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Easy Access to *C*-Glycosides from Aldonolactones by a Claisen-Type Chain-Extension Reaction

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Abstract: Chain elongated 2,4-diuloses **2**, **4**, **6**, **9-11**, **24**, **25** were conveniently obtained from the corresponding aldonolactones **1**, **3**, **5** by their reaction with carbonyl compounds in the presence of sodium hydride. These hemiacetalic products can be transformed into *C*-glycosides by deoxygenation with $Et_3SiH/BF_3{\cdot}Et_2O$.

INTRODUCTION

Carbohydrates have long been a source of scientific interest due to the synthetic challenges paired with their polyhydroxylated structures. The commercial use of carbohydrates, however, has been greatly limited by the hydrolytic lability of the glycosidic bond. *C*-Glycosides overcome this limitation and represent valuable starting materials for new generations of carbohydrate-based products. *C*-Glycoside as well as *C*-nucleoside chemistry has recently attracted much attention[1] and have been studied as stable pharmacophores [2], β-glucosidase [3, 4] and β-galactosidase inhibitors [5-7], fucosyltransferase inhibitors [8], as well as *C*-glycosidic analogs of Lipid A and Lipid X [9], virustatics [10], leucotriene and as LTD_4 antagonists.[11]

C-Glycosides have been prepared by numerous different approaches among them electrophilic and nucleophilic sugar substitutions, transition metal mediated *C*-glycosidations, they were accessed from anomeric radicals, by rearrangements, cycloadditions as well as by a broad diversity of sugar ring transformations.[11]

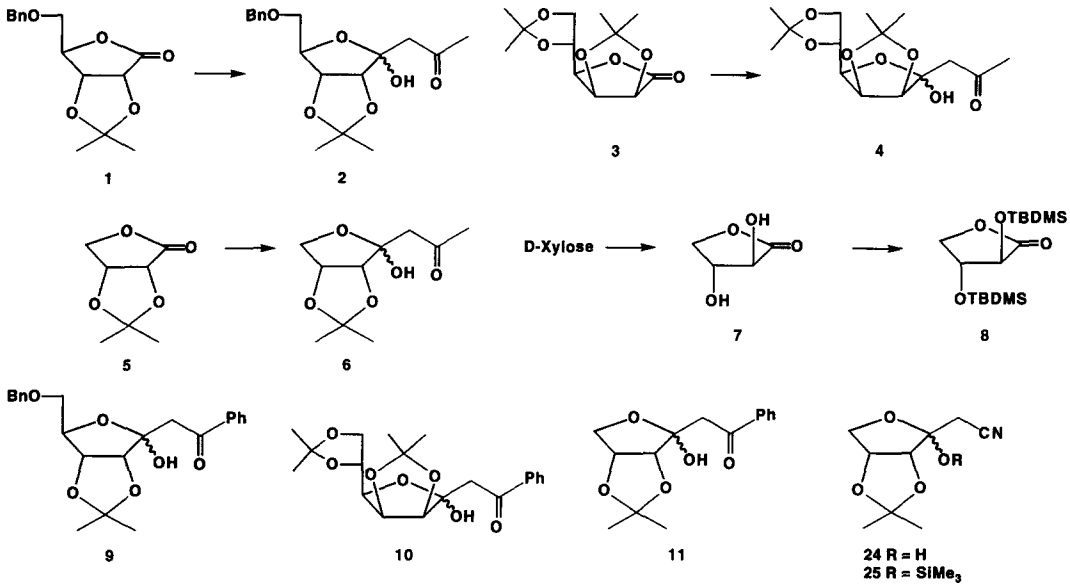
The use of readily available sugar lactones [12], however, for nucleophilic additions followed by lactol reduction has been limited to the addition of alkyl/aryl lithium reagents [13, 14], Grignard reactions [15], Reformatsky-type reactions [16] and more recently to the fluoride anion mediated reaction of α-trimethylsilylated esters and -nitriles [17], zinc-mediated Dreiding-Schmidt reactions [18] as well as to the reaction with trimethylsilyl ketene acetals.[19, 20]

RESULTS AND DISCUSSION

Carboxylic esters can be treated in the presence of suitable bases with ketones to give β-diketones in a reaction similar to the Claisen condensation. Interestingly enough, to the best of our knowledge this very

convenient reaction has never been applied in the carbohydrate field for the easy and extraordinary cheap preparation of *C*-glycosides and derivatives thereof.

Thus, reaction of 5-*O*-benzyl-2,3-*O*-isopropylidene-D-ribono-1,4-lactone (**1**)[21] with acetone in the presence of sodium hydride gave in a very clean reaction the chain elongated hemi acetal **2** in 95% yield. **2** is characterized in its IR spectrum by a strong band at $\nu = 3390$ cm^{-1} for the anomeric hydroxyl group and at $\nu = 1705$ cm^{-1} for the carbonyl moiety that is also found in the ^{13}C NMR spectrum at $\delta = 207.54$ ppm. Similarly from the protected mannono lactone[22] **3** a 49% yield of **4** was obtained. Yields somewhat dropped for the reaction of acetone/sodium hydride with the 2,3-*O*-isopropylidene-D-erythrono-1,4-lactone (**5**)[23] and only 21% of **6** were obtained. No product could be isolated from the reaction of the silylated D-threono-1,4-lactone derivative **8** due to huge deterioration of the starting material under a variety of different reaction conditions. **8** can be easily obtained in large quantities by the silylation of D-threono-1,4-lactone[24] (**7**) with *tert.* butyl dimethyl chlorosilane in pyridine in the presence of catalytic amounts of 4-dimethylamino-pyridine.



The obtained yields were lower for the reaction of the lactones with acetophenone as compared to their reaction with acetone. Thus, only a moderate yield was obtained for the reaction of **1** affording **9** (66%) and from **3** 64% of **10** could be isolated. Finally, yields again dropped for **5** to give only 19% of **11** whereas with the pyranoid lactone **12** firstly a chain extension was observed that was followed by a trans-acetalization reaction and **13** was obtained in 89% yield. **13** is characterized in its IR spectrum by the presence of two characteristic bands at $\nu = 1607$ cm^{-1} and 1575 cm^{-1}, respectively. **13** showed no signal for a hydroxyl group but in the ^{1}H NMR a signal at $\delta = 6.75$ ppm was detected; the presence of only one CH_2-group in the ^{13}C NMR spectrum at $\delta = 66.36$ ppm and the presence of an olefinic CH-moiety at $\delta = 182.58$ ppm clearly established the tautomeric form **14**. The starting material of this reaction **12** was obtained from D-ribono-1,4-lactone (**15**) by the reaction with 2,2-dimethoxy-propane in the presence of catalytical amounts of *p*-toluene

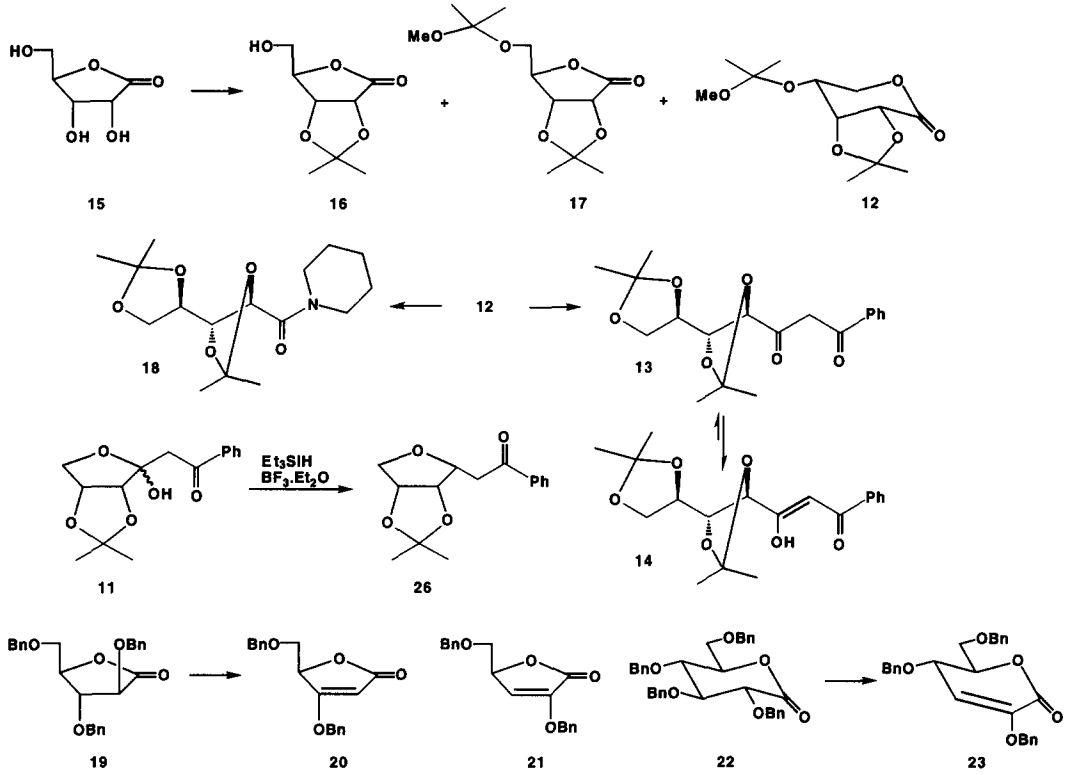
sulfonic acid.[25] Whereas the acetalization of **15** with acetone/conc. sulfuric acid[26, 27] cleanly leads to 2,3-*O*-isopropylidene-D-ribono-1,4-lactone (**16**) in good yield, the acetalization with 2,2-dimethoxy-propane leads to a mixture of **16**, the furanoid derivative **17** and pyranoid **12** in the ratio of 23:40:37. 2,3-*O*-Isopropylidene-5-*O*-(1-methoxy-1-methylethyl)-D-ribono-1,4-lactone (**17**) results from the reaction of already formed **16** with the excess of the 2,2-dimethoxypropane and is characterized in its ^{1}H NMR spectrum by the presence of 4 methyl groups at δ = 1.27, 1.30, 1.33 and 1.40 ppm, respectively. 2,3-*O*-Isopropylidene-4-*O*-(1-methoxy-1-methyl-ethyl)-D-*ribono*-1,5-lactone (**12**) shows in its ^{1}H NMR spectrum also 4 methyl groups (δ = 1.25, 1.31, 1.34 and 1.50 ppm) as well as one methoxy group (δ = 3.70 ppm). An unambiguous assignment of all signals was performed on the basis of first order spin analysis, H,H-COSY and H,C-COSY spectra and verification of the obtained spectral parameters was performed using the PERCH program. The quaternary carbons of **12** showed in the ^{13}C spectra chemical shifts of δ = 109.7 and 110.9 ppm, respectively, thus excluding the alternate structure of a 3,5-*O*-isopropylidene-2-*O*-(1-methoxy-1-methylethyl)-D-ribono-1,4-lactone. Aminolysis of **12** with piperidine afforded **18** whose structure was established by a combination of several spectroscopic experiments. In addition, the MS spectrum of **18** shows a signal at m/e=101 that is typical for 1,2-*O*-isopropylidenated compounds.

The 2,3,5-tri-*O*-benzyl-D-arabino-1,4-lactone[28] (**19**) gave upon reaction with acetophenone/sodium hydride not a chain elongated product but **20** as a product of an elimination reaction. **20** shows in the IR spectrum the presence of a carbonyl group at ν = 1762 cm^{-1} that is also found in the ^{13}C NMR spectrum at δ = 167.22 ppm. An olefinic CH-group was found in the ^{1}H NMR spectrum at δ = 6.49 ppm and two signals for the HC=C moiety were detected in the ^{13}C NMR spectra at δ = 146.59 and δ = 115.39 ppm, respectively. The formation of **20** seems somewhat unusual since under basic conditions from **19** or 2,3,5-tri-*O*-benzyl-D-ribono-1,4-lactone always a butenolide, 2,5-di-O-benzyl-3-deoxy-D-glycero-pent-2-enono-1,4-lactone (**21**) is formed.[29] The formation of a 2-substituted 2-eno-lactone is observed, however, upon treatment of 2,3,4,6-tetra-*O*-benzyl-D-glucono-1,5-lactone[30] (**22**) with sodium hydride/acetophenone to afford the α,β-unsaturated lactone **23** in 95% yield.[31]

As exemplified for the reaction of **5** with acetonitrile/sodium hydride this type of elongation reaction can be extended to the use of nitriles instead of a ketone.[32] Thus, **5** gave a 64% yield of **24**. **24** is characterized by its hydroxylic signal in the IR at ν = 3402 cm^{-1} and a signal at ν = 2270 cm^{-1} that is typical for nitriles. The nitrile group was also observed in the ^{13}C NMR spectrum at δ = 116.25 ppm. Silylation of **24** gave **25** which has already been independently prepared by the reaction of **5** with trimethylsilyl acetonitrile in the presence of fluoride anion.[17]

The advantage of this unexpectedly easy and cheap method resides in the convenient transformation of these hemiacetalic chain elongation products into β-functionalized *C*-glycosides as exemplified for **11**. Thus, treatment of **11** with triethylsilane[33] in the presence of $BF_3.Et_2O$ resulted in the formation of **26** in 60% yield. **26** is characterized in its IR spectrum by a carbonyl band at ν = 1681 cm^{-1} corresponding in the ^{13}C NMR to a signal at δ = 197.70 ppm. As for the determination of the absolute configuration of the newly created stereogenic center, extensive NMR experiments were performed. Thus, a first assignment of all signals was performed by H,H-COSY and H,C-COSY experiments. The $^4J_{H\text{-}C(1),H_B\text{-}C(4)}$ = –0.6 Hz is typical for a W-arrangement of these protons H-C(4) shows only a coupling with H_B-C(4) but no coupling was detected to H-C(3); this can only be rationalized by assuming a torsion angle of approx. 90° between these two protons. Since both $^3J_{H\text{-}C(1),H\text{-}C(2)}$ and $^3J_{H\text{-}C(3),H_B\text{-}C(4)}$ shows 3,6 Hz, H-C(1) and H_B-C(4) must possess the same

relative orientation. This assumption was ascertained by a 2D-NOESY spectrum showing strong NOE-effects between H-C(1)/H-C(2), H-C(1)/H_B-C(4) as well as between H-C(3)/H-C(2) and H-C(3)/H_B-C(4) thus locating all these substituents onto the same side of the molecule. Since the configuration at C(2) and C(3) is known, the CH_2-X elongation at the anomeric centre has to be α-oriented.



In conclusion, a convenient method for the construction of *C*-glycosides and their hemiacetalic precursors has been elaborated from easily accessible aldonolactones. These valuable intermediates are presently in consideration to be used for synthetic approaches to milbemycins [34, 35] and for the construction of the 22,23-dihydroavermectin B1b aglycon. [36, 37]

EXPERIMENTAL

Melting points are uncorrected (*Reichert* hot stage microscope), optical rotations were obtained using a Perkin-Elmer 243B polarimeter (1 cm micro-cell), NMR spectra (internal Me_4Si) were recorded using either a Bruker AM250, a Varian XL300 or a Varian Unity 500 instrument (δ given in ppm, *J* in Hz, internal Me_4Si), IR spectra (film or KBr pellet) on a Perkin-Elmer 298 instrument or on a Perkin-Elmer 1605 FT-IR, MS spectra were taken either on a MAT311A or a Varian-112S instrument; for elemental analysis a Foss-Heraeus

Vario EL instrument was used. TLC was performed on silica gel (Merck 5554, detection by dipping in a solution containing 10% sulfuric acid (400 *ml*), ammonium molybdate (20 g) and cerium$^{(IV)}$ sulfate (20 mg) followed by heating to 150°C. The tetrahydrofuran used throughout for all reactions was freshly distilled from sodium/benzophenone; all reactions were performed under dry argon.

8-*O*-Benzyl-1,3-dideoxy-5,6-*O*-isopropylidene-α,β-D-*ribo*-octo-2,4-diulo-4,7-furanose (2) .– To a suspension of sodium hydride (69 mg, 2.9 mmol) in abs. THF (8 *ml*) at 40° C dry acetone (0.4 g, 6.8 mmol) was added and stirred for 20 min. The reaction mixture was cooled to 25 °C and a solution of **1** (200 mg, 0.72 mmol) in abs. THF (2 *ml*) was added. After 5 min the reaction came to completion (as checked by tlc) and was stopped by the addition of a saturated aqueous solution of ammonium chloride (5 *ml*). The reaction mixture was diluted with diethyl ether (50 *ml*), the organic layer was washed in succession with an aqueous solution of NH_4Cl (3x10 *ml*) and brine (20 *ml*), dried ($MgSO_4$), and the solvent was removed under reduced pressure to afford a residue that was subjected to column chromatography (silica, hexane/ ethyl acetate 5:1, containing 1% of triethylamine for deactivation); **2** (230 mg, 95%) was obtained as a colorless oil; $[\alpha]_D^{20}$ –17.5° (*c*, 2.1 $CHCl_3$); R_F = 0.61 (hexane/ethyl acetate 1:1); IR (NaCl, film): 3390*bw*, 3064*w*, 3031*w*, 2986*m*, 2938*m*, 2867*m*, 1788*w*, 1705*s*, 1604*w*, 1497*w*, 1454*m*, 1422*m*, 1373*s*, 1256*m*, 1210*s*, 1162*s*, 1074*s*; ^{1}H NMR (300 MHz, $CDCl_3$): δ = 7.39-7.30 (*m*, 5 H, H-C(ar)), 5.21 (*s*, 1 H, OH), 4.79 (*dd*, 1 H, *J* = 1.2, 5.9 Hz, H-C(3)), 4.61 (*d*, 1 H, *J* = 11.7 Hz, H_A-CH_2(ar)), 4.55 (*s*, 1 H, H-C(2)), 4.55 (*d*, 1 H, *J* = 11.7 Hz, H_B-CH_2(ar)), 4.29 (*m*, 1 H, H-C(4)), 3.60 (*m*, 2 H, C(5)), 3.01 (*d*, 1 H, *J* = 16.4 Hz, H_A-C(3')), 2.91 (*d*, 1 H, *J* = 16.4 Hz, H_B-C(3')), 2.25 (*s*, 3 H, H_3C(1')), 1.48, 1.31 (*s*, 3 H, 2 x CH_3(isopropyl)); ^{13}C NMR (75 MHz, $CDCl_3$): δ = 207.54 (*s*, C(2')), 136.80 (*s*, C_q(ar)), 128.36, 127.87, 127.73 (*d*, C_t(ar)), 112.54 (*s*, C_q(isopropyl)), 106.10 (*s*, C(1)), 86.63, 84.46, 82.28 (*d*, C(2), C(3), C(4)), 73.55 (*t*, CH_2(ar)), 71.01 (*t*, C(5)), 47.63 (*t*, C(3')), 31.45 (*q*, C(1')), 26.45, 24.97 (*q*, 2 x CH_3(isopropyl)); MS (ei, 80 eV, 126° C): 336 (M, 0.4%), 321 (M–CH_3, 1.5%), 318 (0.7%), 293 (0.5%), 260 (21.6%), 229 (4.3%), 197 (3.4%), 157 (13.1%), 139 (8.6%), 127 (14.7%), 107 (15.9%), 91 (100%); anal. calcd. for $C_{18}H_{24}O_6$ (336.39): C, 64.27; H, 7.19; found: C, 64.23; H, 7.39.

1,3-Dideoxy-5,6;8,9-di-*O*-isopropylidene-α,β-D-*manno*-nono-2,4-diulo-4,7-furanose (4) .– Following the procedure given for the preparation of **2** from NaH (98 mg, 4.1 mmol) in THF (10 *ml*), acetone (394 mg, 6.8 mmol) and 2,3;5,6-di-*O*-isopropylidene-D-*mannono*-1,4-lactone (**3**) (110 mg, 0.43 mmol) in THF (3 *ml*) after column chromatography (silica, hexane/ethyl acetate 3:1 containing 1% triethylamine) **4** (67 mg, 49%) was obtained as a colorless oil; $[\alpha]_D^{20}$+4.7° (*c*, 1.3 $CHCl_3$); R_F = 0.72 (hexane/ethyl acetate 1:1); IR (NaCl, film): 3439*bm*, 2988*m*, 2938*m*, 1706*s*, 1373*s*, 1210*s*, 1070*s*; ^{1}H NMR (300 MHz, $CDCl_3$): δ = 4.90 (*bs*, 1 H, OH), 4.83 (*dd*, 1 H, *J* = 3.8, 5.9 Hz, H-C(3)), 4.47 (*d*, 1 H, *J* = 5.9 Hz, H-C(2)), 4.34 (*ddd*, 1 H, *J* = 4.6, 6.1, 8.1 Hz, H-C(5)), 4.08 (*dd*, 1 H, *J* = 3.7, 8.1 Hz, H_A-C(6)), 4.04 (*d*, 1 H, *J* = 6.1 Hz, H_B-C(6)), 4.00 (*dd*, 1 H, *J* = 4.6, 8.7 Hz, H-C(4)), 3.00 (*d*, 1 H, *J* = 17.3 Hz, H_A-C(3')), 2.84 (*d*, 1 H, *J* = 17.3 Hz, H_B-C(3')), 2.24 (*s*, 3 H, CH_3(1')), 1.48, 1.44, 1.37, 1.32 (*s*, 3 H, 4 x CH_3(isopropyl)); ^{13}C NMR (75 MHz, $CDCl_3$): δ = 209.24 (*s*, C(2')), 112.55, 109.06 (*s*, 2 x C_q(isopropyl)), 104.38 (*s*, C(1)), 85.66 (*d*, C(2)), 79.84 (*d*, C(3)), 79.28 (*d*, C(4)), 72.95 (*d*, C(5)), 66.85 (*t*, C(6)), 45.83 (*t*, C(3')), 31.59 (*q*, C(1')), 26.89, 25.89, 25.29, 24.39 (*q*, 4 x CH_3(isopropyl)); MS (ei, 80 eV, 93° C): 301 (M–CH_3, 48.3%), 243 (6.1%), 183 (7.5%), 165 (4.8%), 156 (7.5%), 140 (33.5%), 131 (10.2%), 128 (12.0%), 126 (11.4%), 103 (12.3%), 101 (85.0%), 98 (28.5%), 81 (16.9%), 72 (24.4%), 68 (21.7%), 59 (45.3%), 55 (9.9%), 43 (100%); HRMS calcd. for $C_{15}H_{24}O_7$: 316.1522; found: 316.1523.

1,3-Dideoxy-5,6-*O*-isopropylidene-α,β-D-*erythro*-hepto-2,4-diulo-4,7-furanose (6) .– Following the procedure given for the preparation of **2** from NaH (144 mg, 6.0 mmol) in THF (10 *ml*), acetone (394 mg, 6.8 mmol) and 2,3-*O*-isopropylidene-D-*erythrono*-1,4-lactone (**5**) (420 mg, 2.65 mmol) in THF (2 *ml*) after column chromatography **6** (120 mg, 21%) was obtained as a colorless oil; $[\alpha]_D^{20}$–63.8° (*c*, 1.4 $CHCl_3$); R_F =

0.53 (hexane/ethyl acetate 1:1); IR (NaCl, film): 3440*bm*, 2987*m*, 2940*m*, 2881*w*, 1706*s*, 1460*w*, 1425*m*, 1374*s*, 1323*m*, 1273*m*, 1210*s*, 1165*s*, 1096*s*, 1073*s*, 1036*s*, 1011*m*; ^{1}H NMR (300 MHz, $CDCl_3$): δ = 4.85 (*dd*, 1 H, *J* = 3.7, 5.9 Hz, H-C(3)), 4.00 (*s*, 1 H, OH), 4.42 (*d*, 1 H, *J* = 5.9 Hz, H-C(2)), 4.04 (*dd*, 1 H, *J* = 3.7, 10.3 Hz, H_A-C(4)), 3.92 (*d*, 1 H, *J* = 10.3 Hz, H_B-C(4)), 3.06 (*d*, 1 H, *J* = 17.5 Hz, H_A-C(3')), 2.88 (*d*, 1 H, *J* = 17.5 Hz, H_B-C(3')), 2.25 (*s*, 3 H, H_3C(1')), 1.48, 1.31 (*s*, 3 H, 2 x CH_3(isopropyl)); ^{13}C NMR (75 MHz, $CDCl_3$): δ = 209.42 (*s*, C(2')), 112.28 (*s*, C_q(isopropyl)), 104.97 (*s*, C(1)), 85.25 (*d*, C(2)), 80.24 (*d*, C(3)), 71.11 (*t*, C(4)), 45.94 (*t*, C(3')), 31.58 (*q*, C(1')), 26.25, 24.74 (*q*, 2 x CH_3(isopropyl)); MS (ei, 80 eV, 60° C): 201 (M–CH_3, 3.2%), 158 (M–acetone, 1.4%), 141 (2.8%), 114 (6.8%), 103 (13.7%), 85 (26.1%), 73 (4.5%), 59 (37.5%), 43 (100%); anal. calcd. for $C_{10}H_{16}O_5$ (216.23): C, 55.55; H, 7.46; found: C, 55.42; H, 7.49.

D-Threono-1,4-lactone (7)[24].– A solution of D-xylose (20 g, 13.3 mmol) in 2N KOH (200 *ml*) was saturated with oxygen and stirring was continued under oxygen for 10h at 40° C. The reaction mixture was filtered through an ion exchange resin (Dowex 50 WX 8, 500 *ml*), the solvent was removed under reduced pressure, and the residue was dissolved in acetonitrile (190 *ml*) containing *p*-TsOH (500 mg) and heated under reflux for 5h. The solvent was removed under reduced pressure and the residue subjected to column chromatography (silica, ethyl acetate) to afford **7** (5.8 g, 37%) as an oil that was brought to crystallization by storage at -18°C; mp 70-72° C; $[\alpha]_D^{20}$–28.5° (*c*, 0.8 H_2O); R_F = 0.51 (ethyl acetate); (lit.:[24] mp 75-77° C; $[\alpha]_D^{20}$–29° (*c*, 0.8 H_2O)); IR (NaCl, film): 3366*bs*, 2916*w*, 1775*s*, 1636*w*, 1343*m*, 1186*m*, 1144*s*, 1099*s*, 1011*s*, 905*m*, 717*m*, 567*m*, 492*w*, 419*w*, 415*w*, 408*w*; ^{1}H NMR (300 MHz, DMSO-d_6): δ = 6.13 (*d*, 1 H, *J* = 6.1 Hz, exchangeable with D_2O, OH), 5.78 (*d*, 1 H, *J* = 4.6 Hz, exchangeable with D_2O, OH), 4.33 (*dd*, 1 H, *J* = 6.4, 8.7 Hz, H-C(2)), 4.14 (*ddd*, 1 H, *J* = 4.7, 6.6, 13.4 Hz, H-C(3)), 4.07 (*dd*, *virt. t*, *J* = 6.6 Hz, H_A-C(4)), 3.84 (*dd*, 1 H, *J* = 6.8, 8.7 Hz, H_B-C(4)); ^{13}C NMR (75 MHz, DMSO-d_6): δ = 175.23 (*s*, C(1)), 72.81 (*d*, C(2)), 72.00 (*d*, C(3)), 69.62 (*t*, C(4)).

2,3-Di-*O*-(*tert.*-butyldimethylsilyl)-D-threono-1,4-lactone (8).– To a solution of **7** (4.92g, 41.7 mmol) in dry pyridine (50 *ml*) under argon *tert.*-butyldimethylchlorosilane (12.56 g, 83.33 mmol) and a catalytic amount of 4-dimethylaminopyridine (ca. 100 mg) was added and the mixture was stirred at 25°C for 24h. Then cold water (50 *ml*) was added, the aqueous phase extracted with diethyl ether (3 x 100 *ml*) and the combined organic phases were washed with brine (20 *ml*), dried ($MgSO_4$) and the solvent was removed under reduced pressure. The residue was subjected to column chromatography (silica, hexane/ethyl acetate 10:1) to afford **8** (11.3 g, 78%) as white crystals; mp 51° C; $[\alpha]_D^{20}$–51° (*c*, 1.0 $CHCl_3$); R_F = 0.83 (hexane/ethyl acetate 10:1); IR (KBr): 2959*m*, 2929*m*, 2889*m*, 2857*m*, 1791*s*, 1776*s*, 1473*m*, 1465*m*, 1442*w*, 1411*w*, 1379*w*, 1361*w*, 1349*w*, 1319*w*, 1268*m*, 1253*m*, 1204*m*, 1175*s*, 1120*s*, 1059*m*, 1012*m*, 985*s*, 939*w*, 917*m*, 894*m*, 867*s*, 841*s*, 781*s*, 681*m*, 669*w*, 445*w*; ^{1}H NMR (300 MHz, $CDCl_3$): δ = 4.36 (*d*, 1 H, *J* = 6.4 Hz, H_A-C(4)), 4.32 (*dd*, 1 H, *J* = 3.6, 6.4 Hz, H_B-C(4)), 4.22 (*d*, *J* = 6.1 Hz, H-C(2)), 3.89 (*m*, 1 H, H-C(3)), 0.93, 0.90 (*s*, 9 H, CH_3(*tert.*-butyl), 0.19, 0.16, 0.12, 0.09 (*s*, 3 H, CH_3Si); ^{13}C NMR (75 MHz, $CDCl_3$): δ = 173.39 (*s*, C(1)), 74.85 (*d*, C(3)), 74.33 (*d*, C(2)), 69.93 (*t*, C(4)), 25.58 (*q*, CH_3(TBDMS)), 18.17, 17.85 (*s*, C_q(TBDMS)); MS (ei, 80 eV, 47°C): 331 (M–CH_3, 1.2%), 289 (M–*tert.*-but., 35.9%), 261 (10.3%), 231 (3.6%), 189 (6.9%), 147 (100%); anal. calcd. for $C_{16}H_{34}O_4Si$ (346.61): C, 55.44; H, 9.89; found: C, 55.40; H, 9.82.

7-*O*-Benzyl-2-deoxy-4,5-*O*-isopropylidene-1-phenyl-α,β-D-*ribo*-hepto-1,3-diulo-3,6-furanose (9)
To a suspension of NaH (77 mg, 3.2 mmol) in abs. THF (8 *ml*) at 45 °C dry acetophenone (394 mg, 6.8 mmol) was added and stirred for 30 min. The reaction was cooled to 25 °C and a solution of **1** (200 mg, 0.72 mmol) in abs. THF (2 *ml*) was added. The reaction came to completion after 5 min (as checked by tlc) and was stoppend by the addition of a saturated aqueous solution of NH_4Cl (5 *ml*). The mixture was diluted with diethyl ether (50 *ml*), the organic layer was washed in succession with an aqueous solution of NH_4Cl-Lösung (3x10 *ml*) and brine (20 *ml*), dried ($MgSO_4$), the solvent was removed under reduced pressure and the residue

subjected to column chromatography (silica, hexane/ethyl acetate 10:1 → 5:1 containing 1% triethylamine) to afford **9** (183 mg, 66%) as a white solid; mp 86 - 87° C; $[\alpha]_D^{20}$–35.1° (*c*, 0.9 $CHCl_3$); R_F = 0.37 (hexane/ethyl acetate 3.5:1); IR (KBr): 3468*m*, 3032*w*, 2992*w*, 2942*w*, 2867*w*, 1684*s*, 1596*m*, 1453*m*, 1448*m*, 1380*m*, 1362*m*, 1332*m*, 1273*m*, 1212*s*, 1164*m*, 1099*s*, 1074*s*, 1050*s*, 1029*m*; ^{1}H NMR (300 MHz, $CDCl_3$): δ = 8.00-7.97 (*m*, 2 H, H_{ortho}-C(ar)), 7.61-7.55 (*m*, 1 H, H_{para}-C(ar)), 7.49-7.44 (*m*, 2 H, H_{meta}-C(ar)), 7.38-7.5 (*m*, 5 H, H-(ar, benzyl)), 5.35 (*bs*, 1 H, OH), 4.84 (*dd*, 1 H, *J* = 1.3, 5.8 Hz, H-C(3)), 4.69 (*d*, 1 H, *J* = 5.8 Hz, H-C(2)), 4.61 (*d*, 1 H, *J* = 12.1 Hz, H_A-CH_2(ar)), 4.56 (*d*, 1 H, *J* = 12.1 Hz, H_B-CH_2(ar)), 4.32 (*m*, 1 H, H-C(4)), 3.65-3.62 (*m*, 2 H, $H_{A,B}$-C(5)), 3.63 (*d*, 1 H, *J* = 17.1 Hz, H_A-C(2')), 3.42 (*d*, 1 H, *J* = 17.1 Hz, H_B-C(2')), 1.48, 1.32 (*s*, 3 H, 2 x CH_3(isopropyl)); ^{13}C NMR (75 MHz, $CDCl_3$): δ = 198.72 (*s*, C(1')), 137.14 (*s*, C_q(ar)), 136.86 (*s*, C_q(ar)), 133.27, 128.38, 128.32, 128.31, 128.14, 127.73, 127.69 (*d*, C_t(ar)), 112.35 (*s*, C_q(isopropyl)), 106.62 (*s*, C(1)), 86.51 (*d*, C(2)), 84.50 (*d*, C(3)), 82.55 (*d*, C(4)), 73.44 (*t*, CH_2(ar)), 71.10 (*t*, C(5)), 42.57 (*t*, C(2')), 26.57, 25.06 (*q*, 2 x CH_3(isopropyl)); MS (ei, 80 eV, 135° C): 383 (M–CH_3, 0.1%), 322 (8.4%), 293 (0.6%), 291 (5.7%), 277 (1.6%), 249 (1.5%), 219 (6.7%), 165 (11.7%), 147 (13.3%), 127 (4.1%), 105 (100%); anal. calcd. for $C_{23}H_{26}O_6$ (398.46): C, 69.33; H, 6.58; found: C, 69.05; H, 6.81.

2-Deoxy-4,5;7,8-di-*O*-isopropylidene-1-phenyl-α,β-D-*manno*-octo-1,3-diulo-3,6-furanose (10) .– Following the procedure given for the preparation of **9** from NaH (80 mg, 3.3 mmol) in THF (8 *ml*), acetophenone (430 mg, 3.6 mmol) and 2,3;5,6-di-O-isopropylidene-D-*mannono*-1,4-lactone (**3**) (200 mg, 0.77 mmol) in THF (10 *ml*) after work up and column chromatography (silica, hexane/ethyl acetate 10:1 → 5:1 → 3:1) **10** (188 mg, 64%) was obtained as white crystalls; mp 83° C; $[\alpha]_D^{20}$+21.6° (*c*, 0.9 $CHCl_3$); R_F = 0.82 (hexane/ethyl acetate 1:1); IR (KBr): 3539*m*, 3452*m*, 3066*w*, 2987*s*, 2924*m*, 1699*s*, 1683*s*, 1598*m*, 1582*w*, 1449*m*, 1401*m*, 1379*s*, 1338*m*, 1264*s*, 1214*s*, 1166*m*, 1154*m*, 1116*m*, 1098*m*, 1059*s*; ^{1}H NMR (300 MHz, $CDCl_3$): δ = 8.00-7.95 (*m*, 2 H, H_{ortho}-C(ar)), 7.63-7.58 (*m*, 1 H, H_{para}-C(ar)), 7.51-7.45 (*m*, 2 H, H_{meta}-C(ar)), 5.13 (*s*, 1 H, OH), 4.89 (*dd*, 1 H, *J* = 3.7, 5.9 Hz, H-C(3)), 4.60 (*d*, 1 H, *J* = 5.9 Hz, H-C(2)), 4.35 (*ddd*, 1 H, *J* = 4.8, 5.8, 8.1 Hz, H-C(5)), 4.15 (*dd*, 1 H, *J* = 3.7, 8.1 Hz, H-C(4)), 4.04 (*dd*, 1 H, *J* = 5.9, 8.6 Hz, H_A-C(6)), 3.99 (*dd*, 1 H, *J* = 4.8, 8.6 Hz, H_B-C(6)), 3.60 (*d*, 1 H, *J* = 17.5 Hz, H_A-C(2')), 3.31 (*d*, 1 H, *J* = 17.5 Hz, H_B-C(2')), 1.50, 1.42, 1.37, 1.34 (*s*, 3 H, 4 x CH_3(isopropyl)); ^{13}C NMR (75 MHz, $CDCl_3$): δ = 199.91 (*s*, C(1')), 136.62 (*s*, C_q(ar)), 133.63, 128.50, 128.10 (*d*, C_t(ar)), 112.61, 109.06 (*s*, 2 x C_q(isopropyl)), 104.79 (*s*, C(1)), 85.97 (*d*, C(5)), 79.94, 79.41, 73.01 (*d*, C(2), C(3), C(4)), 66.93 (*t*, C(6)), 41.26 (*t*, C(2')), 26.87, 26.01, 25.35, 24.47 (*q*, 4 x CH_3(isopropyl)); MS (ei, 80 eV, 79°C): 363 (M–CH_3, 15.5%), 305 (4.0%), 277(2.2%), 245 (1.6%), 219 (4.4%), 190 (4.1%), 165 (6.9%), 147 (12.6%), 141 (9.9%), 105 (100%); anal. calcd. for $C_{20}H_{26}O_7$ (378.43): C, 63.48; H, 6.93; found: C, 63.56; H, 6.86.

2-Deoxy-4,5-*O*-isopropylidene-1-phenyl-α,β-D-*erythro*-hexo-1,3-diulo-3,6-furanose (11) .– Following the procedure given for the preparation of **9** from NaH (96 mg, 4.0 mmol) in THF (8 *ml*), acetophenone (430 mg, 3.6 mmol) and 2,3-*O*-isopropylidene-D-*erythrono*-1,4-lactone (**5**) (240 mg, 1.52 mmol) in THF (2 *ml*) after work up and chromatography (silica, hexane/ethyl acetate 7:1) **11** (80 mg, 19%) was obtained as white crystalls; mp 68-69°C; $[\alpha]_D^{20}$–57.8° (*c*, 1.1 $CHCl_3$); R_F = 0.67 (hexane/ethyl acetate 1:1); IR (KBr): 3493*s*, 332*w*, 3087*w*, 2988*m*, 2976*m*, 2957*m*, 2943*m*, 2919*m*, 1673*s*, 1598*m*, 1581*w*, 1461*m*, 1449*m*, 1400*s*, 1379*s*, 1302*m*, 1275*s*, 1211*s*, 1160*s*, 1101*s*, 1066*s*, 1045*s*, 1025*s*, 1003*s*; ^{1}H NMR (300 MHz, $CDCl_3$): δ = 7.97-8.00 (*m*, 2 H, H_{ortho}-C(ar)), 7.57-7.63 (*m*, 1 H, H_{para}-C(ar)), 7.45-7.50 (*m*, 2 H, H_{meta}-C(ar)), 5.07 (*s*, 1 H, OH), 4.90 (*dd*, 1 H, *J* = 3.8, 5.9 Hz, H-C(3)), 4.55 (*d*, 1 H, *J* = 5.9 Hz, H-C(2)), 4.10 (*dd*, 1 H, *J* = 3.8, 10.3 Hz, H_A-C(4)), 3.96 (*d*, 1 H, *J* = 10.3 Hz, H_B-C(4)), 3.67 (*d*, 1 H, 17.6 Hz, H_A-C(2')), 3.34 (*d*, 1 H, *J* = 17.6 Hz, H_B-C(2')), 1.50, 1.33 (*s*, 3 H, 2 x CH_3(isopropyl)); ^{13}C NMR (63 MHz, $CDCl_3$): δ = 187.04 (*s*, C(1')), 136.82 (*s*, C_q(ar)), 133.84, 128.69, 128.32 (*d*, C_t(ar)), 112.50 (*s*, C_q(isopropyl)), 105.54 (*s*, C(1)), 85.62 (*d*, C(2)), 80.43 (*d*, C(3)), 71.37 (*t*, C(4)), 41.32 (*t*, C(2')), 26.37, 24.85 (*q*, 2 x CH_3(isopropyl));

MS (ei, 80 eV, 65°C): 363 (M–CH_3, 1.8%), 235 (M–Isopropyl, 0.7%), 220 (8.3%), 177 (2.6%), 165 (10.4%), 147 (11.3%), 143 (3.3%), 120 (22.8%), 105 (100%); anal. calcd. for $C_{15}H_{18}O_5$ (278.31): C, 64.74; H, 6.52; found: C, 64.57; H, 6.38.

2,3-*O*-Isopropylidene-4-*O*-(1-methoxy-1-methyl-ethyl)-D-*ribono*-1,5-lactone (12), 2,3-*O*-isopropylidene-D-*ribono*-1,4-lactone (16) and 2,3-*O*-isopropylidene-5-*O*-(1-methoxy-1-methyl-ethyl)-D-*ribono*-1,4-lactone (17) .– A solution of D-*ribono*-1,4-lactone (**15**) (5.0 g, 33.7 mmol) in dry dimethoxypropane (134 *ml*) and *p*-TsOH (100 mg) was stirred at 25 °C for 24h. After neutralization by the addition of solid K_2CO_3 the reaction mixture was filtered and the solvent was removed under reduced pressure. The residue was subjected to column chromatography (silica gel, hexane/ethyl acetate 10.1 → 5:1 → 3:1) to afford **12** (3.1 g, 35%), then **17** (2.8 g, 32%) and finally **16** (1.3 g, 21%).

Data for **12**: oil; $[\alpha]_D^{20}$–15.7° (*c*, 1.0 $CHCl_3$); R_F = 0.24 (hexane/ethyl acetate 5:1) IR (NaCl, film): 2988*s*, 2940*m*, 1757*s*, 1447*m*, 1438*m*, 1382*s*, 1372*s*, 1246*s*, 1209*s*, 1163*s*, 1075*s*; ^{1}H NMR (500 MHz, $CDCl_3$): δ = 4.66 (*d*, 1 H, *J* = 6.5 Hz, H-C(2)), 4.18 (*dd*, 1 H, *J* = 6.5, 8.6 Hz, H-C(3)), 4.03 (*ddd*, 1 H, *J* = 4.9, 6.2, 8.6 Hz, H-C(4)), 4.00 (*dd*, 1 H, *J* = 6.2, -8.1 Hz, H_A-C(5)), 3.86 (*dd*, 1 H, *J* = 4.9, -8.1 Hz, H_B-C(5)), 3.70 (*s*, 3 H, OCH_3), 1.50, 1.34, 1.31, 1.25 (*s*, 3 H, 4 x CH_3(isopropyl)); ^{13}C NMR (126 MHz, $CDCl_3$): δ = 168.92 (*s*, C(1)), 110.77 (*s*, C_q(isopropyl) at C(4)), 109.57 (*s*, C_q(isopropyl) between C(2)/C(3)), 78.30 (*d*, C(2)), 75.80 (*d*, C(3)), 73.62 (*d*, C(4)), 67.10 (*t*, C(5)), 51.94 (*q*, OCH_3), 27.21, 26.76, 25.52, 25.29 (*q*, 4 x CH_3(isopropyl)); MS (ei, 80 eV, 40°C): 260 (M, 0.04%), 245 (M–CH_3, 21.7%), 202 (1.8%), 187 (4.1%), 167 (2.4%), 159 (3.9%), 143 (16.1%), 113 (5.9%), 101 (68.9%), 85 (11.2%), 73 (17.1%), 59 (24.7%), 43 (100%); anal. calcd. for $C_{12}H_{20}O_6$ (260.29): C, 55.37; H, 7.74; found: C, 55.15; H, 7.78.

Data for **16**: mp 138-139° C; $[\alpha]_D^{20}$–84.0° (*c*, 1.3 $CHCl_3$); R_F = 0.79 (ethyl acetate); (lit.: [26] mp 138-139°C; $[\alpha]_D^{20}$–84.2° (*c*, 0.9 $CHCl_3$)); IR (KBr): 3490*bs*, 3000*s*, 2960*m*, 2940*m*, 2900*m*, 2840*w*, 1775*s*, 1470*s*, 1390*s*, 1380*s*, 1280*s*, 1220*bs*, 1155*s*, 1085*s*, 1010*s*; ^{1}H NMR (500 MHz, $CDCl_3$): δ = 4.80 (*d*, 1 H, *J* = 5.6 Hz, H-C(2)), 4.75 (*d*, 1 H, *J* = 5.6 Hz, H-C(3)), 4.59 (*m*, 1 H, *J* = 1.9, 2.2 Hz, H-C(4)), 3.94 (*m*, 1 H, *J* = -12.3, 2.2, 5.4 Hz, H_AC(5)), 3.77 (*m*, 1 H, *J* = -12.3, 1.9, 5.6 Hz, H_B-C(5)), 2.94 (*m*, 1 H, 5.4, 5.6 Hz, OH), 1.43 (*s*, 3 H, CH_3(isopropyl)), 1.34 (*s*, 3 H, CH_3(isopropyl)); ^{13}C NMR (126 MHz, $CDCl_3$): δ = 175.13 (*s*, C(1)), 113.08 (*s*, C_q(isopropyl)), 82.92 (*d*, C(4)), 78.25 (*d*, C(3)), 75.64 (*d*, C(2)), 61.82 (*t*, C(5)), 26.95 (*q*, CH_3(isopropyl)), 25.39 (*q*, CH_3(isopropyl)); MS (FAB, glycerol): 189 (M+1, 0.5%), 174 (6.2%), 173 (M–CH_3, 83.4%), 129 (7.0%), 85 (15.1%), 59 (24.7%), 43 (100%).

Data for **17**: mp 96-98° C; $[\alpha]_D^{20}$–73.4° (*c*, 1.0 $CHCl_3$); R_F = 0.74 (hexane/ethyl acetate 1.5:1); IR (KBr): 3004*m*, 2962*m*, 2897*w*, 2841*w*, 1784*s*, 1469*m*, 1461*m*, 1390*s*, 1366*m*, 1275*s*, 1244*s*, 1221*s*, 1188*s*, 1153*s*, 1090*s*, 1061*s*, 1021*s*; ^{1}H NMR (500 MHz, $CDCl_3$): δ = 4.72 (*d*, 1 H, *J* = 5.5 Hz, H-C(2)), 4.69 (*d*, 1 H, *J* = 5.5 Hz, H-C(3)), 4.66 (*m*, 1 H, *J* = 1.6, 2.3 Hz, H-C(4)), 3.74 (*dd*, 1 H, *J* = -10.8, 2.3 Hz, H_AC(5)), 3.51 (*dd*, 1 H, *J* = 1.6, -10.8 Hz, H_B-C(5)), 3.16 (*s*, 3 H, OCH_3), 1.45, 1.37, 1.30, 1.28 (*s*, 3 H, 4 x CH_3(isopropyl)); ^{13}C NMR (126 MHz, $CDCl_3$): δ = 174.34 (*s*, C(1)), 113.09 (*s*, C_q(isopropyl) between C(2) and C(3)), 100.52 (*s*, C_q(isopropyl) at C(4)), 80.90 (*d*, C(4)), 78.49 (*d*, C(3)), 75.70 (*d*, C(2)), 60.25 (*t*, C(5)), 48.83(*q*, OCH_3), 26.78, 25.60, 24.39, 23.87 (*q*, CH_3(isopropyl)); MS (ei, 80 eV, 30°C): 246 (0.9%), 245 (M–CH_3, 10.5%), 230 (1.1 %), 229 (5.4%), 215 (1.2%), 173 (2.4%), 143 (7.4%), 107 (2.7%), 73 (100%); anal. calcd. for $C_{12}H_{20}O_6$ (260.29): C, 55.37; H, 7.74; found: C, 55.43; H, 7.83.

2-Deoxy-4,5;6,7-di-*O*-isopropylidene-1-phenyl-D-*ribo*-hepto-1,3-diulose (13).– Following the procedure given for the preparation of **9** from NaH (160 mg, 6.7 mmol) in THF (20 *ml*), acetophenone (700 mg, 5.8 mmol) and **12** (420 mg, 1.61 mmol) in THF (2 *ml*) after work up and chromatography (silica, hexane/

ethyl acetate 5:1 containing 1% triethylamine) **13** (500 mg, 89%) was obtained as a white solid that was recrystallized from diethyl ether/pentane (1:10) at –25° C; mp 68-69° C; $[\alpha]_D^{20}$+25.5° (*c*, 1.1 $CHCl_3$); R_F = 0.73 (hexane/ethyl acetate 3:1); IR (KBr): 3065*w*, 2988*m*, 2934*m*, 2905*w*, 1607*s*, 1575*s*, 1495*m*, 1460*m*, 1419*w*, 1382*m*, 1370*m*, 1257*s*, 1207*s*, 1149*m*, 1073*s*; ^{1}H NMR (300 MHz, acetone-d_6): δ = 7.98-8.02 (*m*, 2 H, H-C(ar)), 7.52-7.66 (*m*, 3 H, H-C(ar)), 6.75 (*s*, 1 H, H-C(2')), 4.55 (*d*, 1 H, *J* = 5.9 Hz, H-C(2)), 4.30 (*m*, 2 H, H_2C(5)), 4.14 (*dd*, 1 H, *J* = 6.0, 8.5 Hz, H-C(3)), 3.99 (*dd*, 1 H, *J* = 4.9, 8.5 Hz, H-C(4)), 3.0 (*bs*, 1 H, OH), 1.46, 1.44, 1.36, 1.31 (*s*, 3 H, 4 x CH_3(isopropyl)); ^{13}C NMR (63 MHz, $CDCl_3$): δ = 192.23 (*s*, C=O)), 182.58 (*s*, C_q(C=C)), 134.32 (*s*, C_q(ar)), 132.64, 128.71, 127.14 (*d*, C_t(ar)), 111.51, 109.91 (*s*, 2 x C_q(isopropyl)), 94.11 (*d*, C(2')), 80.28 (*d*, C(2)), 79.54 (*d*, C(3)), 76.54 (*d*, C(4)), 66.36 (*t*, C(5)), 27.22, 26.52, 26.42, 25.25 (*q*, 4 x CH_3(isopropyl)); MS (ei, 80 eV, 71° C): 348 (M, 1.3%), 333 (M–CH_3, 13.9%), 290 (4.8%), 272 (2.7%), 260 (1.3%), 247 (2.3%), 232 (11.0%), 218 (8.5%), 201 (4.8%), 189 (9.4%), 171 (11.1%), 147 ($COCH_2COPhe$, 100%); anal. calcd. for $C_{19}H_{24}O_6$ (348.40): C, 65.50; H, 6.94; found: C, 65.66; H, 7.14.

2,3;4,5-Di-*O*-isopropylidene-D-ribono-piperidide (18).– A solution of **12** (0.5 g) in dry piperidine (10 *ml*) was heated under reflux for 12h. After cooling to 25 °C the mixture was diluted with diethyl ether (50 *ml*) and the pH was adjusted to 6 by the careful addition of acetic acid. After extraction with water (3 x 20 *ml*) the organic phase was washed in succession with an aqueous solution of $NaHCO_3$ and brine (each 20 *ml*), dried (MgSO4) and the solvent was removed under reduced pressure to afford a residue that was subjected to column chromatography (silica, hexane/ ethyl acetate 7:1 → 5:1) to yield **18** (160 mg, 27%) as a colorless oil; $[\alpha]_D^{20}$+20.7° (*c*, 1.2 $CHCl_3$); R_F = 0.28 (hexane/ethyl acetate 4:1); IR (NaCl, film) 2987*m*, 2937*s*, 2859*m*, 1651*s*, 1446*s*, 1382*s*, 1371*s*, 1252*s*, 1213*s*, 1153*m*, 1071*s*; ^{1}H NMR (500 MHz, $CDCl_3$): δ = 4.68 (*dd*, 1 H, *J* = 5.3, 7.0 Hz, H-C(3)), 4.56 (*d*, 1 H, *J* = 5.3 Hz, H-C(2)), 4.12 (*ddd*, 1 H, *J* = 5.3, 6.4, 7.0 Hz, H-C(4)), 4.03 (*dd*, 1 H, *J* = 6.4, -8.7 Hz, H_A-C(5)), 3.85 (*dd*, 1 H, *J* = 5.3, -8.7 Hz, H_B-C(5)), 3.67-3.61 and 3.34-3.33 (m, 4 H, H_2-C(2'), H-C(6')), 1.65-1.43 (m, 6 H, H-C(3', 4', 5')), 1.37, 1.34, 1.31, 1.27 (*s*, 3 H, 4 x CH_3(isopropyl)); ^{13}C NMR (126 MHz, $CDCl_3$): δ = 167.24 (*s*, C(1)), 110.63 (*s*, C_q(isopropyl) between C(1)/C(2)), 109.44 (*s*, C_q(isopropyl) between C(3)/C(4)), 78.16 (*d*, C(3)), 76.03 (*d*, C(4)), 75.16 (*d*, C(2)), 66.73 (*t*, C(5)), 46.63, 43.42 (*t*, C(2'), C(6')), 27.28, 26.43, 26.13, 25.17 (*q*, 4 x CH_3(isopropyl)), 26.33, 25.55, 24.52 (*t*, C(3'), C(4'), C(5')); MS (ei, 80 eV, 116° C): 314 (M+1, 1.2%), 313 (M, 5.1%), 298 (M–CH_3, 12.8%), 255 (10.6%), 254 (12.0%), 238 (20.0%), 212 (8.5%9, 197 (21.6%), 183 (49.0%), 180 (15.2%), 154 (24.9%), 143 (100%); HRMS calcd. for $C_{16}H_{27}NO_5$: 313.1889; found: 313.1888.

3,5-Di-*O*-benzyl-2-deoxy-D-*glycero*-pent-2-enono-1,4-lactone (20).– Following the procedure given for the preparation of **9** from NaH (67 mg, 2.8 mmol) in THF (8 *ml*), acetophenone (100 mg, 0.83 mmol) and 2,3,5-tri-*O*-benzyl-D-*arabinono*-1,4-lactone (**19**) (70 mg, 0.17 mmol) in THF (2 *ml*) after work up and chromatography (silica, hexane/ ethyl acetate 5:1 containing 1% triethylamine) **20** (20 mg, 38%) was obtained as a white solid; mp 82°C; $[\alpha]_D^{20}$–18.9° (*c*, 0.4 $CHCl_3$); R_F = 0.76 (hexane/ethyl acetate 1:1); IR (KBr): 3093*w*, 2872*w*, 1762*s*, 1734*w*, 1717*w*, 1700*w*, 1684*w*, 1648*m*, 1635*w*, 1616*w*, 1559*w*, 1500*w*, 1456*m*, 1394*w*, 1368*w*, 1116*s*, 1080*m*, 1030*w*, 997*w*, 975*w*, 820*w*, 780*w*, 761*m*, 749*m*, 704*m*; ^{1}H NMR (250 MHz, acetone-d_6): δ = 7.25-7.47 (*m*, 10 H, H-C(ar)), 6.49 (*d*, 1 H, *J* = 2.1 Hz, H-C(2)), 5.14 (*ddd*, 1 H, *J* = 1.9, 3.6, 5.6 Hz, H-C(4)), 5.07, 4.75 (*s*, 2 H, CH_2(ar)), 3.78 (*dd*, 1 H, *J* = 3.6, 10.9 Hz, H_A-C(5)), 3.61 (*dd*, 1 H, *J* = 5.5, 10.9 Hz, H_B-C(5)); ^{13}C NMR (126 MHz, $CDCl_3$): δ = 167.23 (*s*, C(1)), 146.59 (s, C(3)), 137.43, 134.77 (*s*, C_q(ar)), 128.69, 128.57, 128.51, 127.94, 127.73, 127.61 (*d*, C(ar)), 115.39 (*d*, C(2)), 77.58 (*d*, C(4)), 73.76, 72.90 (*t*, CH_2(ar)), 70.72 (*t*, C(5)); MS (ei, 80 eV, 111° C): 281 (0.6%), 280 (2.8%), 220 (1.9%), 219 (M–Bn, 14.9%), 190 (0.5%), 189 (4.1%), 182 (2.3%), 181 (1.2%), 107 (1.3%), 91 (100%); anal. calcd. for $C_{19}H_{18}O_4$ (310.35): C, 73.53; H, 5.85; found: C, 73.24; H, 6.14.

2,4,6-Tri-*O*-benzyl-3-deoxy-D-*erythro*-hex-2-enono-1,5-lactone (23).– To a suspension of NaH (80 mg, 3.3 mmol) in abs. THF (10 *ml*) at 45° C under argon acetophenone (110 mg, 0.92 mmol) was added and the mixture was stirred for 30 min at 45 °C. Then a solution of 2,3,4,6-tetra-*O*-benzyl-D-*glucono*-1,5-lactone (**22**) (100 mg, 0.19 mmol) in abs. THF (1 *ml*) was added and the mixture was stirred for 5 min at 25 °C. After dilution with diethyl ether (50 *ml*) the pH was adjusted at 5 °C by the careful addition of to 7 and the mixture was washed in succession with an aqueous solution of $NaHCO_3$ and brine (each 30 *ml*), dried ($MgSO_4$) and the solvent was removed under reduced pressure. The residue was subjected to chromatography (silica, hexane/ethyl acetate 4:1 containing 1% triethylamine) to afford **23** (76 mg, 95%) as a colorless oil; $[\alpha]_D^{20}$+62.5° (*c*, 0.6 $CHCl_3$); R_F = 0.66 (hexane/ethyl acetate 2:1); IR (NaCl, film): 3063*w*, 3029*w*, 2865*m*, 1743*s*, 1643*m*, 1585*w*, 1559*w*, 1507*w*, 1496*m*, 1453*m*, 1399*w*, 1363*w*, 1313*w*, 1250*m*, 1161*s*, 1117*s*, 1067*s*, 1027*m*; ^{1}H NMR (300 MHz, $CDCl_3$): δ = 7.23-7.42 (*m*, 15 H, H-C(ar)), 5.63 (*d*, 1 H, *J* = 4.2 Hz, H-C(3)), 4.89 (*d*, 1 H, *J* = 12.2 Hz, H_A-CH_2(ar)), 4.84 (*d*, 1 H, *J* = 12.2 Hz, H_B-CH_2(ar)), 4.56 (*dd*, 1 H, *J* = 4.2, 5.8 Hz, H-C(5)), 4.50-4.53 (*m*, 4 H, 2 CH_2(ar)), 4.46 (*dd*, 1 H, *J* = 4.2, 5.8 Hz, H-C(4)), 3.72 (*dd*, 1 H, *J* = 3.8, 10.6 Hz, H_A-C(6)), 3.63 (*dd*, 1 H, *J* = 4.6, 10.6 Hz, H_B-C(6)); ^{13}C NMR (75 MHz, $CDCl_3$): δ = 159.27 (*s*, C(1)), 143.93, 137.34, 137.19 (*s*, C_q(ar)), 135.10 (*s*, C(2)), 128.53, 128.46, 128.43, 128.41, 128.37, 128.34, 128.18, 128.15, 127.98, 127.81, 127.76, 127.61, 127.48, 127.27, 126.84 (*d*, C_t(ar)), 110.12 (*d*, C(3)), 79.75 (*d*, C(4)), 73.55, 71.12, 70.35 (*t*, CH_2(ar)), 69.37 (*d*, C(5)), 68.31 (*t*, C(6)); MS (ei, 80 eV, 203° C): 340 (0.5%), 339 (M–Bn, 2.2%), 322 (0.1%), 311 (0.2%), 247 (0.4%), 197 (0.9%), 182 (1.4%), 181 (3.9%), 171 (0.3%), 161 (0.7%), 92 (8.6%), 91 (100%); HRMS calcd. for $C_{27}H_{26}O_5$: ber.: 430.1780; found: 430.1780.

2-Deoxy-4,5-*O*-isopropylidene-D-*erythro*-3-hexulo-3,6-furanoso-nitrile (24).– To a suspension of NaH (55 mg, 2.3 mmol) in abs. THF (8 *ml*) at 45°C acetonitrile (1.5 *ml*, 28.5 mmol) was added and stirred for 20 min. A solution of 2,3-*O*-isopropylidene-D-*erythrono*-1,4-lactone (**5**) (100 mg, 0.63 mmol) in abs. THF (1 *ml*) was added, the reaction mixture was stirred for 2 h and then stoppend by the addition of an aqueous solution of NH_4Cl (5 *ml*) After dilution with diethyl ether (50 *ml*) the organic layer was washed in succession with an aqueous solution of NH_4Cl (3 x 10 *ml*) and brine (20 *ml*), dried ($MgSO_4$), the solvent was removed under reduced pressure and the residue subjected to column chromatography (silica, hexane/ethyl acetate 5:1 containing 1% triethylamine) to afford **24** (80 mg, 64%) as white crystalls; mp 137-139° C; $[\alpha]_D^{20}$–63.9° (*c*, 1.0 $CHCl_3$); R_F = 0.53 (hexane/ethyl acetate 1:1); IR (KBr): 3402*s*, 3007*m*, 2952*m*, 2883*w*, 2521*s*, 2270*m*, 1734*w*, 1701*w*, 1410*m*, 1456*m*, 1383s, 1378*s*, 1337*w*, 1299*m*, 1266*m*, 1215*s*, 1166*m*, 1124*m*, 1396*s*, 1084*s*, 1064*s*, 1040*s*; ^{1}H NMR (300 MHz, acetone-d_6): δ = 4.93 (*dd*, 1 H, *J* = 3.3, 5.8 Hz, H-C(5)), 4.5 (*d*, 1 H, *J* = 5.8 Hz, H-C(4)), 4.00 (*dd*, 1 H, *J* = 3.7, 10.4 Hz, H_A-C(6)), 3.87 (*d*, 1 H, *J* = 10.4 Hz, H_B-C(6)), 2.96 (*d*, 1 H, *J* = 16.7 Hz, H_A-C(2)), 2.93 (*s*, 1 H, exchangeable with D_2O, OH), 2.90 (*d*, 1 H, *J* = 16.7 Hz, H_B-C(2)), 1.44, 1.31 (*s*, 3 H, 2 x CH_3(isopropyl)); ^{13}C NMR (75 MHz, $CDCl_3$): δ = 116.25 (*s*, C(1)), 113.06 (*s*, C_q(isopropyl)), 103.72 (*s*, C(3)), 84.34 (*d*, C(4)), 80.46 (*d*, C(5)), 71.89 (*t*, C(6)), 45.94 (*t*, C(2)), 26.08, 24.63 (*q*, 2 x CH_3(isopropyl)); MS (ei, 80 eV, 76° C): 184 (M–CH_3, 26.7%), 159 (M–CH_2CN, 0.7%), 141 (0.9%), 124 (16.5%), 114 (2.1%), 99 (5.6%), 85 (13.3%), 83 (2.5%), 73 (3.5%), 71 (4.9%), 68 (5.8%), 59 (89.5%), 55 (16.2%), 43 (100%); HRMS calcd. for $C_8H_{10}NO_4$ (M-CH_3): 184.0610; found: 184.0609. Silylation of **24** (trimethylchlorosilane, pyridine, catalytic amounts of 4-dimethylaminopyridine, 25 °C, 24 h) gave 2-deoxy-4,5-*O*-isopropylidene-3-*O*-trimethylsilyl-β-D-erythro-3-hexulo-3,6-furanosonitrile (**25**) in 80% yield: $[\alpha]_D^{20}$ -45.2 ° (*c* 0.2, $CHCl_3$) [lit.[17] -46.13° (*c* 0.3, $CHCl_3$)].

2-(2,3-*O*-isopropylidene-1,4-anhydro-α-D-*arabino*-furanos-1-yl)-1-phenylethan-1-one (26).– To a solution of **11** (100 mg, 0.36 mmol) in abs. dichloromethane (3 *ml*) at –70° C under argon in succession borontrifluoride diethyl etherate (0.14 *ml*, 1.1 mmol) and triethylsilane (0.17 *ml*, 1.07 mmol) were added. The mixture was stirred at -70 °C for 5 h, then allowed to warm to 25°C and neutralized by the careful addition of

a saturated aqueous solution of $NaHCO_3$ (2 *ml*). The organic layer was separated, the aqueous phase was extracted (5 x 30 *ml*) with dichloromethane and the combined organic layers were dried ($MgSO_4$), the solvent was removed under reduced pressure and the residue subjected to column chromatography (silica, hexane/ethyl acetate 10:1) to afford **26** (56 mg, 60%) as a white solid; mp 95-96° C; $[\alpha]_D^{20}$–42.6° (*c*, 0.7 $CHCl_3$); R_F = 0.26 (hexane/ethyl acetate 3:1); IR (KBr): 2967*w*, 2932*m*, 2850*w*, 1681*s*, 1597*w*, 1579*w*, 1452*w*, 1384*m*, 1342*w*, 1297*w*, 1277*m*, 1211*m*, 1167*m*, 1132*w*, 1097*m*, 1058*w*, 1027*w*; ^1H NMR (500 MHz, $CDCl_3$): δ = 7.98-8.03 (*m*, 2 H, H_{ortho}-C(ar)), 7.55-7.63 (*m*, 1 H, H_{para}-C(ar)), 7.45-7.51 (*m*, 2 H, H_{meta}-C(ar)), 4.83 (*dd*, 1 H, *J* = 3.6, 6.2 Hz, H-C(2)), 4.80 (*dd*, 1 H, *J* = 3.6, 6.2 Hz, H-C(3)), 4.04 (*ddd*, 1 H, *J* = -0.6, 3.6, 6.5 Hz, H-C(1)), 4.00 (*dd*, 1 H, *J* = -0.6, -10.8 Hz, H_A-C(4)), 3.50 (*dd*, 1 H, *J* = 3.6, -10.8 Hz, H_B-C(4)), 3.46 (*dd*, 2 H, *J* = 6.5 Hz, C(2')), 1.44; 1.28 (*s*, 3 H, 2 x CH_3(isopropyl)); ^{13}C NMR (126 MHz, $CDCl_3$): δ = 197.70, (*s*, C(1'), 136.58 (*s*, C_q(ar)), 133.03, 128.39, 127.98 (*d*, C_t(ar)), 111.83 (*s*, C_q(isopropyl)), 81.01 (*d*, C(3)), 80.65 (*d*, C(2)), 78.30 (*d*, C(1)), 72.42 (*t*, C(4)), 37.84 (*t*, C(2')), 26.04, 24.76 (*q*, 2 x CH_3(isopropyl)); MS (ei, 80 eV, 70°C): 263 (M+1, 0.1%), 262 (M, 0.1%), 247 (M–CH_3, 17.3%), 204 (38.0%), 187 (17.8%), 145 (11.9%), 120 (17.0%), 105 (100%); anal. calcd. for $C_{15}H_{18}O_4$ (262.31): C, 68.69; H, 6.92; found: C, 68.87; H, 7.18.

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Dedicated to Professor Hans Paulsen on the occasion of his 75th birthday. Ad multos annos!

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