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FULL PAPER

Synthesis of symmetrical dodeco-6,7-diuloses

Marius Bayer,[a] Simon Stocker,[a] Cäcilia Maichle-Mössmer,[a] and Thomas Ziegler*[a]

Dedicated to Professor Franz Effenberger on the occasion of his 90th Birthday

Abstract: Dodeco-6,7-diuloses represent a rare class of sugars and can be considered as anomerically linked di-hexoses with two hemiacetal functions in the middle. Here, the synthesis of three symmetrical dodeco-6,7-diuloses (*gluco-gluco*, *galacto-galacto*, *manno-manno*) is described. For their preparation four synthetic strategies were pursued, whose mutual key step, the connection of the anomeric centers, is particularly emphasized. Specifically, *CC*-bond forming methods are employed, such as a Grubbs metathesis, a stannyl glycal homocoupling reaction, a coupling of a sulfinyl glycal with a sugar lactone and a Ramberg-Bäcklund rearrangement. Since the ring closure via hemiacetal formation of the target compounds cannot be predicted, intensive NMR spectroscopic structure elucidation of the diuloses was performed.

Introduction

Carbohydrates are the most abundant class of natural products and play a major role in biological and biochemical processes in living systems.[1] Besides naturally occuring glycoconjugates, synthetically designed sugar mimetics attained considerable interest in current carbohydrate research.[2] Especially stable structures resisting enzymatic degradation are of significant importance, for instance, due to their eligibility to act as glycosidase inhibitors.[3,4] In this context, bicyclic and 1,2-annulated sugars emerged as highly potential candidates and the development of new synthetic methodologies for this group of carbohydrates became attractive over the last two decades.[5–11] The emphasis of this work will be on the synthesis of symmetrical dodeco-6,7-diuloses which depict a rather rare class of bicyclic disaccharides. In their open-chain form, dodeco-6,7-diuloses can be represented either as vicinal di-ketones preferring to constitute six-membered hemiacetals like 1,2-annulated sugars (type A) or anomerically 1,1'-connected scaffolds which can be regarded as trehalose analogues (type B) (Figure 1).

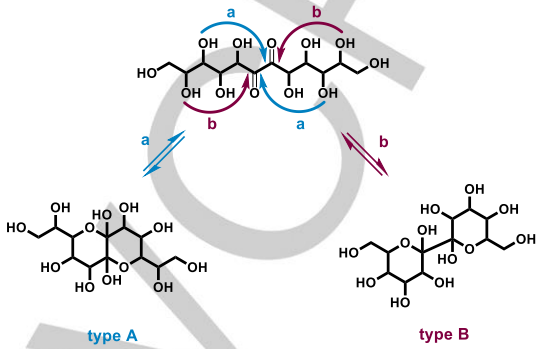

Figure 1. Hemiacetalic ring-closures of dodeco-6,7-diuloses.

This structural diversity of vicinal diuloses enhances scientific attraction and provides a larger scope of retrosynthetic approaches to gain access to these compounds. Nevertheless, there are only two examples mentioned in the literature for the synthesis of higher (C ≥ 10) symmetrical diuloses. In both cases, the crucial key step was the connection of the anomeric centers followed by an oxidation and deprotection sequence. To this end, Mochizuki and Shiozaki used a coupling reaction of a stannyl glucal with a glucono lactone,[12] whereas Menzel and Ziegler performed the anomeric connection by means of a Grubbs metathesis (Figure 2).[13] The ambition of Menzel's work was the synthesis and structural elucidation of the hypoglycemic active deco-5,6-diulose Peltalosa which was isolated from the roots and rhizomes of the Mexican plant *Psacalium peltatum*, due to the fact that its stereochemistry is yet unknown.[14]

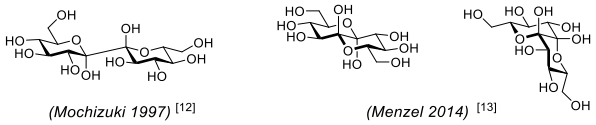

Figure 2. Higher symmetrical diuloses in the literature: D-*gluco*-L-*gulo*-dodeco-6,7-diulose (Mochizuki 1997), L-*manno*-D-*erythro*-Deco-5,6-diulose and L-*gulo*-D-*erythro*-Deco-5,6-diulose (Menzel 2014).

In this study, we examined the applicability of Menzel's protocol for the preparation of homologous dedeco-6,7-diuloses. Furthermore, we expanded the spectrum of synthetic options and accentuated the significance of the imperative anomeric connection as the key step in every suggested route as well. Therefore, we employed nucleophilic glycal derivates as versatile

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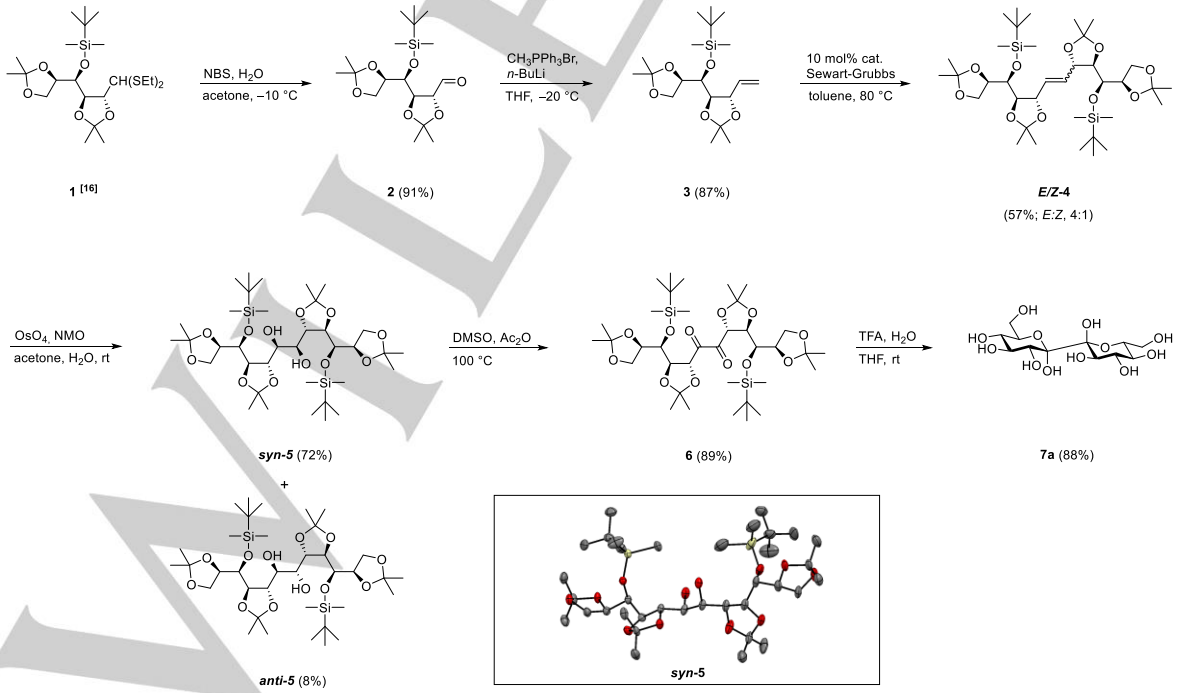
precursors. Stannylated glycals perform homocoupling reactions under Stille conditions to furnish *endo*-glycalic dimers,[15] whereas phenylsulfinyl glycals attack carbohydrate lactones in the presence of a strong lithium base in a similar fashion as described by Mochizuki and Shiozaki. In addition, we present the formation of dimeric *exo*-glycals via a Ramberg-Bäcklund reaction using sulfone bridged dipyranosides. Oxidation and deprotection of the C1-C1' linked intermediates provided the appropriate dodeco-6,7-diuloses in all cases.

Results and Discussion

Grubbs-Metathesis

Inspired by the diulose structure of the hypoglycemic active natural product Peltalosa, first investigations on the synthesis of deco-5,6-diuloses has been described by our group in 2014.[13] Starting from the aldopentoses L- and D-arabinose, the corresponding 3,4:5,6-di-*O*-isopropylidene-protected hex-1-enitols were prepared by a Wittig olefination. Next, a metathesis-hydroxylation-oxidation sequence was used for the conversion of the hex-1-enitols into the symmetrical deco-5,6-diuloses, which were obtained as open-chain vicinal diketones in their fully protected form. After acidic removal of the isopropylidene acetals, X-Ray and NMR analysis were employed to determine the 1,2-annulated dipyranose conformations of the resulting plain carbohydrates (Figure 2). In an endeavour to apply this methodology to the synthesis of homologous longer chain dodeco-6,7-diuloses, we commenced with the preparation of the completely protected D-glucose derivative **1** according to literature procedure.[16] The application of a *tert*-butyl-dimethylsilyl-ether as an additional protection group at position 4 seemed to be suitable for our purpose for this protecting group is insensitive towards oxidative conditions and its removal can be performed simultaneously along with the hydrolysis of the acetonide groups in acidic milieu.

First, the thioacetal function in **1** was cleaved by oxidation using *N*-bromosuccinimide to afford aldehyde **2** in 91% yield (Scheme 1). Treatment of the aldehyde with methyl triphenyl phosphonium bromide and *n*-butyllithium resulted in the formation of terminal hept-1-enitol **3** in 87% yield. In order to accomplish the anomeric coupling of two hept-1-enitols, we employed an olefin-metathesis similar to previous one.[13] However, contrary to the previously high yielding reaction when using Hoveyda-Grubbs second generation-catalyst,[17] we isolated merely 17% of the appropriate coupling product under the same conditions. Presumably, the bulky TBDMS-groups are to be to blame for the moderate conversion. Therefore, we deployed the sterically less demanding Stewart-Grubbs catalyst[18] which implies two tolyl-entities attached to the NHC-ligand, unlike the Hoveyda-Grubbs



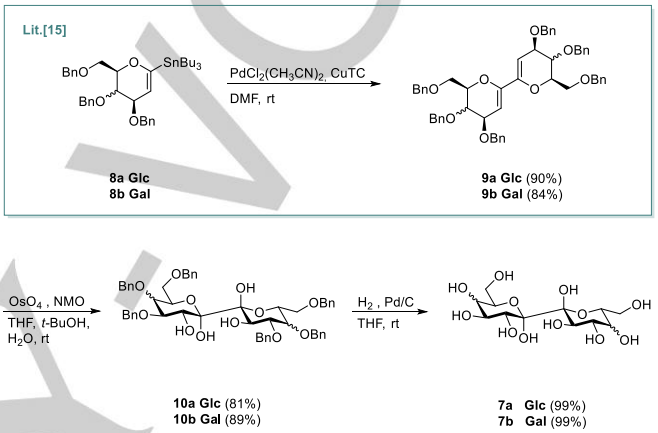
Scheme 1. Synthesis of D-*gluco*-L-*gulo*-Dodeco-6,7-diulose **7a** via Grubbs metathesis.

catalyst which contains two mesityl-groups at the same positions. Indeed, the yields were increased up to 57%, obtained as an inseparable diastereomeric mixture of ***E*-4** and ***Z*-4** (4:1). The following *cis*-selective dihydroxylation of the alkene-mixture ***E*-4/*Z*-4** with OsO_4 and *N*-methylmorpholine *N*-oxide gave two chromatographically separable diols ***syn*-5** and ***anti*-5** in 72% and 8% yield, respectively. The anticipated C_2-symmetry of the major-product ***syn*-5**, which resulted in the stereoselective osmoylation of ***E*-4** from the sterically more accessible face, was proved by ^{13}C-NMR-experiment since only six signals between 65 and 85 ppm were detectable. Furthermore, diamond-shaped crystals suitable for X-ray crystallography were obtained by recrystallization of ***syn*-5** in *n*-hexane (Scheme 1). Dihydroxylation of ***Z*-4** resulted in the formation of the unsymmetrical minor product ***anti*-5**. Thus, the determination of ***E*-4** as the major diastereomer as it occurred in previous olefin metathesis was verified. Next, examinations have been carried out on the oxidation of diol ***syn*-5** in order to convert it efficiently into the corresponding diketone **6**. For this purpose, we confined our attempts to DMSO-mediated Swern-type oxidation methods as these provided the best results for similar cases.[13,19] Classical Swern oxidation (oxalyl chloride)[20] and the alternative Omura-Sharma-Swern modification (trifluoroacetic anhydride)[21] proceeded imperfectly and exhibited solely the mono-oxidized α-hydroxy ketone here. Fortunately, oxidation under Albright-Goldman conditions (acetic anhydride)[22] turned out to be the method of choice, for it is known to succeed for hindered alcohols and can be performed at elevated temperatures. Consequently, we converted the diol ***syn*-5** into the vicinal diketone **6** with DMSO and acetic anhydride at 100 °C in 89% yield. Finally, the protection groups were removed synchronously with trifluoracetic acid (TFA) to afford dodeco-6,7-diulose **7a** in 88% yield.

Homo-coupling of stannyl glycals

In a previous study we scrutinized the palladium-catalyzed homo-coupling reaction of stannylated glycals **8a** and **8b** for the preparation of *endo*-glucal dimers **9a** and **9b**.[15] In continuation, these dimeric enol ethers were now utilized as precursors for the synthesis of the glucose-dimer **7a** and its galactose configurated counterpart **7b** as follows.

Benzylated glucal- and galactal-dimers **9a** and **9b** were treated with OsO_4 and *N*-methylmorpholine *N*-oxide under standard Upjohn conditions to furnish the symmetrical diuloses **10a** and **10b** in 81% and 89% yield, respectively (Scheme 2). ^{1}H-NMR-experiments confirmed that the bis-dihydroxylation occurs in a *cis*-selective manner from the *si*-face, as the coupling constants match those of a *gluco*- for **10a** and a *galacto*-configuration for **10b**. Eventually, debenzylation with palladium on activated charcoal under hydrogen-atmosphere yielded the desired products **7a** and **7b** quantitatively. Compound **7a** was previously prepared from 3,4,6-tri-*O*-benzyl-1-stannyl-D-glucal via stereospecific addition reaction of lithioglucal to 2,3,4,6-tetra-*O*-benzyl-D-glucono-1,5-lactone.[12]



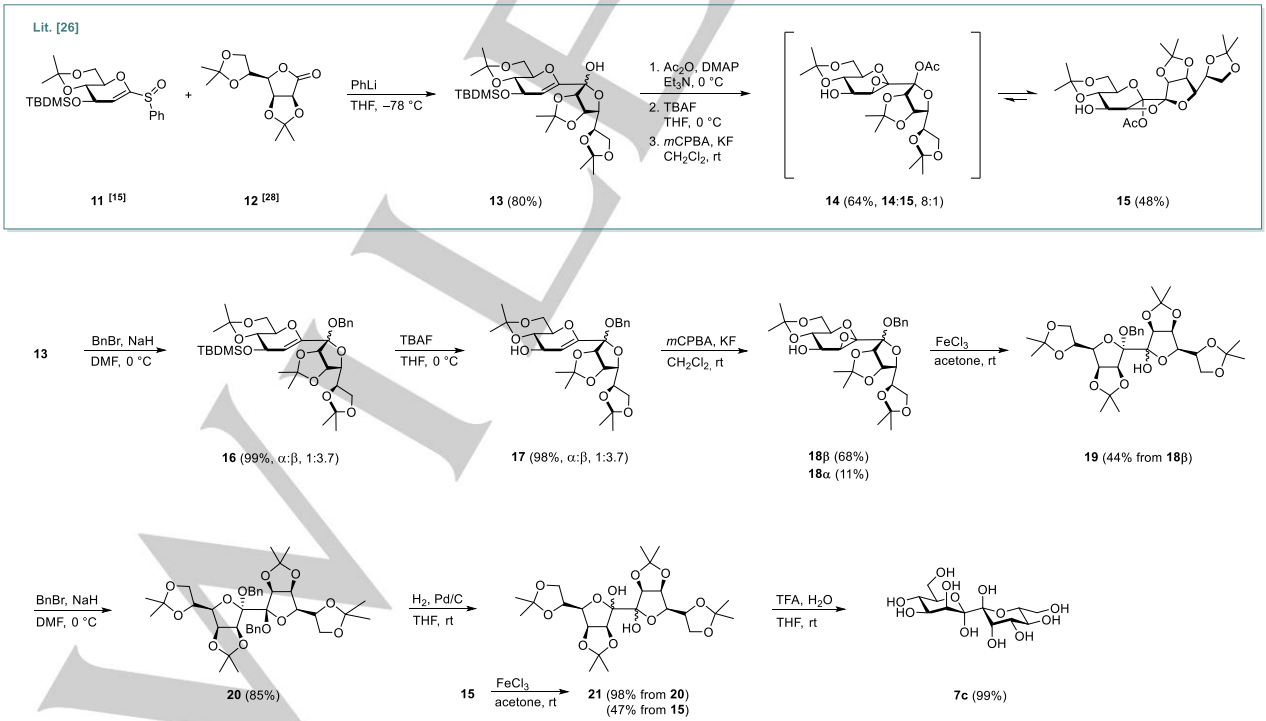
Scheme 2. Synthesis of D-*gluco*-L-*gulo*-Dodeco-6,7-diulose **7a** and D-*galacto*-L-*galacto*-Dodeco-6,7-diulose **7b** via stannyl glycal homocoupling.

Sulfoxide-lactone coupling

Since our ambition was to synthesize all symmetrical dodeco-6,7-diuloses regardless of their configuration, we had to find a route in which the dihydroxylation of the *endo*-glycal entity proceeds selectively from the less favorable *re*-side. Accordingly, a glucal moiety had to be converted to a mannose derivative. Common methods for resolving similar problems are based on substrate-directing reagents such as molybdenum catalysts,[23] vanadylacetyl acetonate ($VO(acac)_2$)[7,24] or *meta*-chloroperbenzoic acid (*m*CPBA)[24,25] for an epoxidation. Thereafter, hydrolysis of the oxirane leads stereoselectively to the desired configuration. The prerequisite for the application of these procedures in our case was the presence of a hydroxyl group adjacent to the double bond which can coordinate the oxidizing agent to the *re*-side. Thus, a protection group strategy with isopropylidene and TBDMS was applied, allowing the orthogonal deprotection of the allyl position. Attempts to stereoselectively dihydroxylate *endo*-glucal dimers analogous to **9a** and **9b** with unprotected allyl-positions under the conditions mentioned above,

resulted in inseparable diastereomeric mixtures since both, the epoxidation and the subsequent ring-opening occurred simultaneously at two double bonds. In order to minimize the formation of various diastereomers, disaccharide scaffolds were synthesized in which only one glucal moiety had to be oxidized. Parts of the synthesis presented here have already been published under the focus of an unexpected rearrangement of an epoxide to an oxetane.[26] For better comprehension, our previous results will be explained briefly. First, the coupling of the anomeric centers was accomplished by the attack of a lithiated glucal on a sugar lactone similar to the synthesis of Mochizuki and Shiozaki.[12] These authors used stannylated glycals as precursors which could be converted in situ into the corresponding highly reactive lithiated glycals by the addition of *n*-butyllithium. In 2008 Koncienski et al. reported an alternative preparation of lithiated glycals by treatment of phenylsulfinyl glycals with phenyllithium.[27] Since phenylsulfinyl glycals are more easily accessible and non-toxic compared to their stannylated counterparts we chose the known 4,6-isopropylidene-3-*tert*-butyldimethylsiliyl-protected phenylsulfinyl glucal **11**[15] as our starting compound (Scheme 3). Treatment of **11** with 1 equivalent of phenyllithium followed by quenching with mannono-lactone **12**[28] after 5 minutes furnished the coupling product **13** in 80% yield as an anomeric mixture (α:β, 1:5). Next, the anomeric position of the furanose moiety was esterified with acetic anhydride. Subsequent desilylation was performed with tetra-*n*-butylammonium fluoride (TBAF) to excavate the rigid allyl alcohol system that enables the aspired β-selective epoxidation. The best epoxidation results were obtained using the Camps reagent (*m*CPBA/KF).[25,29] However, the pure β-epoxide **14** could not be isolated because of a reversible rearrangement to an oxetane-bridged disaccharide **15**. If the reaction was quenched early, merely an epoxide-oxetane mixture in a ratio of 8:1 could be obtained, whereas the formation of oxetane was preferred by extending the reaction times. The structure of **15** was confirmed by X-ray crystallography and a mechanistic suggestion for the unusual rearrangement involving an ester group migration was provided in our early work.[26]

In order to avoid such an epoxide-oxetane-rearrangement, the acetic ester was replaced by an ether protecting group. Thus, the tertiary alcohol group in compound **13** was masked under standard benzylation conditions with benzyl bromide and sodium hydride to afford **16** quantitatively as an inseparable anomeric mixture (α:β, 1:3.7). After cleavage of the silyl ether with TBAF, allyl alcohol **17** (α:β, 1:3.7) could be obtained in 98% yield. Next, the diastereoselective β-epoxidation with Camps reagent was investigated, and indeed, the rearrangement to oxetane could be prevented. At this point, the two anomers could be completely



Scheme 3. Synthesis of D-*manno*- D-*manno* -Dodeco-6,7-diulose **7c** via sulfoxide-lactone coupling.

separated chromatographically and the oxiranes **18β** and **18α** were isolated in 68% and 11% yields, respectively.

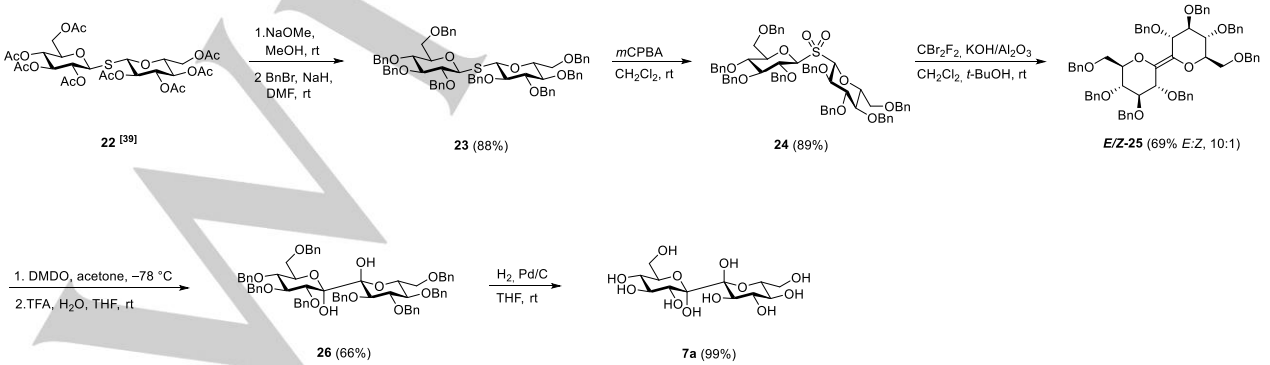
Based on compounds **18β** and **15**, experiments were first performed in which first the anomeric protecting groups were cleaved, followed by acid-catalyzed ring-opening reactions of the *O*-heterocycles (epoxide ring in **18β** and oxetane ring in **15**), which take place simultaneously with the removal of the isopropylidene groups. In both cases, however, the formation of the symmetrical target molecule, as was observed in the case of compounds **7a** and **7b**, could not be verified by NMR spectroscopy. Instead, a product mixture was obtained which leads to the assumption that the ring-opening of the epoxide and oxetane rings occured non-selectively and resulted in a mixture of the desired *manno*- and the unwanted *gluco*-configuration. Since the separation of unprotected mixtures of saccharides generally proves to be rather difficult, this approach was also not a feasible option in our situation. We have therefore decided to develop a synthesis in which both disaccharide units bear the *manno*-configuration prior to the final deprotection step. Thus, the oxirane ring-opening of compound **18β** was induced by ferric chloride catalysis in acetone. The synchronous acetonide protection of the released hydroxyl groups gave diulose **19** in 44% yield. It is worth mentioning in this context that a re-acetalation from 1,3-linked dioxane to a 1,2-linked dioxolane takes place. This was evident from the chemical shifts of the quaternary carbon atoms in the ^{13}C-NMR spectrum of compound **19** (dioxane 97–101 ppm; dioxolane 108–111 ppm).[30] Compound **19** was unfortunately not obtained as a single substance though. The coupling constants of the major product correspond to those of two mannose fragments. However, it could not be determined whether it was a mixture of anomers or *gluco*- and *manno*-configured diastereomers. Nevertheless, the remaining alcohol group in **19** was benzylated and afforded the diulose **20** in anomerically pure form in 85% yield.

The ^{13}C-NMR spectrum of the latter indicates an asymmetric structure, whereby the stereo descriptors of the anomeric centers have to be α and β. After we were able to isolate the fully protected double-sided *manno*-configured dodeco-6,7-diulose **20**, the protecting groups were cleaved off. Debenzylation of **20** with palladium on activated charcoal under hydrogen atmosphere afforded **21** quantitatively. **21** could also be prepared from compound **15** in a yield of 47% under iron chloride catalyzed oxetane opening with simultaneous isopropylidenation and acetyl cleavage. Finally, the acetonides were removed with TFA in an aqueous tetrahydrofuran solution to afford the target molecule **7c** in quantitative yield.

Ramberg-Bäcklund reaction

In 1998 Taylor[31] and Franck[32] independently described a new method for the preparation of *C*-glycosides via a Ramberg-Bäcklund rearrangement. Starting from sulfonyl glycosides, *exo*-glycals are formed by in situ halogenations followed by base-induced 1,3-elimination under exclusion of sulfur dioxide. The easy availability of the starting materials made this approach a powerful tool for preparing a broad number of new *exo*-glycals, which in turn play an important role in the synthesis of *C*-glycosidic antibiotics,[33] glycolipids[34] or glycopeptides.[35] Furthermore, Ramberg-Bäcklund reactions were used to prepare methylene- and ethylene-bridged trehalose related disaccharides.[36–38] In our present studies, we were also interested in exploiting this synthetic pathway to gain access to anomerically linked *exo*-glucal dimers in which the carbon spacer between glycoside moieties is completely removed.

We started our synthesis with literature-known peracetylated 1,1-thio-di-glycopyranoside **22** (Scheme 4).[39] Since it had proved successful to conduct the Ramberg-Bäcklund reaction with benzyl-protected sulfonyl glycosides, the acetyls were replaced by benzyl ethers. The removal of the acetic esters was performed



22 [39] **23** (88%) **24** (89%) ***E*/*Z*-25** (69% *E*:*Z*, 10:1) **26** (66%) **7a** (99%)

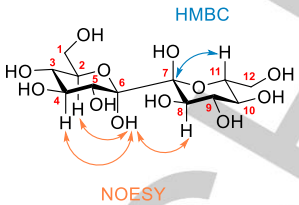
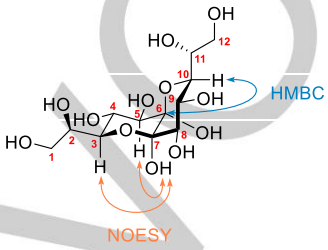
Scheme 4. Synthesis of D-*gluco*-L-*gulo*-Dodeco-6,7-diulose **7a** via Ramber-Bäcklund reaction.

under standard Zemplén conditions with sodium methanolate, subsequent benzylation with benzyl bromide and sodium hydride then gave the thio-bi-glucopyranoside **23** in 88% yield. Next, the thio group in **23** was oxidized to a sulfone group by *m*CPBA and compound **24** could be isolated in 89% yield. For the synthesis of *exo*-glucals, two modifications of the Ramberg-Bäcklund reaction are commonly applied. While Meyer used carbon tetrachloride for halogenation and potassium hydroxide as the base,[40] Chan employed a heterogeneous system consisting of dibromodifluoromethane and aluminum oxide coated with potassium hydroxide.[41] By means of Chan's protocol (CBr_2F_2, KOH/Al_2O_3, CH_2Cl_2, *t*-BuOH, rt), a large number of *exo*-glucals could be obtained in high yields. However, sterically demanding tetra-substituted alkenes could only be prepared using the more forcing Meyer conditions (CCl_4, KOH, aq. *t*-BuOH, 60 °C).[37,42] However, with regard to the transformation of sulfonyl bi-glucopyranoside **24** to the highly substituted *exo*-glucal dimer **25**, we could not confirm this tendency. Under Meyer's conditions no conversion could be observed at all, whereas Chan's method furnished product **25** as an inseparable diastereomeric mixture (*E*:*Z*, 10:1) in 69% yield. In order to finally achieve the envisaged diulose scaffold **26**, the double bond was dihydroxylated. For steric reasons though, harsh conditions for epoxidation with dimethyldioxirane (DMDO) and subsequent acidic hydrolysis with TFA were mandatory. Thus, compound **26** could only be obtained in 66% yield. Finally, the benzyl ethers were removed by hydrogenation with palladium on charcoal to give **7a** in quantitative yield.

Structure determination by NMR spectroscopy

Detailed NMR spectroscopic investigations were carried out to gain insights into the actual structures of the synthesized diuloses **7a**, **7b** and **7c**. Based on the assumption that the compounds are symmetrical with two pyranose (six-membered) rings, four different structural options are possible: two constitutional isomers (type A and type B; Figure 1) with αα- or ββ-conformation of the anomeric centers which could be distinguished by HMBC- and NOESY-NMR spectroscopy. The results of the structural evaluation are summarized in Table 1. Due to the symmetry of the molecules there are 6 carbon atoms, each of which has a spectroscopically equivalent counterpart (C-1 = C-12, C-2 = C-11 etc.) and thus, for simplification, the couplings were only displayed for one side. HMBC couplings could be used to identify which two hydroxyl groups were involved in the hemiacetal formation thereby defining the constitution. The HMBC-NMR spectrum of compound **7a** revealed coupling constants for H-2 and H-11 to the anomeric carbons C-6 and C-7, whereas in compound **7b** the protons H-3 and H-10 coupled to C-6 and C-7 (Supporting Information). Consequently, it could be proven unambiguously that diulose **7a** is present as a 6,7-linked trehalose analogue (type B) and **7b** in a more highly annulated form (type A). The stereo descriptors of the anomeric centers could be defined considering the NOESY couplings of the anomeric hydroxyl groups with the surrounding axial protons and were determined as ββ at both **7a** and **7b**. Apparently, both compounds occur in their energetically most favorable form with the fewest possible axially standing hydroxyl groups. However, if a type B constitution is predominant, the anomeric alcohols align themselves axially, allowing a more undisturbed rotation of the pyranose-linking bond. In the case of the twice *manno*-configured diulose **7c**, there is no sterically preferred structure, since all discussed variants feature four axial hydroxyl groups. Indeed, the ^{13}C-NMR spectrum reveals four symmetrical and two asymmetrical isomers in solution. Due to the high complexity of the NMR spectra and frequent signal overlays, the stereochemistry of the individual isomers could not be unambiguously determined. However, the ratios could be determined by integrating the signals of the anomeric alcohols and are shown in Table 1. In summary, the following trend could be noted when inspecting the NMR spectra of the target compounds. Dodeco-6,7-diuloses, which have a sterically preferred conformation, adopt this conformation in solution. If no conformation is favored, all four symmetric isomers that are converted into each other and further asymmetric isomers that occur during the conversion can be observed. This tendency may serve to finally clarify the configuration of the hypoglycemically active deco-5,6-diulose Peltalosa. Since the NMR spectrum of Peltalosa exhibits a symmetrical isomerically pure compound,[14] the number of possible configurations could be restricted to two diuloses (*arabino*-*arabino* or *xylo*-*xylo*). However, Menzel's work excluded the possibility that Peltalosa consists of two arabinose units. Thus, it appeared to be most probable that Peltalosa is a double *xylo*-configured deco-5,6-diulose, which is present as a type B ββ isomer.

Table 1. NMR-spectroscopic structure elucidation of the target compounds **7a**, **7b** and **7c**.

Compound	HMBC couplings[a]	NOESY couplings[a]	Structure[b]	Constitution / anomeric Configuration
7a	H-2: C-6 H-11: C-7	OH-6: H-2, H-4, H-8 OH-7: H-5, H-9, H-11		**type B / ββ**
7b	H-3: C-7 H-10: C-6	OH-6: H-8, H-10 OH-7: H-3, H-5		**type A / ββ**
7c[c]	—	—	4 symmetrical isomers (**S₁**, **S₂**, **S₃** and **S₄**) + 2 asymmetrical isomers (**A₁** and **A₂**) ratio **S₁** : **S₂** : **S₃** : **S₄** : **A₁** : **A₂** 3.57 : 1.96 : 1.47 : 1.00 : 1.78 : 1.30	—

[a] All NMR spectra were measured in DMSO-d_6 and are provided in the supporting information. [b] The HMBC and NOESY couplings have each been illustrated just for one side of the symmetrical molecule. [c] For none of the six isomers the stereochemistry could be determined by NMR spectroscopy.

Conclusions

In this work we have demonstrated that dodeco-6,7-diuloses can be prepared using a variety of synthetic strategies. Starting from aldohexoses, four different methods were applied in which the intermolecular linkage of two anomeric carbons plays a central role. Thus, the interconnection of two open-chain terminal sugar alkenes was achieved by Grubbs metathesis, stannylated glycals were fused to *endo*-glycalic dimers via a Stille-like homocoupling reaction and a phenylsulfinyl glucal was added by base-induced attack on a carbohydrate lactone. In addition, a Ramberg-Bäcklund rearrangement could be employed to generate a directly anomerically linked *exo*-glucalic dimer. Subsequently, all C1-C1' bridged derivatives could be converted into the desired target compounds by oxidation and removal of the protecting groups and a total of three dodeco-6,7-diuoses (*gluco-gluco*, *galacto-galacto*, *manno-manno*) could be isolated. NMR-spectroscopic investigations indicated that these highly flexible structures preferably adopt double hemiacetal forms with the least hydroxyl groups in axial orientation.

Experimental Section

General Methods: All reactions were performed under an atmosphere of nitrogen using solvents dried by standard procedures. Reaction progress was monitored by TLC on Polygram SIL G/UV_{254} silicagel plates from Macherey & Nagel. Detection of spots was effected by charring with sulphuric acid (5% in ethanol), staining by spraying the plates with an alkaline aqueous solution of potassium permanganate or by inspection of the TLC plates under UV light (254 nm). For the R_f values of products **2**, **7a**, **7b**, **7c**, **13** and **21** ranges were given, since the compounds are likely to decompose or anomerically rearrange on the TLC plates. Preparative flash chromatography was performed

on silica gel (0.032–0.063 mm) from Macherey & Nagel, using plastic cartridges from Götec. The flowrate was regulated by a Sykam S1122 solvent delivery system. For preparative RP C18 chromatography fully end-capped silica gel 100 from Sigma Aldrich was used. NMR spectra were recorded with the following spectrometers: Bruker Avance III HD 400 (^{1}H: 400.2 MHz; ^{13}C: 100.6 MHz), Bruker Avance III HDX 600 (^{1}H: 600.2 MHz; ^{13}C: 150.9 MHz) and Bruker Avance III HDX 700 (^{1}H: 700.3 MHz; ^{13}C: 176.1 MHz); and calibrated for the solvent signal (^{1}H: $CDCl_3$: δ = 7.26 ppm; acetone-d_6: δ = 2.05 ppm; dichloromethane-d_2: δ = 5.32 ppm; DMSO-d_6: δ = 2.50 ppm; ^{13}C: $CDCl_3$: δ =77.16 ppm; acetone-d_6: δ = 29.92 ppm; dichloromethane-d_2: δ = 54.0 ppm; DMSO-d_6: δ = 39.51 ppm). All NMR-assignments were proven by 2D-experiments to be correct. ESI-TOF-HRM spectrometry was performed on a Bruker MAXIS 4G spectrometer. Elemental analyses were obtained from a HEKAtech Euro EA 3000 apparatus. Optical rotations were determined with a Perkin-Elmer Polarimeter 341 in a 10 cm cuvette at 20 °C with a wavelength of 589 nm (Na-lamp). Melting points were measured with a Büchi Melting Point M-560 apparatus.

4-*O*-(*tert*-Butyldimethylsilyl)-2,3:5,6-di-*O*-isopropylidene-D-glucose (2): To a stirred solution of **1** (1.80 g, 3.74 mmol) in 95% aq. acetone (20 mL) was added *N*-bromosuccinimide (1.47 g, 8.24 mmol) at –10 °C in portions. After 10 min TLC showed complete consumption of the starting material and the reaction was quenched by addition of $Na_2S_2O_3$ (2.5 g) and $NaHCO_3$ (2.5 g). The mixture was warmed to ambient temperature, the organic solvent was removed and the aqueous residue was diluted with $CHCl_3$ (100 mL). Subsequently, the organic phase was washed with brine (3 × 50 mL) and dried with Na_2SO_4. Purification by column chromatography (petroleum ether / ethyl acetate, 5:1) gave **2** (1.27 g, 3.40 mmol, 91%) as a pale yellow oil. R_f = 0.27–0.41 (petroleum ether / ethyl acetate, 5:1). $[\alpha]_D^{20}$=+10.4 (c = 1.0, $CHCl_3$). ^{1}H-NMR (400 MHz, $CDCl_3$): δ(ppm) = 9.79 (d, 1H, $J_{1,2}$ = 1.3 Hz, H-1), 4.39 (dd, 1H, $J_{2,1}$ = 1.3 Hz, $J_{2,3}$ = 7.3 Hz, H-2), 4.07–4.15 (m, 2H, H-3, H-5), 4.03 (dd, 1H, *J* = 8.1 Hz, *J* = 6.3 Hz, H-6a), 3.82–3.90 (m, 2H, H-4, H-6b), 1.47, 1.40, 1.36, 1.31 (4s, 12H, C(CH_3)$_2$), 0.89 (s, 9H, SiC(CH_3)$_3$), 0.12, 0.11 (2s, 6H, SiCH_3). ^{13}C-NMR (101 MHz, $CDCl_3$): δ(ppm) = 201.0 (C-1), 110.9, 109.2 (*C*(CH$_3$)$_2$), 80.8 (C-2), 79.2 (C-3), 76.6 (C-5), 73.4 (C-4), 66.8 (C-6), 26.7, 26.7, 26.2 (C(*C*H$_3$)$_2$), 26.1 (SiC(*C*H$_3$)$_3$), 25.3 (C(*C*H$_3$)$_2$), 18.5 (Si*C*(CH$_3$)$_3$), –3.9, –4.1 (Si*C*H$_3$). HRESIMS *m/z* 397.2018 calcd for $C_{18}H_{34}O_6SiNa$, 397.2017; anal. C 57.36, H 9.25, calcd for $C_{18}H_{34}O_6Si$, C 57.72, H 9.15.

5-*O*-(*tert*-Butyldimethylsilyl)-3,4:6,7-di-*O*-isopropylidene-1,2-dideoxy-D-*gluc*-1-enitol (3): A solution of methyl triphenylphosphonium bromide (17.5 g, 48.0 mmol) in THF (60 mL) was treated dropwise with *n*-butyllithium (1.6 M in *n*-hexane, 29.9 mL, 48.0 mmol) at −20 °C. After 15 min the orange solution was warmed to room temperature and stirring was continued for 1 h. The reaction mixture was cooled again to –20 °C and a solution of **2** (4.50 g, 12.0 mmol) in THF (60 mL) was added slowly. The resulting suspension was brought to ambient temperature and was stirred for 14 h until TLC indicated complete conversion of the starting material. Subsequently the mixture was diluted with diethyl ether (300 mL) and the reaction was quenched by addition of sat. aq. NH_4Cl-solution (24 mL). The suspension was filtered through silica gel and the filter cake was washed with ethyl acetate (3 L). The filtrate was evaporated until 300 mL remained. The organic residue was washed with brine (3 × 100 mL), dried with Na_2SO_4 and the solvent was removed. After purification of the crude product by column chromatography (petroleum ether / ethyl acetate, 20:1) **3** (3.86 g, 10.4 mmol, 87%) was isolated as a colorless oil. R_f = 0.53 (petroleum ether / ethyl acetate, 10:1). $[\alpha]_D^{20}$=+11.4 (c = 1.0, $CHCl_3$). ^{1}H-NMR (400 MHz, $CDCl_3$): δ(ppm) = 5.85 (ddd, 1H, $J_{2,1a}$ = 17.2 Hz, $J_{2,1b}$ = 10.4 Hz, $J_{2,3}$ = 6.8 Hz, H-2), 5.40 (ddd, 1H, $J_{1a,2}$ = 16.9 Hz, *J* = 1.4 Hz, *J* = 1.3 Hz, H-1a), 5.26 (ddd, 1H, $J_{1b,2}$ = 10.4 Hz, *J* = 1.2 Hz, *J* = 1.0 Hz, H-1b), 4.36 (dd, 1H, $J_{3,4}$ = 8.1 Hz, $J_{3,2}$ = 7.1 Hz, H-3), 4.06–4.12 (m, 1H, H-6), 3.87–3.97 (m, 3H, H-5, H-7a, H-7b), 3.69 (dd, 1H, $J_{4,3}$ = 8.2 Hz, $J_{4,5}$ = 4.4 Hz, H-4), 1.41, 1.41, 1.39, 1.32 (4s, 12H, C(CH_3)$_2$), 0.91 (s, 9H, SiC(CH_3)$_3$), 0.12, 0.11 (2s, 6H, SiCH_3). ^{13}C-NMR (101 MHz, $CDCl_3$): δ(ppm) = 135.9 (C-2), 118.7 (C-1), 109.0, 108.6 (*C*(CH$_3$)$_2$), 82.9 (C-4), 77.9 (C-3), 76.8 (C-6), 71.9 (C-5), 65.8 (C-7), 27.1, 27.0, 26.6 (C(*C*H$_3$)$_2$), 26.2 (SiC(*C*H$_3$)$_3$), 25.4 (C(*C*H$_3$)$_2$), 18.5 (Si*C*(CH$_3$)$_3$), –3.8, –3.9 (Si*C*H$_3$). HRESIMS *m/z* 395.2226 calcd for $C_{19}H_{36}O_5SiNa$, 395.2224; anal. C 61.50, H 9.82, calcd for $C_{19}H_{36}O_5Si$, C 61.25, H 9.74.

(*E,Z*)-3,10-Di-*O*-(*tert*-butyldimethylsilyl)-1,2:4,5:8,9:11,12-tetra-*O*-isopropylidene-6,7-dideoxy-D-*gluco*-L-*gulo*-dodec-6-enitol (*E/Z*-4): A reaction mixture containing **3** (1.72 g, 4.62 mmol) and Stewart-Grubbs catalyst (10 mol%, 26 mg, 46 µmol) in toluene (10 mL) was stirred at 80 °C for 48 h. Subsequently, the solvent was removed and the crude product was purified by column chromatography (petroleum ether / ethyl

acetate, 20:1). An inseparable diastereomeric mixture of ***E*-4** and ***Z*-4** (*E*/*Z*, 4:1, 939 mg, 1.31 mmol, 57%) was obtained as a yellow oil.

***E*-4** (major diastereomer): R_f = 0.38 (petroleum ether / ethyl acetate, 10:1). ^{1}H-NMR (400 MHz, $CDCl_3$): δ(ppm) = 5.92 (dd, 2H, *J* = 3.0 Hz, *J* = 1.5 Hz, H-6, H-7), 4.40–4.44 (m, 2H, H-5, H-8), 4.03–4.08 (m, 2H, H-2, H-11), 3.85–3.97 (m, 6H, H-1a, H-1b, H-3, H-10, H-12a, H-12b), 3.70 (dd, 2H, *J* = 8.2 Hz, *J* = 4.2 Hz, H-4, H-9), 1.40, 1.40, 1.38, 1.31 (4s, 24H, C(C*H*$_3$)$_2$), 0.90 (s, 18H, SiC(C*H*$_3$)$_3$), 0.12, 0.10 (2s, 12H, SiC*H*$_3$). ^{13}C-NMR (101M Hz, $CDCl_3$): δ(ppm) = 130.7 (C-6, C-7), 108.9, 108.7 (*C*(CH$_3$)$_2$), 83.3 (C-4, C-9), 76.9 (C-2, C-11), 76.5 (C-5, C-8), 72.0 (C-3, C-10), 66.1 (C-1, C-12), 27.1, 27.0, 26.6 (C(*C*H$_3$)$_2$), 26.2 (SiC(*C*H$_3$)$_3$), 25.4 (C(*C*H$_3$)$_2$), 18.5 (Si*C*(CH$_3$)$_3$), –3.7, –3.9 (Si*C*H$_3$).

***Z*-4** (minor diastereomer): R_f = 0.33 (petroleum ether / ethyl acetate, 10:1). ^{1}H-NMR (400 MHz, $CDCl_3$, significant signals): δ(ppm) = 5.60 (dd, 1H, *J* = 6.1 Hz, *J* = 1.8 Hz, H-6, H-7), 4.60–4.65 (m, 1H, H-5, H-8).

^{13}C-NMR (101 MHz, $CDCl_3$): δ(ppm) = 132.8 (C-6, C-7), 109.3 (*C*(CH$_3$)$_2$), 83.6 (C-4, C-9), 76.1 (C-2, C-11)*, 72.7 (C-5, C-8)*, 72.5 (C-3, C-10)*, 65.0 (C-1, C-12), 27.3, 27.1, 26.5 (C(*C*H$_3$)$_2$), 26.1 (SiC(*C*H$_3$)$_3$), 25.2 (C(*C*H$_3$)$_2$), 18.5 (Si*C*(CH$_3$)$_3$), –3.9, –4.1 (SiCH$_3$). HRESIMS *m/z* 739.4245 calcd for $C_{36}H_{68}O_{10}Si_2Na$, 739.4243; anal. C 60.19, H 9.50, calcd for $C_{36}H_{68}O_{10}Si_2$, C 60.30, H 9.56.

*Signals can be interchanged

3,10-Di-*O*-(*tert*-butyldimethylsilyl)-1,2:4,5:8,9:11,12-tetra-*O*-isopropylidene-D-*erythro*-L-*galacto*-L-*gulo*-dodecositol (*syn*-5) and 3,10-Di-*O*-(*tert*-butyldimethyl-silyl)-1,2:4,5:8,9:11,12-tetra-*O*-isopropylidene-D-*erythro*-L-*gulo*-L-*gulo*-dodecositol (*anti*-5): To a stirred solution of diasteromeric mixture ***E*/*Z*-4** (*E*/*Z*, 4:1) (1.63 g, 2.27 mmol) and *N*-methylmorpholine *N*-oxide (1.86 g, 15.9 mmol) in acetone (40 mL) and water (8 mL) was added OsO_4 (4% in water, 2.9 mL, 0.454 mmol) at room temperature. After 20 h TLC showed complete conversion of the starting material and the reaction mixture was diluted with ethyl acetate (80 mL). To reduce the Os(VIII)-species, sat. aq. $Na_2S_2O_3$-solution (8 mL) was added and stirring was continued for further 20 min. Sodium chloride was added till saturation and the organic layer was separated, washed with sat. aq. $Na_2S_2O_3$-solution (3 × 50 mL) and brine (2 x 50 mL). The organic layer was dried with $MgSO_4$ and the solvent was removed. Purification of the crude product by column chromatography (petroleum ether / ethyl acetate, 10:1) furnished ***syn*-5** (1.22 g, 1.62 mmol, 72%) and ***anti*-5** (143 mg, 0.190 mmol, 8%) each as white solids. Recrystallization of ***syn*-5** in *n*-hexane provides rhombic crystals suitable for X-ray structural analysis. The X-ray crystal structure was uploaded at the cambridge crystallographic data centre with the deposition number CCDC 1998924.

***syn*-5** (major diastereomer): R_f = 0.37 (petroleum ether / ethyl acetate, 5:1). $[\alpha]_D^{20}$ = 0 (c = 1.0, $CHCl_3$). M.p. 174 °C (*n*-hexane). ^{1}H-NMR (400 MHz, $CDCl_3$): δ(ppm) = 4.11–4.22 (m, 4H, H-2, H-5, H-8, H-11), 4.00–4.08 (m, 4H, H-4, H-9, H-1a, H-12a), 3.97 (dd, *J* = 5.1 Hz, *J* = 4.0 Hz, 2H, H-3, H-10), 3.90 (dd, *J* = 7.3 Hz, 2H, H-1b, H-12b), 3.77 (d, $J_{6,5}$ = $J_{7,8}$ = 8.3 Hz, 2H, H-6, H-7), 3.05 (br. s, 2H, OH), 1.42, 1.40, 1.36, 1.33 (4s, 24H, C(C*H*$_3$)$_2$), 0.90 (s, 18H, SiC(C*H*$_3$)$_3$), 0.14, 0.14 (2s, 12H, SiC*H*$_3$). ^{13}C-NMR (101 MHz, $CDCl_3$): δ(ppm) = 109.3, 108.8 (*C*(CH$_3$)$_2$), 82.5 (C-4, C-9), 76.9 (C-2, C-11), 75.9 (C-5, C-8), 73.3 (C-3, C-10), 72.7 (C-6, C-7), 66.5 (C-1, C-12), 27.3, 27.2, 26.6 (C(*C*H$_3$)$_2$), 26.2 (SiC(*C*H$_3$)$_3$), 25.3 (C(*C*H$_3$)$_2$), 18.5 (Si*C*(CH$_3$)$_3$), –3.7, –3.9 (Si*C*H$_3$). HRESIMS *m/z* 773.4300 calcd for $C_{36}H_{70}O_{12}Si_2Na$, 773.4298; anal. 57.36, H 9.46, calcd for $C_{36}H_{70}O_{12}Si_2$, C 57.57, H 9.39.

***anti*-5** (minor-diastereomer): R_f = 0.26 (petroleum ether / ethyl acetate, 5:1). $[\alpha]_D^{20}$ = –6.3 (c = 1.0, $CHCl_3$). M.p. 107 °C (*n*-hexane). ^{1}H-NMR (400 MHz, $CDCl_3$): δ(ppm) = 4.05–4.29 (m, 6H, H-2, H-4, H-5, H-8, H-9, H11), 3.87–4.05 (m, 6H, H-1a, H-1b, H-3, H-10, H-12a, H-12b), 3.83 (dd, *J* = 5.6 Hz, *J* = 1.0 Hz, 1H, H-6), 3.72–3.79 (m, 1H, H-7), 3.00 (br. s, 2H, OH), 1.43, 1.41, 1.40, 1.39, 1.35, 1.33, 1.32 (7s, 24H, C(C*H*$_3$)$_2$), 0.91, 0.90 (s, 18H, SiC(C*H*$_3$)$_3$), 0.13, 0.13, 0.12 (3s, 12H, SiC*H*$_3$). ^{13}C-NMR (101 MHz, $CDCl_3$): δ(ppm) = 109.8, 109.3, 108.7, 108.7 (*C*(CH$_3$)$_2$), 83.0, 78.7, 77.3, 77.2, 76.6, 76.6 (C-2, C-4, C-5, C-8, C-9, C-11), 76.5 (C-7), 73.2, 72.5 (C-3, C-10), 68.7 (C-6), 66.6, 66.1 (C-1, C-12), 27.6, 27.5, 27.2, 27.0, 26.7, 26.6 (C(*C*H$_3$)$_2$), 26.2, 26.2 (SiC(*C*H$_3$)$_3$), 25.4, 25.2 (C(*C*H$_3$)$_2$), 18.6, 18.5 (Si*C*(CH$_3$)$_3$), –3.6, –3.8, –3.9, –4.1 (Si*C*H$_3$). HRESIMS *m/z* 773.4297 calcd for $C_{36}H_{70}O_{12}Si_2Na$, 773.4298; anal. C 57.48, H 9.48, calcd for $C_{36}H_{70}O_{12}Si_2$, C 57.57, H 9.39.

3,10-Di-*O*-(*tert*-butyldimethylsilyl)-1,2:4,5:8,9:11,12-tetra-*O*-isopropylidene-D-*gluco*-L-*gulo*-dodeco-6,7-diulose (6): To a solution of ***syn*-5** (553 mg, 0.74 mmol) in DMSO (5.5 mL) was added acetic anhydride (2.1 mL, 22.2 mmol) and the reaction mixture was stirred for 2 h at 100 °C until TLC indicated complete consumption of the starting material. The volatile compounds

were removed and the crude residue was purified by column chromatography (petroleum ether / ethyl acetate, 10:1) to furnish **6** (495 mg, 0.66 mmol, 89%) as a yellow viscous liquid. R_f = 0.80 (petroleum ether / ethyl acetate, 3:1). $[\alpha]_D^{20}$ = +25,3 (c = 1.0, $CHCl_3$). ^{1}H-NMR (400 MHz, $CDCl_3$): δ(ppm) = 4.97 (d, $J_{5,4} = J_{8,9}$ = 6.7 Hz, 2H, H-5, H-8), 4.36 (dd, $J_{4,5} = J_{8,9}$ = 6.7 Hz, $J_{4,3} = J_{9,10}$= 4.5 Hz, 2H, H-4, H-9), 4.07 (dd, *J* = 6.2 Hz, *J* = 6.2 Hz, 2H, H-2, H-11), 4.00–4.04 (m, 2H, H-1a, H-12a), 3.89–3.94 (m, 4H, H-1b, H-3, H-10, H-12b), 1.45, 1.39, 1.29, 1.28 (4s, 24H, C(CH_3)$_2$), 0.90 (s, 18H, SiC(CH_3)$_3$), 0.14, 0.12 (2s, 12 H, Si(CH_3)$_2$). ^{13}C-NMR (100 MHz, $CDCl_3$): δ(ppm) = 199.3 (C-6, C-7), 111.3, 108.9 (*C*(CH$_3$)$_2$), 79.3 (C-5, C-8), 77.6 (C-4, C-9), 76.5 (C-2, C-11), 73.1 (C-3, C-10), 66.5 (C-1, C-12), 26.7, 26.5, 26.0 (C(*C*H$_3$)$_2$), 26.0 (SiC(*C*H$_3$)$_3$), 25.2 (C(*C*H$_3$)$_2$), 18.3 (Si*C*(CH$_3$)$_3$), –4.1, –4.1 (Si(*C*H$_3$)$_2$). HRESIMS *m/z* 801.4249 calcd for $C_{36}H_{66}O_{12}Si_2NaMeOH$, 801.4247.

General procedure A for homocoupling of stannyl glycals 8a and 8b:[15]

A solution of stannylated glycal **8a** or **8b** (1 mmol scale) in DMF (10 mL) was treated $PdCl_2(CH_3CN)_2$ (0.1 eq) and copper-1-thiophene-2-carboxylate (CuTC) (1 eq). The dark suspension was stirred at ambient temperature. After complete consumption of the starting material (TLC) silicagel (500 wt%) was added and the solvent was evaporated. The residue was purified by column chromatography.

2,6:7,11-Dianhydro-5,8-dideoxy-1,3,4,9,10,12-hexakis-*O*-benzyl-D-*erythro*-L-*gulo*-dodeco-5,7-dienitol (9a):[15] Following general procedure A dimer **9a** was obtained as a white solid and was prepared from **8a** in 90% yield by stirring the reaction mixture for 10 min. A mixture of petroleum ether / ethyl acetate 7:1 containing 0.5% Et_3N was used as the eluent for column chromatography. R_f = 0.60 (petroleum ether / ethyl acetate 2:1). $[\alpha]_D^{20}$= –39.5 (c = 1.0, $CHCl_3$). M.p. 114 °C (acetone). ^{1}H-NMR (400 MHz, in $CDCl_3$): δ (ppm) = 7.28–7.37 (m, 30H, Ph), 5.55 (d, $J_{5,4} = J_{8,9}$ = 2.9 Hz, 2H, H-5, H-8), 4.85 (d, *J* = 11.4 Hz, 2H, PhCH_2), 4.55–4.71 (m, 10H, PhCH_2), 4.31 (dd, $J_{4,3} = J_{9,10}$ = 5.9 Hz, $J_{4,5} = J_{9,8}$ = 3.0 Hz, 2H, H-4, H-9), 4.15 (ddd, $J_{2,3} = J_{11,10}$ = 8.3 Hz, *J* = 3.9 Hz, *J* = 3.9 Hz, 2H, H-2, H-11), 3.91 (dd, $J_{3,2} = J_{10,11}$ = 8.4 Hz, $J_{3,4} = J_{10,9}$ = 6.1 Hz, 2H, H-3, H-10), 3.80–3.88 (m, 4H, H-1a, H-1b, H-12a, H-12b). ^{13}C-NMR (101 MHz, in $CDCl_3$): δ (ppm) = 147.3 (C-6, C-7), 138.5, 138.4, 138.3, 128.5, 128.1, 127.9, 127.7, 127.7 (Ph), 98.0 (C-5, C-8), 77.6 (C-2, C-11), 76.1 (C-4, C-9), 74.4 (C-3, C-10), 73.7, 73.5, 70.5 (Ph*C*H$_2$), 68.7 (C-1, C-12). HRESIMS *m/z* 853.3711 calcd for $C_{54}H_{54}O_8Na$, 853.3711; anal. C 78.19, H 6.55, calcd for $C_{54}H_{54}O_8$, C 78.05, H 6.55.

2,6:7,11-Dianhydro-5,8-dideoxy-1,3,4,9,10,12-hexakis-*O*-benzyl-D-threo-L-galo-dodeco-5,7-dienitol (9b):[15] Following general procedure A dimer **9b** was obtained as a yellow, viscous oil and was prepared from **8b** in 84% yield by stirring the reaction mixture for 2 h. A mixture of petroleum ether / ethyl acetate 5:1 containing 0.5% triethylamine was used as the eluent for column chromatography. R_f = 0.46 (petroleum ether / ethyl acetate 3:1). $[\alpha]_D^{20}$= –44.4 (c = 1.0, $CHCl_3$). ^{1}H-NMR (400 MHz, in $CDCl_3$): δ (ppm) = 7.26−7.33 (m, 30H, Ph), 5.49 (d, $J_{5,4} = J_{8,9}$ = 3.2 Hz, 2H, H-5, H-8), 4.85 (d, *J* = 11.9 Hz, 2H, PhCH_2), 4.57–4.70 (m, 6H, PhCH_2), 4.45–4.53 (m, 4H, PhCH_2), 4.22–4.29 (m, 4H, H-2, H-4, H-9, H-11), 3.94 (dd, $J_{3,2} = J_{10,11}$ = 3.1 Hz, $J_{3,4} = J_{10,9}$ = 3.1 Hz, 2H, H-3, H-10), 3.75−3.84 (m, 4H, H-1a, H-1b, H-12a, H-12b). ^{13}C-NMR (101 MHz, in $CDCl_3$): δ (ppm) = 146.6 (C-6, C-7), 138.7, 138.6, 138.3, 128.5, 128.5, 128.4, 128.2, 127.9, 127.7, 127.6 (Ph), 97.7 (C-5, C-8), 76.5 (C-2, C-11), 73.5, 73.2 (Ph*C*H$_2$), 71.5 (C-3, C-10), 71.1 (C-4, C-9), 71.0 (Ph*C*H$_2$), 68.4 (C-1, C-12). HRESIMS *m/z* 853.3713 calcd for $C_{54}H_{54}O_8Na$, 853.3711; anal. C 77.95, H 6.76, calcd for $C_{54}H_{54}O_8$, C 78.05, H 6.55.

General procedure B for bis-dihydroxylation of 9a and 9b:

To a solution of glycal-dimer **9a** or **9b** (0.5 mmol scale) in a solvent mixture of thf, *t*-BuOH and water (5/1/1, 7 mL) was added *N*-methylmorpholine *N*-oxide (3 eq.) and OsO_4 (4% in water, 0.1 eq.) at ambient temperature. After complete transformation of the starting material, the reaction was quenched by addition of sat. aq. $Na_2S_2O_3$-solution (5 mL) and stirring was continued for 30 min. Subsequently the aqueous layer was extracted with ethyl acetate (3 ×10 mL), the combined organic layers were washed with brine (2 ×10 mL) and dried with Na_2SO_4. The solvent was evaporated and the residue was purified by column chromatography.

1,3,4,9,10,12-Hexakis-*O*-benzyl-D-*gluco*-L-*gulo*-dodeco-6,7-diulose (10a): Following general procedure B **10a** was obtained as a white foam and was prepared from **9a** in 89% yield by stirring the reaction mixture for 20 h. A mixture of petroleum ether / ethyl acetate 3:1 was used as the eluent for column chromatography. R_f = 0.30 (petroleum ether / ethyl acetate 2:1). $[\alpha]_D^{20}$= +50.3 (c = 1.0, $CHCl_3$). ^{1}H-NMR (400 MHz, in $CDCl_3$): δ(ppm) = 7.18–7.37 (m, 30H, Ph), 4.79–4.94 (m, 6H, PhCH_2), 4.63 (br. s, 2H, OH), 4.50–4.58 (m, 4H, PhCH_2), 4.42 (d, *J* = 12.1 Hz, 2H, PhCH_2), 4.09 (d, $J_{5,4} = J_{8,9}$= 9.2 Hz, 2H, H-5, H-8), 3.97 (ddd, *J* = 10.0 Hz, *J* =

2.4 Hz, *J* = 2.4 Hz, 2H, H-2, H-11), 3.82 (dd, $J_{4,3} = J_{9,10}$ = 9.2 Hz, $J_{4,5} = J_{9,8}$= 9.2 Hz, 2H, H-4, H-9), 3.60–3.76 (m, 6H, H-1a, H-1b, H-3, H-10, H-12a, H-12b), 3.34 (br. s., 2H, OH). ^{13}C-NMR (101 MHz, $CDCl_3$): δ(ppm)= 138.9, 138.3, 138.2, 128.6, 128.5, 128.5, 128.1, 128.0, 127.9, 127.9, 127.8, 127.8 (Ph), 97.7 (C-6, C-7), 83.0 (C-4, C-9), 77.2 (C-3, C-10), 75.6, 75.1, 73.3 (Ph*C*H$_2$), 72.6 (C-5, C-8), 71.5 (C-2, C-11), 68.0 (C-1, C-12). HRESIMS *m/z* 921.3821 calcd for $C_{54}H_{58}O_{12}Na$, 921.3821; anal. C 72.28, H 6.61, calcd for $C_{54}H_{58}O_{12}$, C 72.14, H 6.50.

1,3,4,9,10,12-Hexakis-*O*-benzyl-D-*galacto*-L-*galacto*-dodeco-6,7-diulose (10b): Following general procedure B **10b** was obtained as a yellow foam and was prepared from **9b** in 89% yield by stirring the reaction mixture for 60 h. A mixture of petroleum ether / ethyl acetate 2:1 was used as the eluent for column chromatography. R_f = 0.58 (petroleum ether / ethyl acetate 1:1). $[\alpha]_D^{20}$= +36.3 (c = 1.0, $CHCl_3$). ^{1}H-NMR (400 MHz, in $CDCl_3$): δ(ppm) = 7.22–7.35 (m, 30H, Ph), 4.89 (d, *J* = 11.9 Hz, 2H, PhC*H*$_2$), 4.64–4.74 (m, 4H, PhC*H*$_2$), 4.54–4.61 (m, 4H, H-5, H-8, PhC*H*$_2$), 4.39–4.48 (m, 4H, PhC*H*$_2$), 4.16 (dd, $J_{2,1a} = J_{11,12a} = J_{2,1b} = J_{11,12b}$ = 6.7 Hz, 2H, H-2, H-11), 3.98 (d, $J_{3,4} = J_{10,9}$ = 1.8 Hz, 2H, H-3, H-10), 3.79 (dd, $J_{4,5} = J_{9,8}$ = 9.8 Hz, $J_{4,3} = J_{9,10}$ = 2.8 Hz, 2H, H-4, H-9), 3.63 (dd, $J_{1a,1b} = J_{12a,12b}$ = 9.2 Hz, $J_{1a,2} = J_{12a,11}$ = 7.8 Hz, 2H, H-1a, H-12a), 3.52 (dd, $J_{1b,1a} = J_{12b,12a}$ = 9.3 Hz, $J_{1b,2} = J_{12b,11}$ = 5.6 Hz, 2H, H-1b, H-12b). ^{13}C-NMR (101 MHz, $CDCl_3$): δ(ppm) = 139.0, 138.4, 138.2, 128.6, 128.5, 128.3, 127.9, 127.9, 127.8, 127.8, 127.6, 127.4 (Ph), 98.1 (C-6, C-7), 80.0 (C-4, C-9), 74.2 (Ph*C*H$_2$), 73.6 (Ph*C*H$_2$, C-3, C-10), 72.7 (Ph*C*H$_2$), 70.7 (C-2, C-11), 68.7 (C-1, C-12), 68.6 (C-5, C-8). HRESIMS *m/z* 921.3838 calcd for $C_{54}H_{58}O_{12}Na$, 921.3821; anal. C 72.22, H 6.56, calcd for $C_{54}H_{58}O_{12}$, C 72.14, H 6.50.

2,6-Anhydro-5-deoxy-4-*O*-(*tert*-butyldimethylsilyl)-1,3:8,9:11,12-tri-*O*-isopropylidene-D-*arabino*-L-*gulo*-dodeco-7-ulo-6-enitol (13):[26] To a suspension of **11** (2.62 g, 6.18 mmol) and grounded molecular sieve (3 Å, 30 mg) in THF (40 mL) was added phenyllithium (1.9 M in Bu_2O, 3.57 mL, 6.79 mmol) at −78 °C over a period of 15 min. After 5 min a further solution containing **12** (1.75 g, 6.79 mmol) in THF (20 mL) was added dropwise over a period of 30 min. Subsequently the reaction mixture was stirred for 2 h at the same temperature before the cooling bath was removed. The reaction was quenched by addition of sat. aq. NH_4Cl-solution (60 mL) at ambient temperature and the molecular sieve was filtered off. The organic layer was separated, the aqueous layer was extracted with CH_2Cl_2 (3 × 20 mL) and the combined organic layers were dried with Na_2SO_4. Removing of the solvent followed by column chromatography (methylene chloride / ethyl acetate 5:1) furnished **13** (2.77 mg, 4.97 mmol, 80%, anomeric mixture α:β, 1:5) as a colorless crystalline solid. R_f = 0.22–0.46 (methylene chloride / ethyl acetate 5:1).

13β*(major anomer): ^{1}H-NMR (400 MHz, $CDCl_3$): δ(ppm) = 5.04 (d, $J_{5,4}$ = 2.2 Hz, 1H, H-5), 4.82 (dd, $J_{9,8}$ = 5.7 Hz, $J_{9,10}$ = 3.5 Hz, 1H, H-9), 4.53 (d, $J_{8,9}$= 5.9 Hz, 1H, H-8), 4.38–4.44 (m, 1H, H-11), 4.33–4.35 (m, 1H, H-4), 4.15 (dd, $J_{10,11}$ = 7.2 Hz, $J_{10,9}$ = 3.5 Hz, 1H, H-10), 4.07–4.11 (m, 1H, H-12a), 4.03 (dd, *J* = 8.7 Hz, *J* = 4.9 Hz, 1H, H-12b), 3.86–3.95 (m, 2H, H-1a, H-1b), 3.71–3.76 (m, 2H, H-2, H-3), 2.77 (s, 1H, OH), 1.50, 1.44, 1.42, 1.40, 1.38, 1.31 (6s, 18H, C(C*H*$_3$)$_2$), 0.87 (s, 9H, SiC(C*H*$_3$)$_3$), 0.07, 0.06 (2s, 6H,SiC*H*$_3$). ^{13}C-NMR (101 MHz, $CDCl_3$): δ(ppm) = 150.4 (C-6), 113.3, 109.1 (*C*(CH$_3$)$_2$), 104.3 (C-5), 103.4 (C-7), 99.4 (*C*(CH$_3$)$_2$), 86.7 (C-8), 80.0 (C-9), 79.4 (C-10), 73.2 (C-11), 72.9 (C-3), 70.2 (C-2), 68.2 (C-4), 66.7 (C-12), 61.7 (C-1), 28.9, 26.8, 25.8 (C(*C*H$_3$)$_2$), 25.7 (SiC(*C*H$_3$)$_3$), 25.4, 25.0, 19.1 (C(*C*H$_3$)$_2$), 18.1 (Si*C*(CH$_3$)$_3$), –4.4, –4.8 (Si*C*H$_3$).

13α*(minor anomer): ^{1}H-NMR (400 MHz, $CDCl_3$): δ(ppm) = 5.07 (d, $J_{5,4}$= 2.1 Hz, 1H, H-5), 4.79 (dd, $J_{9,8}$ = 6.0 Hz, $J_{9,10}$ = 3.7 Hz, 1H, H-9), 4.62 (d, $J_{8,9}$ = 6.0 Hz, 1H, H-8), 4.34–4.35 (m, 2H, H-4, H-11), 4.10–4.11 (m, 1H, H-12a), 4.01–4.02 (m, 1H, H-12b), 3.85–3.88 (m, 2H, H-1a, H-1b, 3.76–3.80 (m, 3H, H-2, H-3, H-10), 2.77 (s, 1H, OH), 1.57, 1.49, 1.42, 1.40, 1.36 (5s, 18H, C(C*H*$_3$)$_2$), 0.88 (s, 9H, SiC(C*H*$_3$)$_3$), 0.08, 0.07 (2s, 6H, SiC*H*$_3$). ^{13}C-NMR (101 MHz, $CDCl_3$): δ(ppm) = 150.8 (C-6), 113.6, 109.3 (*C*(CH$_3$)$_2$), 103.1 (C-5), 100.6 (C-7), 99.6 (*C*(CH$_3$)$_2$), 80.7 (C-8), 80.0 (C-9), 78.6 (C-10), 73.2 (C-11), 72.8 (C-3), 70.3 (C-2), 67.8 (C-4), 67.2 (C-12), 61.7 (C-1), 28.9, 26.9, 25.9 (C(*C*H$_3$)$_2$), 25.8 (SiC(*C*H$_3$)$_3$), 25.2, 24.6, 19.0 (C(*C*H$_3$)$_2$), 18.2 (Si*C*(CH$_3$)$_3$), –4.4, –4.8 (Si*C*H$_3$). HRESIMS *m/z* 581.2757 calcd for $C_{29}H_{48}O_{10}SiNa$, 581.2752; anal. C 58.37, H 8.21, calcd for $C_{29}H_{48}O_{10}Si$, C 58.04, H 8.39.

*Anomers **13β** and **13α** could be interchanged

5,6-Anhydro-7-*O*-acetyl-1,3:8,9:11,12-tri-*O*-isopropylidene-β-D-*manno*-β-D-*manno*-dodeco-6,7-diulo-2,6-pyranose-7,10-furanose (14) and 5,7-Anhydro-6-*O*-acetyl-1,3:8,9:11,12-tri-*O*-isopropylidene-β-D-*manno*-β-D-*manno*-dodeco-6,7-diulo-2,6-pyranose-7,10-furanose (15):[26]

Acetylation: A solution of **13** (0.5 mmol scale) and DMAP (0.2 eq.) in triethylamine (7 mL) was treated with acetic anhydride

(10 eq.) at 0 °C. After stirring for 12 h at ambient temperature until TLC indicated complete transformation of the starting material, the reaction mixture was diluted with ethyl acetate (20 mL). The organic phase was washed with 1 N hydrochloric acid (3 × 10 mL), sat. aq. NH_4Cl-solution (1 × 10 mL) and brine (1 × 10 mL). The solution was dried with Na_2SO_4, the solvent was removed and the crude product was purified by column chromatography (petroleum ether / ethyl acetate 5:1) to afford the acetylated product as a colorless crystalline solid in 96% yield.

Desilylation: The acetylated product was dissolved in THF (5 mL) and TBAF (1.0 M in THF, 1.5 eq.) was added at 0 °C. The reaction mixture was warmed to room temperature and stirring was continued for 20 h until complete conversion of the starting material was detected by TLC. Subsequently, the solution was diluted with CH_2Cl_2 (10 mL) and washed with brine (3 × 5 mL). The aqueous phase was extracted with CH_2Cl_2 (2 × 10 mL) and the combined organic phases were dried with Na_2SO_4. The solvent was evaporated and the residue was purified by column chromatography (petroleum ether / ethyl acetate 2:1 containing 0.5% Et_3N). The desilylated product was obtained as a white amorphous solid in 71%.

Epoxidation / Oxetane-shift: To a solution of *m*CPBA (2.5 eq.) in CH_2Cl_2 (10 mL) was added potassium fluoride (5 eq.) and the resulting suspension was stirred for 30 min at ambient temperature. A solution containing the desilylated product (0.5 mmol scale) in CH_2Cl_2 (10 mL) was added in one portion and stirring was continued for 2 h (epoxidation). To enforce the rearrangement to the oxetanes the reaction mixture was stirred for 20 h, the white precipitate was filtered off and the solution was stirred for further 20 h. The reaction was quenched by addition of sat. aq $NaHCO_3$-solution (10 mL) and sat. aq. $Na_2S_2O_3$-solution (10 mL). Subsequently, the aqueous layer was extracted by CH_2Cl_2 (3 × 10 mL), the combined organic layers were dried with Na_2SO_4, the solvent was removed and the crude product was purified by column chromatography.

Quenching the reaction after 2 h afforded a mixture of **14** and **15** (8:1) as a white amorphous solid in 94% yield. A mixture of petroleum ether / ethyl acetate 3:1 containing 0.5% Et_3N was used as the eluent for column chromatography. R_f = 0.58 (petroleum ether / ethyl acetate 1:2).

14: ^{1}H-NMR (400 MHz, $CDCl_3$): δ(ppm) = 4.96 (d, $J_{8,9}$ = 6.0 Hz, 1H, H-8), 4.91 (dd, $J_{9,8}$ = 6.0 Hz, $J_{9,10}$ = 3.9 Hz, 1H, H-9), 4.31–4.38 (m, 1H, H-11), 4.20 (dd, $J_{10,11}$ = 6.6 Hz, $J_{10,9}$ = 3.9 Hz, 1H, H-10), 3.85–4.06 (m, 5H, H-1a, H-3, H-4, H-12a, H-12b), 3.77 (dd, *J* = 10.7 Hz, *J* = 10.7 Hz, 1H, H-1b), 3.66 (d, $J_{5,4}$ = 2.4 Hz, 1H, H-5), 3.49 (ddd, *J* = 10.2 Hz, *J* = 10.2 Hz, *J* = 5.7 Hz, 1H, H-2), 2.38 (br. s., 1H, OH), 2.06 (s, 3H, COCH_3), 1.57, 1.48, 1.42, 1.39, 1.35, 1.33 (6s, 18H, C(CH_3)$_2$). ^{13}C-NMR (101 MHz, $CDCl_3$): δ(ppm) = 169.2 (CO), 114.2, 109.2 (*C*(CH$_3$)$_2$), 107.9 (C-7), 99.7 (*C*(CH$_3$)$_2$), 86.2 (C-8), 85.0 (C-6), 82.9 (C-10), 79.9 (C-9), 73.2 (C-11), 73.0 (C-3), 70.6 (C-2), 69.9 (C-4), 66.4, 61.7 (C-1), 57.3 (C-5), 29.1, 27.0, 25.6, 25.3, 24.6 (C(*C*H$_3$)$_2$), 21.9 (CO*C*H$_3$), 19.3 (C(*C*H$_3$)$_2$). HRESIMS *m/z* 525.1945 calcd for $C_{23}H_{34}O_{12}Na$, 525.1943.

Quenching the reaction after 40 h and filtering off the solid mCPBA/KF complex in the meantime furnished **15** as a white crystalline solid in 70% yield. A mixture of petroleum ether / ethyl acetate 2:1 was used as the eluent for column chromatography. R_f = 0.51 (petroleum ether / ethyl acetate 1:2). $[\alpha]_D^{20}$= +18.5 (c = 1.0, $CHCl_3$). M.p. 151 °C (*n*-hexane / ethyl acetate). ^{1}H-NMR (400 MHz, DMSO-d_6): δ(ppm) = 5.30 (d, $J_{OH,4}$ = 5.3 Hz, 1H, OH), 4.89 (d, $J_{8,9}$ = 5.5 Hz, 1H, H-8), 4.78 (d, $J_{5,4}$ = 4.5 Hz, 1H, H-5), 4.67 (dd, $J_{9,8}$ = 5.6 Hz, $J_{9,10}$ = 3.9 Hz, 1H, H-9), 4.23 (ddd, $J_{11,10}$ = 6.6 Hz, *J* = 6.6 Hz, *J* = 5.5 Hz, 1H, H-11), 3.95–4.04 (m, 2H, H-3, H-12a), 3.82–3.90 (m, 2H, H-1a, H-12b), 3.79 (dd, $J_{10,11}$ = 7.2 Hz, $J_{10,9}$ = 3.9 Hz, 1H, H-10), 3.71 (ddd, $J_{4,3}$ = 9.5 Hz, $J_{4,5}$ = 4.9 Hz,$J_{4,OH}$ = 4.9 Hz, 1H, H-4), 3.58–3.68 (m, 2H, H-1b H-2), 2.07 (s, 3H, COCH_3), 1.45, 1.44, 1.33, 1.32, 1.30, 1.26 (6s, 18H, C(CH_3)$_2$). ^{13}C-NMR (101 MHz, DMSO-d_6): δ(ppm) = 169.4 (CO), 112.8 (*C*(CH$_3$)$_2$), 111.9 (C-7), 108.3 (*C*(CH$_3$)$_2$), 98.9 (*C*(CH$_3$)$_2$), 97.4 (C-6), 81.9 (C-5), 78.9 (C-10), 78.2 (C-8), 78.0 (C-9), 72.8 (C-11), 70.1 (C-3), 69.1 (C-2), 67.1 (C-4), 66.1 (C-12), 60.9 (C-1), 28.8, 26.5, 25.7, 25.6, 25.2 (C(*C*H$_3$)$_2$), 20.7 (CO*C*H$_3$), 18.8 (C(*C*H$_3$)$_2$). HRESIMS *m/z* 525.1932 calcd for $C_{23}H_{34}O_{12}Na$, 525.1943; anal. C 55.08, H 7.11, calcd for $C_{23}H_{34}O_{12}$, C 54.97, H 6.82.

2,6-Anhydro-5-deoxy-7-*O*-benzyl-4-*O*-(*tert*-butyldimethylsilyl)-1,3:8,9:11,12-tri-*O*-isopropylidene-α/β-D-*manno*-D-*lyxo*-dodeco-6-enitol (16): To a solution of **13** (200 mg, 0.358 mmol) and benzyl bromide (85 µL, 0.716 mmol) in DMF (2 mL) was added sodium hydride (60% in mineral oil, 29 mg, 0.716 mmol) at 0 °C. Subsequently the reaction mixture was brought to ambient temperature and stirring was continued for 3 h, until TLC showed complete transformation of the starting material. The reaction was quenched by addition of methanol and the solvent was removed. The residue was diluted with ethyl acetate (15 mL) and the solution was washed with water (2 × 5 mL) and

brine (2 × 5 mL). Afterwards the aqueous phase was extracted with methylene chloride (2 × 10 mL) and the combined organic phases were dried with Na_2SO_4. The solvent was removed and the crude product was purified by column chromatography (methylene chloride / ethyl acetate, gradient 100:1 – 1:1) to isolate **16** (229 mg, 0.353 mmol, 99%, anomeric mixture α:β, 1:3.7) as a colorless amorphous solid. R_f = 0.38 (chloroform).

16β (major anomer): ^{1}H-NMR (400 MHz, acetone-d_6): δ(ppm) = 7.29–7.36 (m, 5H, Ph), 5.14 (d, $J_{5,4}$ = 2.1 Hz, 1H, H-5), 4.85 (dd, $J_{9,8}$ = 5.7 Hz, $J_{9,10}$ = 3.3 Hz, 1H, H-9), 4.57 (d, $J_{8,9}$ = 5.7 Hz, 1H, H-8), 4.38–4.47 (m, 4H, H-4, H-11, PhCH_2), 4.01–4.07 (m, 3H, H-10, H-12a, H-12b), 3.80–3.89 (m, 2H, H-1a, H-1b), 3.74–3.77 (m, 1H, H-3), 3.63–3.67 (m, 1H, H-2), 1.50, 1.42, 1.37, 1.36, 1.32, 1.27 (6s, 18H, C(CH_3)$_2$), 0.90 (s, 9H, SiC(CH_3)$_3$), 0.11, 0.10 (2s, 6H, SiCH_3). ^{13}C-NMR (101 MHz, acetone-d_6): δ(ppm) = 148.9 (C-6), 139.5, 129.1, 128.9, 128.3 (Ph), 113.5, 109.2 (*C*(CH$_3$)$_2$), 108.4 (C-7), 106.8 (C-5), 100.1 (*C*(CH$_3$)$_2$), 87.3 (C-8), 81.0 (C-9), 80.6 (C-10), 74.2 (C-11), 74.2 (C-3), 71.0 (C-2), 69.4 (C-4), 67.2 (C-12), 65.3 (Ph*C*H$_2$), 62.3 (C-1), 27.0, 26.4, 26.3 (C(*C*H$_3$)$_2$), 26.2 (SiC(*C*H$_3$)$_3$), 25.9, 25.4, 19.5 (C(*C*H$_3$)$_2$), 18.8 (Si*C*(CH$_3$)$_3$), –4.0, –4.5 (Si*C*H$_3$). HRESIMS *m/z* 671.3209 calcd for $C_{34}H_{52}O_{10}SiNa$, 671.3222.

2,6-Anhydro-5-deoxy-7-*O*-benzyl-1,3:8,9:11,12-tri-*O*-isopropylidene-α/β-D-*manno*-D-*lyxo*-dodeco-6-enitol (17): TBAF (1.0 M in THF, 5.98 mL, 5.89 mmol) was added to a solution of **16** (1.91 g, 2.94 mmol) in THF (20 mL) at 0 °C. The reaction mixture was warmed to room temperature and stirring was continued until complete conversion of the starting material was detected by TLC. Subsequently the solution was diluted with CH_2Cl_2 (50 mL) and washed with brine (3 × 20 mL). The aqueous phase was extracted with CH_2Cl_2 (2 × 30 mL) and the combined organic phases were dried with Na_2SO_4. The solvent was evaporated and the residue was purified by column chromatography (petroleum ether / ethyl acetate 2:1 containing 0.5% Et_3N). **17** (1.54 g, 2.88 mmol, 98%, anomeric mixture α:β, 1:3.7) was obtained as a colorless amorphous solid. R_f = 0.31 (petroleum ether / ethyl acetate 2:1).

17β (major anomer): ^{1}H-NMR (400 MHz, acetone-d_6): δ(ppm) = 7.27–7.35 (m, 5H, Ph), 5.22 (d, $J_{5,4}$ = 2.1 Hz, 1H, H-5), 4.84 (dd, $J_{9,8}$ = 5.9 Hz, $J_{9,10}$ = 3.4 Hz, 1H, H-9), 4.57 (d, $J_{8,9}$ = 5.7 Hz, 1H, H-8), 4.38–4.44 (m, 3H, H-11, PhCH_2), 4.24–4.30 (m, 2H, OH, H-4), 4.07–4.11 (m, 1H, H-12a), 3.98–4.02 (m, 2H, H-10, H-12b), 3.82–3.91 (m, 2H, H-1a,H-1b), 3.75–3.80 (m, 1H, H-3), 3.56–3.63 (m, 1H, H-2), 1.49, 1.41, 1.37, 1.33, 1.31, 1.27 (6s, 18H, C(CH_3)$_2$). ^{13}C-NMR (101 MHz, acetone-d_6): δ(ppm) = 148.6 (C-6), 139.5, 129.1, 128.9, 128 (Ph), 113.4, 109.3 (*C*(CH$_3$)$_2$), 108.3 (C-7), 106.8 (C-5), 100.1 (*C*(CH$_3$)$_2$), 87.2 (C-8), 80.9 (C-9), 80.6 (C-10), 74.2 (C-3), 74.1 (C-11), 71.0 (C-2), 67.9 (C-4), 67.3 (C-12), 65.1 (Ph*C*H$_2$), 62.4 (C-1), 27.1, 26.4, 25.8, 25.3, 19.5 (C(*C*H$_3$)$_2$). HRESIMS *m/z* 557.2348 calcd for $C_{28}H_{38}O_{10}Na$, 557.2357.

5,6-Anhydro-7-*O*-benzyl-1,3:8,9:11,12-tri-*O*-isopropylidene-β-D-*manno*-β-D-*manno*-dodeco-6,7-diulo-2,6-pyranose-7,10-furanose (18β) and 5,6-Anhydro-7-*O*-acetyl-1,3:8,9:11,12-tri-*O*-isopropylidene-α-D-*manno*-β-D-*manno*-dodeco-6,7-diulo-2,6-pyranose-7,10-furanose (18α): To a solution of *m*CPBA (1.61 g, 7.20 mmol) in CH_2Cl_2 (40 mL) was added potassium fluoride (837 mg, 14.4 mmol) and the resulting suspension was stirred for 30 min at room temperature. A solution containing **15** (1.54 g, 2.88 mmol) in CH_2Cl_2 (20 mL) was added in one portion and stirring was continued for 3 h until TLC indicated complete consumption of the starting material. The reaction was quenched by addition of sat. aq. $NaHCO_3$-solution (20 mL) and sat. aq. $Na_2S_2O_3$-solution (20 mL). Subsequently the aqueous layer was extracted by CH_2Cl_2 (3 × 20 mL), the combined organic layers were dried with Na_2SO_4, the solvent was removed and the crude product was purified by column chromatography (petroleum ether / ethyl acetate 3:1 containing 0.5% Et_3N). **18β** (1.08 g, 1.96 mmol, 68%) and **18α** (173 mg, 0.314 mmol, 11%) were isolated as white crystalline solids.

18β (major product): R_f = 0.40 (chloroform / ethyl acetate 2:1). $[\alpha]_D^{20}$ = +1.1 (c = 1.0, $CHCl_3$). M.p. 77 °C (*n*-hexane / ethyl acetate).^{1}H-NMR (400 MHz, acetone-d_6): δ(ppm) = 7.32–7.44 (m, 4H, Ph), 7.25–7.31 (m, 1H, Ph), 4.85 (dd, $J_{9,8}$ = 5.9 Hz, $J_{9,10}$ = 3.7 Hz, 1H, H-9), 4.66–4.70 (m, 2H, PhCH_2, H-8), 4.63 (br. s., 1H, OH), 4.61 (d, *J* = 11.7 Hz, 1H, PhCH_2), 4.36 (dd, *J* = 12.1 Hz, *J* = 6.1 Hz, 1H, H-11), 4.00–4.05 (m, 3H, H-4, H-12a, H-12b), 3.97 (dd, $J_{10,11}$ = 5.9 Hz, $J_{10,9}$ = 3.7 Hz, 1H, H-10), 3.85 (dd, $J_{3,2}$ = 10.2 Hz, $J_{3,4}$ = 8.2 Hz, 1H, H-3), 3.79 (dd, $J_{1a,1b}$ = 10.9 Hz, $J_{1a,2}$ = 5.6 Hz, 1H, H-1a), 3.65 (dd, $J_{1b,1a}$ = $J_{1b,2}$ = 10.5 Hz, 1H, H-1b), 3.56 (d, $J_{5,4}$ = 2.4 Hz, 1H, H-5), 3.50 (ddd, $J_{2,1b}$ = $J_{2,3}$ = 10.2 Hz, $J_{2,1a}$ = 5.5 Hz, 1H, H-2), 1.48, 1.44, 1.33, 1.29 (4s, 18H, C(CH_3)$_2$). ^{13}C-NMR (101 MHz, acetone-d_6): δ(ppm)= 139.3, 129.2, 128.7, 128.4 (Ph), 113.6, 109.2 (*C*(CH$_3$)$_2$), 106.6 (C-7), 99.8 (*C*(CH$_3$)$_2$), 87.4 (C-8), 84.8 (C-6), 81.3 (C-10), 80.5 (C-9), 74.0 (C-11), 73.7 (C-3), 71.2 (C-2), 70.1 (C-4), 66.9 (C-12), 65.0 (Ph*C*H$_2$), 62.2 (C-1), 58.3 (C-5), 29.5, 27.1, 26.0, 25.8, 24.8, 19.4 (C(*C*H$_3$)$_2$).

HRESIMS *m/z* 573.2302 calcd for $C_{28}H_{38}O_{11}Na$, 573.2306; anal. C 60.72, H 7.11, calcd for $C_{28}H_{38}O_{11}$, C 61.08, H 6.96.

18α (minor product): R_f = 0.24 (chloroform / ethyl acetate 2:1). $[\alpha]_D^{20}$= –43.7 (c = 1.0, $CHCl_3$). M.p. 80 °C (*n*-hexane). ^{1}H-NMR (400 MHz, acetone-d_6): δ(ppm) = 7.19–7.43 (m, 5H, H-Ph), 4.77–4.91 (m, 4H, PhC*H*$_2$, H-8, H-9), 4.63 (d, $J_{OH,4}$ = 5.8 Hz, 1H, OH), 4.40 (ddd, $J_{11,10}$ = 6.9 Hz, $J_{11,12a}$ = $J_{11,12b}$ = 5.9 Hz, 1H, H-11), 4.11 (dd, $J_{10,11}$ = 7.1 Hz, $J_{10,9}$ = 4.2 Hz, 1H, H-10), 3.97–4.06 (m, 3H, H-4, H-12a, H-12b), 3.79–3.89 (m, 2H, H-1a, H-3), 3.66 (dd, $J_{1b,1a}$ = $J_{1b,2}$ = 10.4 Hz, 1H, H-1b), 3.46–3.58 (m, 2H, H-2, H-5), 1.46, 1.44, 1.37, 1.32, 1.29 (5s, 18H, C(C*H*$_3$)$_2$). ^{13}C-NMR (101 MHz, acetone-d_6): δ(ppm) = 140.3, 128.9, 128.7, 128.1 (Ph), 114.0, 109.5 (*C*(CH$_3$)$_2$), 105.0 (C-7), 99.9 (*C*(CH$_3$)$_2$), 88.8 (C-6), 83.2 (C-9), 80.9 (C-8), 80.7 (C-10), 74.6 (C-11), 73.6 (C-3), 71.7 (C-2), 70.0 (C-4), 67.4 (C-12), 67.1 (Ph*C*H$_2$), 62.3 (C-1), 59.2 (C-5), 27.2, 25.9, 25.8, 24.9, 19.3 (C(*C*H$_3$)$_2$). HRESIMS *m/z* 573.2297 calcd for $C_{28}H_{38}O_{11}Na$, 573.2306; anal. C 60.82, H 6.96, calcd for $C_{28}H_{38}O_{11}$, C 61.08, H 6.96.

6-*O*-Benzyl-1,2:4,5:8,9:11,12-tetra-*O*-isopropylidene-D-*manno*-β-D-*manno*-dodeco-7-ulose (19): To a solution of **18β** (645 mg, 1.17 mmol) in acetone (15 mL) was added a solution of ferric chloride (57 mg, 0.35 mmol) in acetone (5 mL) at –10 °C. The reaction mixture was brought to room temperature and stirring was continued for 4 h until complete consumption of the starting material was detected by TLC. Afterwards the reaction was quenched by addition of sat. aq. $NaHCO_3$-solution (3 mL) and the acetone was removed. The remaining brown aqueous residue was extracted with CH_2Cl_2 (5 × 10 mL) and the combined organic phases were dried with Na_2SO_4. Purification of the crude product by column chromatography (petroleum ether / ethyl acetate 3:1) gave **19** (314 mg, 0.516 mmol, 44%, anomeric mixture, α:β*, 8:1) as a white foam. R_f = 0.68 (petroleum ether / ethyl acetate 1:1).

19α* (major product): ^{1}H-NMR (400 MHz, CD_2Cl_2): δ(ppm) = 7.26–7.35 (m, 5H, Ph), 4.98–5.05 (m, 2H, H-8, PhC*H*$_2$), 4.70–4.77 (m, 2H, H-4, H-9), 4.66 (d, $J_{5,4}$ = 6.0 Hz, 1H, H-5), 4.62 (d, *J* = 12.1 Hz, 1H, PhC*H*$_2$), 4.35–4.42 (m, 2H, H-2, OH), 4.25–4.33 (m, 1H, H-11), 4.09 (dd, *J* = 8.7 Hz, *J* = 6.4 Hz, 1H, H-1a), 4.01–4.06 (m, 2H, H-10, H-12a), 3.97 (ddd, *J* = 6.0 Hz, *J* = 1.8 Hz, 2H, H-1b, H-3), 3.91 (dd, *J* = 8.7 Hz, *J* = 5.1 Hz, 1H, H-12b), 1.56, 1.49, 1.39, 1.36, 1.34, 1.32, 1.28 (7s, 24H, C(C*H*$_3$)$_2$). ^{13}C-NMR (101 MHz CD_2Cl_2): δ(ppm) = 139.5, 128.9, 128.1, 127.9 (Ph), 113.3, 112.9, 109.5, 109.4 (*C*(CH$_3$)$_2$), 108.9 (C-6), 105.7 (C-7), 87.6 (C-5), 81.7 (C-3), 81.4 (C-8), 80.3 (C-9), 79.4 (C-4), 78.7 (C-10), 74.0 (C-11), 73.6 (C-2), 67.4 (C-12), 66.9 (C-1), 66.1 (Ph*C*H$_2$), 27.2, 27.1, 26.2, 25.7, 25.6, 25.2, 24.7, 23.8 (C(*C*H$_3$)$_2$. HRESIMS *m/z* 631.2718 calcd for $C_{31}H_{44}O_{12}Na$, 631.2725; anal. C 61.29, H 7.39, calcd for $C_{31}H_{44}O_{12}$, C 61.17, H 7.29.

*stereo descriptors α/β could be interchanged

6,7-Di-*O*-benzyl-1,2:4,5:8,9:11,12-tetra-*O*-isopropylidene-α-D-*manno*-β-D-*manno*-dodecose (20): To a solution of **19** (250 mg, 0.411 mmol) and benzyl bromide (97µL, 0.822 mmol) in DMF (5 mL) was added sodium hydride (60% in mineral oil, 33 mg, 0.822 mmol). After 3 h TLC showed complete conversion of the starting material and the reaction was quenched by addition of methanol. The solvent was evaporated and the crude residue was diluted in ethyl acetate (15 mL). Then the solution was washed with water (2 × 5 mL) and brine (5 mL) and was dried with Na_2SO_4. Finally, the solvent was removed and the crude product was purified by column chromatography (petroleum ether / ethyl acetate 5:1) to afford **20** (244 mg, 0.349 mmol, 85%) as a white foam. R_f = 0.55 (petroleumether / ethylacetate 2:1). $[\alpha]_D^{20}$= –12.7 (c = 1.0, $CHCl_3$). M.p. 51 °C. ^{1}H-NMR (400 MHz, acetone-d_6): δ(ppm) = 7.45–7.53 (m, 2H, Ph), 7.17–7.36 (m, 8H, Ph), 5.30 (d, $J_{8,9}$ = 6.5 Hz, 1H, H-8), 5.15 (d, *J* = 13.2 Hz, 1H, PhC*H*$_2$), 5.05 (d, *J* = 12.0 Hz, 1H, PhC*H*$_2$), 4.96 (d, *J* = 13.1 Hz, 1H, PhC*H*$_2$), 4.84 (ddd, *J* = 6.2 Hz, *J* = 4.0 Hz, *J* = 1.8 Hz, 2H, H-4, H-9), 4.73 (d, $J_{5,4}$ = 6.0 Hz, 1H, H-5), 4.65 (d, *J* = 12.0 Hz, 1H, PhC*H*$_2$), 4.35–4.48 (m, 3H, H-2, H-10, H-11), 4.00–4.13 (m, 5H, H-1a, H-1b, H-3, H-12a, H-12b), 1.54, 1.51, 1.36, 1.33, 1.30, 1.28, 1.27 (7s, 24H, C(C*H*$_3$)$_2$). ^{13}C-NMR (101 MHz, acetone-d_6): δ = 141.8, 140.1, 129.2, 128.8, 128.5, 128.1, 128.0, 127.5 (Ph), 113.0, 112.5 (*C*(CH$_3$)$_2$), 110.0 (C-7), 109.3 (C-6), 109.2, 109.1 (*C*(CH$_3$)$_2$), 88.1 (C-5), 83.7 (C-8), 82.4 (C-3), 80.3 (C-9), 79.8 (C-4), 79.2 (C-10), 74.9 (C-11), 74.2 (C-2), 66.9 (Ph*C*H$_2$), 66.9 (C-12)*, 66.8 (C-1)*, 65.9 (Ph*C*H$_2$), 27.2, 27.0, 25.9, 25.8, 25.6, 25.4, 23.9, 23.8 (C(*C*H$_3$)$_2$). *signals could be interchanged. HRESIMS *m/z* 721.3192 calcd for $C_{38}H_{50}O_{12}Na$, 721.3195; anal. C 65.02, H 7.35, calcd for $C_{38}H_{50}O_{12}$, C 65.31, H 7.21.

1,2:4,5:8,9:11,12-Tetra-*O*-isopropylidene-D-*manno*-D-*manno*-dodecose (21):

From **15**: To a solution of **15** (538 mg, 1.07 mmol) in acetone (10 mL) was slowly added another solution of ferric chloride (52 mg, 0.321 mmol) in acetone (5 mL) at –10 °C. The reaction mixture was brought to room temperature and stirring was continued for 48 h until complete consumption of the starting

material was detected by TLC. Subsequently the reaction was quenched with sat. aq. $NaHCO_3$-solution (5 mL) and the acetone was removed. The aqueous brown residue was extracted with ethyl acetate (3 × 20 mL) and the combined organic layers were dried with Na_2SO_4. The solvent was evaporated and the crude product was purified by column chromatography (petroleum ether / ethyl acetate 3:2) to furnish **21** (260 mg, 0.501 mmol, 47%) as a white crystalline solid.

From **20**: **20** (44 mg, 0.0629 mmol) was dissolved in THF (3 mL) and palladium (10% on activated charcoal, 18 mg, 0.0169 mmol) was added. The reaction mixture was stirred for 5 h under hydrogen-atmosphere until TLC showed complete conversion of the educt. The black solid was separated by centrifugation and the residue was suspended in diethyl ether and centrifuged again (3 × 10 mL). Evaporation of the solvent followed by column chromatographic purification (petroleum ether / ethyl acetate 1:1) gave **21** (32 mg, 0.0617 mmol, 98%) as a white crystalline solid.

R_f = 0.31 (petroleum ether / ethyl acetate 1:1) is slowly converting into an anomeric mixture R_f= 0.31–0.49 (petroleum ether / ethyl acetate 1:1). ^{1}H-NMR (400 MHz, acetone-d_6): δ(ppm) = 5.08 (d, $J_{8,9}$ = 6.1 Hz, 1H, H-8), 4.76–4.87 (m, 3H, H-4, H-9, OH), 4.69 (s, 1H, OH), 4.59–4.63 (d, $J_{5,4}$ = 6.0 Hz, 1H, H-5), 4.33–4.39 (m, 1H, H-2), 4.20–4.26 (m, 2H, H-3, H-11), 4.11 (dd, *J* = 8.6 Hz, *J* = 4.8 Hz, 1H, H-12a), 3.89–4.00 (m, 4H, H-1a, H-1b, H-10, H-12b), 1.50, 1.45, 1.36, 1.32, 1.32, 1.28, 1.26 (7s, 24H, C(C*H*$_3$)$_2$). ^{13}C-NMR (101 MHz, acetone-d_6): δ(ppm) = 112.8, 112.7, 109.2, 108.9 (*C*(CH$_3$)$_2$), 106.9 (C-6), 105.3 (C-7), 86.7 (C-5), 81.3 (C-9), 81.1 (C-8), 80.4 (C-3), 80.1 (C-4), 78.9 (C-10), 74.4 (C-11), 74.4 (C-2), 67.3 (C-12), 66.7 (C-1), 27.3, 27.2, 26.2, 25.7, 25.6, 25.5, 24.7, 23.8 (C(*C*H$_3$)$_2$). HRESIMS *m/z* 541.2255 calcd for $C_{24}H_{38}O_{12}Na$, 541.2256; anal. C 55.35, H 7.59, calcd for $C_{24}H_{38}O_{12}$, C 55.59, H 7.39.

2,3,4,6-Tetra-*O*-benzyl-β-D-glucopyranosyl-2,3,4,6-tetra-*O*-benzyl-1-thio-β-D-glucopyranoside (23): To a solution of **22** (436 mg, 0.628 mmol) in methanol (10 mL) was added ammonia (7 N in methanol, 0.5 mL) and the mixture was stirred for 2 h at room temperature until TLC showed complete conversion of the starting material. The volatile compounds were removed and the remaining deprotected disaccharide (225 mg, 0.628 mmol) was dissolved in DMF (10 mL). Addition of benzyl bromide (1.19 mL, 10.1 mmol) followed by treatment with sodium hydride (60% in mineral oil, 400 mg, 10.1 mmol) in portions at 0 °C, initiated the reaction. After stirring for 20 h at room temperature, no further reaction progress could be detected by TLC and the excess of sodium hydride was quenched by slowly addition of methanol (5 mL). The solvent was evaporated and the residue was dissolved in ethyl acetate (60 mL). Subsequently the organic phase was washed with water (2 ×20 mL), brine (2 ×20 mL) and was dried with Na_2SO_4. Purification by column chromatography (petroleum ether / ethyl acetate 7:1) afforded **23** (599 mg, 0.555 mmol, 88%) as a white amorphous solid. R_f = 0.40 (petroleum ether / ethyl acetate 4:1). $[\alpha]_D^{20}$ = –13.4 (c = 1.0, $CHCl_3$). M.p. 104 °C (*n*-hexane). ^{1}H-NMR (400 MHz, in $CDCl_3$): δ(ppm) = 7.17–7.39 (m, 40H, Ph), 4.78–4.96 (m, 10H, H-1, PhC*H*$_2$), 4.74 (d, *J* = 10.6 Hz, 2H, PhC*H*$_2$), 4.54–4.61 (m, 4H, PhC*H*$_2$), 4.50 (d, *J* = 12.0 Hz, 2H, PhC*H*$_2$), 3.54–3.73 (m, H-2, H-3, H-4, H-6a, H-6b), 3.34–3.45 (m, 2H, H-5). ^{13}C-NMR (101 MHz, $CDCl_3$): δ(ppm) = 138.7, 138.3, 138.2, 128.5, 128.5, 128.4, 128.4, 128.0, 127.9, 127.9, 127.8, 127.7, 127.7 (Ph), 86.9 (C-3)*, 82.0 (C-1)*, 81.9 (C-2)*, 79.3 (C-5), 78.1 (C-4)*, 75.8, 75.3, 75.0, 73.5 (Ph*C*H$_2$), 69.0 (C-6). HRESIMS *m/z* 1101.4567 calcd for $C_{68}H_{70}O_{10}SNa$, 1101.4582; anal. C 75.68, H 6.60, S 2.83, calcd for $C_{68}H_{70}O_{10}S$, C 75.67, H 6.54, S 2.97.

*Signals C-1 and C-2 as well as C-3 and C-4 can be interchanged

2,3,4,6-Tetra-*O*-benzyl-β-D-glucopyranosyl-2,3,4,6-tetra-*O*-benzyl-1-sulfonyl-β-D-glucopyranoside (24): A Solution of **23** (1.68 g, 1.56 mmol) and *m*CPBA (77%, 1.05 g, 4.67 mmol) in CH_2Cl_2 (20 mL) was stirred for 16 h at ambient temperature. The R_F-values of the educt and the product are to similar, though the reaction progress was monitored by emergence and disappearance of the appropriate sulfoxide intermediate (R_f = 0.81; petroleum ether / ethyl acetate 1:1). The reaction was quenched by addition of sat. aq. $Na_2S_2O_3$-solution (10 mL) and sat. aq. $NaHCO_3$-solution (10 mL) and the aqueous layer was extracted with methylene chloride (3 × 20 mL). After drying with Na_2SO_4, the solvent was removed and the crude product was purified by column chromatography (petroleum ether / ethyl acetate 5:1). **24** (1.54 g, 1.39 mmol, 89%) was obtained as a colorless highly viscous oil. R_f = 0.87 (petroleum ether / ethyl acetate 1:1). $[\alpha]_D^{20}$ = +10.7 (c = 1.0, $CHCl_3$). ^{1}H-NMR (400 MHz, in $CDCl_3$): δ(ppm) = 7.38–7.44 (m, 4H, Ph), 7.14–7.33 (m, 36H, Ph), 5.04 (d, *J* = 9.9 Hz, 2H, PhC*H*$_2$), 4.94 (d, *J* = 11.1 Hz, 2H, PhC*H*$_2$), 4.85 (d, *J* = 11.1 Hz, 2H, PhC*H*$_2$), 4.76 (dd, *J* = 10.5 Hz, *J* = 6.2 Hz, 4H, PhC*H*$_2$), 4.65 (d, $J_{1,2}$ = 9.8 Hz, 2H, H-1), 4.51 (d, *J* = 11.0 Hz, 2H, PhC*H*$_2$), 4.37–4.46 (m, 4H, PhC*H*$_2$), 4.13 (dd, $J_{2,1}$ = $J_{2,3}$ = 9.3 Hz, 2H, H-2), 3.71 (dd, $J_{3,2}$ = $J_{3,4}$ = 8.9 Hz, 2H, H-3), 3.48–3.58

(m, 4H, H-4, H-6a), 3.41 (dd, $J_{6b,6a}$ = 11.0 Hz, $J_{6b,5}$= 5.4 Hz, 2H, H-6b), 3.22 (ddd, $J_{5,4}$ = 9.8 Hz, $J_{5,6b}$ = 5.3 Hz, $J_{5,6a}$= 1.4 Hz, 2H, H-5). ^{13}C-NMR (101 MHz, $CDCl_3$): δ(ppm) = 138.4, 138.0, 138.0, 137.8, 128.7, 128.6, 128.5, 128.5, 128.1, 128.0, 127.8 (Ph), 87.5 (C-1), 86.4 (C-3), 79.7 (C-5), 77.4 (C-4), 76.6 (C-2), 76.0, 75.4, 75.1, 73.5 (PhCH$_2$), 68.7 (C-6). HRESIMS *m/z* 1133.4464 calcd for $C_{68}H_{70}O_{12}SNa$, 1133.4480; anal. C 73.38, H 6.39, S 2.33, calcd for $C_{68}H_{70}O_{12}S$, C 73.49, H 6.35, S 2.88.

(*E*,*Z*)-2,6:7,11-Dianhydro-1,3,4,5,8,9,10,12-octa-*O*-benzyl-D-*gluco*-L-*gulo*-dodeco-6-enitol (*E*/*Z*-25): A suspension of KOH/Al_2O_3 (25% w/w, 6 g) in *t*-BuOH (20 mL) and CH_2Cl_2 (2 mL) was treated with a solution of **24** (1.11 g, 1.00 mmol) in CH_2Cl_2 (3 mL). The reaction mixture was cooled to 0 °C and CBr_2F_2 (2.73 mL, 30 mmol) was added in one portion. Complete consumption of the starting material was detected after 20 h and the suspension was diluted with CH_2Cl_2 (20 mL). The solid KOH/Al_2O_3-compund was separated by filtration through Celite ® and the filtrate was evaporated. Purification of the crude product by column chromatography (petroleum ether / ethyl acetate 20:1containing 0.5% triethylamine) furnished an inseparable diastereomeric mixture of ***E*-25** and ***Z*-25** (*E*/*Z*, 10:1*, 725 mg, 0.694 mmol, 69%) as a colorless oil.

***E*-25** (major diastereomer): R_f = 0.69 (petroleum ether / ethyl acetate, 2:1). ^{1}H-NMR (400 MHz, acetone-d_6): δ(ppm) = 7.18–7.49 (m, 40H, Ph), 5.03 (d, $J_{5,4} = J_{8,9}$ = 2.1 Hz, 2H, H-5, H-8), 4.40–4.82 (m, 16H, PhC*H*$_2$), 4.29 (ddd, *J* = 9.5 Hz, *J* = 3.6 Hz, *J* = 3.6 Hz, 2H, H-2, H-11), 3.98 (dd, $J_{4,3} = J_{9,10}$ = 5.3 Hz, $J_{4,5} = J_{9,8}$ = 2.1 Hz, 2H, H-4, H-9), 3.65–3.80 (m, 6H, H-1a. H-1b, H-3, H-10, H-12a, H-12b). ^{13}C-NMR (101 MHz, acetone-d_6): δ(ppm) = 140.0, 139.7, 139.7, 139.4 (Ph), 137.4 (C-6, C-7), 129.1, 129.1, 129.1, 128.8, 128.8, 128.7, 128.5, 128.3, 128.3, 128.3 (Ph), 82.4 (C-4, C-9), 78.2 (C-3, C-10), 76.1 (C-2, C-11), 73.8, 73.5 (PhCH$_2$), 72.2 (C-5, C-8), 71.7, 70.8 (PhCH$_2$), 70.4 (C-1, C-12). HRESIMS *m/z* 1067.4696 calcd for $C_{68}H_{68}O_{10}Na$, 1067.4705.

*Diastereomers ***E*-25** and ***Z*-25** can be interchanged.

1,3,4,5,8,9, 10,12-Octa-*O*-benzyl-D-*gluco*-L-*gulo*-dodeco-6,7-diulose (26): To a solution of ***E*/*Z*-25** (410 mg, 0.392 mmol) in degased acetone (3 mL) was added DMDO (0.107 M in acetone, 4.39 mL, 0.470 mmol) at –80 °C over a period of 15 min. After 12 h, the reaction mixture was warmed to ambient temperature and stirring was continued for 1 h until TLC (CH_2Cl_2) showed complete transformation of the starting material. The solvent was removed and the remaining crude product was dissolved in THF (4 mL) and water (1 mL) followed by addition of TFA (10 µL, 0.129 mmol). After stirring for 20 h, the solution was diluted with toluene (2 mL) and the volatile components were evaporated. Initially the crude product was purified by column chromatography (petroleum ether / ethyl acetate 5:1) and subsequently by recrystallization (*n*-hexane / ethyl acetate) to afford **26** (279 mg, 0.259 mmol, 66%) as white crystalline needles. R_f = 0.45 (methylene chloride). $[\alpha]_D^{20}$= +4.8 (c = 1.0, $CHCl_3$). M.p. 123 °C (*n*-hexane / ethyl acetate). ^{1}H-NMR (400 MHz, acetone-d_6): δ(ppm) = 7.20–7.42 (m, 40H, Ph), 4.80–5.03 (m, 10H, PhC*H*$_2$, OH), 4.70–4.80 (m, 4H, PhCH$_2$), 4.59–4.67 (m, 4H, PhC*H*$_2$), 4.02–4.20 (m, 6H, H-2, H-4, H-5, H-8, H-9, H-11), 3.75–3.86 (m, 4H, H-1a, H-1b, H-12a, H-12b), 3.64 (dd, *J* = 9.9 Hz, *J* = 8.3 Hz, 2H, H-3, H-10). ^{13}C-NMR (101 MHz, acetone-d_6): δ(ppm) = 140.0, 139.7, 139.6, 138.7, 129.4, 129.2, 129.2, 128.8, 128.7, 128.5, 128.4 (Ph), 98.4 (C-6, C-7), 84.0 (C-4, C-9), 81.2 (C-5, C-8), 79.9 (C-3, C-10), 75.9, 75.9, 75.5, 73.8 (PhCH$_2$), 73.2 (C-2, C-11), 70.1 (C-1, C-12). HRESIMS *m/z* 1101.4738 calcd for $C_{68}H_{70}O_{12}Na$, 1101.4760; anal. C 75.61, H 6.69, calcd for $C_{68}H_{70}O_{12}$, C 75.67, H 6.54.

Preparation of the target compounds 7a, 7b and 7c

General procedure C for debenzylation of 10a, 10b and 26:

To a solution of benzylated diulose **10a, 10b** or **26** (0.1 mmol scale) in THF (5 mL) was added palladium (10% on activated charcoal, 0.4 eq) and the suspension was stirred at room temperature under hydrogen for 24 h until complete consumption of the starting material was detected. After diluting the mixture with methanol (10 mL), the black solid was separated by centrifugation. The residue was suspended in methanol and centrifuged again (2 × 10 mL). Subsequently, the solvent was removed and the crude product was purified by RP-C18 chromatography (acetonitrile / water, 2:1).

D-*gluco*-L-*gulo*-Dodeco-6,7-diulose (7a):

From **10a** and **26**: Following general procedure C, **7a** was isolated as a white solid in quantitative yield.

From **6**: A solution of **6** (300 mg, 0.40 mmol) in THF/water-mixture (1:1, 2 mL) was treated with trifluoroacetic acid (300 µL, 4.0 mmol) and the yellow solution was stirred at ambient temperature for 4 h until TLC showed complete transformation of the starting material. The volatile components were evaporated and the crude product first was purified by RP-C18

chromatography (acetonitrile / water, 2:1) followed by NP chromatography (chloroform / methanol, 3:2). Unprotected diulose **7a** (125 mg, 0.35 mmol, 88%) was obtained as a white crystalline solid. R_f = 0.05–0.20 (chloroform / methanol, 2:1). $[\alpha]_D^{20}$= +49.3 (c = 1.0, acetonitrile / water, 1:1). M.p. 122 °C. ^{1}H-NMR (700 MHz, DMSO-d_6): δ(ppm) = 5.87 (2H, s, OH-6, OH-7), 5.80 (2H, d, $J_{OH\text{-}5,5}$ = $J_{OH\text{-}8,8}$ = 6.0 Hz, OH-5, OH-8), 4.83 (2H, d, $J_{OH\text{-}3,3}$ = $J_{OH\text{-}10,10}$ = 5.6 Hz, OH-3, OH-10), 4.75 (2H, d, $J_{OH\text{-}4,4}$ = $J_{OH\text{-}9,9}$ = 4.9 Hz, OH-4, OH-9), 4.25 (2H, dd, $J_{OH\text{-}1,1a}$ = $J_{OH\text{-}12,12a}$ = 5.6 Hz, $J_{OH\text{-}1,1b}$ = $J_{OH\text{-}12,12b}$ = 5.6 Hz, OH-1, OH-12), 3.55–3.64 (6H, m, H-1a, H-2, H-5, H-8, H-11, H-12a), 3.43–3.50 (4H, m, H-1b, H-4, H-9, H-12b), 3.06 (2H, ddd, $J_{3,2}$ = $J_{10,11}$ = 9.1 Hz, $J_{3,4}$ = $J_{10,9}$ = 9.1 Hz, $J_{3,OH\text{-}3}$ = $J_{10,OH\text{-}10}$ = 5.4 Hz, H-3, H-10). ^{13}C-NMR (176 MHz, DMSO-d_6): δ (ppm) = 97.2 (C-6, C-7), 73.6 (C-4, C-9), 73.1 (C-2, C-11), 71.3 (C-5, C-8), 70.1 (C-3, C-10), 61.0 (C-1, C-12). HRESIMS *m/z* 357.1043 calcd for $C_{12}H_{22}O_{12}$−H, 357.1039.

D-*galacto*-L-*galacto*-Dodeco-6,7-diulose 7b

From benzylated diulose **10b**: Following general procedure C, **7b** was isolated as a white solid in quantitative yield. R_f = 0.05–0.20 (chloroform / methanol, 2:1). $[\alpha]_D^{20}$= −35.9 (c = 1.0, water). M.p. 76 °C. ^{1}H-NMR (600 MHz, DMSO-d_6): δ(ppm) = 5.42 (2H, br. s., OH-6, OH-7), 4.71 (2H, br. s., OH-4, OH-9), 4.30 (4H, br. s., OH-1, OH-5, OH-8, OH-12), 3.71 (2H, d, *J* = 5.7 Hz, OH-2, OH-11), 3.39 - 3.66 (12H, m, H-1a, H-1b, H-2, H-3, H-4, H-5, H-8, H-9, H-10, H-11, H-12a, H-12b). ^{13}C-NMR (151 MHz, DMSO-d_6) δ(ppm) = 95.5 (C-6, C-7), 74.4 (C-5, C-8), 71.5 (C-3, C-10), 70.2 (C-2, C-11), 68.4 (C-4, C-9), 62.9 (C-1, C-12). HRESIMS *m/z* 357.1044 calcd for $C_{12}H_{22}O_{12}$−H, 357.1039.

D-*manno*-D-*manno*-Dodeco-6,7-diulose (7c)

A solution of **21** (121 mg, 0.233 mmol) in THF (3 mL) and water (3 mL) was treated with trifluoroacetic acid (180 µL, 2.33 mmol) and the reaction mixture was stirred for 8 h at 40 °C until TLC showed total conversion of the educt. All volatile components were removed and the crude product was purified by RP-C18 chromatography (acetonitrile / water, 1:1) followed by NP chromatography (methylene chloride / methanol, 1:1) to afford **7c** (82 mg, 0.229 mmol, 99%) as a white crystalline solid consisting of six isomers (**S_1** : **S_2** : **S_3** : **S_4** : **A_1** : **A_2**, 3.57 : 1.96 : 1.47 : 1.00 : 1.78 : 1.30)*. R_f = 0.36–0.53 (chloroform / methanol, 1:1).

Since the NMR spectra showed a complex mixture of isomers, only significant signals of the quaternary positions were assigned to the respective isomers. ^{1}H-NMR (700 MHz, DMSO-d_6, quaternary OH-signals) δ(ppm) = 6.24 (1H, s, **A_2**), 6.07 (2H, s, **S_3**), 5.85 - 5.92 (3H, m, **S_4**, **A_2**), 5.54 (2H, br. s., **S_1**), 5.48 (2H, s, **S_2**), 5.44 (1H, br. s., **A_1**), 5.14 (1H, d, *J* = 1.7 Hz, A_1). ^{13}C-NMR (176 MHz, DMSO-d_6, quaternary carbons) δ(ppm) = 107.9 (**S_1**), 105.3 (**S_4**), 104.0 (**A_1**), 100.3 (**A_2**), 99.5 (**A_2**), 97.6 (**A_1**), 97.5 (**S_2**), 96.6 (**S_3**). HRESIMS *m/z* 381.1000 calcd for $C_{12}H_{22}O_{12}$Na, 381.1004.

*For none of the six isomers the stereochemistry could be determined

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