, for example macrolide antibiotics erythromycin[8] and streptovaricin[9] as well as even larger molecules such as palytoxin.[10] They were also employed as precursors of *C*-glycosides[11] and, in their own right, have served as targets to probe modern synthetic methodology for the extension and functionalization of carbon chains in highly substituted molecules.[1,12]

Of the methods employed to access octoses and their derivatives via carbon-carbon bond formation at C-6 of suitable, easily available hexoses and functionalisation of the carbon atoms involved, the Wittig-Horner olefination[13] followed by the osmylation of the newly formed double bond have been demonstrated to be very efficient and reliable. In depth research into this field has been conducted by Brimacombe and coworkers,[14] who, over the past years, have contributed valuable information on the chain-extension of dialdoses,[15] in the D-*galacto*-,[16] the D-*manno*-,[17] and the D-*gluco*-series.[14] In addition, the outcome of osmylation reactions with respect to the validity of Kishi's empirical rule[12a] for such functionally crowded molecules has been investigated by this group.

In context with our interest in the synthesis of analogues of the glucosidase inhibitor castanospermine and related studies we have compared methods for the chain-extension of 5-*O*-*tert*-butyldimethylsilyl-1,2-*O*-isopropylidene-α-D-*gluco*- as well as -β-L-*ido*-hexodialdoses, amongst them a Grignard approach[18] and an application of the Reformatsky reaction.[19]

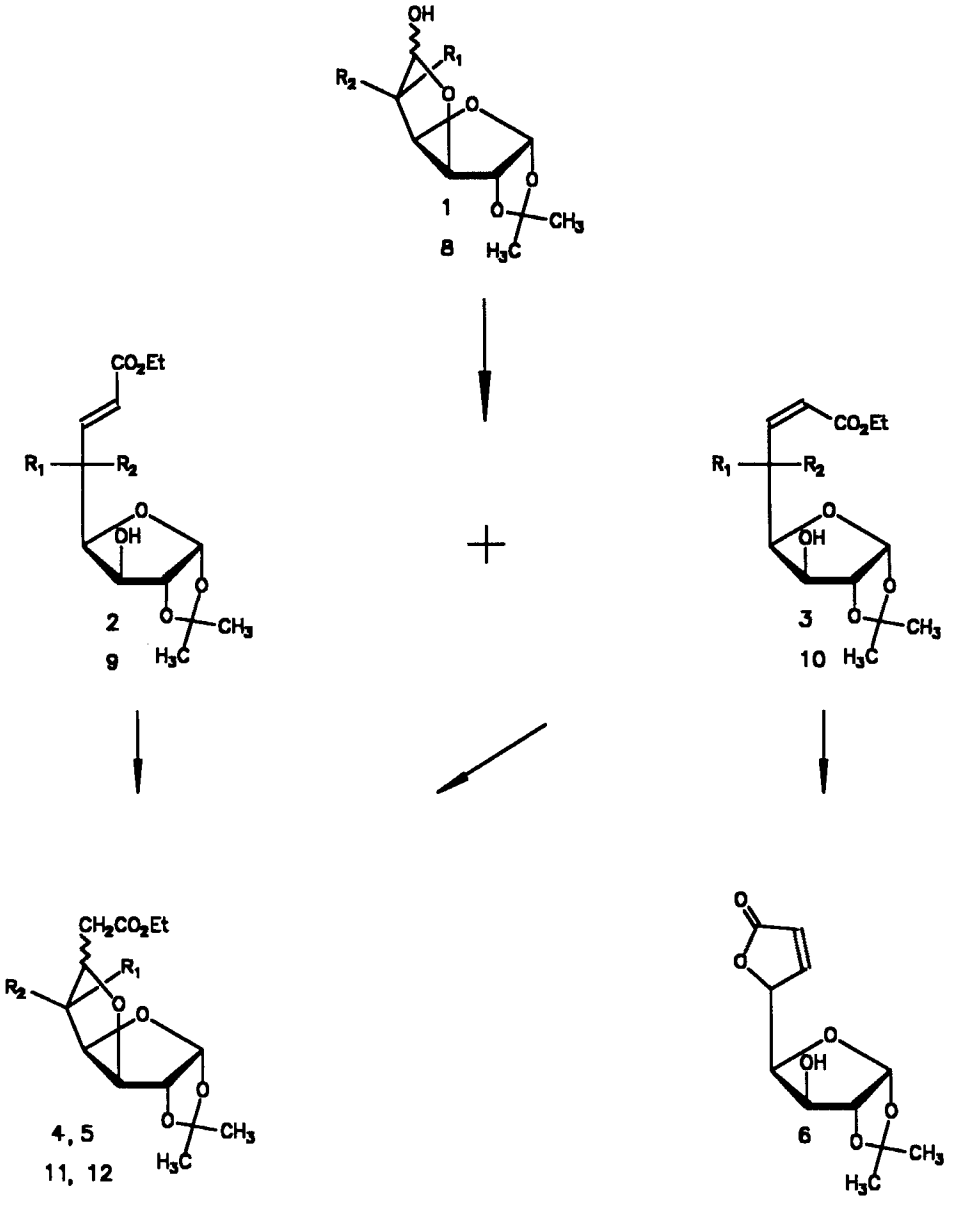
In recent work we have investigated the reactions of 5-*O*-*tert*-butyldimethylsilyl-1,2-*O*-isopropylidene-α-D-*gluco*- (**1**) and -β-L-*ido*-hexodialdose (**8**), respectively, with two different C_2-synthons, namely ethoxycarbonylmethylenetriphenylphosphorane (**A**) and triethyl phosphonoacetate (**B**), as well as the stereochemical outcome of osmylation reactions of the 6,7-unsaturated octoses so obtained.

RESULTS AND DISCUSSION

In the D-*gluco*-series reaction of **1** with two equivalents of phosphorane **A** in tetrahydrofuran at ambient temperature for five days surprisingly gave, after chromatography, the corresponding *(E)*-enoate **2** as the minor product (20%) together with the *(Z)*-enoate **3** (64%) as well as the products of intramolecular 1,4-addition, **4** and **5** (14% combined). Upon storing **3** at ambient temperature this compound was slowly (over weeks) converted into butenolide **6** ($[\alpha]_D$ +105°, *c* 0.9, acetone) due to loss of the protecting group at *O*-5 and intramolecular transesterification (**Scheme 1**).

In contrast, the reaction of **1** with two equivalents of reagent **B** in THF at -50 °C in the presence of 1.8 equivalents of sodium hydride gave, within one hour, the *(E)*-enoate **2** in 84% isolated yield together with traces of the corresponding 3,6-anhydrosugar **4** or **5**. The

SCHEME 1



1,2,3,4,5 R_1 = *O-tert*-butyldimethylsilyl; R_2 = H

8,9,10,11,12 R_1 = H, R_2 = *O-tert*-butyldimethylsilyl

SCHEME 2

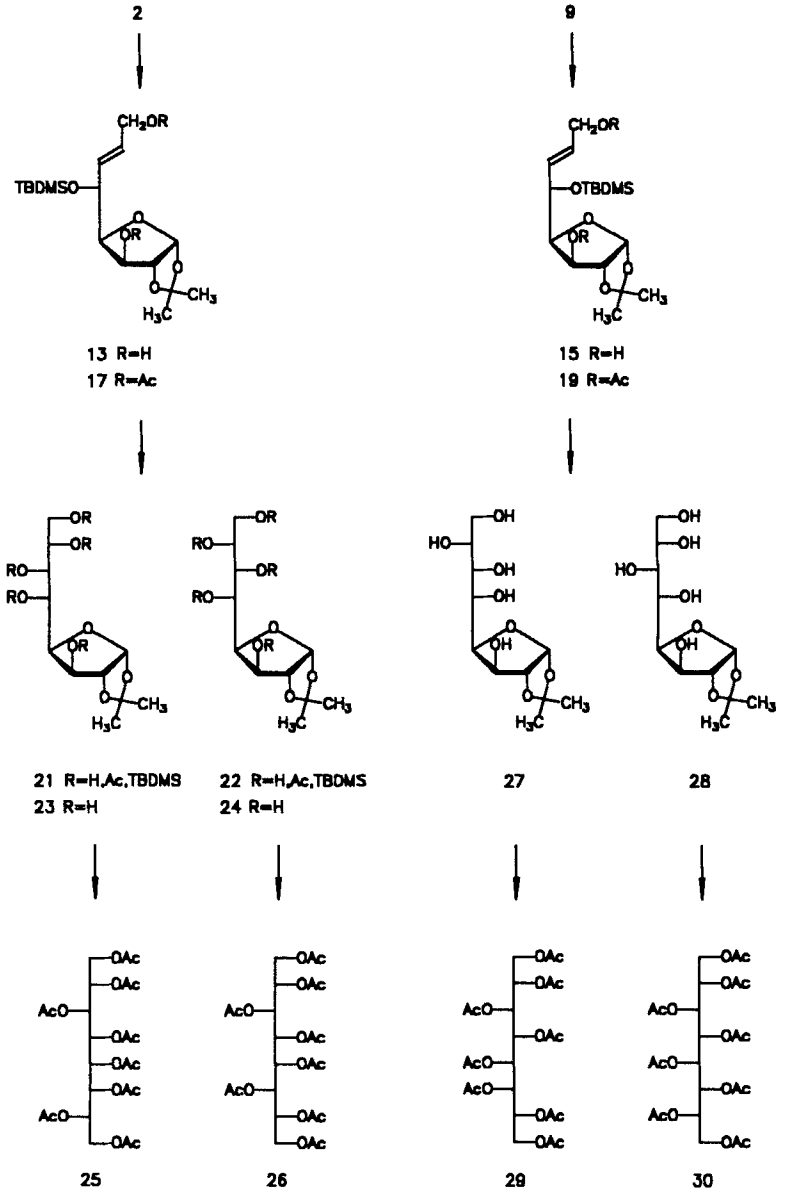
TBDMS = *tert*-butyldimethylsilyl

(Z)-ester **3** was not formed under these conditions. Employing diethylposphonoacetonitrile in this reaction and using the same reaction conditions afforded the corresponding *(E)*-configurated α,β-unsaturated nitrile **7** as the sole product in 81% isolated yield (**Scheme 2**). These findings indicate that in the D-*gluco*-series the two types of reagents, **A** and **B**, nicely complement each other regarding the stereochemical outcome of the 6,7-double bond formation reaction.

In the L-*ido*-series, reaction of dialdose **8** (**Scheme 1**) with phosphorane **A** under the same conditions as those employed for the corresponding chain-extension of **1**, led to the *(E)*-ester **9** as the main product (79% isolated yield) together with *(Z)*-enoate **10** (12%) as well as a mixture of the corresponding 3,6-anhydro derivatives **11** and **12** (6% combined). Interestingly, the configuration at C-5 changes the stereochemical outcome of the double bond formation in this reaction from 3:1 in favour of the *(Z)*-isomer **3** in the D-*gluco*-series to better than 6:1 in favour of the *(E)*-isomer **9** in the L-*ido*-series, under identical reaction conditions. The use of phosphonate **B** as the chain-extension reagent, under the same conditions as in the D-*gluco*-series, again resulted in the exclusive formation of the *(E)*-ester (**9**) in 78% yield after chromatography.

Having the four synthons **2**, **3**, **9**, and **10** at hand, we started an investigation into the stereochemical outcomes of osmylation reactions as a function of the geometry of the respective double bond and the respective configuration at C-5. Initial osmylation attempts with these α,β-unsaturated uronic esters, in our hands, did not give satisfying and reproducible results in terms of yields and stereoselectivities. Consequently, we reduced the

SCHEME 3



TBDMS = *tert*-butyldimethylsilyl

respective carboxylate to the primary allylic alcohol (**13**, **14**, **15**, and **16**, respectively), which in turn (for reasons of solubility and more convenient handling of the corresponding osmylation product) was converted to the corresponding 3,8-diacetate (**17**, **18**, **19**, and **20**, respectively). Catalytic osmylation[12a] of the *(E)*-configurated product in the D-*gluco*-series (**17**) at ambient temperature with OsO_4 in acetone/water in the presence of *N*-methyl morpholine *N*-oxide or (preparatively more convenient) trimethylamine *N*-oxide led to a mixture of the corresponding dihydroxylated products, **21** and **22** (**Scheme 3**). According to Kishi's empirical rule[12a] the L-*threo*-D-*gluco*-octose derivative **21** was expected to be the main product.

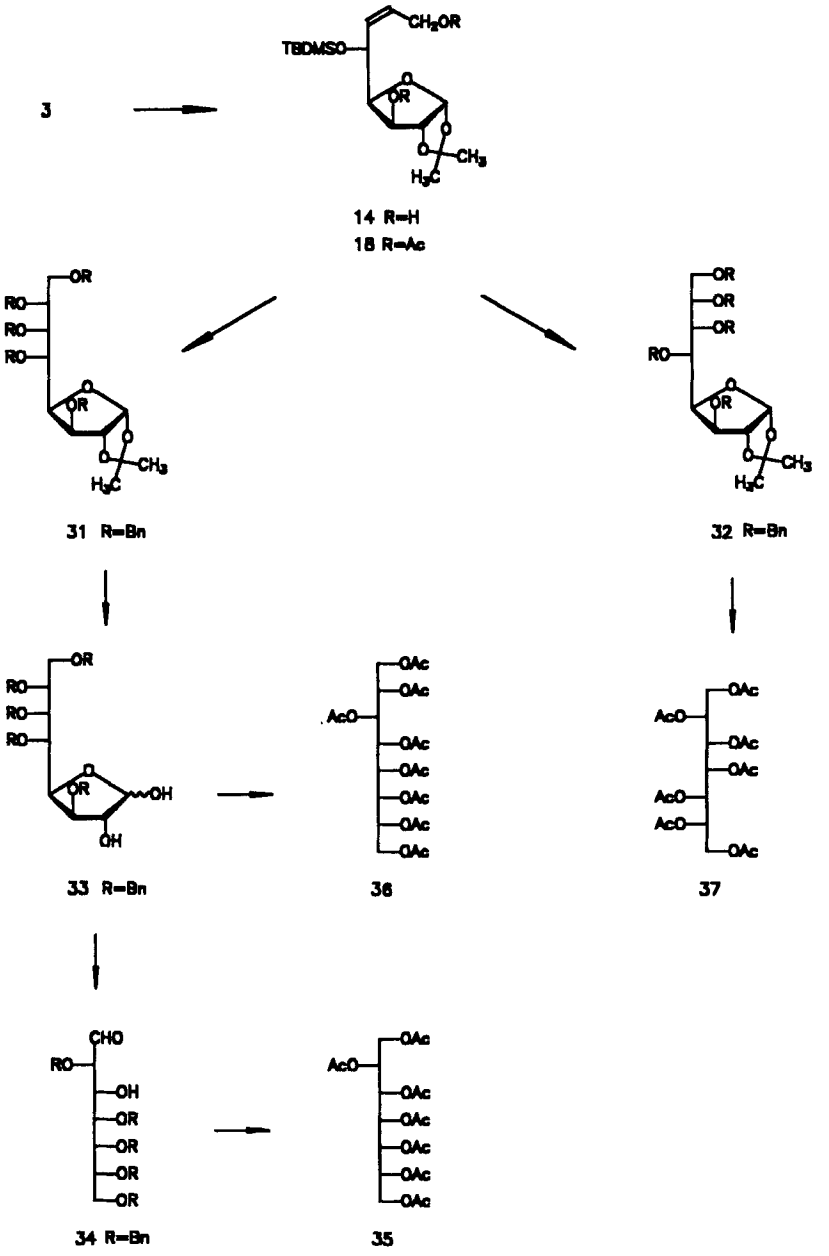
As acetyl migrations were observed under these reaction conditions the products were de-*O*-acetylated with sodium methoxide in methanol in the presence of tetrabutylammonium fluoride, the latter simultaneously removing the silyl group from O-5. This gave an inseparable mixture of the two 1,2-*O*-isopropylidene-protected octofuranoses **23** and **24**, which were per-*O*-acetylated under standard conditions. Unfortunately these two compounds could not be separated at this stage either. The ^1H NMR spectrum of this mixture revealed the ratio of octoses **23**:**24** to be 4:1.

For the determination of the stereochemical outcome of the osmylation reactions we relied on the fact that one of the osmylation products of the respective *(E)*-olefin after deprotection and reduction in the D-*gluco*-series had to give a *meso*-octitol and in the L-*ido*-series an octitol with a C_2-rotation axis as an element of symmetry. Both compounds would exhibit distinctly simplified NMR spectra compared to their "unsymmetrical" isomers. The stereochemistry of the respective "other" stereoisomer in each series could therefore be assigned accordingly.

Following this approach a sample of the above mixture of **23** and **24** was deprotected with ion exchange resin Amberlite IR 120 [H^+] in acetonitrile/water 1:1 (v/v), the mixture of the corresponding unprotected octoses was reduced with sodium borohydride in methanol and the resulting free octitols were *O*-acetylated and chromatographically separated. Due to the simplicity of its NMR spectra and the lack of optical rotation, the minor product could easily be identified as the octaacetate **26** of the known *meso-threo-gluco*-octitol[15] stemming from the corresponding product of osmylation, (partially protected) D-*threo*-D-*gluco*-octofuranose **24**. The main product, as expected, could be identified as the octaacetate of the known L-*threo*-L-*altro*-octitol **25**[17] ($[\alpha]_D$ -30°, $CHCl_3$), derived from L-*threo*-D-*gluco*-octofuranose **23**.

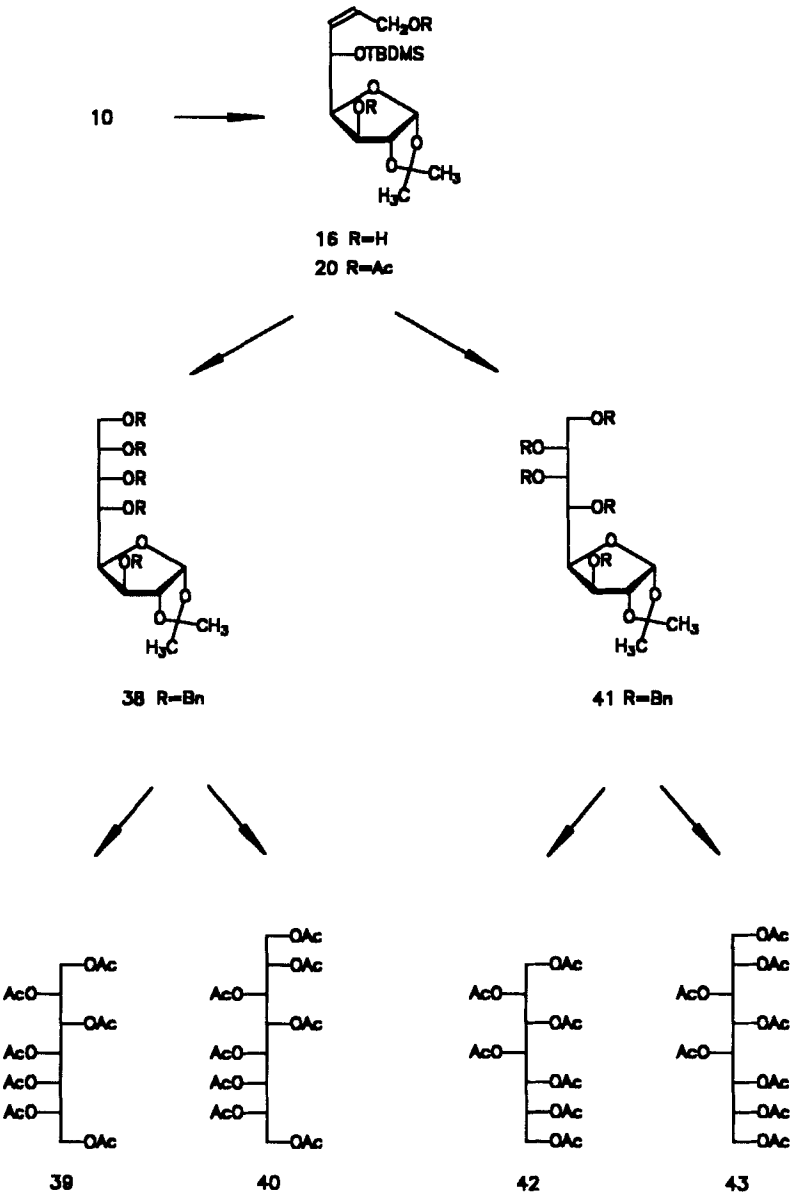
These findings demonstrated that the osmium tetroxide hydroxylation of the *(E)*-ester in the D-*gluco*-series gave the predicted main product, nicely complementing results of Brimacombe and coworkers who had shown that osmylation of the configurationally identical but more rigid tricyclic *(E)*-3,5-*O*-benzylidene-6,7-dideoxy-1,2-*O*-isopropylidene-α-D-*gluco*-

SCHEME 4



TBDMS = *tert*-butyldimethylsilyl; Bn = benzyl.

SCHEME 5



TBDMS = *tert*-butyldimethylsilyl; Bn = benzyl.

oct-6-enofuranuronate did not obey Kishi's empirical rule but gave a D-*threo*-D-*gluco*-octose derivative as the main product.[15]

Catalytic osmylation of the *(E)*-configurated product **19** in the L-*ido*-series, followed by deprotection, again led to an inseparable mixture of the corresponding octoses **27** and **28** (5:1). This, as a mixture, was deprotected, reduced and per-*O*-acetylated to give the new L-*threo*-L-*ido*-octitol octaacetate **30** as the minor product (which again could easily be identified from its NMR spectra by virtue of its C_2-symmetry) the parent octose having been 1,2-*O*-isopropylidene-L-*threo*-L-*ido*-octofuranose **28**. The main product **29** was tentatively assigned to be the octaacetate of L-*threo*-L-*galacto*-octitol (the enantiomer of a compound synthesized by Brimacombe and coworkers[16]), showing D-*threo*-L-*ido*-octofuranose **27** in this case to be the main product of osmylation, which again is in agreement with Kishi's empirical rule. The product ratios in both series were within the expected range of stereoselectivities for the osmylation of isolated *(E)*-configurated double bonds.[12a,17]

As we could not take advantage of a similarily simple approach to assign the structures of the osmylation products of the *(Z)*-olefins in either the D-*gluco*- and the L-*ido*-series we had to resort to chemical degradation of the octoses obtained for this purpose, as depicted in **Schemes 4** to **5**.

Reaction of the *(Z)*-olefin of the D-*gluco*-series **18** with catalytic amounts of osmium tetroxide under standard conditions gave a 3:1 mixture of the corresponding partially acetylated octoses as was evident from the ^{1}H NMR spectrum. De-*O*-acetylation and simultaneous de-*O*-silylation with sodium methoxide in methanol in the presence of tetrabutylammonium fluoride, followed by per-*O*-benzylation with benzyl bromide/sodium hydride in *N,N*-dimethylformamide/tetrahydrofuran, led to the corresponding 1,2-*O*-isopropylidene-3,5,6,7,8-penta-*O*-benzyl-octofuranoses **31** and **32**. These only could be partially separated by chromatography. Removal of the isopropylidene protecting group from the main product, **31**, gave the corresponding partially *O*-benzylated free octofuranose **33** which was treated with sodium metaperiodate to cleave off C-1, and the resulting heptose **34** was immediately reduced to the corresponding penta-*O*-benzylheptitol with sodium borohydride in methanol. De-*O*-benzylation with Pearlman's catalyst (20% $Pd(OH)_2$ on carbon) followed by conventional *O*-acetylation led to a product, identical in its NMR spectroscopic features with the known D-*glycero*-L-*allo*-heptitol heptaacetate **35**.[20] The configuration of the parent octose, the main product of the osmylation, therefore could be assigned to be D-*erythro*-D-*gluco* (the enantiomer of which recently has been synthesized by Vogel and coworkers[1b]) proving the validity of Kishi's rule in this case. To obtain the corresponding, new per-*O*-acetylated D-*erythro*-D-*gluco*-octitol **36**, 3,5,6,7,8-penta-*O*-benzyloctofuranose **33** was deprotected by hydrogenolysis in the presence of Pearlman's

TABLE 1: ^{13}C NMR - Spectroscopic Data of Compounds[a]: Chemical shifts (δ) in ppm.

Compound	*C-1*	*C-2*	*C-3*	*C-4*	*C-5*	*C-6*	*C-7*	*C-8*	*Others*
2	105.0	85.4	75.6	79.9	72.1	145.2	122.7	166.0	111.7, 26.8, 26.1 (isoprop.); 25.7, 18.2 (*tert*-butyl); -4.8 ($SiMe_2$); 60.7, 14.3 (EtO).
3	106.0	85.7	76.3	79.7	70.2	146.9	121.6	165.5	111.9, 27.2, 26.6 (isoprop.); 25.8, 18.7 (*tert*-butyl); -4.9 ($SiMe_2$); 60.8, 14.4 (EtO).
4	107.3	85.6	82.6	84.6	77.8	76.9	37.6	171.0	112.4, 27.6, 27.0 (isoprop.); 26.6, 18.4 (*tert*-butyl); -4.3, -4.6 ($SiMe_2$): 60.9, 14.4 (EtO)
6[b]	106.0	86.1	80.5	82.4	75.1	157.5	121.9	173.0	112.2, 27.0, 26.3 (isoprop.);
7	105.0	85.3	75.5	80.1	71.6	152.5	101.3	117.1	112.1, 26.7, 26.3 (isoprop.); 25.8, 18.3 (*tert*-butyl); -4.7, -4.9 ($SiMe_2$).
9	105.1	85.6	75.9	83.0	71.7	147.2	122.1	166.8	112.0, 27.0, 26.5 (isoprop.); 26.0, 18.5 (*tert*-butyl); -4.6 ($SiMe_2$); 60.8, 14.5 (EtO).
10	105.3	85.3	75.9	82.3	68.7	148.3	120.4	167.3	111.8, 27.0, 26.5 (isoprop.); 26.0, 18.4 (*tert*-butyl); -4.2, -4.5 ($SiMe_2$); 61.4, 14.4 (EtO).
11	106.8	88.4	84.6	84.9	79.2	76.1	34.4	171.4	112.5, 27.6, 26.9 (isoprop.); 25.9, 18.2 (*tert*-butyl); -4.4, -5.0 ($SiMe_2$); 60.8, 14.4 (EtO)

13	105.2	85.7	76.1	80.7	73.7	132.2[c]	129.1[c]	63.0	112.5, 27.1, 26.4 (isoprop.); 25.9, 18.4 (*tert*-butyl); -4.5, -4.8 ($SiMe_2$).
14	105.0	85.5	75.3	81.2	69.6	131.7[c]	131.3[c]	58.4	111.8, 26.7, 26.2 (isoprop.); 25.7, 18.0 (*tert*-butyl); -4.8, -4.9 ($SiMe_2$).
17	105.0	83.1	76.4	81.8	70.1	135.0[c]	127.1[c]	64.3	112.3, 26.8, 26.4 (isoprop.); 25.9, 18.1 (*tert*-butyl); -4.8, -4.2 ($SiMe_2$); 170.7, 169.9, 21.2, 21.0 (Ac).
18	105.0	83.4	76.5	81.5	65.9	134.9[c]	126.8[c]	61.0	112.4, 26.9, 26.5 (isoprop.); 26.1, 18.6 (*tert*-butyl); -3.7, -4.9 ($SiMe_2$); 170.0, 21.4, 21.1 (Ac).
19	105.0	83.9	76.8	82.7	71.9	133.1[c]	126.6[c]	64.3	112.4, 27.0, 26.7 (isoprop.); 26.1, 18.6 (*tert*-butyl); -4.3 ($SiMe_2$); 170.9,169.1, 21.0 (Ac).
20	105.1	83.8	77.2	82.3	67.6	133.1[c]	126.5[c]	60.6	112.6, 26.7, 26.4 (isoprop.); 25.7, 18.3 (*tert*-butyl); -3.8, -4.6 ($SiMe_2$); 170.6, 20.9, 20.8 (Ac).

[a] In $CDCl_3$, if not stated otherwise; [b] in acetone-d_6; [c] assignments in horizontal lines could be interchanged.
Ac, acetyl; EtO, CH_3CH_2O; isoprop., isopropylidene.

TABLE 2: ^{1}H NMR - Spectroscopic Data of Compounds[a]: Chemical Shifts (δ) in ppm, Multiplicities.

Compound	*H-1*	*H-2*	*H-3*	*H-4*	*H-5*	*H-6*	*H-7*	*H-8*	*H-8´*	*Isopropylidene*	*Others*
2	5.88 *d*	4.40 *d*	4.14 *d*	3.97 *dd*	4.83 *dd*	6.94 *dd*	6.08 *d*	----	----	1.38, 1.23 *2s*	$SiMe_2$: 0.06(*s*), 0.03(*s*); *tert*-butyl: 0.85(*s*); EtO: 4.07 - 4.19(*m*), 1.18(*t*); OH-3: 4.44(*d*, 2.7Hz).
3	5.93 *d*	4.46 *d*	4.23 *d*	4.08 *dd*	5.84 *m*	6.28 *m*	5.87 *dd*	----	----	1.44, 1.29 *2s*	$SiMe_2$: 0.11(*s*), 0.07(*s*); *tert*-butyl: 0.86(*s*); EtO: 4.14 - 4.20(*m*), 1.27(*t*); OH-3: 4.94(*d*, 3.6Hz).
4	5.96 *d*	4.49 *d*	4.55 *d*	4.60 *dd*	3.89 *dd*	4.02 ***ddd***	2.62/ 2.37 *dd*	----	----	1.45, 1.29 *2s*	$SiMe_2$: 0.11(*s*), 0.09(*s*); *tert*-butyl: 0.89(*s*); EtO: 4.13(*q*), 1.24(*t*).
6[b]	5.93 *d*	4.59 *dd*	4.34 *dd*	4.02 *dd*	5.33 *ddd*	7.82 *ddd*	6.20 *dd*	----	----	1.40, 1.28 *2s*	OH-3: 4.94(*d*)
7	5.89 *d*	4.43 *d*	4.18 *dd*	3.95 *dd*	4.79 *ddd*	6.86 *dd*	5.71 *dd*	----	----	1.44, 1.27 *2s*	$SiMe_2$: 0.11(*s*), 0.06(*s*); *tert*-butyl: 0.94(*s*); OH-3: 3.82(*d*)
9	5.96 *d*	4.46 *d*	4.19 *dd*	3.96 *dd*	4.66 *ddd*	7.13 *dd*	6.14 *dd*	----	----	1.47, 1.30 *2s*	$SiMe_2$: 0.13(*s*), 0.09(*s*); *tert*-butyl: 0.89(*s*); EtO: 4.16 - 4.24(*m*), 1.27(*t*); OH-3: 2.83(*d*, 4.6Hz).
10	5.97 *d*	4.47 *d*	4.12 *dd*	4.06 *dd*	5.57 *dd*	6.24 *dd*	5.90 *d*	----	----	1.46, 1.30 *2s*	$SiMe_2$: 0.10(*s*), 0.07(*s*); *tert*-butyl: 0.88(*s*); EtO: 4.21(*q*), 1.30(*t*); OH-3: 4.57(*d*, 2.0Hz).
11	5.86 *d*	4.59 *d*	4.62 *d*	4.57 *dd*	4.25 *dd*	4.36 *ddd*	2.61 *m*	----	----	1.49, 1.32 *2s*	$SiMe_2$: 0.11(*s*), 0.05(*s*); *tert*-butyl: 0.89(*s*); EtO: 4.15(*q*), 1.26(*t*).
13	5.96 *d*	4.48 *d*	4.29 *bs*	3.98 *dd*	4.78 *bs*	5.83 *dd*	6.00 *m*		4.21 *bs*	1.48, 1.31 *2s*	$SiMe_2$: 0.13(*s*), 0.09(*s*); *tert*-butyl: 0.89(*s*); OH-3: 4.90(*d*, 2.5Hz), OH-8: 1.77(*bs*)

14	5.93	4.39	4.30	3.89	4.99	5.64	5.79	4.18	1.46, 1.30	$SiMe_2$: 0.11(*s*), 0.09(*s*); *tert*-butyl: 0.89(*s*);
	d	*d*	*dd*	*bs*	*dd*	*m*	*m*	*m*	*2s*	OH-3: 4.49(*d*, 3.6Hz); OH-8: 2.28(*m*).
17	5.84	4.44	5.11	4.04	4.33	5.78	5.83	4.55	1.49, 1.26	$SiMe_2$: 0.11(*s*), 0.08(*s*); *tert*-butyl: 0.81(*s*);
	d	*d*	*d*	*dd*	*ddd*	*dd*	*dd*	*d*	*2s*	OAc: 2.07(*s*), 2.03(*s*).
18	5.82	4.47	5.16	4.08	4.78	5.61	5.70	4.83 4.56	1.51, 1.29	$SiMe_2$: 0.04(*s*), 0.02(*s*); *tert*-butyl: 0.84(*s*);
	d	*d*	*d*	*dd*	*dd*	*dd*	*ddd*	*dd* *dd*	*2s*	OAc: 2.14(*s*), 2.08(*s*).
19	5.92	4.45	5.08	4.11	4.34	5.69	5.84	4.54	1.51, 1.30	$SiMe_2$: 0.11(*s*), 0.07(*s*); *tert*-butyl: 0.90(*s*);
	d	*d*	*d*	*dd*	*m*	*dd*	*ddd*	*m*	*2s*	OAc: 2.09(*s*), 2.06(*s*).
20	5.91	4.45	5.01	4.23	4.66	5.55 - 5.67		4.77 4.53	1.52, 1.30	$SiMe_2$: 0.11(*s*), 0.08(*s*); *tert*-butyl: 0.89(*s*);
	d	*d*	*d*	*dd*	*dd*	*m*		*dd* *dd*	*2s*	OAc: 2.13(*s*), 2.07(*s*).

[a] In $CDCl_3$, if not stated otherwise; [b] in acetone-d_6: *bs*, broad signal; *d*, doublet; *dd*, doublet of doublets; *m*, multiplet; *q*, quartet; *s*, singlet; *t*, triplet; *n.r.*, not resolved.

TABLE 3: ^{1}H NMR Spectroscopic Data of Compounds: Coupling Constants in Hz

Compound	$J_{1,2}$	$J_{3,4}$	$J_{4,5}$	$J_{5,6}$	$J_{5,7}$	$J_{6,7}$	$J_{7,8}$	$J_{7,8'}$	$J_{8,8'}$
2	3.6	3.0	4.2	4.5	1.8	15.7	----	----	----
3	3.6	2.9	2.8	8.3	1.2	11.6	----	----	----
4	3.7	3.7	3.9	8.6	n.r.	8.0/ 3.5	----	----	----
6	3.6	2.9	7.1	1.8	1.8	5.8	----	----	----
7	3.4	2.7	4.3	4.0	2.0	16.2	----	----	----
9	3.6	2.7	6.6	4.4	1.8	15.6	----	----	----
10	3.7	2.2	6.2	9.0	n.r.	11.6	----	----	----
11	3.6	3.3	<1	3.0	n.r.	6.8	----	----	----
13	3.7	2.8	n.r.	5.5	n.r.	15.6	n.r.	n.r.	n.r.
14	3.7	2.7	4.8	8.8	n.r.	10.6	n.r.	n.r.	n.r.
17	3.7	2.7	8.7	4.5	2.1	15.4	4.3	4.3	0.0
18	3.7	2.8	9.1	8.7	n.r.	11.2	8.2	4.9	13.8
19	3.7	3.1	7.5	6.8	n.r.	15.7	5.8	5.8	0.0
20	3.9	3.4	7.5	7.5	n.r.	12.0	6.0	4.6	12.8

$J_{2,3}$ < 0.5 Hz; n.r., not sufficiently resolved.

catalyst and reduced with sodium borohydride in methanol. The free octitol was *O*-acetylated under standard conditions. The minor product therefore was assigned to have the L-*erythro*-D-*gluco*-configuration, which was confirmed after degradation of penta-*O*-benzyloctofuranose **32** by the same sequence of steps to L-*glycero*-L-*galacto*-heptitol heptaacetate **37**, its NMR spectra matching those of its enantiomer.[20]

In the L-*ido*-series hydroxylation of the *(Z)*-olefin **20** gave a 10:1 mixture of the corresponding octofuranoses which, as a mixture, were simultaneously de-*O*-acetylated and de-*O*-silylated, followed by conventional *O*-benzylation. After chromatographic separation the main product **38** was degraded to give L-*glycero*-L-*gluco*-heptitol heptaacetate **39** exhibiting the same ^{1}H and ^{13}C NMR spectra as its enantiomer.[20] The configuration of the parent octose therefore was shown to be L-*erythro*-L-*ido* in agreement with the prediction according to Kishi´s rule. The corresponding octitol **40**, L-*erythro*-L-*ido*-octitol, was obtained as the octaacetate by the same sequence as for the synthesis of octitol **36**. The D-*erythro*-L-*ido*-configuration of the minor osmylation product of the L-*ido*-configurated *(Z)*-olefin **20** was confirmed by analogous degradation of the corresponding penta-*O*-benzyloctofuranose **41** to the known D-*glycero*-L-*gulo*-heptitol heptaacetate **42**.[20]

These results show that for the series of oct-6-enofuranoses under consideration, osmylation of the double bond in the D-*gluco*- as well as in the L-*ido*-series always followed Kishi´s empirical rule, the main product in each case having an *erythro*-relationship between the substituent at C-5 and the newly introduced hydroxyl group at C-6. The product ratios in both, the D-gluco- as well as the L-ido-series, were generally found to be within the expected range,[12a,17] peaking in the case of the osmylation of the (Z)-olefin in the L-ido-series.

EXPERIMENTAL

General Methods

Melting points were determined on a Tottoli-apparatus (BÜCHI) and are uncorrected. TLC was performed on precoated aluminium sheets (Merck 5554) and column chromatography was conducted on Silica Gel 60, 230-400 mesh (Merck 9305) with the solvent systems given in the respective procedure. Optical rotations were measured using a JASCO Digital Polarimeter (DIP 370). NMR spectra were recorded on a BRUKER MSL 300 Spectrometer at 300 MHz (^{1}H) and at 75.47 MHz (^{13}C) with tetramethylsilane or residual protonated solvent as the internal standards.

General Procedures

General procedure for reactions with ethoxycarbonylmethylenetriphenylphosphorane (reagent A). - To a 5% solution of the respective partially protected dialdose in tetrahydrofuran, ethoxycarbonylmethylenetriphenylphosphorane (2 equivalents) was added

and the mixture was stirred at ambient temperature for five days (TLC: petroleum ether/ethyl acetate 2:1, v/v). Dichloromethane (250 mL) was added and the organic layer was consecutively washed with 5% aqueous HCl and 5% aqueous sodium bicarbonate. After drying (sodium sulfate), filtration and concentration of the organic layer under reduced pressure the components of the residue were separated by column chromatography (petroleum ether/ethyl acetate 15:1, v/v).

General procedure for reactions with triethyl phosphonoacetate (reagent B). - To a 10% solution of triethyl phosphonoacetate (2 equivalents) in tetrahydrofuran, sodium hydride (1.8 equivalents) was added, the clear solution was stirred at ambient temperature for one hour and added to a 5% solution of the respective starting material in tetrahydrofuran at -50 °C. The mixture was kept at this temperature for one hour, diluted with dichloromethane and consecutively washed with 5% aqueous HCl and 5% aqueous sodium bicarbonate, dried (sodium sulfate) and concentrated under reduced pressure. Chromatography (petroleum ether/ethyl acetate 15:1, v/v) of the residue led to the respective products.

General procedure for reductions with diisobutylaluminium hydride (DIBAH). - To a 5% solution of the respective ester in dry dichloromethane DIBAH (2.2 equivalents, 1M in toluene) was added at 0 °C. After 30 min the mixture was diluted with dichloromethane and washed with 5% aqueous HCl and 5% aqueous sodium bicarbonate . The organic layer was dried (sodium sulfate) and concentrated under reduced pressure. Chromatography (petroleum ether/ethyl acetate 3:1, v/v; TLC petroleum ether/ethyl acetate 1:1, v/v) of the residue gave the respective allylic alcohol.

General procedure for *O*-acetylations. - To a 10% solution of the respective alcohol in pyridine, acetic anhydride (2 equivalents per free OH-group) and a catalytic amount of *N,N*-dimethylaminopyridine were added and the mixture was kept at ambient temperature until no starting material could be detected by TLC (petrol ether/ethyl acetate 1:1, v/v). Methanol was added and after 30 min the mixture was concentrated. The residue was dissolved in dichloromethane and the organic layer was consecutively washed with 5% aqueous HCl and aqueous sodium bicarbonate. After drying the solution was concentrated under reduced pressure and the remaining residue was chromatographed.

General procedure for dihydroxylations with osmium tetroxide. - To a 5% solution of the respective eno-sugar and *N*-methylmorpholine *N*-oxide or triethylamine *N*-oxide (2.4 equivalents) in acetone/water (8:1, v/v) a catalytic amount of osmium tetroxide was added and the clear, yellow mixture was stirred at ambient temperature until no more starting material could be detected by TLC (petroleum ether/ethyl acetate 1:1, v/v). Sodium sulfide was added, the dark suspension was stirred for 30 min, filtered and concentrated under reduced pressure. The residue was purified on silica gel (petroleum ether/ethyl acetate 1:1).

General deprotection procedure. - To a 5% solution of the respective 5-*O*-silylated partially acetylated 1,2-*O*-isopropylidene-octofuranose in tetrahydrofuran sodium methoxide (1.5 equivalents, 1M in methanol) and tetrabutylammonium fluoride trihydrate (1.5 equivalents, 1M in tetrahydrofuran) were added and the solution was kept at 40 °C for 48 h to remove the *tert*-butyldimethylsilyl and the acetyl groups simultaneously. The mixture was concentrated under reduced pressure, twice co-evaporated with toluene and the residue was immediately used in the next step (TLC ethyl acetate/methanol 3:1, v/v).

General procedure for the removal of the 1,2-*O*-isopropylidene group. - A 5% solution of the respective protected sugar in acetonitrile/water (1:1, v/v) was stirred with Amberlite IR 120 [H^+] at 40 °C until TLC showed that all starting material had been converted to a more polar product. The ion exchange resin was removed by filtration, the filtrate was concentrated under reduced pressure and the residue was used immediately for the next step.

General procedure for reductions with sodium borohydride. - To a stirred suspension of sodium borohydride (10 equivalents) in methanol the respective starting material was added as a 10% solution in the same solvent at 0 °C and the mixture was allowed to reach ambient temperature. In case of non-polar products excess ethyl acetate was added to the mixture to destroy excess reducing agent, the reaction mixture was diluted with dichloromethane, washed consecutively with 5% aqueous HCl and 5% aqueous sodium bicarbonate solution, dried (sodium sulfate) and concentrated under reduced pressure. The residue was subjected to chromatography.

In case of water-soluble polyols, acidic ion exchange resin Amberlite IR 120 [H^+] was added to the reaction mixture. After 20 min the resin was filtered off and the filtrate was concentrated under reduced pressure. The residue was dissolved in dry methanol and the solution was again concentrated *in vacuo* (twice). The remaining material was either chromatographed or immediately subjected to *O*-acetylation according to the respective general procedure.

General procedure for *O*-benzylations. - To a 10% solution of the respective penta-hydroxy sugar in *N,N*-dimethylformamide, sodium hydride (10 equivalents) and benzyl bromide (1.6 equivalents per free OH-group) were added and the mixture was stirred at ambient temperature for 16 h. Methanol was added carefully to destroy excess sodium hydride, the brown suspension was diluted with dichloromethane, washed with 5% aqueous HCl and sodium bicarbonate solution and dried (sodium sulfate). After filtration the filtrate was concentrated under reduced pressure and the brown residue was subjected to chromatography (petroleum ether/ethyl acetate 15:1).

General procedure for reactions with sodium metaperiodate. - A 10% solution of the respective 1,2-unprotected octofuranose in ether was stirred with a solution of sodium

metaperiodate (10 equivalents) in water until all starting material was converted to less polar products (TLC). The ethereal phase was separated and the aqueous layer was washed three times with ether. The combined organic layers were dried (sodium sulfate) and after filtration and concentration under reduced pressure the crude residue was taken into the next step.

General procedure for catalytic hydrogenations with Pearlman's catalyst. - To a 10% solution of the respective free sugar in methanol, Pearlman's catalyst [20% $Pd(OH)_2$ on carbon, 50 mg] and a few drops of acetic acid were added and the mixture was shaken on a PARR-apparatus under an atmosphere of hydrogen (4 bar) for 16 h. After removal of the catalyst the filtrate was concentrated under reduced pressure and the residue was submitted to the next step.

***(E)*- and *(Z)*-Ethyl 5-*O*-*tert*-Butyldimethylsilyl-6,7-dideoxy-1,2-*O*-isopropylidene-α-D-*gluco*-oct-6-enofuranuronate (2) and (3). With Reagent A.** 5-*O*-*tert*-Butyldimethylsilyl-1,2-*O*-isopropylidene-α-D-*gluco*-hexodialdofuranose **1**[18] (6.0 g, 18 mmol) was reacted with ethoxycarbonylmethylenetriphenylphosphorane according to the respective general procedure. Chromatography gave *(Z)*-enoate **3** (4.63 g, 64%), as a colourless syrup, $[\alpha]_D$ 0° (*c* 1.6, chloroform). For NMR data see Tables 1 to 3.

Anal. Calcd for $C_{19}H_{34}O_7Si$: C, 56.69; H, 8.51. Found: C, 56.50; H, 8.67.

Further fractions contained the corresponding *(E)*-enoate **2** (1.43 g, 20%), also a colourless syrup, $[\alpha]_D$ -20.2° (*c* 1.2, chloroform). For NMR data see Tables 1 to 3.

Anal. Calcd for $C_{19}H_{34}O_7Si$: C, 56.69; H, 8.51. Found: C, 56.79; H, 8.58.

From the remaining mixture of products of 1,4-addition of O-3 to C-6, **4** and **5** (in total 1.0 g, 14%), the 6-*(R)*-configurated isomer could be isolated as a slightly yellow oil, $[\alpha]_D$ +63.2° (*c* 1.3, chloroform). For NMR data of compound **4** see Tables 1 to 3.

Anal. Calcd for $C_{19}H_{34}O_7Si$: C, 56.69; H, 8.51. Found: C, 56.55; H, 8.71.

***(E)*-Ethyl 5-*O*-*tert*-Butyldimethylsilyl-6,7-dideoxy-1,2-*O*-isopropylidene-α-D-*gluco*-oct-6-enofuranuronate (2). With Reagent B.** Reaction of partially protected dialdose **1** (4.4 g, 13.2 mmol) following the general procedure gave *(E)*-uronate **2** (4.46 g, 84%) and traces of the side-products **4** and **5**.

***(E)*-5-*O*-*tert*-Butyldimethylsilyl-6,7-dideoxy-1,2-*O*-isopropylidene-α-D-*gluco*-oct-6-enofuranurononitrile (7).** Reaction of **1** (1.25 g, 3.8 mmol) with diethylphosphonoacetonitrile applying the general procedure for reactions with triethyl phosphonoacetate gave the corresponding α,β-unsaturated nitrile **7**, $[\alpha]_D$ -8.5° (*c* 0.8, chloroform), as the sole product (1.08 g, 81%). For NMR data see Tables 1 to 3.

Anal. Calcd for $C_{17}H_{29}NO_5Si$: C, 57.44; H, 8.22. Found: C, 57.41; H, 8.29.

***(E)*- and *(Z)*-Ethyl 5-*O*-*tert*-Butyldimethylsilyl-6,7-dideoxy-1,2-*O*-isopropylidene-β-L-*ido*-oct-6-enofuranuronate (9) and (10). With Reagent A.** Applying the respective general procedure L-*ido*-dialdose **8**[18] (1.5g, 4.5 mmol), after chromatography, gave *(E)*-ester **9**

(1.42 g, 79%), a colourless syrup, $[\alpha]_D$ -14° (*c* 1.1, chloroform) as the main product. For NMR data see Tables 1 to 3.

Anal. Calcd for $C_{19}H_{34}O_7Si$: C, 56.69; H, 8.51. Found: C, 56.55; H, 8.60.

(Z)-ester **10** was also isolated as a syrup (220 mg, 12%), $[\alpha]_D$ +29.6° (*c* 1.1, chloroform). For NMR data see Tables 1 to 3.

Anal. Calcd for $C_{19}H_{34}O_7Si$: C, 56.69; H 8.51. Found: C, 56.39; H, 8.44.

A mixture of the corresponding 1,4-addition products **11** and **12** (combined 110 mg, 6%) was obtained as a slightly yellow oil and not further investigated. For NMR data of **11** see Tables 1 to 3.

***(E)*-Ethyl 5-*O*-*tert*-Butyldimethylsilyl-6,7-dideoxy-1,2-*O*-isopropylidene-β-L-*ido*-oct-6-enofuranuronate (9). With Reagent B.** Subjecting L-*ido*-dialdose **8**[18] to the general procedure led to enoate **9** as the only product in 78% yield after chromatography.

***(E)*-5-*O*-*tert*-Butyldimethylsilyl-6,7-dideoxy-1,2-*O*-isopropylidene-α-D-*gluco*-oct-6-enofuranose (13).** Application of the general procedure for DIBAH-reductions to **2** (5.6 g, 13.9 mmol) led to crystalline alcohol **13** (4.91 g, 90%), mp 86-90°, $[\alpha]_D$ -15.3° (*c* 1.3, chloroform). For NMR data see Tables 1 to 3.

Anal. Calcd for $C_{17}H_{32}O_6Si$: C, 56.64; H, 8.95. Found: C, 56.58; H, 9.07.

***(Z)*-5-*O*-*tert*-Butyldimethylsilyl-6,7-dideoxy-1,2-*O*-isopropylidene-α-D-*gluco*-oct-6-enofuranose (14).** Application of the general procedure for DIBAH-reductions to **3** (5.0 g, 12.4 mmol) gave syrupy diol **14** (3.85 g, 86%), $[\alpha]_D$ -21.1° (*c* 2.6, chloroform). For NMR data see Tables 1 to 3.

Anal. Calcd for $C_{17}H_{32}O_6Si$: C, 56.64; H, 8.95. Found: C, 56.63; H, 9.03.

***(E)*-3,8-Di-*O*-acetyl-5-*O*-*tert*-butyldimethylsilyl-6,7-dideoxy-1,2-*O*-isopropylidene-α-D-*gluco*-oct-6-enofuranose (17).** Reaction of **13** (4.9 g, 13.6 mmol) according to the general *O*-acetylation procedure gave oily diacetate **17** (5.92 g, 98%), $[\alpha]_D$ -23.4° (*c* 1.6, chloroform). For NMR data see Tables 1 to 3.

Anal. Calcd for $C_{21}H_{36}O_8Si$: C, 56.73; H, 8.16. Found: C, 56.63; H, 8.11.

***(Z)*-3,8-Di-*O*-acetyl-5-*O*-*tert*-butyldimethylsilyl-6,7-dideoxy-1,2-*O*-isopropylidene-α-D-*gluco*-oct-6-enofuranose (18).** Application of the general *O*-acetylation procedure to **14** (3.8 g, 10.5 mmol) gave *(Z)*-diacetate **18** (4.8 g, 97%) as a white foam, $[\alpha]_D$ -53.1° (*c* 1.2, chloroform). For NMR data see Tables 1 to 3.

Anal. Calcd for $C_{21}H_{36}O_8Si$: C. 56.73; H, 8.16. Found: C, 56.81, H, 8.24.

***(E)*-3,8-Di-*O*-acetyl-5-*O*-*tert*-butyldimethylsilyl-6,7-dideoxy-1,2-*O*-isopropylidene-β-L-*ido*-oct-6-enofuranose (19).** Applying the general procedure for DIBAH-reductions to *(E)-ido*-enoate **9** (5.0 g, 12.4 mmol) followed by the general *O*-acetylation procedure applied to the resulting diol **15** gave diacetate **19** (4.87 g, 88%) as an oil, $[\alpha]_D$ -15.6° (*c* 0.9, chloroform). For NMR data see Tables 1 to 3.

Anal. Calcd for $C_{21}H_{36}O_8Si$: C, 56.73; H, 8.16. Found: C, 56.59; H, 8.15.

***(Z)*-3,8-Di-*O*-acetyl-5-*O*-*tert*-butyldimethylsilyl-6,7-dideoxy-1,2-*O*-isopropylidene-β-L-*ido*-oct-6-enofuranose (20).** Reaction of *(Z)-ido*-enoate **10** (5.2 g, 12.9 mmol) according to the general procedure for reductions with DIBAH and followed by the general *O*-acetylation procedure furnished syrupy diacetate **20** (4.9 g, 85%), $[\alpha]_D$ -13° (*c* 0.8, chloroform). For NMR data see Tables 1 to 3.

Anal. Calcd for $C_{21}H_{36}O_8Si$: C, 56.73; H, 8.16. Found: C, 56.82; H, 8.28.

3,8-Di-*O*-acetyl-5-*O*-*tert*-butyldimethylsilyl-1,2-*O*-isopropylidene-β-L-*threo*-D-*gluco*-octofuranose (21) and 3,8-Di-*O*-acetyl-5-*O*-*tert*-butyldimethylsilyl-1,2-*O*-isopropylidene-α-D-*threo*-D-*gluco*-octofuranose (22). Submission of unsaturated diacetate **17** (220 mg, 0.49 mmol) to the general procedure for osmylations gave an inseparable mixture of the corresponding dihydroxylated octofuranoses **21** and **22**, which was taken into the next step.

1,2-*O*-Isopropylidene-β-L-*threo*-D-*gluco*-octofuranose (23) and 1,2-*O*-Isopropylidene-α-D-*threo*-D-*gluco*-octofuranose (24). Application of the general deprotection procedure to the mixture of partially protected octoses **21** and **22** gave a mixture of compounds **23** and **24**, which could not be separated at this stage. Conventional *O*-acetylation gave a 4:1-mixture of **23**-pentaacetate (^{1}H NMR: H-1, 5.92 ppm; $J_{1,2}$ = 3.5 Hz) and **24**-pentaacetate (H-1, 5.97 ppm; $J_{1,2}$ = 3.4 Hz). ^{13}C NMR (δ in ppm): **23-pentaacetate**: 105.7 (C-1), 83.0, 76.8, 75.3, 70.8, 69.4, 67.5 (C-2 to C-7), 62.5 (C-8); 112.9, 27.0, 26.6 (isopropylidene); **24-pentaacetate**: 105.3 (C-1), 83.4, 77.2, 74.7, 70.0, 69.4, 67.3 (C-2 to C-7), 62.2 (C-8); 112.7, 26.9, 26.6 (isopropylidene); the acetyl groups gave the expected signals.

1,2,3,4,5,6,7,8-Octa-*O*-acetyl-L-*threo*-L-*altro*-octitol (25) and 1,2,3,4,5,6,7,8-Octa-*O*-acetyl-*meso*-*threo*-*gluco*-octitol (26). Deprotection of a mixture of **23** and **24** following the general procedure for the removal of the isopropylidene group gave a mixture of the two corresponding free octoses, which, in turn, were immediately reduced with sodium borohydride in methanol according to the respective general procedure and the resulting material was subjected to the general *O*-acetylation procedure (TLC petroleum ether/ethyl acetate 1:2, v/v). Chromatography (petroleum ether/ethyl acetate 1:1, v/v) of the products gave per-*O*-acetylated octitol **25** (40 mg, 14% from **17**), $[\alpha]_D$ -30.0° (*c* 0.7, chloroform) as the main product. ^{13}C NMR: δ 70.7, 69.4, 68.7 (2 carbons), 68.2 (C-2 to C-7), 62.3, 61.5 (C-1, C-8); the signals of the acetyl groups are displayed in the expected regions; ^{1}H NMR: δ 5.37-5.29 (m, 5 H), 4.95 (dd, 1 H), 4.22-4.17 (m, 2 H, H-1, H-8), 3.90-3.83 (m, 2 H, H-1′, H-8′), 2.18-1.93 (8 s, 3 H each, acetyl).

Anal. Calcd for $C_{24}H_{34}O_{16}$: C, 49.83; H, 5.92. Found: C, 49.69; H, 5.88.

The minor product was *meso*-compound **26** (15 mg, 5.3% from **17**). ^{13}C NMR: δ 69.7, 68.3, 67.9 (C-2 to C-7), 62.2 (C-1, C-8); ^{1}H NMR: δ 5.35 (bd, 2 H), 5.26 (bs, 2 H), 5.12 (m, 2 H), 4.36 (dd, 2 H, J_{vic} = 3.4 Hz; J_{gem} = 12.3 Hz, H-1, H-8), 4.15 (dd, 2 H,

J_{vic} = 5.5 Hz; J_{gem} = 12.3 Hz, H-1′, H-8′); the resonances of the acetyl groups appear in the expected regions.

Anal. Calcd for $C_{24}H_{34}O_{16}$: C, 49.83; H, 5.92. Found: C, 49.75; H, 6.00.

1,2-*O*-Isopropylidene-α-D-*threo*-L-*ido*-octofuranose (27) and 1,2-*O*-isopropylidene-β-L-*threo*-L-*ido*-octofuranose (28). Application of the general osmylation conditions to allylic acetate **19** (230 mg, 0.52 mmol), followed by the general deprotection procedure led to a mixture of penta-ols **27** and **28** from which a sample of the hygroscopic main product **27** could be isolated after chromatography (petroleum ether/ethyl acetate 3:2, v/v). It had $[\alpha]_D$ -12.6° (*c* 0.8, water). ^{13}C NMR: δ 105.7 (C-1), 82.5 C-2), 78.9 (C-3), 80.6 (C-4), 72.2, 71.6 (C-5, C-6),71.3 (C-7), 64.5 (C-8); 112.9, 26.9, 26.3 (isopropylidene); ^1H NMR: δ 6.01 (d, 1 H, H-1, $J_{1,2}$ = 3.4 Hz), 4.49 (d, 1 H, H-2), 4.35 (d, 1 H, H-3, $J_{3,4}$ = 2.6 Hz), 4.25 (d, 1 H, H-4), 4.04 (d, 1 H, H-5, $J_{5,6}$ = 9.4 Hz), 3.60 (d, 1 H, H-6), 3.86 (m, 1 H, H-7), 3.62 (m, $J_{7,8}$ = $J_{7,8'}$ = 6.1 Hz).

Anal. Calcd for $C_{11}H_{20}O_8$: C, 47.14; H, 7.22. Found: C, 46.86; H, 7.29.

1,2,3,4,5,6,7,8-Octa-*O*-acetyl-L-*threo*-L-*galacto*-octitol (29) and 1,2,3,4,5,6,7,8-Octa-*O*-acetyl-L-*threo*-L-*ido*-octitol (30). Submission of the crude mixture of octoses **27** and **28** to the sequence of the general procedures for the removal of the isopropylidene group, for sodium borohydride reductions, and the *O*-acetylation gave a mixture of the two octitol peracetates (TLC petroleum ether/ethyl acetate 1:2, v/v) from which **29** (56 mg, 19% from **19**) was isolated (LC petroleum ether/ethyl acetate 1:1, v/v) as the main product.
It had $[\alpha]_D$ -13.9° (*c* 0.7, chloroform). ^{13}C NMR: δ 68.8, 68.4, 67.9, 67.7, 67.4, 67.2 (C-2 to C-7), 62.3, 61.9 (C-1, C-8); ^1H NMR: δ 5.53 (m, 1 H), 5.30 (dd, 1 H, J_{vic} = 8.4 Hz; J_{vic} = 1 Hz), 5.20 (m, 1 H), 5.1 (m, 2 H), 5.04 (dd, 1 H, J_{vic} = 9.3 Hz; J_{vic} = 2.2 Hz), 4.20 (dd, 1 H, J_{gem} = 11.7 Hz; J_{vic} = 4.7 Hz), 4.04 (dd, 1 H, J_{gem} = 11.5 Hz; J_{vic} = 5.6 Hz), 3.96 (dd, 1 H, J_{gem} = 11.5 Hz; J_{vic} = 6.5 Hz), 3.76 (dd, 1 H, J_{gem} = 11.7 Hz; J_{vic} = 7.7 Hz); the resonances of the acetyl groups are displayed in the expected regions.

Anal. Calcd for $C_{24}H_{34}O_{16}$: C, 49.83; H, 5.92. Found: C, 49.76; H, 5.90.

The minor product was octitol **30** (12 mg, 4% from **19**), $[\alpha]_D$ -15.6° (*c* 0.62, chloroform). ^{13}C NMR: δ 69.2, 68.9, 68.6 (C-2 to C-7), 61.9 (C-1, C-8); ^1H NMR: δ 5.35 (m, 2 H), 5.28 (m, 2 H), 5.21 (m, 2 H), 4.23 (dd, 2 H, J_{gem} = 11.9 Hz; J_{vic} = 4.6 Hz, H-1, H-8), 3.95 (dd, 2 H, J_{gem} = 11.9 Hz; J_{vic} = 5.8 Hz, H-1′, H-8′); the acetyl groups exhibit their resonances in the expected regions.

Anal. Calcd for $C_{24}H_{34}O_{16}$: C, 49.83; H, 5.92. Found: C, 49.89; H, 6.03.

3,5,6,7,8-Penta-*O*-benzyl-1,2-*O*-isopropylidene-α-D-*erythro*-D-*gluco*-octofuranose (31) and 3,5,6,7,8-Penta-*O*-benzyl-1,2-*O*-isopropylidene-β-L-*erythro*-D-*gluco*-octofuranose (32). Osmylation of *(Z)*-diacetate **18** (200 mg, 0.45 mmol), followed by the general deprotection procedure and the general procedure for *O*-benzylations gave a difficult to separate mixture

of the two fully protected octofuranoses **31** and **32** (TLC petroleum ether/ethyl acetate 3:1, v/v), from which a pure sample of main product **31** could be obtained by chromatography (petroleum ether/ethyl acetate 15:1, v/v). The mixture was taken into the next step. **31**: ^{13}C NMR: δ 139.4, 139.35, 139.3 (*ipso*-carbons of benzyl groups), 129.0-127.7 (other aromatic carbons of benzyl groups), 83.0, 81.8, 79.3 (2 carbons), 78.5 (2 carbons), 73.9, 73.5, 72.9, 72.8, 72.1, 70.4 (C-2 to C-8, 5 CH_2-Ph); ^1H NMR: δ 5.90 (d, 1 H, H-1, $J_{1,2}$ = 3.7 Hz), 4.58 (d, 1 H, H-2), 4.14 (d, 1H, H-3, $J_{3,4}$ = 3 Hz), 4.88-4.02 (m, 13 H, H-4, H-5, H-6, 5 CH_2Ph), 4.05 (ddd, 1 H, H-7, $J_{6,7}$ = 4.9 Hz; $J_{7,8}$ = 1.8 Hz; $J_{7,8'}$ = 4.7 Hz), 3.83 (dd, 1 H, H-8, $J_{8,8'}$ = 11 Hz), 3.69 (dd, 1 H, H-8'); the remaining protecting groups exhibit the expected resonances.

Degradation of 3,5,6,7,8-Penta-*O*-benzyl-1,2-*O*-isopropylidene-α-D-*erythro*-D-*gluco*-octofuranose (31) to 1,2,3,4,5,6,7-Hepta-*O*-acetyl-D-*glycero*-L-*allo*-heptitol (35). Removal of the isopropylidene protecting group from fully protected octose **31** gave 1,2-unprotected octose **33** (TLC petroleum ether/ethyl acetate 1:1), which was degraded following the general procedure for reactions with sodium metaperiodate, to the corresponding 2,4,5,6,7-penta-*O*-benzyl-heptose **34** (TLC petroleum ether/ethyl acetate 1:1, v/v). This intermediate, without purification, was subjected to the general hydrogenolysis procedure and the sodium borohydride reduction (TLC methanol) followed by the general procedure for *O*-acetylations to give, after chromatographic purification (petroleum ether/ethyl acetate 1:1, v/v), title compound **35**.[20]

1,2,3,4,5,6,7,8-Octa-*O*-acetyl-D-*erythro*-D-*gluco*-octitol (36). Hydrogenolysis of 1,2-unprotected octose **33** to the corresponding free octose applying the general hydrogenolysis procedure, followed by submission of this intermediate to the general procedure for reductions with sodium borohydride gave a crude material which was conventionally *O*-acetylated to give, after chromatographic purification, per-*O*-acetylated octitol **36** (31 mg, 12% from **18**), $[\alpha]_D$ +8.4° (*c* 1.5, chloroform). ^{13}C NMR: δ 70.3, 70.1, 69.5, 69.2, 69.1 (C-2 to C-7), 62.1, 61.9 (C-1, C-8); ^1H NMR: δ 5.41 (m, 2 H), 5.29 (m, 3 H), 5.16 (m, 1 H), 4.32 (dd, 1 H, J_{gem} = 12.1 Hz; J_{vic} = 3.1 Hz), 4.31 (dd, 1 H, J_{gem} = 11.8 Hz, J_{vic} = 4.8 Hz), 4.03 (dd, 1 H, J_{gem} = 12.1 Hz, J_{vic} = 6.5 Hz), 3.96 (dd, 1 H, J_{gem} = 11.8 Hz, J_{vic} = 6.1 Hz); the acetyl groups exhibit their resonances at the expected values.

Anal. Calcd for $C_{24}H_{34}O_{16}$: C, 49.83, H, 5.92. Found: C, 49.77; H, 5.97.

Degradation of 3,5,6,7,8-Penta-*O*-benzyl-1,2-*O*-isopropylidene-β-L-*erythro*-D-*gluco*-octose (32) to 1,2,3,4,5,6,7-Hepta-*O*-acetyl-L-*glycero*-L-*galacto*-heptitol (37). Applying essentially the same sequence of reactions as described for the preparation of heptitol **35** to octofuranose **32** gave **37** as a colourless glass displaying the same NMR spectroscopic features as have been reported for its enantiomer.[20]

3,5,6,7,8-Penta-*O*-benzyl-1,2-*O*-isopropylidene-β-L-*erythro*-L-*ido*-octofuranose (38) and 3,5,6,7,8-Penta-*O*-benzyl-1,2-*O*-isopropylidene-α-D-*erythro*-L-*ido*-octofuranose (41). Application of the same sequence of reactions as for the synthesis of *O*-benzylated octofuranoses **31** and **32** to oct-6-enofuranose **20** (390 mg, 0.88 mmol) gave a mixture of fully protected octoses **38** and **41**, which could be separated chromatographically. The main product **38** (265 mg, 41%) was a colourless oil, $[\alpha]_D$ -23.5° (*c* 1.5, chloroform). ^{13}C NMR: δ 139.9, 139.25, 139.2, 138.0 (*ipso*-carbons of the benzyl groups), 129.0-127.6 (other aromatic carbons of the benzyl groups), 105.1 (C-1), 83.6, 82.8, 82.5, 79.3, 78.6, 78.1, 74.4, 73.6, 72.6, 72.4, 72.0, 70.2 (C-2 to C-8, 5 CH_2Ph); ^1H NMR: δ 5.98 (d, 1 H, H-1, $J_{1,2}$ = 3.8 Hz), 4.59 (d, 1 H, H-2), 4.09 (d, 1 H, H-3, $J_{3,4}$ = 3.4 Hz), 4.51 (dd, 1 H, H-4, $J_{4,5}$ = 7.7 Hz), 4.12 (dd, 1 H, H-5, $J_{5,6}$ = 3.3 Hz), 3.78 (dd, 1 H, H-6, $J_{6,7}$ = 6.8 Hz), 3.99 (ddd, 1 H, H-7, $J_{7,8}$ = 2.7 Hz; $J_{7,8'}$ = 4.4 Hz), 3.73 (dd, 1 H, H-8, $J_{8,8'}$ = 10.5 Hz), 3.70 (dd, 1 H, H-8′); the remaining protecting groups exhibit the expected resonances.

Anal. Calcd for $C_{46}H_{50}O_8$: C, 75.59; H, 6.89. Found: C, 75.60; H, 6.98.

The minor product **41** (28 mg, 4.4%) was also an oil, $[\alpha]_D$ -4.1° (*c* 0.1, chloroform).

Anal. Calcd for $C_{46}H_{50}O_8$: C, 75.59; H, 6.89. Found: C, 75.49; H, 6,91.

Degradation of 3,5,6,7,8-Penta-*O*-benzyl-β-L-*erythro*-L-*ido*-octofuranose (38) to 1,2,3,4,5,6,7-Hepta-*O*-acetyl-L-*glycero*-L-*gluco*-heptitol (39). The same sequence of steps as employed for the synthesis of heptitol **35** from octose **31** applied to fully protected octose **38** led to the heptitol heptaacetate **39** exhibiting the same NMR spectroscopic characteristics as its enantiomer.[20]

1,2,3,4,5,6,7,8-Octa-*O*-acetyl-L-*erythro*-L-*ido*-octitol (40). Application of the same protocol as for the synthesis of octitol **36** from octose **31** to octofuranose **38** (725 mg) gave the title compound **40** (66 mg, 11.5%) as a colourless glass, $[\alpha]_D$ -19° (*c* 1.1, chloroform). ^{13}C NMR: δ 70.0, 69.3, 69.1 (2 carbons), 68.8, 68.5 (C-2 to C-7), 62.2, 61.9 (C-1, C-8); ^1H NMR: δ 5.43 (m, 2 H), 5.36 (dd, 1 H, J_{vic} = 3.8 Hz; J_{vic} = 7.1 Hz), 5.26 (dd, 1 H, J_{vic} = 4.1 Hz; J_{vic} = 7.1 Hz), 5.20 (m, 1 H), 5.12 (dd, 1 H, J_{vic} = 4.4 Hz; J_{vic} = 6.9 Hz), 4.31 (dd, 1 H, J_{gem} = 12.1 Hz, J_{vic} = 3.3 Hz), 4.23 (dd, 1 H, J_{gem} = 11.9 Hz; J_{vic} = 4.5 Hz), 4.15 (dd, 1 H, J_{gem} = 12.1 Hz; J_{vic} = 6.5 Hz), 4.00 (dd, 1 H, J_{gem} = 11.9 Hz; J_{vic} = 6.6 Hz); the resonances of the acetyl groups appear at the expected positions.

Anal. Calcd for $C_{24}H_{34}O_{16}$: C, 49.83; H, 5.92. Found: C, 49.78; H, 5.88.

Degradation of 3,5,6,7,8-Penta-*O*-benzyl-1,2-*O*-isopropylidene-α-D-*erythro*-L-*ido*-octofuranose (41) to 1,2,3,4,5,6,7-Hepta-*O*-acetyl-D-*glycero*-L-*gulo*-heptitol (42). Subjecting octose **41** to the same sequence of steps as described for the preparation of heptitol **35** from compound **31**, furnished a colourless glass exhibiting NMR spectroscopic features identical with the ones reported from per-*O*-acetylated heptitol **42**.[20]

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