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Diastereoselective Dimerization of Aldonolactones

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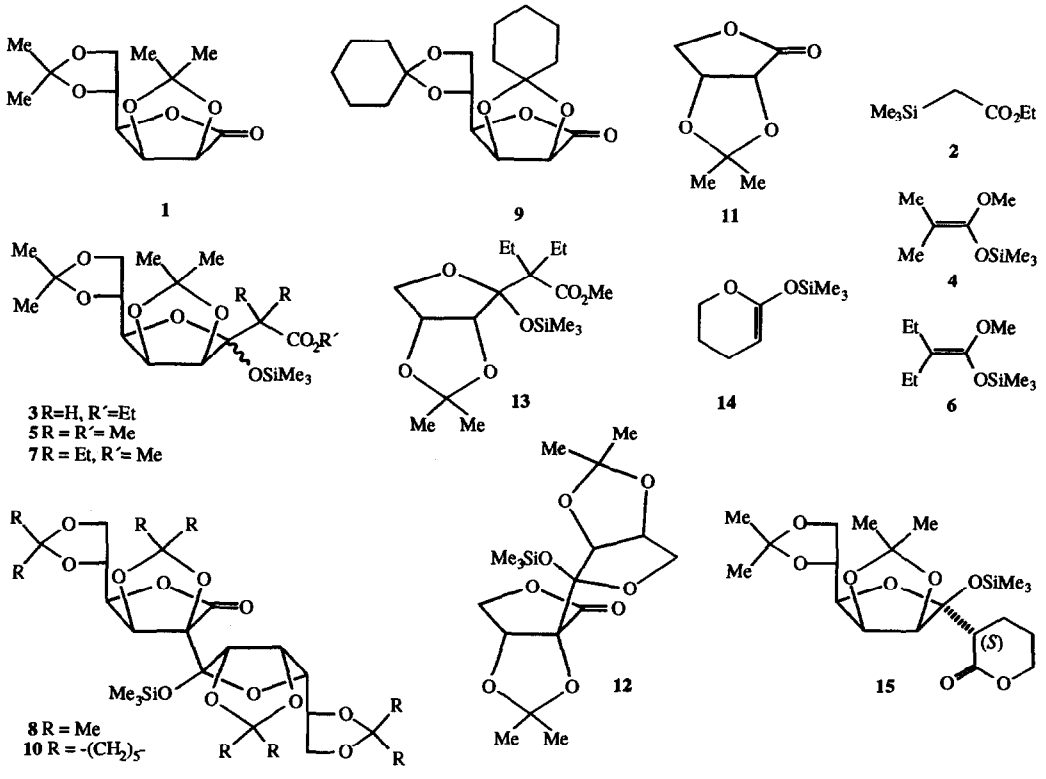
Abstract: The tris(dimethylamido)sulfonium difluorotrimethylsilicate (TAS-$TMSF_2$) mediated reaction of dialkyl substituted trimethylsilyl ketene acetals **4** or **6** with aldonolactones **1**, **9** or **11** affords dimers **8**, **10** and **12** in an unprecedented but diastereoselective manner. In addition, under the same conditions the reaction of a suitable protected aldonolactone with a cyclic trimethylsilyl ketene acetal **14** results in a diastereoselective chain elongation thus creating two new stereogenic centers diastereoselectively.

Many different approaches for the synthesis of branched or chain-elongated monosaccharides have been devised. Silyl ketene acetals are known to easily react in the presence of fluoride anion or Lewis acid catalysts with aldehydes and ketones, [1-3] Michael acceptors [4, 5] or with organic halides.[6-9] The Lewis acid mediated reaction of trimethylsilyl ketene acetals with lactones, however, has been obtained only under forced conditions in the presence of triphenylium hexachloroantimonate.[10] Very recently we reported first successful examples of the very smooth reaction between silyl ketene acetals and lactone carbonyl using tris(dimethylamido)sulfonium difluorotrimethylsilicate (TAS-$TMSF_2$) as a catalyst.[11]

During a systematic investigation of the scope and limitations of this reaction it was found, however, that the yields of the desired chain-elongated products dropped significantly upon using dialkyl substituted and sterically more demanding TMS ketene acetals. Thus, reaction of 2,3:5,6-di-*O*-isopropylidene-D-mannono-1,4-lactone (**1**) with ethyl trimethysilylacetate (**2**)[12]/TAS-$TMSF_2$ gave a combined yield of 88% of the corresponding anomeric ethyl 3-*O*-trimethylsilyl-D-manno-3-octulofuranosonates[13] **3** and 1-methoxy-2-methyl-1-trimethylsilyloxy-propene (**4**), *i.e.* the TMS ketene acetal of methyl isobutyrate, gave 63% of the corresponding 2,2-dimethyl analogue[11] **5** whereas the reaction of 1-methoxy-2-ethyl-1-trimethylsilyloxy-butene (**6**) afforded under the same conditions only 16% of **7** although complete consumption of the educt was observed and **6** has been used in a 2-3 molar excess. Careful chromatographic work up of the reaction mixture revealed the formation of another product **8** whose IR spectrum indicated (adsorption at ν = 1800 cm^{-1}) the presence of a lactone carbonyl which is found in the ^{13}C NMR spectrum at δ = 172.17 ppm. The ^{29}Si NMR showed a signal at δ = 19.3 ppm being indicative for a *O*-TMS moiety. In addition, from the ^{13}C NMR

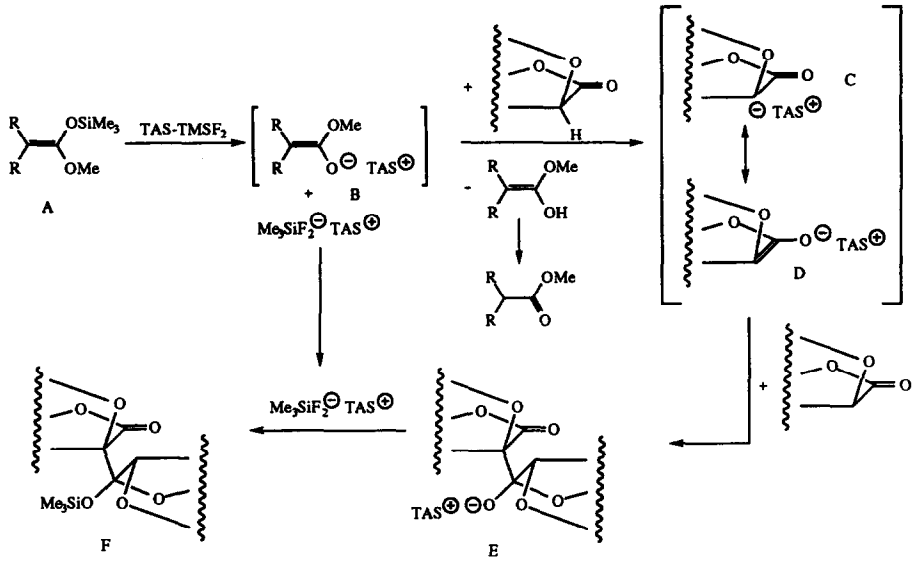
spectrum the presence of six quaternary carbons between δ = 89-115 ppm was deduced; four of these signals were assigned to the quaternary carbons of four isopropylidene acetals. The chemical shift of δ = 105.8 ppm is typical for a C(R,R´,OR, OTMS)-moiety; this signal was therefore assigned to an anomeric center. Thus, the remaining signal at δ = 89.2 ppm indicates a branching point. Neither the ^{1}H NMR nor the ^{13}C NMR spectra showed any signal resulting from an incorporation of parts of the carbon skeleton of the TMS ketene acetal. Hence, **8** was assigned the structure of a dimer possessing branching points at C(1) and C(2), respectively. Due to the presence and influence of the 2,3-*O*-acetal the branching reaction affords always just one stereoisomer.[14]



Similarly, the 2,3:5,6-di-*O*-cyclohexylidene analogue **9** [15] afforded upon reaction with **6** in the presence of TAS-TMSF$_2$ a 56% yield of dimer **10**. From 2,3-*O*-isopropylidene-D-erythrono-lactone (**11**)[16] the dimer **12** was obtained in 61% yield besides 33% of the chain-elongation product **13**.

It is well known that the reaction of non-enolizable carbonyl compounds with α-TMS substituted esters or TMS ketene acetals affords the β-trimethylsilyloxy esters in good yields whereas enolizable carbonyl compounds are transformed into their respective TMS enol ethers.[17] For a mechanistic explanation of this unprecedented carbohydrate-carbohydrate coupling it seems likely that the TMS ketene acetal **A** is transformed into a "free enolate" **B** which abstracts the H-C(2) proton of the aldonolactone. The reaction of either the resulting mesomeric species **C** or **D** with the C=O function of another aldonolactone from the less hindered side

results in the formation of a dimeric structure **E** whose hemiacetalic hydroxy group is trimethysilylated by Me_3SiF or more likely by TAS^+ $[Me_3SiF_2]^-$ to afford **F**. [14]



To confirm this mechanistic proposal, the aldonolactone **1** was allowed to react in succession with lithium diisopropylamide and chlorotrimethylsilane for 30 min at 0°C. The reaction proceeded slowly and under decomposition.[18] After work up, however, a 24% yield of the expected dimer **8** was isolated after careful and repeated chromatography.

As a further but more indirect proof for the proposed mechanism the reaction of a cyclic TMS ketene acetal was investigated. Thus, reaction of **1** with 3,4-dihydro-6-trimethylsilyloxy-2*H*-pyran (**14**)[19] in the presence of $TAS\text{-}TMSF_2$ afforded 31% of **15**. The reaction proceeded with high stereoselectivity and only one of the possible four stereoisomers (including the anomers) was formed. Since the absolute configuration of the two newly created stereogenic centers could not be deduced from spectroscopic data, suitable crystals of **15** were grown and subjected to X-ray analysis, the result of which is shown in Fig.1.

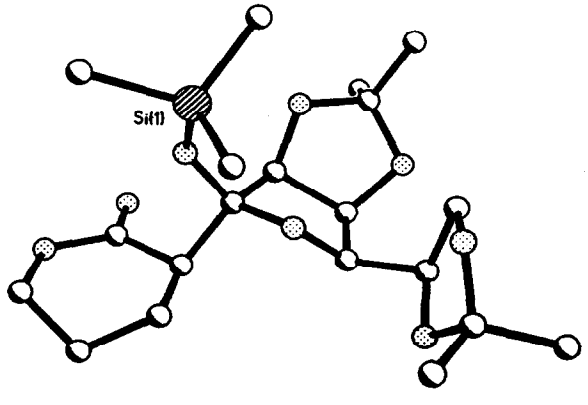


Fig. 1: Crystal structure of **15**

Space group $P2_12_12_1$

a = 10.341(8),

b = 12.285(7),

c = 18-087(11)Å

The formation of **15** as a single stereoisomer can be explained by an attack of the *si*-face of the TMS ketene acetal onto the *re*-face of the lactone carbonyl moiety; the *si*-face of lactone carbonyl group is less accessible due to the presence of the isopropylidene acetals. Inspection of *Dreiding* models revealed that the transition state from this *si-re* attack shows only minor steric interactions. The transition states resulting from a *re-re* attack, however, possess such interactions, *i.e.* the *re-re* attack of a pseudo $^{O(1),C(4)}B$ conformation of **14** gives rise to steric interactions between H-C(4) of **14** and H-C(2) of **1** whereas in the transition state from the *re-re* attack of the pseudo $B_{O(1),C(4)}$ conformation steric hinderance between H-C(5) of **14** and H-C(2) of **1** is observed. Hence the formation of the product should rather follow a pathway starting with a *si-re* attack leading finally *via* a six-membered chair-like transition state followed by a silico[3.3]sigmatropic rearrangement to **15**. From this mechanistic model a (*S*)-configuration at C(2) and a pseudoequatorial oriented anomeric trimethylsilyloxy group located at C(3) is deduced; this is in excellent agreement with the results from the X-ray analysis.

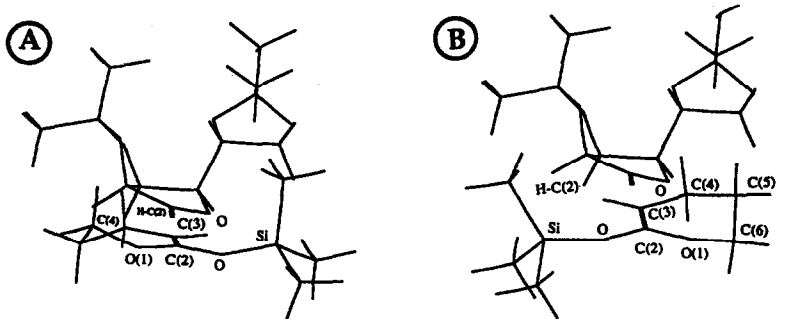


Fig. 2: Simulation [software Sybyl, Tripos Ass., St. Louis, MO; individual conformations were optimized by AM1 calculations] of the approach of the TMS ketene acetal **14** onto the *re*-face of the lactone carbonyl group of **1**: A: disfavoured *re-re*-approach; B: favoured *si-re* approach

EXPERIMENTAL

The 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 or a Varian XL300 instrument (δ given in ppm, *J* in Hz), IR spectra (film or KBr pellet) on a Perkin-Elmer 298 instrument, 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.

X-ray analysis of 15.- Crystals were cut to appropriate size and mounted on a glass pin using oil as an adhesive. Data were collected on a modified STOE four-circle diffractometer with a Mo-K_α source for a 2Θ -range between 5.5° and 60° at low temperature (-185°C). The structure was solved with the SHELXTL-package (program XS)[20] and refined with SHELXL 93 (UNIX-Version).[21] **15** crystallizes in space group

$P2_12_12_1$ (a = 10.341(8), b = 12.285(7), c = 18.087(11)Å, V = 2298.0(9) Å^3) with Z = 4 ($C_{20}H_{36}O_8Si$, ρ_{calc} = 1.245 gcm^{-3}, μ = 0.143 mm^{-1}). Cell dimensions were determined by least squares from the setting angles of 33 reflections with 7.5° ≤ 2Θ ≤15.6°. Data collection (ω-scan, Δω = 1.2°) involved all reflections of one octant of reciprocal space (4251 reflections observed, 4129 unique with R_{int} = 6.2% and 2913 with I > 2σ (I)). The structure was refined against F^2 quantities (269 parameters, 4129 observations) using empirical weights (W = 1/[$\sigma^2(F_{obs}^2)+(0.076*P)^2$ + 0.27P] with P = [Max(F_{obs}^2,0) + 2F_{calc}^2]/3) R1 = 0.0585 for 2913 F_{obs} > 4σF_{obs}, wR2 = 0.1685 for all data;[21] GooF = 1.108 for F_{obs} > 4 F_{obs}, 1.130 for all data; Flack x parameter[22] = 0.0652 (0.8670 if inverted) with esd 0.2701 (exp. 0 for correct, 1 for inverted absolute structure).[23]

General procedure.- To a solution of the lactone in dry THF (2 *ml*) and **6** a catalytic amount of TAS-$TMSF_2$ was added at 0°C and the mixture was stirred under argon at 25°C for 2h. Upon the addition of TAS-$TMSF_2$ the colour of the reaction mixture turned yellow/orange. The mixture was then diluted with ethyl acetate (25 *ml*) and washed with ice water and brine (2 *ml* each). The combined organic layers were dried (Na_2SO_4), the solvent was removed *in vacuo* and the residue subjected to flash chromatography (silica gel, ethyl acetate / hexane 1:10) to yield the products.

2,3-*O*-Isopropylidene-2-(2,3-*O*-isopropylidene-1-*O*-trimethylsilyl-α-D-erythrosyl)-D-erythrono-1,4-lactone (12) and **methyl 2-desoxy-4,5-*O*-isopropylidene-2,2-diethyl-3-*O*-trimethylsilyl-α-D-erythro-3,6-furanoso-3-hexulosonate (13).-** From the reaction of **11** (0.24 g, 1.5 mmol) and **6** (0.61 g, 3 mmol) **12** (0.36 g, 61%) and **13** (0.18 g, 33%) were obtained.

Data for **12**.- mp 69-71°C, $[\alpha]_D^{20}$ -32.7° (*c* 1.1, $CHCl_3$), R_F = 0.6 (hexane / ethyl acetate 3:1); IR (KBr): 2970*s*, 2950*s*, 2860*w*, 1760*s*, 1435*m*, 1370*m*, 1360*m*, 1230*m*, 1095*w*, 1070*w*, 820*w*; ^{1}H NMR (250 MHz, $CDCl_3$): 0.23 (*s*, 9 H, $SiMe_3$), 1.40 (*s*, 3 H, Me), 1.47 (*s*, 6 H, 2 x Me), 1.62 (*s*, 3 H, Me), 3.99 (*dd*, *J* = 2.6, 10.0 Hz, 1 H), 4.06 (*dd*, *J* = 5.2, 10.0 Hz, 1 H), 4.36-4.38 (*m*, 2 H), 4.82-4.92 (*m*, 3 H); ^{13}C NMR (62 MHz, $CDCl_3$): 173.91 (*s*, COO), 115.05, 113.01 (each *s*, C_q of isopropylidene), 106.84 (*s*, $C_{anomeric}$), 87.49 (*s*, C(2)), 80.73, 80.21, 78.56 (each *d*), 72.47, 70.52 (each *t*, C(5,5')), 27.22, 26.53, 25.82, 23.93 (each *q*, Me), 1.96 (q, $SiMe_3$); MS (ei, 65°C, 80 eV): 373 (18.2%), 315 (9.6%), 275 (18.0%), 231 (100%), 185 (10.7%), 172 (24.3%), 157 (86.5%), 145 (24.4%), 131 (60.8%); Anal. Calcd. for $C_{17}H_{28}O_8Si$ (388.49): C, 52.56; H, 7.26; found: C, 52.61; H, 7.18.

Data for **13**.- oil, $[\alpha]_D^{20}$ +12.9° (*c* 1.4, $CHCl_3$), R_F 0.74 (hexane / ethyl acetate 3:1); IR (film): 2960*s*, 2895*m*, 1730*s*, 1465*m*, 1440*w*, 1390*m*, 1380*m*, 1250*s*, 1230*s*, 1210*s*, 1170*m*, 1130*m*, 1100*s*, 1035*m*; ^{1}H NMR (250 MHz, $CDCl_3$): 0.20 (*s*, 9 H, $SiMe_3$), 0.87 (*t*, *J* = 7.0 Hz, 3 H, Me), 0.93 (*t*, *J* = 7.0 Hz, 3 H, Me), 1.35 (*s*, 3 H, Me), 1.55 (*s*, 3 H, Me), 1.60-1.95 (*m*, 4 H, 2 x CH_2), 3.65 (*s*, 3 H, OMe), 3.85-4.0 (*m*, 2 H, $H_{A,B}$-C(6)), 4.75 (*m*, 1 H, H-C(5)); 4.98 (*d*, *J* = 6.0 Hz, H-C(4)); ^{13}C NMR (62 MHz, $CDCl_3$): 175.34 (*s*, COO), 113.07, 110.88 (each *s*, C_q of isopropylidene and $C_{anomeric}$), 82.02, 80.07 (each *d*), 71.82 (*t*, C(6)), 58.96 (*s*, C(2)), 51.51 (*q*, OMe), 26.11 (*q*, Me), 25.46 (*t*, CH_2), 24.30 (*q*, Me), 23.56 (*t*, CH_2), 9.88 (*q*, Me), 9.74 (*q*, Me), 2.23 (*q*, $SiMe_3$); ^{29}Si NMR (40 MHz, $CDCl_3$): 12.01; MS (ei, 78°C, 80 eV): 345 (6.2%), 287 (4.2%), 247 (16.7%), 231 (61.1%), 211 (11.8%), 202 (6.6%), 187 (6.5%), 157 (13.9%), 131 (23.0%); Anal. Calcd. for $C_{17}H_{32}O_6Si$ (360.53): C, 56.64; H, 8.95; found: C, 56.57; H, 8.73.

2,3:5,6-Di-*O*-isopropylidene-2-(2,3;5,6-di-*O*-isopropylidene-1-*O*-trimethylsilyl-β-D-mannofuranosyl)-mannono-1,4-lactone (8) and **methyl 2-deoxy-4,5:7,8-di-*O*-isopropylidene-2,2-diethyl-3-*O*-trimethylsilyl-β-D-manno-3,6-furanoso-3-octulosonate (7).**- From **1** (0.52 g, 2 mmol) and **6** (0.81 g, 4 mmol) **8** (0.27 g, 45%) and **7** (0.35 g, 38%) were obtained.

Alternatively, to a solution of lithium diisopropylamide (prepared from diisopropylamine (0.28 *ml*, 2 mmol) and *n*-butyllithium (1.25 *ml*, 2.0 mmol, of a 1.6 M solution in *n*-hexane) in THF a solution of **1** (1.0 g, 3.9 mmol) in THF (5 *ml*) was slowly added at 0°C. After stirring for 30 min chlorotrimethylsilane (0.25 *ml*, 2.0 mmol) was slowly added, stirred for another 30 min and warmed to 25°C. The reaction mixture was diluted with ethyl acetate (50 *ml*) and washed with ice water and brine (5 *ml* each), dried (Na_2SO_4) and the solvent was removed under reduced pressure. The residue was subjected to chromatography (silica gel, hexane / ethyl acetate 10:1) to afford **8** (0.28 g, 25%). [24]

Data for **8**.- mp 136-138°C, $[\alpha]_D^{20}$ +21.1° (*c* 0.9, $CHCl_3$), R_F 0.38 (hexane / ethyl acetate 3:1); IR (KBr): 2995*s*, 2940*m*, 2900*w*, 1800*s*, 1455*m*, 1385*s*, 1250*s*, 1190*m*, 1140*w*, 1115*m*, 1070*s*, 1010*w*, 975*w*, 940*w*, 900*w*, 890*w*, 845*s*; ^{1}H NMR (300 MHz, $CDCl_3$): 0.18 (*s*, 9 H, $SiMe_3$), 1.39 (*s*, 9 H, 3 x Me), 1.44, 1.45, 1.46, 1.48, 1.61 (each *s*, 3 H, Me), 4.0-4.17 (*m*, 5 H), 4.26-4.40 (*m*, 3 H), 4.69 (*d*, *J* = 6.1 Hz, 1 H), 4.76 (*d*, *J* = 4.6 Hz, 1 H), 4.80 (*d*, *J* = 3.4 Hz, 1 H); ^{13}C NMR (62 MHz, $CDCl_3$): 172.17 (*s*, COO), 114.95, 112.76, 109.85, 109.58 (each *s*, C_q of isopropylidene), 105.80 (*s*, $C_{anomeric}$), 89.20 (*s*, C(2)), 80.96, 80.06, 79.77, 79.47, 78.79, 72.87, 72.52 (each *d*), 67.36, 66.71 (each *t*, C(6,6'), 27.26, 27.04, 26.89, 26.68, 25.20, 25.18, 23.32 (each *q*, Me), 1.95 (*q*, $SiMe_3$); ^{29}Si NMR (40 MHz, $CDCl_3$): 19.30; MS (ei, 92°C, 80 eV): 572 (14.5%), 514 (2.5%), 456 (1.0%), 374 (4.0%), 330 (48.4%), 292 (5.7%), 271 (8.1%); Anal. Calcd. for $C_{27}H_{44}O_{12}Si$ (588.72): C, 55.09; H, 7.53; found: C, 55.37; H, 7.58.

Data for **7**.- oil, $[\alpha]_D^{20}$ -30.4° (*c* 1.2, $CHCl_3$); IR (film): 2990*s*, 2960*s*, 2915*m*, 1740*s*, 1465*m*, 1445*m*, 1385*s*, 1375*s*, 1265*s*, 1250*s*, 1210*s*, 1130*s*, 1115*s*, 1060*s*, 1020*m*, 880*m*, 845*m*; ^{1}H NMR (300 MHz, $CDCl_3$): 0.18 (*s*, 9 H, $SiMe_3$), 0.85 (*t*, *J* = 7.0 Hz, 3 H, Me), 0.92 (*t*, *J* = 7.0 Hz, 3 H, Me), 1.32 (*s*, 3 H, Me), 1.38 (*s*, 3 H, Me), 1.40 (*s*, 3 H, Me), 1.55 (*s*, 3 H, Me), 1.60-2.90 (*m*, 4 H, 2 x CH_2), 3.65 (*s*, 3 H, OMe), 3.67-3.71 (*m*, 1 H), 3.95-4.50 (*m*, 3 H), 4.75 (*dd*, *J* = 6.0, 8.9 Hz, 1 H), 5.11 (*d*, *J* = 6 Hz, 1 H, H-C(4)); ^{13}C NMR (75 MHz, $CDCl_3$): 172.34 (*s*, COO), 112.00, 110.31, 109.93 (each *s*, C_q of isopropylidene and $C_{anomeric}$), 81.75, 79.95, 77.80, 73.50 (each *d*), 66.92 (*t*, C(8)), 51.30 (*q*, OMe), 50.05 (*s*, C(2)), 27.10 (*q*, Me), 25.80 (*t*, CH_2), 25.61 (*q*, Me), 24.05 (*q*, Me), 24.02 (*t*, CH_2), 10.93 (*q*, Me), 9.95 (*q*, Me), 1.92 (*q*, $SiMe_3$); ^{29}Si NMR (40 MHz, $CDCl_3$): 13.03; MS (ei, 105°C, 80 eV): 445 (8.7%), 387 (14.2%), 331 (49.9%), 273 (7.5%), 247 (19.9%), 215 (17.2%), 187 (6.8%), 171 (10.0%), 157 (14.7%), 141 (36.3%); Anal. Calcd. for $C_{22}H_{40}O_8SI$ (460.64): C, 57.36; H, 8.75; found: C, 57.06; H, 8.72.

2,3:5,6-Di-*O*-cyclohexylidene-2-(2,3:5,6-di-*O*-cyclohexylidene-1-*O*-trimethylsilyl-β-D-mannofuranosyl)-D-mannono-1,4-lactone (10).- From **9** (0.68 g, 2 mmol) and **6** (0.81 g, 4 mmol) **10** (0.42 g, 56%) was obtained as a crystalline solid: mp 58-60°C, $[\alpha]_D^{20}$ +12.0° (*c* 1.4, $CHCl_3$), R_F 0.73 (hexane / ethyl acetate 3:1); IR (KBr): 2990*s*, 2810*m*, 1775*s*, 1710*m*, 1430*m*, 1345*m*, 1320*w*, 1270*m*, 1230*w*, 1140*w*, 1075*m*, 1030*m*, 825*w*; ^{1}H NMR (250 MHz, $CDCl_3$): 0.16 (*s*, 9 H, $SiMe_3$), 1.26-1.82 (*m*, 20 H, 10 x CH_2), 4.00-4.14 (*m*, 4 H), 4.21 (*dd*, *J* = 4.6, 7.8 Hz, 1 H), 4.29-4.40 (*m*, 3 H), 4.61 (*d*, *J* = 6.0 Hz, 1 H), 4.75 (*d*, *J* = 4.6 Hz, 1 H), 4.77 (*d*, *J* = 3.1 Hz, 1H); ^{13}C NMR (62 MHz, $CDCl_3$): 172.05 (*s*, COO), 115.36, 113.32, 110.19, 109.72 (each *s*, C_q of cyclohexylidene), 105.72 (*s*, $C_{anomeric}$), 88.84 (*s*, C(2)), 80.54, 79.86, 79.76, 79.36, 79.12, 72.59, 72.33 (each *d*), 66.82, 66.30 (each *t*, C(6,6')), 36.74, 36.61,

36.17, 35.07, 34.99, 34.75, 32.83, 25.22, 25.10, 24.64, 24.02, 23.93, 23.83, 23.58 (each *t*), 2.01 (*q*, $SiMe_3$); ^{29}Si NMR (40 MHz, $CDCl_3$): 19.1; MS (ei, 157°C, 80 eV): 748 (43.4%), 706 (10.7%), 635 (1.8%), 454 (5.9%), 411 (100%), 312 (9.9%), 196 (23.2%), 171 (38.2%), 157 (31.4%), 141 (67.7%); Anal. Calcd. for $C_{39}H_{60}O_{12}Si$ (748.99): C, 62.54; H, 8.07; found: C, 62.58; H, 8.16.

(2S)-2-Deoxy-2-(3´-hydroxypropyl)-4,5:7,8-di-*O*-isopropylidene-3-*O*-trimethylsilyl-β-D-manno-3,6-furanoso-3-octulosonate-1,3´-lactone (15).- From **1** (0.75 g, 2.9 mmol) and **14** (1.5 g, 8.7 mmol) **15** (0.38 g, 31%) was obtained as colourless, fine needles; mp 123-125°C, $[\alpha]_D^{20}$ -9.0° (*c* 2, $CHCl_3$), R_F 0.11 (hexane / ethyl acetate 3:1); ^1H NMR (300 MHz, $CDCl_3$): 0.19 (*s*, 9 H, $SiMe_3$), 1.37, 1.38, 1.44, 1.57 (each *s*, 3 H, 4 x Me), 1.82-1.99 (*m*, 4 H, 2 x CH_2), 2.69 (*t*, *J* = 8 Hz, 1 H, H-C(2)), 3.51 (*dd*, *J* = 4.4, 7.9 Hz, 1 H, H-C(6)), 3.98 and 4.11 (*AB* part of *ABX*, *J* = 4.5, 6.2, 8.6 Hz, $H_{A,B}$-C(8)), 4.24-4.43 (*m*, 3 H, OCH_2 and H-C(5)), 4.75 (*dd*, *J* = 4.5, 6.0, 1 H, H-C(5)), 5.20 (*d*, *J* = 6.0, 1 H, H-C(4)); ^{13}C NMR (75 MHz, $CDCl_3$): 170.03 (*s*, COO), 112.34, 109.26, 106.85 (each *s*, C_q of isopropylidene and $C_{anomeric}$), 81.17, 79.04, 77.86, 72.99 (each *d*), 69.13 (*t*, C(8)), 66.94 (*t*, OCH_2), 46.33 (*d*, C(2)), 26.94, 25.38, 25.18, 24.08 (each *q*, Me), 22.18, 20.21 (each *t*, CH_2), 2.42 (q, $SiMe_3$); MS (ei, 81°C, 80 eV): 415 (6.3%), 357 (3.6%), 331 (4.3%), 329 (4.5%), 299 (2.3%), 265 (1.9%), 243 (3.5%), 217 (44.5%), 201 (3.0%), 172 (9.9%), 141 (29.5%); Anal. Calcd. for $C_{20}H_{34}O_8Si$ (430.57): C, 55.79; H, 7.97; found: C, 56.03; H, 7.96.

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12 As previously shown [11] α-trimethylsilylated esters can be used quite efficiently for the *in-situ* preparation of the corresponding TMS ketene acetals.

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