# Stereospecific Synthesis of α- and β-C-Glycosides from Glycosyl Sulfoxides: Scope and Limitations

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C-Glycosides derived from α-L-fuco-, α-D-gluco-, β-D-gluco-, and α-D-mannopyranose have been synthesized from the corresponding glycosyl phenyl sulfoxide through phenylsulfinyl−lithium exchange, to generate an anomeric carbanion, and subsequent reaction with a carbon electrophile. The reactions were stereospecific and proceeded with retention of the configuration at the anomeric center. Improved yields of C-glycosides were obtained by an inverse addition protocol. Trapping of the anomeric carbanion with aldehydes gave best results. Reaction with ketones, chloroformates, nitriles, and alkyl halides was also explored. Mechanistic aspects of the reaction are discussed.

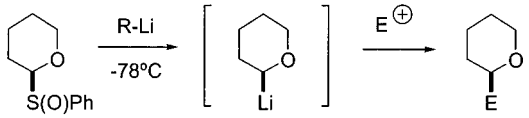
## Introduction

Over the past two decades a considerable amount of work has been devoted to the synthesis of C-glycosides.[1] These compounds are important not only because they are structural subunits of a variety of natural products[2] but they can also be regarded as mimics of biologically relevant O-glycosides, in which a methylene group replaces the exo-anomeric oxygen.[3] This modification makes C-glycosides resistant to acid and enzymatic hydrolysis, and, thus, they can be studied as stable drugs. In contrast to O-glycosides, C-glycosides do not suffer an exo-anomeric effect, providing structures of great value for studies about the conformation around the glycosidic linkage.[4]

Many synthetic approaches have been devised for the preparation of C-glycosides.[1,5] A good number of synthetic strategies including anomeric carbocations, carbanions, radicals, and carbenes have been intensively exploited. Despite this, there is as yet no general synthetic strategy for a direct and stereocontrolled route to a large variety of these compounds.

Among the approaches that use nucleophilic glycosyl donors,[6] nonstabilized anomeric carbanions bearing oxygenated substituents at position 2 have been generated by sequential two-electron transfer with either lithium naphthalenide[7] (from glycosyl chlorides) or samarium diiodide (from glycosyl sulfones,[8] phosphates[9] or chlorides[10]) or by lithium exchange with *n*-butyllithium[11] (from glycosyl stannanes). We recently described[12] a new method to synthesize C-fucopyranosides from easily accessible fucopyranosyl phenyi sulfoxides, based on the generation of a glycosyl carbanion through a phenylsulfinyl−lithium exchange (Scheme 1). This method was shown to be stereospecific: C-fucopyranosides were obtained from the corresponding fucopyranosyl phenyl sulfoxide with retention of the configuration at the anomeric center. In the present work we examine the potential of this method for the synthesis of C-glycosyl derivatives by using a variety of electrophiles and glycosyl sulfoxides. Some practical considerations and mechanistic aspects are discussed.

**Scheme 1**




## Results and Discussion

To optimize the reaction conditions, the sulfinyl−lithium exchange was first examined with the fucosyl phenyl sulfoxide **1** quenching with $CD_3OD$ (Scheme 2). Compound **1** was prepared efficiently from L-fucose following a procedure described by us.[12b] To prevent 1,2-elimination, the 2-hydroxyl must be deprotonated before anomeric lithiation. The same lithiating reagent *t*-BuLi could serve as base to remove the proton. However, it has been shown[13] that *t*-BuLi reacts faster at sulfur (affording *tert*-butyl phenyl sulfoxide) than it removes a proton from an alcohol. This difference of

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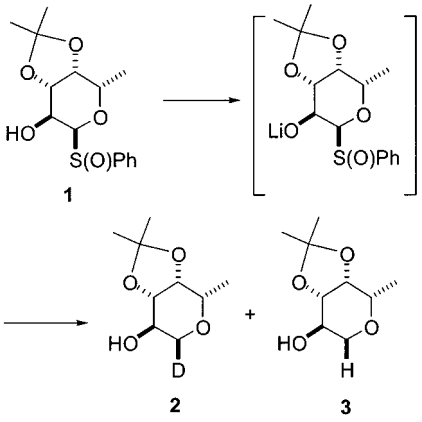
**Scheme 2**[a]




| Conditions | Yield (%) 2+3 | Ratio 2:3 |
|---|---|---|
| A | 80 | 2:1 |
| B | 77 | 6:1 |
| C | 83 | 8:1 |

[a] Conditions: (A) (i) **1**, *t*-BuLi, THF, −78 °C; (ii) $CD_3OD$, −78 °C; (B) (i) **1**, MeLi·LiBr, THF, −78 °C, then *t*-BuLi; (ii) $CD_3OD$, −78 °C; (C) (i) *t*-BuLi, THF, −78 °C, then, a solution of **1** and MeLi·LiBr in THF (inverse addition); (ii) $CD_3OD$, −78 °C.

reactivity could lead to the formation of the 1,5-*anhydro*-fucitol **3** by an intramolecular proton transfer from the hydroxyl HO-2 to the newly generated anomeric carbanion. Indeed, a high proportion of **3** was obtained in our previous experiments when sulfoxide **1** was treated with an excess of *t*-BuLi followed by quenching with deuterated methanol (conditions A in Scheme 2). In accordance with the above arguments, the percentage of protonation was substantially decrease when sulfoxide **1** was previously treated with MeLi·LiBr (conditions B), a base that has been successfully used in deprotonation of glycosyl stannane.[14] We have now enhanced the deuterium content by inverse addition of the reagents.[13,15] In this modification the *t*-BuLi was first added dropwise to THF at −78 °C in order to remove the trace moisture in THF. To this solution is added the glycosyl sulfoxide, previously treated with MeLi·LiBr, dissolved in a minimum amount of THF. When the anomeric carbanion so generated was trapped with $CD_3OD$, the ratio of deuterated/protonated products increased to 8:1.

The reaction was next examined with a variety of carbon electrophiles, which furnished C-fucopyranoside compounds (Scheme 3). Table 1 summarizes the results. With isobutyraldehyde and the aldehyde derived from D-galactose **4**, the reaction was assayed using the conditions described previously[12] (in THF instead of $Et_2O$) and the inverse addition protocol. We were pleased to observe that the yield of the corresponding C-glycoside was improved using the inverse addition. With this protocol the amount of protonation is substantially reduced which in turn leads to higher yields of C-glycosidation. Thus, in the reaction with sugar aldehyde **4** the effect of

**Table 1. Reaction of 1 with Different Electrophiles (Scheme 3)**

| electrophile | C-glycoside | yield (%) of C-glycoside (a:b) | ratio[c] of C-glycoside:**3** |
|---|---|---|---|
| *i*PrCHO[a] | **5a**,**b** | 57 | 2.3:1 |
| *i*PrCHO[b] | **5a**,**b** | 61 (2:1) | 4.0:1 |
| **4**[a] | **6a**,**b** | 16 | 0.4:1 |
| **4**[b] | **6a**,**b** | 44 (1:1) | 1.2:1 |
| PhCHO[b] | **7a**,**b** | 49 (2:1) | 1.6:1 |
| PhCN[b] | **8a**,**b**[d] | 50 (1.3:1) | n.d.[e] |
| MeI[b] | **9** | 19 | 0.7:1 |
| cyclohexanone[b] | **10** | 28 | 0.6:1 |
| EtOCOCl[b] | **11** | 42 | 1.8:1 |

[a] Using the direct addition procedure. [b] Using the inverse addition procedure. [c] Determined by $^1H$ NMR spectroscopy of the crude mixture. [d] After reduction and acetylation. [e] n.d., not determined.

changing the protocol was more than a 2-fold increase in yield, affording the C-disaccharide **6** with α-stereoselectively in 44% yield.

The other electrophiles were tested using only the inverse addition. With benzaldehyde—an aromatic aldehyde—the yield was lower than with isobutyraldehyde. A clean reaction, however, was obtained with benzonitrile, which after hydrogenation to reduce the generated imine and subsequent acetylation afforded the acetamide **8** in 50% overall yield. This is an interesting result since it offers the possibility of obtaining amino-C-glycosides as potential enzyme inhibitors[16] in a straightforward manner. With less reactive electrophiles, MeI and cyclohexanone, the yield of C-glycoside was low. As a general feature we observed that the lower the reactivity of the electrophile the higher the ratio of protonated species **3**. This suggests that with electrophiles of low reactivity a certain amount of glycosyl carbanion could remain at the time that the reaction is quenched by addition of ammonium chloride, giving protonated product. With ethoxycarbonyl chloride the reaction afforded an interesting compound, **11**, containing the carboxylate group at the anomeric position that can be further manipulated for the preparation of other C-glycosides.

Concerning the stereoselectivity of the process at the anomeric carbon, the C-glycosides **5**−**11** showed in their $^1H$ NMR spectra a $J_{1,2}$ value in the range of 1−4 Hz, corresponding to a 1,2-cis configured fucopyranosyl moiety. Therefore, the reactions proceeded with retention of the configuration at the anomeric center. With regard to the diastereomeric ratio at the newly generated chiral center in the reactions with aldehydes, in some condensations we observed a slight excess of one diastereoisomer (see Table 1, a:b ratio). Nevertheless, the attack on the aldehyde by the lithiated anomeric species was basically unselective.

The procedure was next tested with sulfoxides by varying the nature of the glycosyl moiety. We prepared sulfoxides derived from β-glucopyranoside (**12**) and α-mannopyranoside (**13**) (Scheme 4) by controlled oxidation of the corresponding 1-thio-glycopyranosides, prepared as described previously.[17] The α-glucopyranosyl derivative **14** was obtained from the ortho ester **15**. Acid hydrolysis of **15** gave a mixture of 1- and 2- acetates,

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(15) Inverse addition of the reagents has been used in different sulfinyl−lithium exchage reactions to prevent protonation, see ref 13 and Satoh, T.; Kobayashi, S.; Nakanishi, S.; Horiguchi, K.; Irisa, S. *Tetrahedron* **1999**, *55*, 2515−2528.

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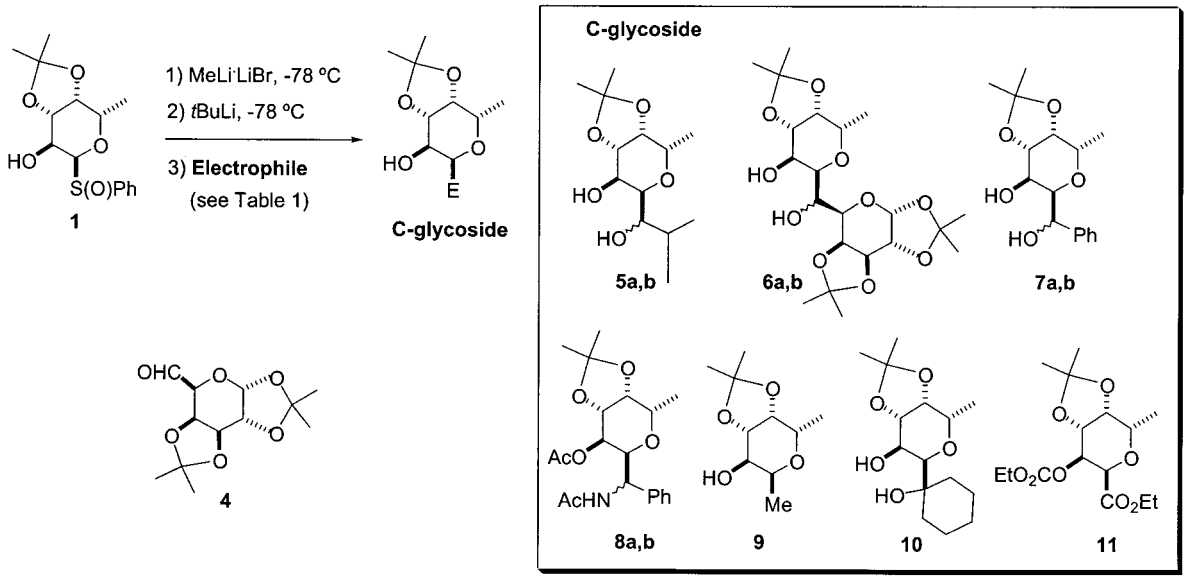
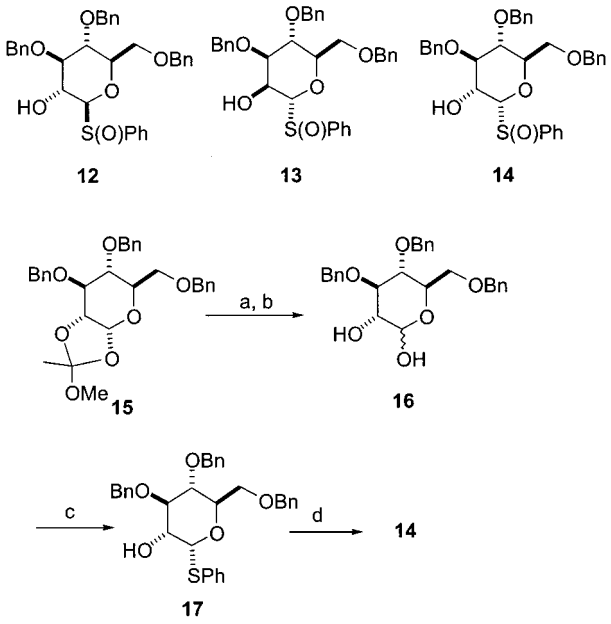
**Scheme 3**

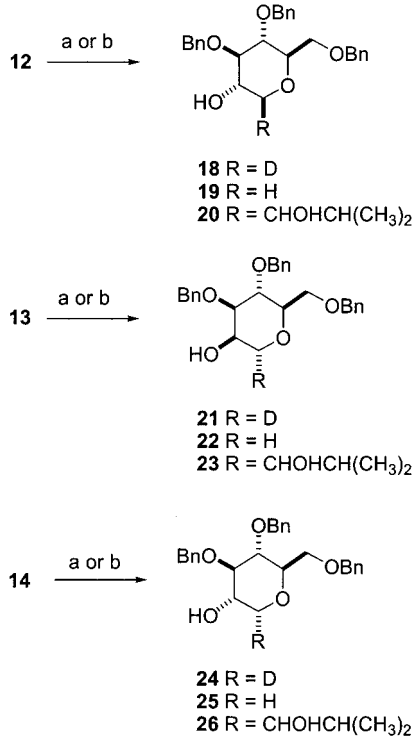



**Scheme 4**[a]




[a] Reagents and conditions: (a) AcOH, rt; (b) NaOMe, MeOH, rt, 81% (2 steps); (c) $(PhS)_2$, $Bu_3P$, 0 °C, 25%; (d) *m*CPBA, $NaHCO_3$, 97%.

**Scheme 5**[a]



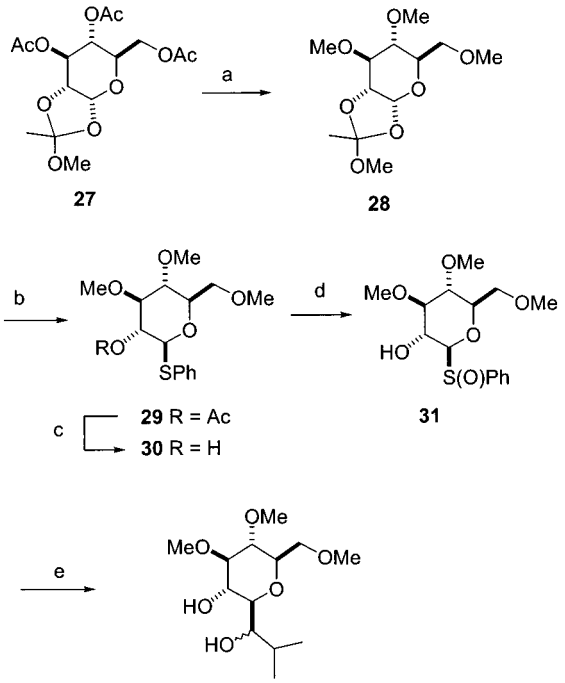

[a] Reagents and conditions: (a) (i) MeLi·LiBr, THF, −78 °C, then *t*-BuLi (inverse addition); (ii) $CD_3OD$, −78 °C; (b) (i) Ibid.; (ii) *i*PrCHO, −78 °C.

which was subsequently treated with NaOMe to afford the 1,2-diol **16**. Thioglycosidation was performed by applying to **16** a method described by Fürstner[18] for the synthesis of thioglycosides from hexoses and pentoses having free the anomeric position. In this manner the α-thioglycoside **17** was obtained with moderate stereoselectivity (α:*β*, 3:1).

As in the case of the fucopyranosyl sulfoxide, we first examined the stereoselectivity of the sulfinyl−lithium exchange by quenching the anomeric carbanion with deuterated methanol (Scheme 5). The reactions of sulfoxides **12**, **13**, and **14** using the inverse addition protocol gave deuterated 1,5-anhydroalditols **18**, **21**, and **24**, respectively, but in low deuteration/protonation ratios (**18**/**19**, 7:3; **21**/**22**, 3:2; **24**/**25**, 2:3). Nevertheless, in all cases we detected only deuterated 1,5-anhydroalditols with the deuterium on the same side as the leaving sulfinyl, indicating that the process took place with retention of configuration at this center. More disappointing results were obtained when the lithiation of the sugars was followed by reaction with a carbon electrophile (Scheme 5). In the presence of isobutyraldehyde as electrophile, the reactions of **12**, **13**, and **14** led to low yields of C-glycosides (10, 21, and 37% yields, respectively), together with 1,5-*anhydro*-alditols and decomposition products. We hypothesized that under the basic conditions used the benzylic hydrogens could be deprotonated, giving, in this way, decomposition. To test

(18) Fürstner, A. *Liebigs Ann. Chem.* **1993**, 1211.

**Scheme 6**[a]



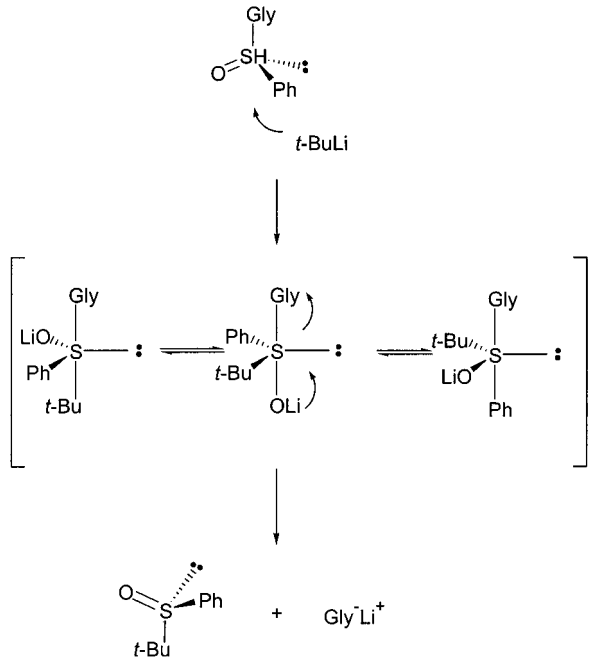

[a] Reagents and conditions: (a) MeI, KOH, THF, reflux, 61%; (b) PhSH, $MeNO_2$, 100 °C, 42 %; (c) NaOMe, MeOH, rt, 91%; (d) *m*CPBA, $NaHCO_3$, 86%; (e) MeLi·LiBr, THF, −78 °C, then *t*-BuLi (inverse addition), then *i*PrCHO, 50%.

this hypothesis experimentally, we prepared the phenyl β-D-glucopyranosyl sulfoxide **31** having methyl instead of benzyl groups (Scheme 6). The synthesis of **31** was carried out by following a sequence of reactions similar to that for **12**. The lithiation of **31** by inverse addition and subsequent treatment with isobutyraldehyde gave a cleaner reaction than that with the benzylated sulfoxides, allowing the isolation of the C-glycoside **32** in 50% yield. Again the product **32** retained the configuration at the anomeric center. Although the conditions of the reactions limit the use of protecting groups to those resistant to strong basic media, we showed that the method can be applied to different glycopyranosyl sulfoxides, affording stereospecific C-glycosidations.

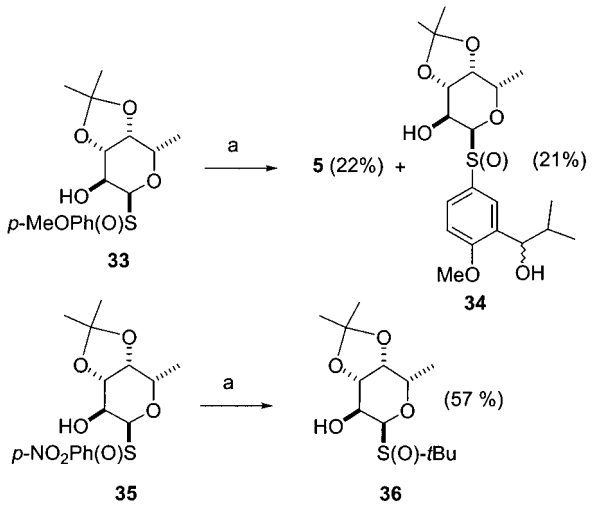
**Mechanistic Considerations.** Phenyl *tert*-butyl sulfoxide was always present in the mixtures analyzed at the end of the reactions, indicating that the process takes place through ligand exchange. On the basis of the mechanism proposed for similar reactions,[19] this would involve attack of the *t*-BuLi on the sulfur atom, generating a σ-sulfurane (Scheme 7), with the sulfur in the center of a trigonal bypyramid. By a pseudorotation process different complexes are formed with the ligands occupying equatorial and apical positions. The complex that has the more electronegative group occupying the apical position is the more stable and the one which results in bond rupture. In our case, the glycosyl ligand is the more electronegative group, and thus, the anomeric carbanion is formed which is configurationally stable at −78 °C.

In view of this mechanism, the nucleophilic attack of the *t*-BuLi to the sulfinyl group and the subsequent progress of the reaction will be influenced by the stereo-

**Scheme 7**




**Scheme 8**[a]




[a] Reagents and conditions: (a) MeLi·LiBr, THF, −78 °C, then *t*-BuLi (inverse addition), then *i*PrCHO.

electronic properties of the aromatic ligand. To evaluate this factor we performed the sulfinyl−lithium exchange on two aryl fucopyranosyl sulfoxides having an electron-donating and an electron-withdrawing group in the aromatic ring (Scheme 8). Compounds **33** and **35** were obtained by following the procedure used to prepare **1**. The reaction of **33** with *t*-BuLi and subsequent trapping with isobutyraldehyde gave the C-glycoside **5** isolated in only 22% yield. The presence of the methoxy substituent in the *para* position to the sulfinyl must decrease the electrophilicity of the latter toward attack of *t*-BuLi. In addition, a mixture of products derived from coupling of the aldehyde to the aromatic ring of the sulfoxide was also formed from which the major isomer **34**[20] could be isolated in 21% yield. The formation of **34** can be explained by metalation *ortho*-directed by the methoxy group, through a lithium−oxygen coordination, followed by coupling to the aldehyde. On the other hand, the reaction of the *p*-nitrophenyl sulfoxide **35** led to the

(19) Oae, S.; Kawai, T.; Furukawa, N. *Tetrahedron Lett.* **1984**, *25*, 69−72.

displacement of the aromatic group by the *tert*-butyl group, giving glycosyl *tert*-butyl sulfoxide **36**[21] as the main product isolated in 57% yield. This result supports the mechanism described in Scheme 7. In the $\sigma$-sulfurane derived from **35**, the *p*-nitrophenyl is now the group that can best carry a negative charge, and the one which results in bond rupture.

**Conclusions.** There are few methods reported in the literature to synthesize C-glycosides in a stereospecific manner. In the present work we show that the sulfinyl−lithium exchange on different glycosyl sulfoxides and the subsequent reaction with carbon electrophiles proceeds with retention of configuration at the anomeric center. In addition, the sulfoxide substrates are readily accessible in both anomeric configurations. By application of this method we have obtained a C-disaccharide and other functionalyzed C-glycosides of utility for enzymatic[22] and conformational studies. Manipulation of the obtained glycosides, as well as studies aimed to further improve reaction conditions, are currently underway.

## Experimental Section

**General Methods.** The methods described[12b] previously were applied.

**3,4,6-Tri-*O*-benzyl-α,*β*-D-glucopyranose (16).** A suspension of **15**[17] (100 mg, 0.197 mmol) in 60% aqueous AcOH (2 mL) was stirred at room temperature for 2 h. After this time the reaction mixture was concentrated, and the residue was purified by FC (hexane/EtOAc 7:1 → 5:1 → 3:1) to give a mixture of 1-*O*-acetyl- and 2-*O*-acetyl-3,4,6-tri-*O*-benzyl-α,*β*-D-glucopyranoses (84 mg) which was treated with a solution of NaOMe in MeOH (25 mM, 6 mL) at room temperature for 90 min. Then, the reaction was neutralized with Amberlyst IR-120 ($H^+$), filtered and concentrated. The residue was purified by FC (hexane/EtOAc 7:1 → 5:1 → 2:1) to give **16** (72 mg, 81%, α:*β* 2.5:1): mp 80−82 °C; $[\alpha]_D$ +56.6° (*c* 1.0, $CHCl_3$); $^1$H NMR (200 MHz, $CDCl_3$) $\delta$ 7.39−7.16 (m, 15 H), 5.27 (t, *J* = 3.4 Hz,), 4.85 (m), 4.55−4.47 (m), 4.06 (dt, *J* = 3.4, 9.7 Hz), 3.81 (t, *J* = 9.0 Hz), 3.35 (d, *J* = 3.2 Hz), 2.43 (br s), 2.22 (d, *J* = 3.4 Hz), 1.61 (br s). $^{13}$C NMR (50 MHz, $CDCl_3$) $\delta$ 138.05, 137.77, 133.27, 128.48, 128.39, 127.99, 127.92, 127.75, 92.40, 82.47, 77.69, 75.29, 74.83, 73.50, 72.77, 70.56, 68.81. Anal. Calcd for $C_{27}H_{30}O_6$: C, 71.98; H, 6.71. Found: C, 72.21; H, 7.09.

**Phenyl 3,4,6-Tri-*O*-benzyl-1-thio-α-D-glucopyranoside (17).** To a mixture of **16** (500 mg, 1.11 mmol), $CH_3CN$ (10 mL), and PhSSPh (291 mg, 1.33 mmol) was added $Bu_3P$ (558 $\mu$L, 2.22 mmol) at 0 °C, and the solution was stirred for 4 h. The reaction mixture was cooled, diluted with $CH_2Cl_2$ (5 mL), washed with $H_2O$ (10 mL), and dried ($Na_2SO_4$) and the solvent was evaporated. The residue was purified by FC (hexane/EtOAc 10:1 → 7:1 → 5:1 → 2:1) to give **17** (151 mg, 25%): mp 123−125 °C; $^1$H NMR (200 MHz, $CDCl_3$) $\delta$ 7.55−7.16 (m, 20 H), 5.65 (d, *J* = 5.3 Hz, 1 H), 4.94−4.40 (m, 6 H), 4.40−4.30 (m, 1 H), 4.90−3.90 (m, 1 H), 3.84 (dd, *J* = 5.9, 9.0 Hz, 1 H), 3.74−3.62 (m, 3 H). Anal. Calcd for $C_{33}H_{34}O_5S$: C, 73.04, H, 6.31, S, 5.91. Found: C, 73.32, H, 6.53, S, 5.59.

**3,4,6-Tri-*O*-methyl-α-D-glucopyranose 1,2-(Methyl orthoacetate) (28). 27** (100 mg, 0.276 mmol) was solved in THF (4 mL), and KOH (206 mg, 3.671 mmol) and $CH_3I$ (103 $\mu$L, 1.656 mmol) were added. The reaction mixture was stirred at reflux temperature for 4 h. Then, more KOH (206 mg, 3.671 mmol) and $CH_3I$ (103 $\mu$L, 1.656 mmol) were added and the reaction was allowed to proceed at reflux temperature for 7 h. The reaction mixture was cooled to room temperature, diluted with $CH_2Cl_2$ (10 mL), and washed with $H_2O$ (3 × 5 mL), saturated $NaHCO_3$ (2 × 5 mL), and $H_2O$ (5 mL). The organic layer was dried ($Na_2SO_4$) and concentrated. The residue was purified by FC (hexane/EtOAc, 4:1 → 1:1 → 1:2) to give **28** (47 mg, 61%): mp 73−75 °C; $[\alpha]_D$ +122.8° (*c* 1.0, $CHCl_3$); $^1$H NMR (300 MHz, $CDCl_3$) $\delta$ 5.66 (d, *J* = 5.3 Hz, 1 H), 4.35 (ddd, *J* = 1.0, 3.3, 5.3 Hz, 1 H), 3.68−3.62 (m, 3 H), 3.46 (s, 3 H), 3.43 (s, 3 H), 3.38, (s, 3 H), 3.32 (dd, *J* = 1.0, 3.3 Hz, 1 H), 3.25 (s, 3H), 1.64 (s, 3H); $^{13}$C NMR (75 MHz, $CDCl_3$) $\delta$ 121.16, 97.44, 79.43, 76.78, 57.68, 50.73, 20.53. Anal. Calcd for $C_{12}H_{22}O_7$: C, 51.79; H, 7.97. Found: C, 51.32; H, 7.61.

**Phenyl 2-*O*-Acetyl-3,4,6-tri-*O*-methyl-1-thio-*β*-D-glucopyranoside (29).** Thiophenol (308 $\mu$L, 3.021 mmol) was added to a solution of **28** (280 mg, 1.007 mmol) in $CH_3NO_2$ (2 mL), warmed to 100 °C, and stirred for 24 h. After this time, the reaction mixture was cooled to room temperature, diluted with $CH_2Cl_2$ (10 mL), and washed with saturated $NaHCO_3$ (5 mL) and $H_2O$ (2 mL). The organic layer was dried ($Na_2SO_4$) and concentrated. The residue was purified by FC (hexane/EtOAc, 3:1) to give **29** (150 mg, 42%): mp 60−62 °C; $[\alpha]_D$ +2.6° (*c* 0.9, $CHCl_3$); $^1$H NMR (200 MHz, $CDCl_3$) $\delta$ 7.50−7.28 (m, 5 H), 4.89 (t, *J* = 10.1 Hz, 1 H), 4.58 (d, *J* = 10.0 Hz, 1 H), 3.65−3.22 (m, 5 H), 3.53 (s, 6 H), 3.39 (s, 3 H), 2.13 (s, 3 H). $^{13}$C NMR (50 MHz, $CDCl_3$) $\delta$ 169.65, 132.03, 128.93, 128.41, 86.05, 79.30, 79.12, 71.80, 71.40, 60.56, 59.52, 21.14. Anal. Calcd for $C_{17}H_{24}O_6S$: C, 57.28; H, 6.79. Found: C, 57.61; H, 7.03.

**Phenyl 3,4,6-Tri-*O*-methyl-1-thio-*β*-D-glucopyranoside (30). 29** (125 mg, 0.350 mmol) was treated with a solution of NaOMe in MeOH (50 mM, 1.5 mL) at room temperature for 4 h. Then, the reaction mixture was neutralized with Amberlyst IR-120 (H+), filtered, and concentrated. The residue was purified by FC (hexane/EtOAc 1:1) to give **30** (100 mg, 91%) as a syrup: $[\alpha]_D$ −29.7° (*c* 0.7, $CHCl_3$); $^1$H NMR (300 MHz, $CDCl_3$) $\delta$ 7.55−7.52 (m, 2 H), 7.31−7.26 (m, 3 H), 4.47 (d, *J* = 9.7 Hz, 1 H), 3.68−3.56 (m, 4 H), 3.65 (s, 3 H), 3.52 (s, 3 H), 3.40, (s, 3 H), 3.35 (m, 1 H), 3.19 (m, 1 H); $^{13}$C NMR (75 MHz, $CDCl_3$) $\delta$ 132.56. 132.17, 128.91, 127.92, 88.32, 87.47, 79.16, 79.02, 72.23, 71.25, 60.89, 60.36, 59.35. Anal. Calcd for $C_{15}H_{22}O_5S$: C, 57.30; H, 7.05; S, 10.20. Found: C, 57.31; H, 7.17; S, 9.89.

***p*-Methoxyphenyl 3,4-*O*-Isopropylidene-1-thio-α-L-fucopyranoside (37).** To a solution of L-fucose (1 g, 6.10 mmol) in DMF (3 mL) containing $Et_3N$ (5 mL), cooled to 0 °C, was added dropwise TMSCl (4.5 mL, 35.5 mmol). The mixture was warmed to room temperature and stirred for 2 h. Then the reaction was quenched with $H_2O$/ice (3 × 40 mL), dried ($Na_2SO_4$), and concentrated to give a residue which was dissolved in $CH_2Cl_2$ (15 mL) and treated with TMSI (0.88 mL, 6.47 mmol), at room temperature for 1 h. The reaction was then cooled to 5 °C, and a solution of *p*-methoxy-thiophenol (793 $\mu$L, 6.45 mmol) and *2,6*-di-*tert*-butyl-4-methylpyridine (1.13 mg, 5.49 mmol) in $CH_2Cl_2$ (15 mL) was added. After 21 h, MeOH (30 mL) was added, and stirring was continued for 30 min. Evaporation of the solvent gave a crude which was dissolved in $Me_2CO$ (30 mL) and treated with 2,2-dimethoxypropane (1.5 mL, 12.2 mmol) and *p*TsOH·$H_2O$ (60 mg, 0.31 mmol). After 2 h, the reaction mixture was neutralized with $Et_3N$ and concentrated to give a residue which was purified by FC (hexane/EtOAc, 6:1), giving the title compound (1.25 g, 63%): mp 119−120 °C; $[\alpha]_D$ −246.7° (*c* 0.9, $CHCl_3$); $^1$H NMR (300 MHz, $CDCl_3$) $\delta$ 7.40−7.39 (m, 2 H), 6.84−6.81 (m, 2 H), 5.34 (d, *J* = 4.9 Hz, 1 H), 4.55 (qd, *J* = 2.2, 6.7 Hz, 1 H), 4.12 (t, *J* = 5.0 Hz, 1 H), 4.08 (dd, *J* = 2.2, 5.8 Hz, 1 H), 4.01 (q, *J* = 5.8 Hz, 1 H), 3.77 (s, 3 H), 2.50 (d, *J* = 6.2 Hz, 1 H) 1.48 (s, 3H), 1.33 (s, 3 H), 1.32 (d, *J* = 6.6 Hz, 3 H); $^{13}$C NMR (75 MHz, $CDCl_3$) $\delta$ 159.64, 134.54, 123.89, 114.70, 109.37, 89.37, 76.98, 76.12, 69.85, 65.30, 55.29, 27.81, 25.84, 16.23. Anal. Calcd for $C_{16}H_{22}O_5S$: C, 58.87; H, 6.79; S, 9.82. Found: C, 58.51; H, 6.97; S, 10.18.

**Oxidation of Phenyl 1-Thio-glycopyranosides. General Procedure.** To a mixture of the aryl 1-thio-glycopyranoside (0.33 mmol), $CH_2Cl_2$ (8 mL), and $NaHCO_3$ (33 mg, 0.40

(20) Selected $^1$H NMR (200 MHz, $CDCl_3$) data for **34**: $\delta$ 7.64 (m, 2H), 7.05 (d, *J* = 8.4 Hz, 1H), 5.52 (br s, 1H), 4.65 (m, 2H), 4.40 (m, 2H), 4.19 (dd, *J* = 1.1, 7.5 Hz, 1H), 3.91 and 3.90 (2s, OMe), 2.05 (m, 1H), 1.2−1.4 (m, $(CH_3)_2C$), 0.9−1.00 (m, $CH_3$Fuc).

(21) Selected $^1$H NMR (200 MHz, $CDCl_3$) data for **36**: $\delta$ 5.42 (d, *J* = 4.9 Hz, 1H), 4.51 (m, 1H), 4.02 (dd, *J* = 2.4, 5.1 Hz, 1H), 1.54 (s, 3H), 1.39 (s, 9H), 1.35 (s, 3H), 1.33 (d, *J* = 6.7 Hz, 3H).

(22) A full description about the activity of some of the C-glycosides as α-fucosidase and α-fucosyltransferase inhibitors will be described elsewhere.

mmol) at −78 °C was added a solution of *m*-CPBA (63 mg, 0.36 mmol) in $CH_2Cl_2$ (1.5 mL). The reaction mixture was stirred for 5 h and, then, heated to room temperature. The mixture was diluted with $CH_2Cl_2$ (5 mL) and washed with 20% $Na_2S_2O_3$ (5 mL) and saturated $NaHCO_3$ (5 mL). The organic layer was dried ($Na_2SO_4$) and concentrated. The residue was purified by FC (hexane/EtOAc 4:1 → 3:1 → 2:1 → 1:2) to give the sulfoxide.

**Phenyl 3,4,6-Tri-*O*-benzyl-β-D-glucopyranosyl Sulfoxide (12).** Following the general procedure phenyl 3,4,6-tri-*O*-benzyl-1-thio-β-D-glucopyranoside[17] was oxidized to give **12** (95%) as 2:1 diastereomeric mixture (**12a**/**12b**): $[\alpha]_D$ +28.0° (*c* 1.0, $CHCl_3$); $^1$H NMR (200 MHz, $CDCl_3$) δ 5.05 (d, *J* = 11.0 Hz, **12a**), 4.95 (d, *J* = 11.0 Hz, **12b**), 4.87 (d, *J* = 11.3 Hz, **12a**), 4.81 (d, *J* = 11.0 Hz, **12b**), 4.81 (d, *J* = 11.3 Hz, **12a**), 4.56 (d, *J* = 10.8 Hz, **12a**), 4.52 (s, **12a**). Anal. Calcd for $C_{33}H_{34}O_6S$: C, 70.95; H, 6.13; S, 5.74. Found: C, 70.84; H, 6.22; S, 5.76.

**Phenyl 3,4,6-Tri-*O*-benzyl-α-D-mannopyranosyl Sulfoxide (13).** Following the general procedure phenyl 3,4,6-tri-*O*-benzyl-L-thio-α-D-mannopyranoside[17] was oxidized to give **13** (93%) as a solid: mp 125−128 °C; $[\alpha]_D$ +15.6° (*c* 1.0, $CHCl_3$); $^1$H NMR (200 MHz, $CDCl_3$) δ 7.67−7.18 (m, 20 H), 4.80 (d, *J* = 11.5 Hz, 1 H), 4.79 (d, *J* = 11.0 Hz, 1 H), 4.75 (d, *J* = 11.5 Hz, 1 H), 4.68−4.63 (m, 2 H), 4.57 (d, *J* = 12.0 Hz, 1 H), 4.49 (d, *J* = 11.0 Hz, 1 H), 4.46 (d, *J* = 12.0 Hz, 1 H), 4.20 (dd, *J* = 3.0, 7.9 Hz, 1 H), 4.16 (ddd, *J* = 2.3, 5.4, 9.4 Hz, 1 H), 3.84 (dd, *J* = 7.9, 9.4 Hz, 1 H), 3.76 (dd, *J* = 2.3, 10.9 Hz, 1 H), 3.65 (dd, *J* = 5.4, 10.9 Hz, 1 H); $^{13}$C NMR (50 MHz, $CDCl_3$) δ 137.96, 137.85, 137.61, 131.33, 129.14, 128.59, 128.42, 128.36, 128.06, 127.88, 127.85, 127.76, 127.66, 124.51, 96.69, 79.23, 77.05, 74.49, 74.15, 73.44, 72.69, 69.22, 65.67. Anal. Calcd for $C_{33}H_{34}O_6S$: C, 70.95; H, 6.13; S, 5.74. Found: C, 71.24; H, 6.48; S, 5.51.

**Phenyl 3,4,6-Tri-*O*-benzyl-β-D-glucopyranosyl Sulfoxide (14).** Following the general procedure compound **17** was oxidized to give **14** (97%) as a syrup: $[\alpha]_D$ +7.4° (*c* 1.0, $CHCl_3$); $^1$H NMR (200 MHz, $CDCl_3$) δ 7.73−7.18 (m, 20 H), 4.96 (d, *J* = 11.2 Hz, 1 H), 4.82−4.68 (m, 2 H), 4.67 (d, *J* = 4.5 Hz, 1 H), 4.51 (d, *J* = 11.2 Hz, 1 H), 4.45 (d, *J* = 12.0 Hz, 1 H), 4.38 (d, *J* = 12.0 Hz, 1 H), 4.34−4.18 (m, 3 H), 3.65−3.56 (m, 3 H); $^{13}$C NMR (50 MHz, $CDCl_3$) δ 138.49, 137.89, 131.64, 129.78, 129.17, 128.39, 128.04, 127.96, 127.90, 127.81, 127.69, 124.40, 93.16, 85.42, 73.42, 76.16, 75.44, 75.18, 74.30, 73.35, 68.54. Anal. Calcd for $C_{33}H_{34}O_6S$: C, 70.95; H, 6.13; S, 5.74. Found: C, 70.67; H, 6.07; S, 5.98.

**Phenyl 3,4,6-Tri-*O*-methyl-β-D-glucopyranosyl Sulfoxide (31).** Following the general procedure compound **30** was oxidized to give **31** (86%) as a syrup: $[\alpha]_D$ +49.0° (*c* 1.0, $CHCl_3$); $^1$H NMR (300 MHz, $CDCl_3$) δ 5.34−5.28 (m, 1 H), 4.88−4.18 (m, 6 H), 3.52 (m, 3 H), 3.44 (s, 3 H), 3.40 (s, 3 H). Anal. Calcd for $C_{15}H_{22}O_6S$: C, 54.53; H, 6.71. Found: C, 54.81; H, 6.93.

***p*-Methoxyphenyl 3,4-*O*-Isopropylidene-α-L-fucopyranosyl Sulfoxide (33).** Following the general procedure compound **37** was oxidized to give **33** (99%): mp 155−157 °C; $[\alpha]_D$ +85.6° (*c* 1.1, $CHCl_3$); $^1$H NMR (300 MHz, $CDCl_3$) δ 7.64−7.61 (m, 2 H), 7.06−7.03 (m, 2 H), 5.95 (d, *J* = 4.4 Hz, 1 H), 4.59 (qd, *J* = 1.5, 6.6 Hz, 1 H), 4.50−4.42 (m, 3 H), 4.18 (dd, *J* = 1.4, 7.7 Hz, 1 H), 3.86 (s, 3 H), 1.36 (s, 3 H), 1.31 (s, 3 H), 1.26 (d, *J* = 6.5 Hz, 3 H); $^{13}$C NMR (75 MHz, $CDCl_3$) δ 162.30, 130.54, 126.94, 114.81, 109.54, 92.15, 74.57, 73.85, 68.88, 65.00, 55.49, 26.19, 24.20, 16.63. Anal. Calcd for $C_{16}H_{22}O_6S$: C, 56.12; H, 6.48; S, 9.36. Found: C, 56.36; H, 6.75; S, 9.08.

**Deuteration Experiment.** A solution of the glycosyl sulfoxide (0.320 mmol) and MeLi·BrLi (1.1 M in $Et_2O$, 0.350 mmol) in a minimun amount of dry THF was added dropwise to a solution fo *t*BuLi (1.64 M in hexanes, 1.60 mmol) in dry THF (2 mL) at −78 °C. After 5 min, $CD_3OD$ (5 equiv) was added and the mixture was stirred for 5 min at −78 °C and, then, quenched with saturated aqueous solution of $NH_4Cl$ (1 mL). After partitioning between water and $CH_2Cl_2$, the organic layer was dried ($Na_2SO_4$) and concentrated. The crude mixture was analyzed by $^1$H NMR (200 MHz, $CDCl_3$). (1*S*)-1,5-Anhydro-3,4-*O*-isopropylidene-(1-$^2$H$_1$)-L-fucitol (**2**): δ 4.03 (dd, *J* = 2.2, 5.5 Hz, 1 H), 3.98−3.80 (m, 3 H), 3.76 (qd, *J* = 2.2, 6.6 Hz, 1 H), 3.11 (dd, *J* = 10.3, 11.1 Hz, 1 H), 1.53 (s, 3 H), 1.37 (s, 3 H), 1.36 (d, *J* = 6.6 Hz, 3 H). (1*S*)-1,5-Anhydro-3,4,6-tri-*O*-benzyl-(1-$^2$H$_1$)-D-glucitol (**18**): δ 7.37−7.15 (m, 15 H), 5.00−4.50 (m, 6 H), 3.70−3.65 (m, 1 H), 3.68−3.64 (m, 2 H), 3.56 (dd, *J* = 8.7, 9.4 Hz, 1 H), 3.45 (t, *J* = 8.6 Hz, 1 H), 3.39 (ddd, *J* = 2.7, 3.8, 9.4 Hz, 1 H), 3.20 (d, *J* = 10.3 Hz, 1 H). (1*R*)-1,5-Anhydro-3,4,6-tri-*O*-benzyl-(1-$^2$H$_1$)-D-mannitol (**21**): δ 7.39−7.16 (m, 15 H), 4.09 (d, *J* = 2.0 Hz, 1 H), 4.0 (dd, *J* = 2.0, 3.3 Hz, 1 H), 3.73 (t, *J* = 9.3 Hz, 1 H), 3.69 (dd, *J* = 2.0, 10.6 Hz, 1 H), 3.62 (dd, *J* = 5.5, 10.6 Hz, 1 H), 3.43 (dd, *J* = 3.4, 9.0 Hz, 1 H), 3.35 (ddd, *J* = 2.0, 5.5, 9.7 Hz, 1 H). (1*R*)-1,5-Anhydro-3,4,6- tri-*O*-benzyl-(1-$^2$H$_1$)-D-glucitol (**24**): δ 7.37−7.15 (m, 15 H), 4.50−5.00 (m, 6 H), 4.02 (d, *J* = 5.3 Hz, 1 H), 3.7 (m, 1 H), 3.64−3.68 (m, 2 H), 3.56 (dd, *J* = 8.7, 9.4 Hz, 1 H), 3.45 (t, *J* = 8.6 Hz, 1 H), 3.39 (ddd, *J* = 2.7, 3.8, 9.4 Hz, 1 H).

**C-Glycosylation. General Procedure.** A solution of the glycosyl sulfoxide (0.320 mmol) and MeLi·BrLi (1.1 M in $Et_2O$, 0.350 mmol) in a minimun amount of dry THF was added dropwise to a solution fo *t*BuLi (1.64 M in hexanes, 1.60 mmol) in dry THF (2 mL) at −78 °C. After 5 min electrophile (0.96 mmol) was added, and the mixture was stirred for 5 min at −78 °C and then quenched with a saturated aqueous solution of $NH_4Cl$ (1 mL). After partitioning between water and $CH_2Cl_2$, the organic layer was dried ($Na_2SO_4$) and concentrated. The residue was purified by FC (hexane/EtOAc 10:1 → 5:1 → 2:1).

**4,8-Anhydro-6,7-*O*-isopropylidene-2-*C*-methyl-1,2,9-trideoxy-L-*threo*-D-*gulo*-nonitol (5a) and 4,8-Anhydro-6,7-*O*-isopropylidene-2-*C*-methyl-1,2,9-trideoxy-L-*threo*-D-*ido*-nonitol (5b).** Using the general procedure sulfoxide **1** was treated with isobutyraldehyde as electrophile to give separated **5a** (40%) and **5b** (21%). **5a**: mp 92−95 °C; $[\alpha]_D$ −57.2° (*c* 0.9, $CHCl_3$); $^1$H NMR (300 MHz, $CDCl_3$) δ 4.29 (qd, *J* = 1.5, 6.7 Hz, 1 H), 4.21 (dd, *J* = 2.1, 8.8 Hz, 1 H), 4.17 (ddd, *J* = 0.6, 1.5, 7.2 Hz, 1 H), 4.01 (t, *J* = 1.2 Hz, 1 H), 3.81 (m, 1 H), 3.31 (t, *J* = 9.1 Hz, 1 H), 2.29 (d, *J* = 9.8 Hz, 1 H), 1.92 (m, 1 H), 1.58 (s, 1 H), 1.48 (s, 3 H), 1.35 (s, 3 H), 1.29 (d, *J* = 6.6 Hz, 3 H), 1.01 (d, *J* = 6.7 Hz, 3 H), 0.94 (d, *J* = 6.8 Hz, 3 H); $^{13}$C NMR (50 MHz, $CDCl_3$) δ 109.51, 80.73, 73.63, 72.27, 66.88, 66.19, 31.42, 28.27, 26.32, 19.16, 18.72, 18.27. Anal. Calcd for $C_{13}H_{24}O_5$: C, 60.21; H, 8.94. Found: C, 60.64; H, 9.28. **5b:** mp 78−83 °C; $[\alpha]_D$ −38.3° (*c* 0.5, $CHCl_3$); $^1$H NMR (300 MHz, $CHCl_3$) δ 4.35 (qd, *J* = 1.3, 6.6 Hz, 1 H), 4.22 (dd, *J* = 2.1, 7.7 Hz, 1 H), 4.18 (d, *J* = 7.6 Hz, 1 H), 4.02−3.97 (m, 2 H), 3.58 (dt, *J* = 3.1, 9.2 Hz, 1 H), 2.70 (d, *J* = 9.8 Hz, 1 H), 1.84 (m, 1 H), 1.56 (s, 1 H), 1.48 (s, 3 H), 1.35 (s, 3 H), 1.32 (d, *J* = 6.6 Hz, 3 H), 1.07 (d, *J* = 6.5 Hz, 3 H), 0.90 (d, *J* = 6.7 Hz, 3 H); $^{13}$C NMR (50 MHz, $CDCl_3$) δ 108.79, 79.99, 14 75.18, 73.47, 68.83, 68.34, 66.07, 29.79, 26.69, 23.99, 19.78, 18.66, 18.34. Anal. Calcd. for $C_{13}H_{24}O_5$: C, 60.21; H, 8.94. Found: C, 60.03; H, 9.10.

**(6*R* and 6*S*)-6-*C*-(3,4-*O*-Isopropylidene-α-L-fucopyranosyl)-1,2:3,4-di-*O*-isopropylidene-α-D-galactopyranose (6).** Using the general procedure sulfoxide **1** was treated with galactopyranose aldehyde **4** as electrophile to give **6** (44%) in approximately a 1:1 diastereomeric mixture: mp 57−59 °C; $[\alpha]_D$ −76.1° (*c* 0.5, $CHCl_3$); $^1$H NMR (200 MHz, $CDCl_3$) δ 5.57 (d, *J* = 5.0 Hz), 4.61 (dd, *J* = 2.4, 7.9 Hz), 4.46 (s), 4.42−4.31 (m), 4.27 (dd, *J* = 2.3, 7.7 Hz), 4.19−3.96 (m), 2.89 (br s), 1.54 (s), 1.48 (s), 1.43(s), 1.35 (s), 1.30 (s), 1.24 (d, *J* = 6.6 Hz); $^{13}$C NMR (50 MHz, $CDCl_3$): δ 109.34, 109.03, 108.85, 96.44, 75.61, 74.30, 74.06, 70.92, 70.83, 70.80, 70.69, 68.09, 66.98, 66.06, 26.65, 25.93, 25.86, 25.09, 24.20, 24.13, 18.11. Anal. Calcd for $C_{21}H_{34}O_{10}$: C, 56.62; H, 7.47. Found: C, 56.91; H, 7.71.

**2,6-Anhydro-7-deoxy-4,5-*O*-isopropylidene-1-*C*-phenyl-L-*threo*-D-*gulo*-heptitol and 2,6-Anhydro-7-deoxy-4,5-*O*-isopropylidene-1-*C*-phenyl-L-*threo*-D-*ido*-heptitol (7a,b).** Using the general procedure sulfoxide **1** was treated with benzaldehyde as electrophile to give about a 2:1 diastereomeric mixture of **7a**/**7b** (49%) as crystals: mp 126−128 °C; $[\alpha]_D$ −69.3° (*c* 1.1, $CHCl_3$); $^1$H NMR (300 MHz, $CDCl_3$) δ 7.39−7.28 (m, 5 H), 4.87 (t, *J* = 4.9 Hz, **7b**), 4.47 (q, *J* = 6.7 Hz, **7a**), 4.34 (q, *J* = 6.6 Hz, **7b**), 4.01 (d, *J* = 2.2 Hz, **7a**), 3.77 (d, *J* = 2.0 Hz, **7b**), 3.67 (s, **7a**), 3.10 (d, *J* = 2.4 Hz, **7a**), 3.03 (d, *J* = 2.7 Hz, **7b**), 1.47 (s, **7b**), 1.44 (s, **7a),** 1.38 (d, *J* = 6.6 Hz, 3H),

1.33 (s, **7b**), 1.30 (s, **7a**). Anal. Calcd for $C_{16}H_{22}O_5$: C, 65.29; H, 7.53. Found: C, 65.65; H, 7.80.

**2,6-Anhydro-1,7-dideoxy-4,5-*O*-isopropylidene-L-*glycero*-D-*gluco*-heptitol (9).** Using the general procedure sulfoxide **1** was treated with methyl iodide as electrophile to give **9** (19%) as crystals: mp 79−84 °C; $[\alpha]_D$ −61.8° (*c* 0.7, $CHCl_3$); $^1$H NMR (300 MHz, $CDCl_3$) $\delta$ 4.22 (dd, $J$ = 3.4, 6.9 Hz, 1 H), 4.16 (qd, $J$ = 3.0, 6.8 Hz, 1 H), 4.14−4.08 (m, 2 H), 3.68 (q, $J$ = 3.3 Hz, 1 H), 1.97 (d, $J$ = 4.3 Hz, 1 H), 1.51 (s, 3 H), 1.35 (s, 3 H), 1.30 (d, $J$ = 6.5 Hz, 3 H), 1.21 (d, $J$ = 6.9 Hz, 3 H); $^{13}$C NMR (300 MHz, $CDCl_3$) $\delta$ 108.96, 75.24, 75.17, 70.51, 67.40, 64.79, 27.14, 24.80, 17.76, 15.59. Anal. Calcd for $C_{10}H_{18}O_4$: C, 59.39; H, 8.97. Found: C, 59.59; H, 9.12.

**1-*C*-(3,4-*O*-Isopropylidene-α-L-fucopyranosyl)-cyclohexan-1-ol (10).** Using the general procedure sulfoxide **1** was treated with cyclohexanone as electrophile to give **10** (28%) as crystals: mp 69−71 °C; $[\alpha]_D$ −56.1° (*c* 0.8, $CHCl_3$); $^1$H NMR (200 MHz, $CDCl_3$) $\delta$ 6.61 (s, 1 H), 4.31 (qd, $J$ = 1.4, 6.6 Hz, 1 H), 4.24 (dd, $J$ = 2.1, 7.8 Hz, 1 H), 4.16 (dd, $J$ = 1.1, 7.7 Hz, 1 H), 4.02 (t, $J$ = 1.8 Hz, 1 H), 3.64 (d, $J$ = 1.4 Hz, 1 H), 2.41 (s, 1 H), 1.48 (s, 3 H), 1.35 (s, 3 H), 1.94−1.38 (m, 10 H), 1.30 (d, $J$ = 6.5 Hz, 3 H); $^{13}$C NMR (50 MHz, $CDCl_3$) $\delta$ 108.64, 75.24, 78.80, 73.29, 72.36, 67.85, 66.19, 35.51, 32.23, 25.58, 21.54, 21.28, 26.23, 23.86, 18.14. Anal. Calcd for $C_{15}H_{26}O_5$: C, 62.91; H, 9.15. Found: C, 63.18; H, 9.42.

**Ethyl 2,6-Anhydro-7-deoxy-3-ethoxycarbonyl-4,5-*O*-isopropylidene-L-*glycero*-D-*gluco*-heptate (11).** Using the general procedure sulfoxide **1** was treated with ethoxycarbonyl chloride as electrophile to give **11** (42%) as a syrup: $[\alpha]_D$ −27.20 (*c* 0.8, $CHCl_3$); $^1$H NMR (200 MHz, $CDCl_3$) $\delta$ 5.30 (t, $J$ = 3.8 Hz, 1 H), 4.72 (d, $J$ = 4.4 Hz, 1 H), 4.45 (dd, $J$ = 3.4, 7.2 Hz, 1 H), 4.28−4.11 (m, 6 H), 1.56 (s, 3 H), 1.51 (s, 3 H), 1.38−1.11 (m, 9 H); $^{13}$C NMR (50 MHz, $CDCl_3$) $\delta$ 169.43, 153.92, 110.26, 74.89, 71.63, 61.19, 71.06, 64.65, 61.17, 26.49, 24.86, 16.72, 14.13, 14.08. Anal. Calcd for $C_{15}H_{24}O_8$: C, 54.21; H, 7.28. Found: C, 53.98; H, 6.93.

**1-Acetamido-2,6-anhydro-1,7-dideoxy-4,5-*O*-isopropylidene-1-*C*-phenyl-L-*threo*-D-*gulo*-heptitol (8a) and 1-Acetamido-2,6-anhydro-1,7-dideoxy-4,5-*O*-isopropylidene-1-*C*-phenyl-L-*threo*-D-*ido*-heptitol (8b).** A solution of sulfoxide **1** (0.32 mmol) and MeLi·BrLi (1.5 M, 0.350 mmol) in a minimun amount of dry THF was added dropwise to a solution fo *t*BuLi (1.4 M in hexanes, 1.60 mmol) in dry THF (2.0 mL) at −78 °C. After 5 min PhCN (1.6 mmol) was added, and the mixture was stirred for 5 min at −78 °C. Then MeOH (1.0 mL) and $NaBH_4$ (60 mg, 1.6 mmol) were added, and the reaction was allowed to proceed at room temperature for 2 h. After this time AcOH (1.0 mL) was added and the solvents were evaporated. The residue was solved in pyridine (0.5 mL)- and treated with $Ac_2O$ (0.25 mL), and the mixture was stirred at room temperature for 24 h and concentrated. The residue was purified by FC (hexane/EtOAc 10:1) to give separated **8a** (33 mg, 28%) and **8b** (26 mg, 22%). **8a**: mp 59−60 °C; $[\alpha]_D$ −6.3° (*c* 0.6, $CHCl_3$); $^1$H NMR (300 MHz, $CDCl_3$) $\delta$ 7.34−7.19 (m, 5 H), 6.33 (d, $J$ = 7.6 Hz, 1 H), 5.20−5.08 (m, 2 H), 4.36 (dd, $J$ = 2.5, 7.3 Hz, 1 H), 4.20 (dd, $J$ = 2.5, 7.6 Hz, 1 H), 4.12−4.02 (m, 2 H), 1.89 (s, 3 H), 1.83 (s, 3 H), 1.49 (s, 3 H), 1.31 (s, 3 H), 1.22 (d, $J$ = 6.5 Hz, 3 H); $^{13}$C NMR (75 MHz, $CDCl_3$) $\delta$ 170.08, 169.33, 140.13, 128.92, 128.62, 128.35, 128.08, 127.65, 110.01, 75.13, 72.29, 71.49, 67.82, 66.69, 53.63, 26.68, 24.30, 23.59, 21.03, 17.76. Anal. Calcd for $C_{20}H_{27}NO_6$: C, 63.64; H, 7.21; N, 3.71. Found: C, 63.89; H, 7.16; N, 3.70. **8b:** mp 81−83 °C; $[\alpha]_D$ −1.5° (*c* 1.0, $CHCl_3$); $^1$H NMR (300 MHz, $CDCl_3$) $\delta$ 7.29−7.19 (m, 5 H), 6.33 (d, $J$ = 7.2 Hz, 1 H), 5.07 (dd, $J$ = 7.5, 8.8 Hz, 1 H), 4.67 (t, $J$ = 3.0 Hz, 1 H), 4.30 (dd, $J$ = 3.1, 8.8 Hz, 1 H), 4.22 (dd, $J$ = 3.0, 7.3 Hz, 1 H), 4.11−4.06 (m, 2 H), 2.01 (s, 3 H), 1.96 (s, 3 H), 1.47 (s, 3 H), 1.30 (d, $J$ = 6.5 Hz, 3 H), 1.29 (s, 3 H); $^{13}$C NMR (75 MHz, $CDCl_3$) $\delta$ 169.62, 169.23, 139.06, 128.73, 127.83, 127.06, 109.71, 74.75, 71.91, 71.68, 68.12, 66.58, 54.17, 26.47, 24.23, 23.38, 20.82, 17.25. Anal. Calcd for $C_{20}H_{27}NO_6$: C, 63.64; H, 7.21; N, 3.71. Found: C, 63.82; H, 6.96; N, 3.72.

**4,8-Anhydro-6,7,9-tri-*O*-benzyl-1,2-dideoxy-2-*C*-methyl-D-*erythro*-L-*talo*-nonitol and 4,8-Anhydro-6,7,9-tri-*O*-benzyl-1,2-dideoxy-2-*C*-methyl-D-*erythro*-L-*galacto*-nonitol (20).** Using the general procedure sulfoxide **12** was treated with isobutyraldehyde as electrophile to give **20** (13%) in approximately a 1:1 diastereomeric mixture: $[\alpha]_D$ +18.0° (*c* 0.95, $CHCl_3$); $^1$H NMR (400 MHz, $CDCl_3$) $\delta$ 7.33−7.17 (m, 15 H), 3.78 (dd, $J$ = 7.8, *8.5* Hz), 3.68 (t, $J$ = 7.8 Hz), 3.58 (t, $J$ = 9.2 Hz), 3.53 (t, $J$ = 8.9 Hz), 2.07 (m), 1.87 (m), 1.03 (d, $J$ = 6.7 Hz), 0.96 (d, $J$ = 6.9 Hz), 0.90 (d, $J$ = 6.7 Hz), 0.88 (d, $J$ = 6.9 Hz). Anal. Calcd for $C_{31}H_{38}O_6$: C, 73.49; H, 7.56. Found: C, 73.63; H, 7.31.

**4,8-Anhydro-6,7,9-tri-*O*-benzyl-1,2-dideoxy-2-*C*-methyl-D-*erythro*-L-*manno*-nonitol and 4,8-Anhydro-6,7,9-tri-*O*-benzyl-1,2-dideoxy-2-*C*-methyl-D-*erythro*-L-*allo*-nonitol (23).** Using the general procedure sulfoxide **13** was treated with isobutyraldehyde as electrophile to give **23** (41%) in approximately a 1:1 diastereomeric mixture: $[\alpha]_D$ +5.0° (*c* 0.6, $CHCl_3$); $^1$H NMR (200 MHz, $CHCl_3$) $\delta$ 7.24−7.37 (m, 15 H), 4.50−4.68 (m, 6H), 3.64−3.96 (m, 6H), 2.58 (br s,), 2.35 (br s), 2.02−2.18 (m), 1.65−1.84 (m), 0.99 (d, $J$ = 6.8 Hz), 0.95 (d, $J$ = 6.6 Hz), 0.94 (d, $J$ = 6.8 Hz), 0.91 (d, $J$ = 6.8 Hz); $^{13}$C NMR (75 MHz, $CDCl_3$) $\delta$ 78.33, 78.16, 76.30, 74.35, 74.08, 73.40, 73.31, 73.27, 73.21, 72.95, 72.79, 72.77, 72.45, 68.55, 68.28, 65.43, 30.70, 28.58, 19.52, 19.47, 17.92, 14.70. Anal. Calcd for $C_{31}H_{38}O_6$: C, 73.49; H, 7.56. Found: C, 73.42; H, 7.71.

**4,8-Anhydro-1,2-dideoxy-6,7,9-tri-*O*-methyl-2-*C*-methyl-D-*erythro*-L-*talo*-nonitol and 4,8-Anhydro-1, 2-dideoxy-6,7,9-tri-*O*-methyl-2-*C*-methyl-D-*erythro*-L-*galacto*-nonitol (32).** Using the general procedure sulfoxide **31** was treated with isobutyraldehyde as electrophile to give **32** (50%) in approximately a 1:1 diastereomeric mixture: $[\alpha]_D$ +18.3° (*c* 0.6, $CHCl_3$); $^1$H NMR (200 MHz, $CDCl_3$) $\delta$ 3.68 (s), 3.67 (s), 3.55 (s), 3.53 (s), 3.39 (s), 3.37 (s), 2.88 (d), 2.82 (br s), 2.10 (m), 1.88 (m), 1.01 (d, $J$ = 6.7 Hz), 0.98 (d, $J$ = 7.1 Hz), 0.91 18 (d, $J$ = 6.7 Hz), 0.89 (d, $J$ = 6.8 Hz). Anal. Calcd for $C_{13}H_{26}O_6$: C, 56.09; H, 9.41. Found: C, 56.42; H, 9.71.

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