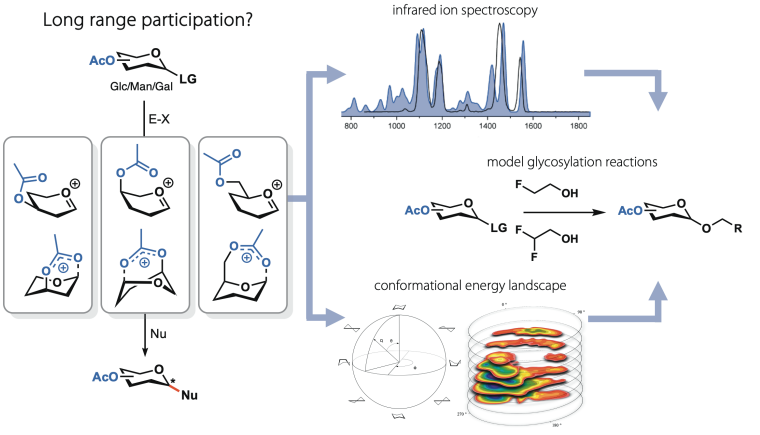
Glycosyl cations in glycosylation reactions

Hansen, T.

Chapter 4

Characterization of Glycosyl Dioxolenium Ions and Their Role in Glycosylation Reactions



Abstract | Controlling the stereoselectivity of a chemical glycosylation reaction remains the major challenge in the synthesis of oligosaccharides. Though 1,2-*trans* glycosidic linkages can be installed using neighboring group participation, the construction of 1,2-*cis* linkages is difficult and has no general solution. Long-range participation (LRP) by distal acyl groups may steer the stereoselectivity, but contradictory results have been reported on the role and strength of this stereoelectronic effect. It has been exceedingly difficult to study the bridging dioxolenium ion intermediates because of their high reactivity and fleeting nature. In this chapter an integrated approach is reported, using infrared ion spectroscopy, DFT calculations and a systematic series of glycosylation reactions to probe these ions in detail. This chapter reveals how distal acyl groups can play a decisive role in shaping the stereochemical outcome of a glycosylation reaction and opens new avenues to exploit these species in the assembly of oligosaccharides and glycoconjugates to fuel biological research.

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Introduction

The principle challenge in chemical oligosaccharide synthesis is the stereoselective installation of glycosidic bonds.[1–4] Glycosidic bonds connecting monosaccharides can either exist as 1,2-*trans* or 1,2-*cis* diastereomers and the nature of the linkage has a profound influence on the structure and function of glycans. The most common approach to chemically create glycosidic bonds is a nucleophilic substitution reaction between a glycosyl donor carrying an anomeric leaving group, and a glycosyl acceptor containing a nucleophilic alcohol. The stereochemical outcome of glycosylation reactions can be controlled using neighboring group participation (NGP).[5,6] Acyl groups at the C-2 position of glycosyl donors can engage in NGP affording bicyclic C-1,C-2 dioxolenium ion intermediates that react in a stereospecific manner with glycosyl acceptors to afford 1,2-*trans* products (Figure 1A).[7] NGP of an *O*- or *N*-acyl functionality at C-2 is applicable to a wide variety of monosaccharides, and has enabled the stereoselective synthesis of numerous oligosaccharides both in solution and on solid support. For these reasons, NGP is one of the pillars upon which chemical oligosaccharide synthesis stands.[8,9]

By definition, NGP by a C-2 acyl group only allows access to 1,2-*trans* glycosides, and because of this it cannot be applied to the synthesis of C-2-deoxy or 1,2-*cis* glycosides. Long-range participation (LRP) of acyl functionalities farther away from the anomeric center, *i.e.* placed on the C-3, C-4 or C-6 hydroxyl groups, has also been suggested to direct the stereoselectivity of glycosylation reactions (Figure 1). Importantly, LRP potentially allows for the utilization of the relative stereochemistry of C-3, C-4, or C-6 groups to control the facial selectivity in glycosylation reactions thereby enabling the stereoselective synthesis of C-2-deoxy and 1,2-*cis* glycosides. However, contradictory results have been reported and there is an ongoing debate as to the role and strength of this stereoelectronic effect.[10–24] Indirect proof for LRP has been derived from the stereochemical outcome of glycosylation reactions and studies using model systems.[24] The ability of acyl substituents positioned at C-3, C-4 or C-6 to engage in LRP likely depends on their distance and stereochemical orientation with respect to the cationic center. In addition, the relative configuration of the neighboring substituents may influence LRP by steric and electronic effects.

Due to the instability of the intermediate dioxolenium ions and their short life time in solution, they are exceedingly difficult to detect. Direct characterization has only been reported with respect to NGP.[25,26] Although glycosyl cations have been characterized in super acid solution by NMR, protonation of the acetyl groups under these conditions prevents the assessment of their ability to engage in LRP.[27,28] This hampers the fundamental understanding of LRP and prevents its systematic development to advance stereoselective oligosaccharide synthesis.[27–30]

This chapter describes the use of infrared ion spectroscopy (IRIS) to characterize glucosyl, mannosyl and galactosyl dioxolenium ions formed *via* LRP and shows how the stability and reactivity of these species depend on the position and configuration of the acyl group. Using DFT calculations, the conformational energy landscape (CEL) of these

glycosyl cations was systematically mapped in gas and solution phase. Finally, through a series of glycosylation reactions, employing a set of model nucleophiles of gradually decreasing nucleophilicity, the importance of the remote dioxolenium ions in glycosylation reactions could be mapped. The combination of these techniques established the strength of LRP as: 3-Ac-Man >> 4-Ac-Gal > 3-Ac-Glc ~ 3-Ac-Gal > 4-Ac-Glc > 4-Ac-Man ~ 6-Ac-Glc/Gal/Man. The establishment of dioxolenium ion intermediates as possible reactive intermediates in glycosylation reactions opens up avenues to exploit these species for more stereoselective glycosylations.

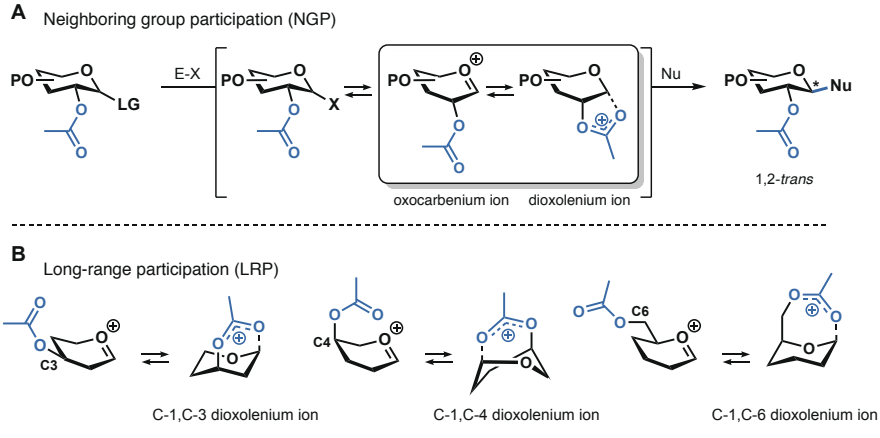


Figure 1. NGP (A) and LRP (B) in glycosylation reactions offers an opportunity to control the stereoselectivity of glycosylations. P = protection group; E-X = promoter system; and Nu = nucleophile.

Results and discussion

Recently, the group of Boltje and others have employed IRIS to characterize both glycosyl oxocarbenium and dioxolenium ions in the gas-phase.[31–34] In this method, glycosyl donors are introduced into the mass spectrometer *via* electrospray ionization (ESI) and, in a tandem-mass spectrometric (MS^2) scheme, glycosyl cations are formed from the isolated donors by collision induced dissociation (CID). This allowed the generation of "naked" glycosyl cations in the absence of a counter ion and solvent molecules, and characterization using multi photon infrared ion spectroscopy.[32,33] The IR spectra showed diagnostic vibrational bands and were used to characterize both C-1,C-2 dioxolenium ions and oxocarbenium ions.[32] In addition, the group of Boltje provided the first example of dioxolenium ions formed by LRP in uronic acid derivatives.[33] To systematically investigate whether LRP plays a role in glycosylation reactions, two sets of glycosyl donors were assembled, derived from the most commonly used pyranosides, D-glucose, D-mannose and D-galactose donors. They were equipped with an acyl group at either the C-3, C-4 or C-6 hydroxyl group (see Figure 2). The first set comprises *S*-phenyl donors equipped with

methyl ethers and acetyl esters (**1**-**9**) used for the IRIS studies and computational studies to minimize computing costs. The second set features benzyl ethers and benzoate esters (**10**-**18**) used in a matrix of model glycosylation reactions, as these represent the most commonly used protecting groups in synthetic carbohydrate chemistry. The benzyl ether and benzoate esters are structurally very similar, while differing significantly in electronic properties and their ability to stabilize an oxocarbenium ion.[35,36]

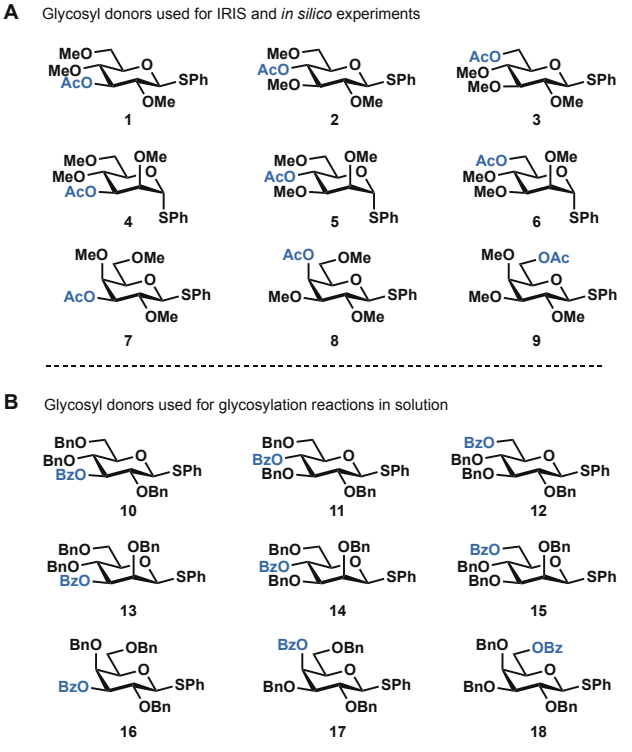


Figure 2. *S*-phenyl donors equipped with ester protection groups on systematically varied positions on the ring. (A). Glycosyl donors used for IRIS experiments and DFT computations. Donors **3**-**9** and **13**-**15** were converted into their corresponding sulfoxides prior for the IRIS experiments to improve the yield of the glycosyl cation generation;[33] (B) Glycosyl donors used for chemical glycosylation reaction in solution.

Glycosyl cations derived from **1**-**9** were formed from precursor ions using tandem-MS (see SI Figure S2-S10). IRIS of the glycosyl cations was carried out using the FELIX infrared free electron laser (IR-FEL) operating in the 700-1850 cm^{-1} frequency range which is well suited to detect the characteristic bands of oxocarbenium and dioxolenium ion structures (Figure 3A).[37] For example, oxocarbenium ions derived from **1**-**9** can be assigned on the basis of their characteristic $C_1{=}O_5^+$ stretch (~1600 cm^{-1}) and preservation of the acetyl C=O stretch near 1800 cm^{-1}. Conversely, the formation of a dioxolenium ion is signified by the absence of the acetyl C=O stretch and the $C_1{=}O_5^+$ stretch and appearance of a dioxolenium ion O-C=O^+ stretch- (~1550 cm^{-1}) and bending mode (~1500 cm^{-1}). Accurate spectral

assignments were made by comparing the experimental IR spectra with computed IR spectra obtained by high-level density functional theory (DFT) calculations (B3LYP/6-31++G(d,p)).[38] The experimental IR spectra of **1**-**9** are presented in Figure 3B-D (black line) together with the best matching calculated spectra (blue filled).

The IR spectra of the gluco-, manno- and galacto-C-3 acetyl derivatives **1**, **4** and **7** all confirm LRP of the C-3 acetyl group (Figure 3B), as indicated by a characteristic dioxolenium O-C=O$^+$ stretch (~1550 cm^{-1}) and the absence of an oxocarbenium C_1=O_5^+ or acetyl C=O stretch. The DFT calculated IR spectra of the formed dioxolenium ions matched well with the experimentally obtained spectra, while the computational spectra of the possible oxocarbenium ions derived from **1**, **4** and **7** did not (see SI Figure S2, S5, and S8).

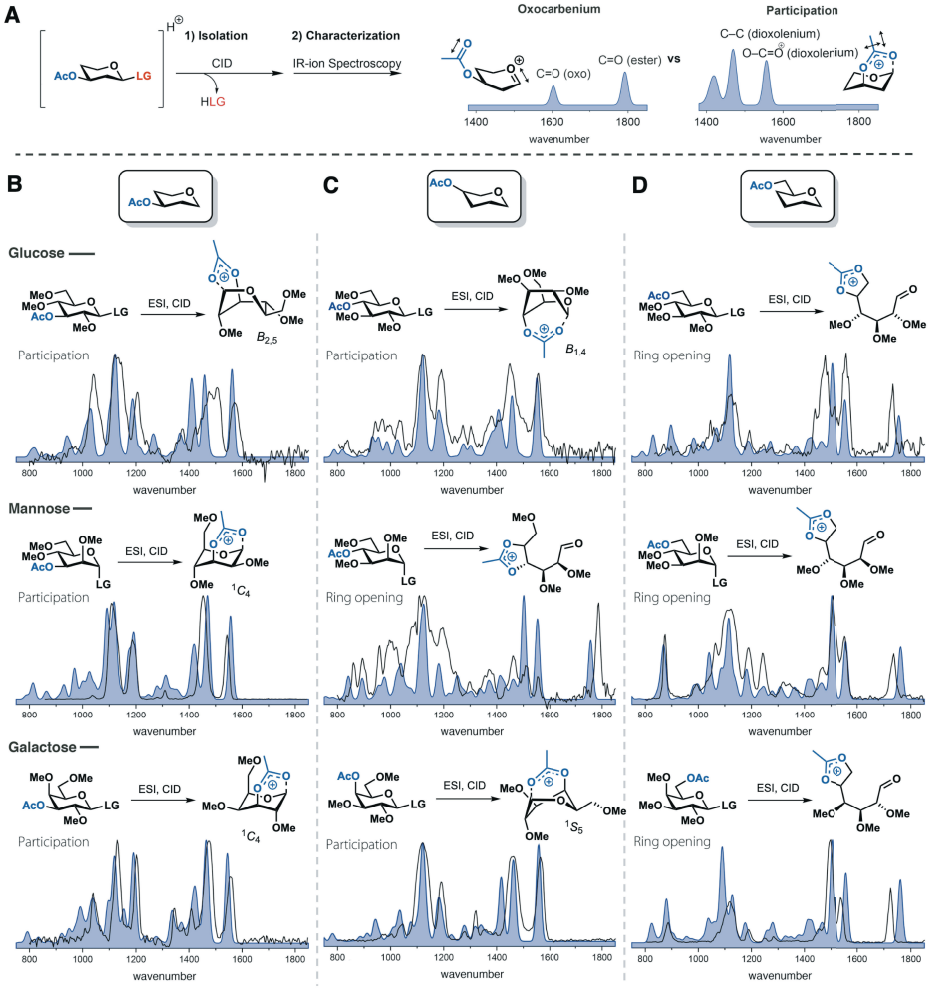


Figure 3. Comparison of the computed IR-ion spectra (filled) and the measured IR-ion spectra (black line) of the glycosyl cations derived from 3-Ac (A), 4-Ac (B) and 6-Ac (C) glucosyl, mannosyl and galactosyl donors **1**-**9**. Ring-opening of donors **3**, **5**, **6** and **9** have been presented as accessible structures, their exact conformation is presented in supporting information S4, S6, S7 and S10.

The calculated energy difference between the dioxolenium ions and the corresponding oxocarbenium ions also indicate LRP to be favorable for the C-3-acyl glycosides as all C-1,C-3 dioxolenium ions are lower in energy than their oxocarbenium ion counterparts (*vide infra*). From these experiments, it is clear that LRP of the equatorial C3-acetyl group of gluco-, manno- and galactopyranosides is favorable.

IRIS of C-4 acetyl derivatives **2**, **5** and **8** also produced characteristic IR spectra (Figure 3C, black line). The IRIS spectra of glucoside **2** and galactoside **8** showed the absence of a C=O ester stretch and instead showed diagnostic dioxolenium ion signals. In these cases, agreement between the experimental and calculated IR spectra provide clear evidence for LRP. Alternative structures lacking LRP were calculated but did not match the experimental spectrum (see SI, Figure S3 and S9). The IRIS spectrum of the ion resulting from C-4 acetyl mannose donor **5** showed distinctive dioxolenium absorptions at 1550 and 1500 cm^{-1} and a significant band at 1790 cm^{-1} suggesting the presence of a carbonyl functionality. A mixture of dioxolenium ions formed by LRP and oxocarbenium ions could explain this observation. However, comparing and mixing the DFT calculated spectra of these ions did not lead to a good match with the experimental spectrum (see SI, Figure S6). The only structure that was in good agreement with the experimental spectrum is the dioxolenium ion, formed by attack of the C-4 acetyl on the C-5 of the initially formed oxocarbenium ion (see Figure 3C, middle panel). This leads to ring opening and the formation of the C-4,C-5 dioxolenium ion with an aldehyde functionality at C-1. To the best of my knowledge, this type of rearrangement has not been reported before and the used gas-phase experimental conditions likely promote the formation of this species. Hence, the C-4 acetyl in mannose does not directly engage in LRP at the anomeric center. Taken together, these results show that the axial and equatorial C-4 esters in the glucose and galactose ions can engage in LRP, while the mannose ion provides a C-4,C-5 dioxolenium ion.

Finally, the cations of C-6 acetyl glycosides **3**, **6** and **9** were investigated. In all cases, a strong absorption near 1730 cm^{-1} was observed indicating the presence of a carbonyl functionality. However, a clear dioxolenium ion signature (~1550 cm^{-1}) was also observed. Again, neither the DFT calculated IR spectra of the oxocarbenium ion or LRP dioxolenium ion nor a mixture of the two matched with the experimental spectrum (see SI Figure S4, S7, and S10 respectively). Similar to the C-4 acetyl mannose donor **5**, the experimental spectrum was matched best with calculated spectra corresponding to the ring-opened structures featuring a C-5,C-6 dioxolenium ion, producing both the aldehyde C=O and the dioxolenium O-C=O^+ stretching bands. This suggests that C-6 acetyls are unlikely to provide LRP.

To verify that the methyl ether/acetyl ester protected set of glycosyl donors behave similar to their benzyl ether/benzoyl ester counterparts, IRIS experiments are performed with the mannosyl set **13**-**15** (see SI Figure S11-S13) and compared their spectra to those of

4-**6** (see SI Figure S5-S7). These experiments confirmed that the LRP behavior of these two sets of glycosyl donors is the same in the IRIS experiments.

To understand why some acetyl esters engage in LRP and lead to the formation of bicyclic dioxolenium ions from the parent oxocarbenium ions, while others do not, a computational method can be employed to investigate their relative stability. Chapter 2 describes the development of a DFT protocol to compute the relative energy of a large ensemble of oxocarbenium ion conformers, filling the complete conformational space these cations can occupy and plotted their relative energy to afford conformational energy landscape (CEL) maps.[29,39–41] Employing this method, one is able to find low energy conformers and relevant (conformational) pathways which connect these on the CEL. In the present chapter, the DFT method is adopted (see workflow in Figure 4) to evaluate the relative stability of the oxocarbenium and dioxolenium ions derived from **1**-**9** (Figure 5). Two rotamers of the acetyl ester were taken into account and separately visualized as a CEL map: rotamer 1 (R1) in which the acetyl is pointing towards C-1 making LRP geometrically feasible (Figure 5, left CEL map); and rotamer 2 (R2) in which the acetyl points away from C-1 making the inspection of the oxocarbenium ion possible (Figure 5, right CEL map). The geometry of all the conformers was optimized by DFT using the hybrid functional B3LYP and the basis set 6-311G(d,p), which presents an practicable trade-off between computing time and accuracy (For more information see Supplementary Information). To probe the difference in glycosyl cation structure between the IRIS gas-phase experiments devoid of solvent and glycosylation experiments performed in solution (*vide infra*), CEL maps were generated for ions formed in the gas-phase at room temperature and in solvent (computationally evaluated using a polarizable continuum model, see SI) at −60 °C at which the experimental glycosylations take place, respectively. Figure 5A-C depict the maps for the solution-phase ions, while Figure 5D summarizes the relative energy of the structures found in the solution-phase and the gas-phase (all gas-phase CEL maps can be found in SI Figure S14).

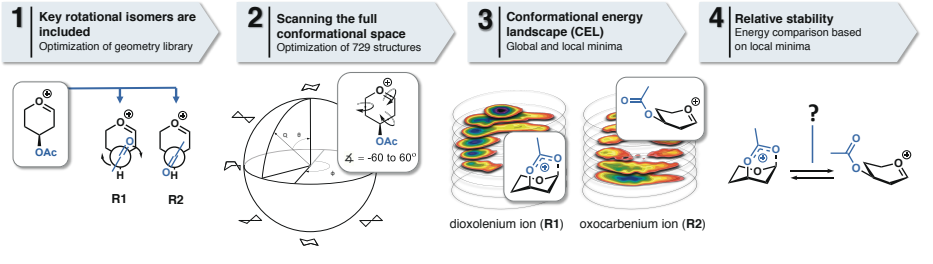
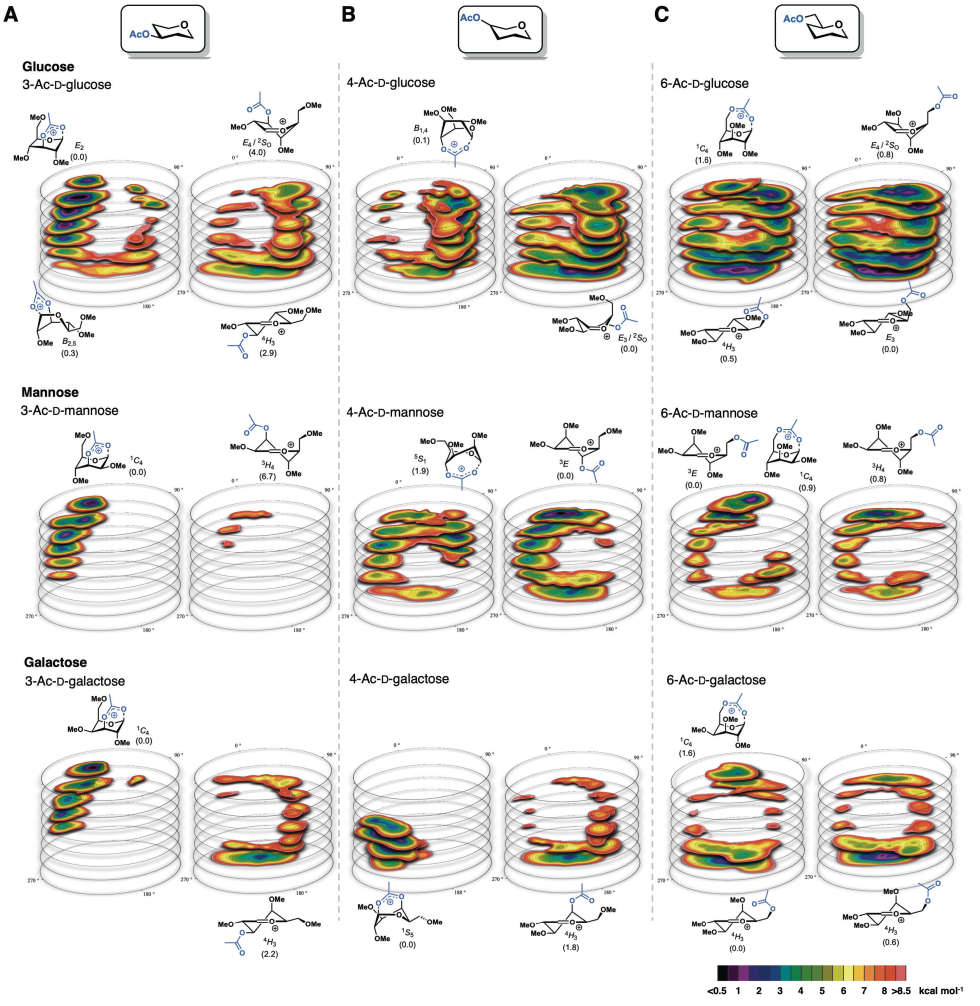


Figure 4. Overview of the workflow to map the relative stability of glycosyl dioxolenium- and oxocarbenium ions. (1) Two rotamers are used to probe long-range participation: R1 makes it geometrically feasible to form dioxolenium ions, where R2 generates the free oxocarbenium ion; (2) The complete conformational space of the six-membered rings was scanned by computing 729 pre-fixed structures per rotamer. A few canonical conformations (chair, half-chair, envelope, and boat) are depicted; (3) The associated energies were graphed on slices dividing the Cremer-Pople sphere. The CEL map of the R1 rotamer (left) and CEL map of the R2 rotamer (right); (4) Based on the CEL maps of R1 and R2 the relative stability of both intermediates can be evaluated.

Figure 5A shows the solution-phase CEL maps of the C-3 acetyl protected glucosyl, mannosyl, and galactosyl dioxolenium (R1) and oxocarbenium ions (R2). The computed local minima (in dark), show that formation of the dioxolenium ions (Figure 5A, left CEL-maps) is energetically favorable. For the gas-phase, the maps are similarly but with larger energy differences between the lowest energy dioxolenium and oxocarbenium ions (Figure 5D, final row). The comparison shows that the energy difference is largest for the C-3 acetyl mannose system, with the most favorable mannose C-1,C-3 dioxolenium ion adopting a $^{1}C_{4}$-conformation. The glucose and galactose ions benefit from LRP with the E_{2}-glucose and $^{1}C_{4}$-galactose C-1,C-3 dioxolenium ions being 2-3 kcal mol^{-1} more stable than the corresponding lowest energy $^{4}H_{3}$-oxocarbenium ions. In the mannose system the lowest energy oxocarbenium and dioxolenium ions are close in conformational space (*i.e.*, both conformations present in the top part of the CEL map), indicating that only a small conformational change is required for the formation of the dioxolenium ion from the oxocarbenium ion. In the glucose and galactose systems, the lowest energy oxocarbenium and dioxolenium ions are found in different regions of the conformational space. Hence, the conformational change required for the transition from the initially formed oxocarbenium ion to the more stable dioxolenium ion necessitates the crossing of a significant energy barrier. Overall the CEL maps suggest that participation of a C-3 acyl group is favorable for all three diastereoisomeric ions studied, which is corroborated by the IRIS experiments and is most beneficial in the mannose configured C-3 acetyl system.

A similar analysis of the C-4 acetyl systems (Figure 5B) reveals important differences between the glucose, mannose and galactose systems, again consistent with the IRIS experiments. The participation of the C-4 acetyl in the mannose ion is unfavorable, while the C-4 acetyl glucose and galactose systems benefit from LRP. The formation of the galactosyl C-1,C-4 dioxolenium ion, adopting a $^{1}S_{5}$-like structure, from the $^{4}H_{3}$-oxocarbenium ion requires only a minimal adjustment of the sugar ring conformation and is therefore facile. For the glucosyl C-4 acetyl case this requires significantly more structural rearrangement from the E_{3}-oxocarbenium ion to the lowest energy $B_{1,4}$-structure. Furthermore, the computations indicate that the glucose C-1,C-4 dioxolenium ion is more stable than the oxocarbenium ion in the gas-phase, while the relative energy of both ions is similar in solution. The relative instability of the mannosyl C-1,C-4 dioxolenium ion may be due to the *pseudo*-axial orientation of all substituents in the $^{5}S_{1}$-like structure, with the C-2 and C-3 substituents experiencing unfavorable eclipsing interactions that are not present in the glucose and galactose dioxolenium ions.

Finally, the C6-acetyl systems were probed. As can be seen from Figure 5C and 5D, the energy difference between the two acyl rotamers (R1 and R2) is small, indicating that LRP does not lead to significant stabilization of the ions.



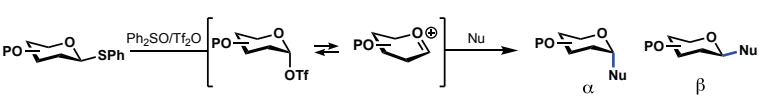
D

	dioxolenium ion		oxocarbenium ion			
	ΔG_{gas}	$\Delta G_{CH_2Cl_2}$	ΔG_{gas}	$\Delta G_{CH_2Cl_2}$	$\Delta\Delta G_{gas}$	$\Delta\Delta G_{CH_2Cl_2}$
3-Ac-glucose	E_2 (0.0) / $B_{2,5}$ (0.0)	E_2 (0.0)	E_4 / $^2S_0$ (5.5)	$^4H_3$ (2.9)	–5.5	–2.9
3-Ac-mannose	$^1C_4$ (0.0)	$^1C_4$ (0.0)	^3E (20.0)	$^3H_4$ (6.7)	–20.0	–6.7
3-Ac-galactose	$^1C_4$ (0.0)	$^1C_4$ (0.0)	$^4H_3$ (6.0)	$^4H_3$ (2.2)	–6.0	–2.2
4-Ac-glucose	$B_{1,4}$ (0.0)	$B_{1,4}$ (0.1)	^3E / $^2S_0$ (1.5)	^3E / $^2S_0$ (0.0)	–1.5	+0.1
4-Ac-mannose	$^5S_1$ (1.0)	$^5S_1$ (1.9)	^3E (0.0)	^3E (0.0)	+1.0	+1.9
4-Ac-galactose	$^1S_5$ (0.0)	$^1S_5$ (0.0)	$^4H_3$ (6.1)	$^4H_3$ (1.8)	–6.1	–1.8
6-Ac-glucose	$^1C_4$ (2.8)	$^1C_4$ (1.6)	E_4 / $^2S_0$ (0.0)	E_3 (0.0)	+2.8	+1.6
6-Ac-mannose	$^1C_4$ (0.4)	$^1C_4$ (0.9)	^3E (0.0)	^3E (0.0)	+0.4	+0.9
6-Ac-galactose	$^1C_4$ (0.6)	$^1C_4$ (1.6)	$^4H_3$ (0.0)	$^4H_3$ (0.0)	+0.6	+1.6

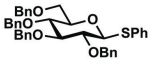
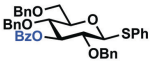
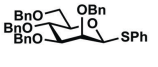
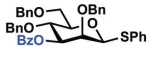
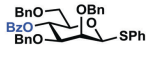
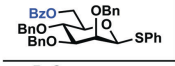
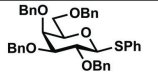
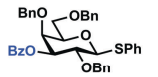
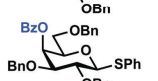
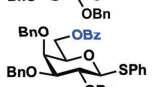
Figure 5. CEL maps of selected glycosyl cations in which the local minima identified are shown with their respective energy. Two acetyl ester rotamers (R1 = left and R2 = right) were considered for all computed glycosyl cations generating two sperate CEL maps. All energies are as computed at PCM(CH_2Cl_2)-B3LYP/6-311G(d,p) at T=213.15 K and expressed as solution-phase Gibbs free energy. A) CEL maps for the C3-acetyl pyranosyl ions; B) CEL maps for the C4-acetyl pyranosyl ions; C) CEL maps for the C6-acetyl pyranosyl ions; D) Table summarizing the relative energy of the dioxolenium and oxocarbenium ion conformers in the gas- and solution-phase.

Table 1. Experimentally found stereoselectivities for model glycosylation reactions. Experimental conditions: pre-activation based glycosylation conditions; nucleophile (2 eq.), Tf_2O (1.3 eq.), Ph_2SO (1.3 eq.), TTBP (2.5 eq.), DCM (0.05 M), –80 °C to –60 °C. The stereoselectivity of the reaction is expressed as α:β and based on ^{1}H-NMR of the purified compounds. In all cases, the NMR spectra for both the crude and purified compounds were compared to analyze whether the obtained stereoselectivity did not alter upon purification.

A



B

					
	>98:2 (41%)	75:25 (80%)	48:52 (58%)	36:64 (75%)	15:85 (70%)
	>98:2 (28%)	76:24 (91%)	58:42 (97%)	44:56 (95%)	40:60 (88%)
	>98:2 (19%)	79:21 (76%)	48:52 (70%)	34:66 (82%)	15:85 (76%)
	>98:2 (30%)	95:5 (82%)	77:23 (82%)	35:65 (83%)	17:83 (94%)
	>98:2 (39%)	>98:2 (84%)	80:20 (65%)	60:40 (75%)	33:67 (70%)
	>98:2 (61%)	>98:2 (79%)	>98:2 (87%)	>98:2 (87%)	>98:2 (94%)
	>98:2 (50%)	88:12 (77%)	71:29 (81%)	60:40 (83%)	31:69 (88%)
	>98:2 (64%)	>98:2 (56%)	78:22 (89%)	51:49 (99%)	35:65 (69%)
	>98:2 (33%)	87:13 (79%)	66:34 (69%)	31:69 (84%)	17:83 (73%)
	>98:2 (54%)	86:14 (77%)	66:34 (81%)	40:60 (82%)	41:59 (79%)
	>98:2 (55%)	97:3 (79%)	87:13 (65%)	63:37 (84%)	45:55 (86%)
	>98:2 (57%)	89:11 (74%)	61:39 (81%)	33:67 (83%)	15:85 (88%)

>90:10 >80:20 >60:40 >50:50 <50:50 <40:60 <20:80 <10:90 (α:β)

To correlate the IRIS and CEL map findings to solution-phase experiments, the influence of LRP in glycosylation reactions was probed using **10**-**18** (Table 1, Entry 2-4, 6-8 and 10-12 respectively). To this end, a matrix of glycosylation reactions was performed with a set of model alcohol nucleophiles of gradually increasing nucleophilicity.[42,43] The

trends observed relate to changes from an S_N2-type substitution reaction of the covalent intermediate (*e.g.*, a glycosyl triflate) for the most nucleophilic alcohols, to reactions involving more oxocarbenium character for the poorest nucleophiles (Table 1A). The glycosylation reactions were performed under pre-activation conditions using diphenyl sulfoxide (Ph_2SO)/triflic anhydride (Tf_2O) as an activator and the results compared to donors bearing solely benzyl ether protecting groups (Table 1, Entry 1, 5 and 9).[44]

The glycosylations of the C-3 benzoyl donors reveal a shift in stereoselectivity with respect to their C-3 benzyl counterparts towards the side of the α-products, formed on the S_N1-side of the reaction mechanism spectrum. The change in stereoselectivity between the benzoyl/benzyl donors can be explained as arising from the LRP of the C-3 acyl groups. This shift is most pronounced in the mannose series, where all glycosylations proceed to give solely the α-product (this is also observed in the glycosylation with the methyl/acetyl protected donor analog, supporting information, Table S1). These observations are in excellent agreement with the IRIS and the CEL maps results which indicate that C-1,C-3 dioxolenium ion formation is possible and most pronounced in the mannose system. For the glucose and galactose donors (Table 1, Entry 2 and 6), C-3 LRP provides less stabilization, which is reflected by the smaller impact on the α-selectivity in these cases.

In contrast, the stereoselectivity of the C-4 benzoate glucose and mannose donors is virtually identical to the selectivity of the C-4 benzyl glucose and mannose donors, revealing little influence of the group present at C-4 position. The IRIS experiments and CEL maps revealed that the formation of the mannosyl C-1,C-4 dioxolenium ion is not favorable. The C-4 acyl group in mannose thus has relatively little effect on the position of the mechanistic continuum at which the substitution reactions take place and LRP can be excluded. While IRIS and the CEL maps have shown that the formation of the glucosyl C-1,C-4 dioxolenium ion is favorable in the gas-phase, the glycosylation reactions of the glucosyl donor appear to be unaffected by the nature of the C-4 substituent. The solution-phase CEL maps have revealed the C-1,C-4 dioxolenium ion, and oxocarbenium ions to be of similar energy. This may account for the moderate effect of the C-4 acetyl group on the stereochemical outcome of the glucosylation reactions. In contrast to the C-4 acyl glucose and mannose series, the C-4 acyl group in the galactose donor is capable of LRP. Both IRIS and the CEL maps provide support for the formation of the bridged C-1,C-4 dioxolenium ion. The stability of this ion translates into the formation of more α-product in the glycosylations of the C-4 acyl galactosides.

Finally, the IRIS spectra of the C-6 acyl gluco-, manno,- and galactosyl donors provide no evidence for LRP of an acyl functionality on this position. This is corroborated by the CEL maps indicate that the formation of the dioxolenium ion bridging the C-1 and C-6 positions does not lead to significant stabilization of the ions. The matrix of glycosylation reactions indeed shows little influence of the C-6 acyl groups. Based on this combined dataset, LRP by C-6 acyl appears to have little influence on glycosylation reactions.

Conclusion

In conclusion, this chapter describes a systematic evaluation of LRP in glucosyl, mannosyl and galactosyl donors bearing an acyl protecting group at their C-3, C-4 or C-6 hydroxyl group functionality. A three-pronged approach consisting of IRIS, CEL computations, and glycosylation reactions was used to assess the effect of LRP in these glycosyl donors. These studies confirm that LRP can play a decisive role in shaping the stereochemical outcome of a glycosylation reaction. LRP plays a major role in glycosylations of C-3 acyl mannosides and to a somewhat lesser extent C-4 acyl galactosides. C-3 acyl groups in glucose and galactosyl donors can engage in LRP but this anchimeric assistance has relatively little influence on the stereochemical course of glycosylations of these donors. No important role for C-6 acyl LRP has been found. The strength of LRP thus follows the order: 3-Ac-Man >> 4-Ac-Gal > 3-Ac-Glc ~ 3-Ac-Gal > 4-Ac-Glc > 4-Ac-Man ~ 6-Ac-Glc/Gal/Man. The establishment of dioxolenium ion intermediates as possible reactive intermediates in glycosylation reactions opens up avenues to enhance and exploit this effect to gain stereocontrol.[14,45,46] These are expected to accelerate the assembly of glycoconjugates to fuel biological research.

Supporting information

Tandem-MS combined with IR ion spectroscopy

General procedure I: ion spectroscopy in a modified ion trap mass spectrometer • The experimental apparatus is based on a modified 3D quadrupole ion trap mass spectrometer (Bruker, AmaZon Speed ETD) that has been coupled to the beam line of the FELIX infrared free electron laser (IR-FEL).[37] Ammonium adducts of each thioether compound ($[M+NH_4]^+$) or protonated adducts from each thiosulfinyl compound ($[M+H]^+$) were generated by electrospray ionization from solutions of 10^{-6} M (in 50:50 acetonitrile:water) containing 2% ammonium acetate infused at 2 µl min^{-1}. The mass-isolated ions of interest were collisionally activated for 40 ms in order to generate the relevant oxonium products. These fragment ions were subsequently mass isolated and irradiated by the tunable mid-infrared beam. The FEL was operated to provide 5 µs optical pulses at 10 Hz having 60-120 mJ pulse energy over the entire IR frequency range (bandwidth ~0.4% of the center frequency). The actual pulse energy used for measurements was appropriately attenuated in order to avoid saturation of the signal. When a sufficient number of photons is absorbed, typically during a single macropulse, unimolecular dissociation occurs generating frequency-dependent fragment ion intensities in the mass spectrum. Relating the precursor ion intensity to the total fragmentation intensity in the observed mass spectrum (yield=ΣI(fragment ions)/ΣI(parent+fragment ions)) for each frequency position generates an infrared vibrational spectrum. The yield is obtained from several averaged mass spectra and is linearly corrected for laser power; the IR frequency is calibrated using a grating spectrometer. A frequency step size of 3 cm^{-1} was used in all spectra reported here.

General procedure II: simulation of IR spectra • For the calculation of gas-phase geometries and corresponding IR spectra we have used a workflow that has been reported previously.[47] The SMILES structure format of the oxocarbenium, dioxolenium and rearranged ions were used as input for the workflow using the cheminformatics toolbox RDKit.[48] A conformational search was performed using a distance geometry algorithm, yielding 500 random 3D-conformations, which were minimized using a classical forcefield.[49] A maximum of 40 conformations were selected by hierarchical on the root means squared distance between geometries.[50] These selected conformations were then submitted to Gaussian 16 for geometry optimization and frequency calculations using the semi-empirical PM6 level.[51] By comparing relative energies (electronic and thermal), unfavorable conformations were filtered by using an energy cut-off of 10 kcal/mol. When generating pyranosyl cations, this cut-off was increased to 20 kcal/mol, as the oxocarbenium ions would otherwise be filtered out because dioxolenium ions that were formed in the optimization were much lower in energy. Additionally, similar geometries were filtered based on (close to) identical calculated frequencies and corresponding intensities. After these filtering steps, the remaining structures were reoptimized using the B3LYP density functional and 6-31++G(d,p) basis set and thereafter a frequency calculation was performed. Harmonic vibrational frequencies were scaled by 0.975. To aid comparison to experimental spectra, Gaussian broadening (20 cm^{-1} at full width half maximum) was applied to the calculated vibrational lines. To obtain reliable energies the thermal energy of the frequency calculation was combined with the electronic energies calculated using second order Møller-Plesset perturbation theory and the 6-31++G(d,p) basis set.

DFT calculations

General procedure III: conformational energy landscape calculation of pyranosyl oxocarbenium ions • To keep the calculation time manageable, large protecting groups (*i.e.*, *O*-Bn) were substituted with electronic comparable smaller groups (*i.e.*, *O*-Me). The initial structure for the conformational energy landscape (CEL) mapping of the six-membered glycosyl cation was optimized by starting from a 'conformer distribution search' option included in the Spartan 10 program by utilizing DFT as the level of theory and B3LYP as hybrid functional in gas phase with 6-31G(d) as the basis set. All generated gas-phase geometries were re-optimized with Gaussian 09 rev. D.01 by using B3LYP/6-311G(d,p), after which a vibrational analysis was computed to obtain the thermodynamic properties. The gas-phase structures were then solvated by using the PCM implicit solvation model, with CH_2Cl_2 as solvent. Solvent effects were explicitly used in solving the SCF equations and during the optimization of the geometry. The geometry with

the lowest energy was selected as the starting point for the CEL. A complete survey of the possible conformational space was done by scanning three dihedral angles ranging from –60° to 60°, including the C1-C2-C3-C4 (D1), C3-C4-C5-O (D3) and C5-O-C1-C2 (D5). The resolution of this survey is determined by the step size which was set to 15° per puckering parameter, giving a total of 729 pre-fixed conformations per glycosyl cation spanning the entire conformational landscape. All other internal coordinates were unconstrained. Except when a C2-substituent was present on the oxocarbenium ring of interest, then the C2-H2 bond length was fixed based on the optimized structure to counteract rearrangements occurring for higher energy conformers. The 729 structures were computed with Gaussian 09 rev. D.01[52] again with a two-step procedure. First, the structures were optimized in the gas-phase with B3LYP/6-311G(d,p), after which a vibrational analysis was computed to obtain the thermodynamic properties. The gas-phase structures were then solvated by using the PCM implicit solvation model, with CH_2Cl_2 as solvent. For glycosyl cation bearing a C5-C6 substituent three separate staggered rotamers (*i.e.*, *gg*, *gt*, *tg*) of the O5-C5-C6-O6 dihedral angle (*i.e.*, –65°, 65°, 175°) were considered. Earlier work showed the importance of these rotamers and their crucial impact on the selectivity and reactivity of the ion.[41] The CEL maps were computed separately and the starting geometry was obtained from the method described above in which the lowest energy generated rotamers were used. For this specific study two extra rotamers were taken into account of the C-O bond rotamer of the ring carbon and the oxygen of one of the substituents which is protected by an acyl protecting group, bringing the total conformations for each glycosyl cation ion configuration to 4374 geometries. CEL maps were separately computed and visualized: rotamer 1 (R1) in which the acetyl is positioned in such a way that dioxolenium ion formation is geometrically feasible and rotamer 2 (R2) in which the acetyl points away and the free oxocarbenium ion can be found. The final denoted free Gibbs energy was calculated using Equation S1 in which ΔE_{gas} is the gas-phase energy (electronic energy), $\Delta G^{T}_{gas,QH}$ (T = reaction temperature, p = 1 atm. and C = 1 M) is the sum of corrections from the electronic energy to free Gibbs energy in the quasi-harmonic oscillator approximation also including ZPE, and ΔG_{solv} is their corresponding free solvation Gibbs energy. The $\Delta G^{T}_{gas,QH}$ were computed using the quasi-harmonic approximation in the gas phase according to the work of Truhlar.[53]

$$\Delta G^{T}_{CH_2Cl_2} = \Delta E_{gas} + \Delta G^{T}_{gas,QH} + \Delta G_{solv} \qquad \text{(Eq. S1)}$$
$$= \Delta G^{T}_{gas} + \Delta G_{solv}$$

The quasi-harmonic approximation is the same as the harmonic oscillator approximation except that vibrational frequencies lower than 100 cm^{-1} were raised to 100 cm^{-1} as a way to correct for the breakdown of the harmonic oscillator model for the free energies of low-frequency vibrational modes. All optimized structures were checked for the absence of imaginary frequencies. To visualize the energy levels of the conformers on the Cremer-Pople sphere, we have generated slices dissecting the sphere that combine closely associated conformers. The OriginPro software was employed to produce the energy heat maps, contoured at 0.5 kcal mol^{-1}. For ease of visualization, the Cremer-Pople globe is turned 180° with respect to its common representation. Visualization of conformations of interest was done with CYLview.[54]

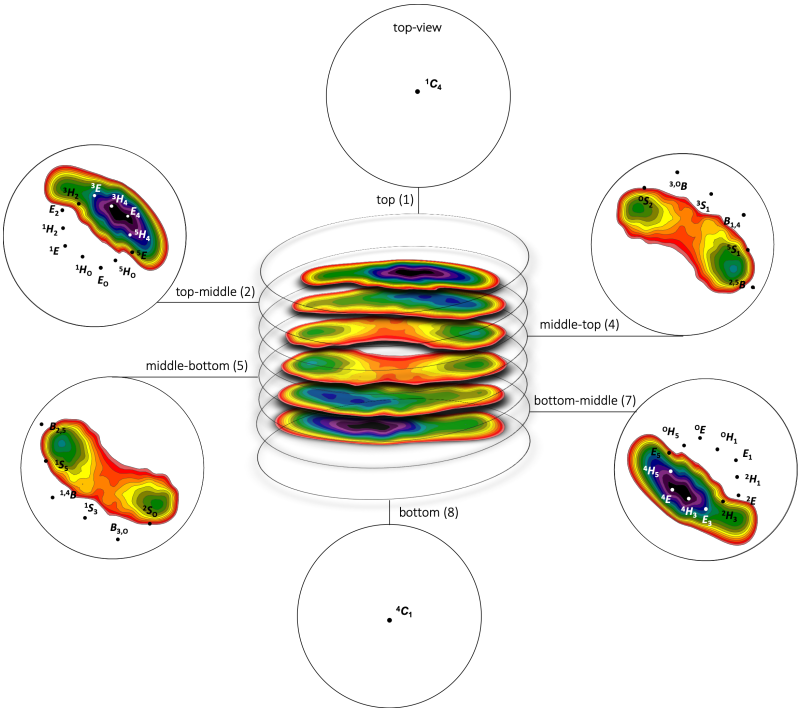


Figure S1. "Deconvolution" of the CEL map of the pyranosyl oxocarbenium ion showing a top view of the most important slices that have been combined to generate the complete CEL map.

IR-spectra • All IR-spectra that are described in this chapter are summarized in the following section. All relevant computed IR-spectra of low energy structures are compared with the measured IR-ion spectrum.

3-*O*-Acetyl-2,4,6-tri-*O*-methyl-gluco-D-pyranosyl cation

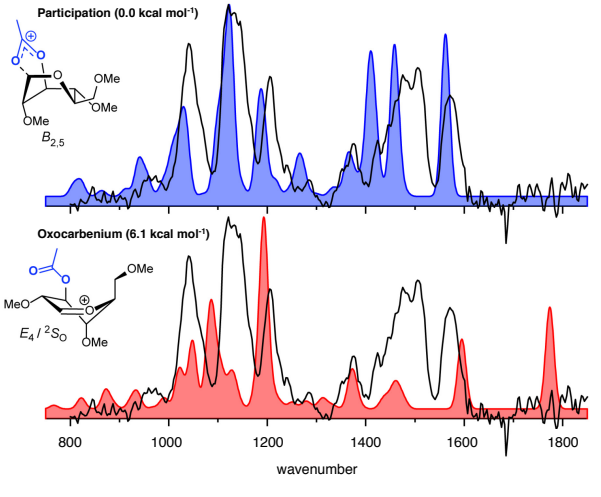


Figure S2. Comparison of the computed IR-spectra of low energy structures (filled) with the measured IR-ion spectrum (black line) of the m/z = 247 CID fragment of compound **1** (top structure). The computed IR-spectrum in blue was assigned as best match with the measured spectrum.

4-*O*-Acetyl-2,3,6-tri-*O*-methyl-gluco-D-pyranosyl cation

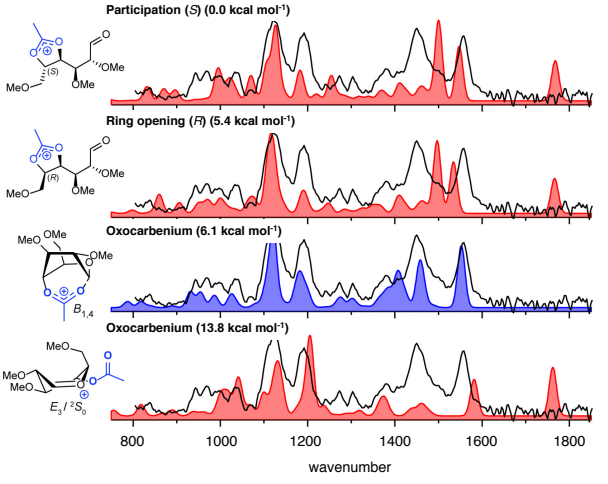


Figure S3. Comparison of the computed IR-spectra of low energy structures (filled) with the measured IR-ion spectrum (black line) of the m/z = 247 CID fragment of compound **2** (top structure). The computed IR-spectrum in blue was assigned as best match with the measured spectrum.

6-*O*-Acetyl-2,3,4-tri-*O*-methyl-gluco-D-pyranosyl cation

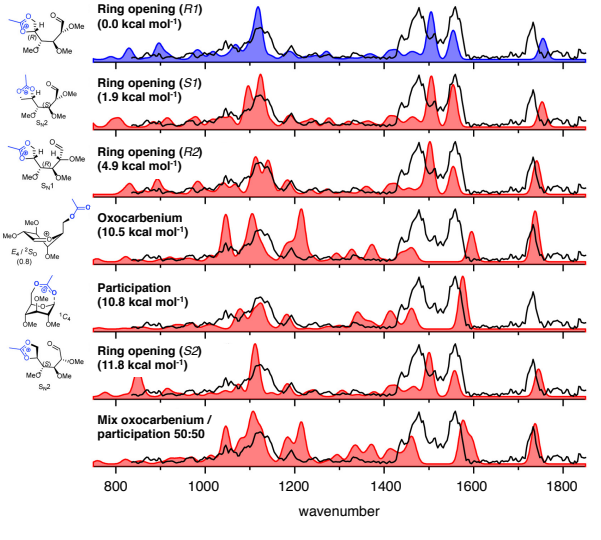


Figure S4. Comparison of the computed IR-spectra of low energy structures (filled) with the measured IR-ion spectrum (black line) of the m/z = 247 CID fragment of compound **3** (top structure). The computed IR-spectrum in blue was assigned as best match with the measured spectrum.

3-*O*-Acetyl-2,4,6-tri-*O*-methyl-manno-D-pyranosyl cation

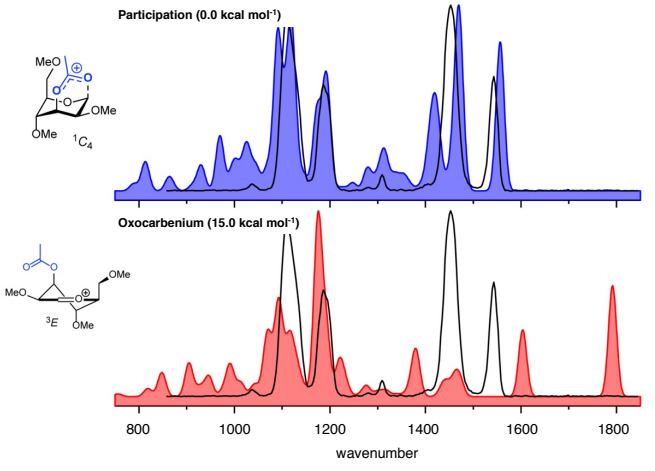


Figure S5. Comparison of the computed IR-spectra of low energy structures (filled) with the measured IR-ion spectrum (black line) of the m/z = 247 CID fragment of compound **4** (top structure). The computed IR-spectrum in blue was assigned as best match with the measured spectrum.

4-*O*-Acetyl-2,3,6-tri-*O*-methyl-manno-D-pyranosyl cation

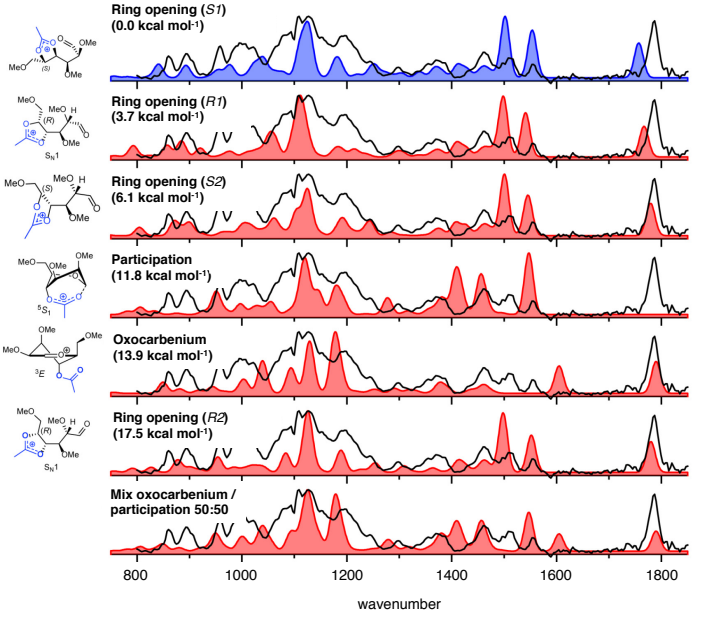


Figure S6. Comparison of the computed IR-spectra of low energy structures (filled) with the measured IR-ion spectrum (black line) of the m/z = 247 CID fragment of compound **5** (top structure). The computed IR-spectrum in blue was assigned as best match with the measured spectrum.

6-*O*-Acetyl-2,3,4-tri-*O*-methyl-manno-D-pyranosyl cation

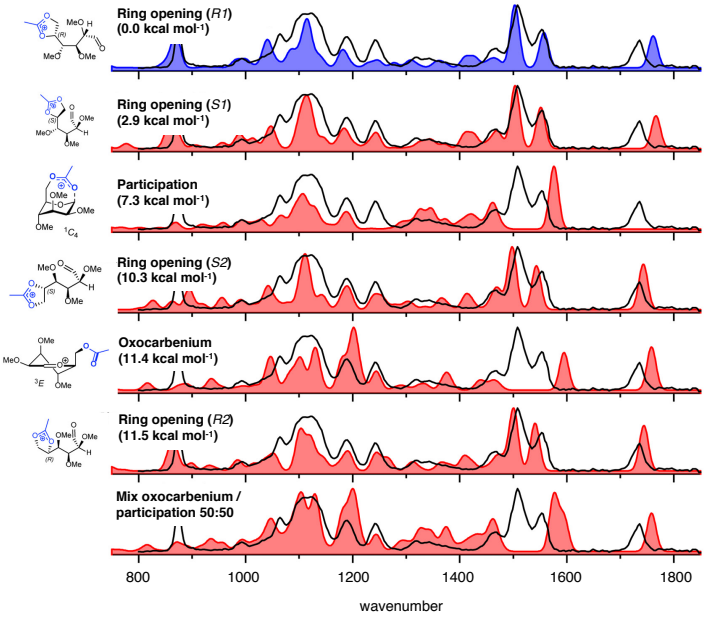


Figure S7. Comparison of the computed IR-spectra of low energy structures (filled) with the measured IR-ion spectrum (black line) of the m/z = 247 CID fragment of compound **6** (top structure). The computed IR-spectrum in blue was assigned as best match with the measured spectrum.

3-*O*-Acetyl-2,4,6-tri-*O*-methyl-galacto-D-pyranosyl cation

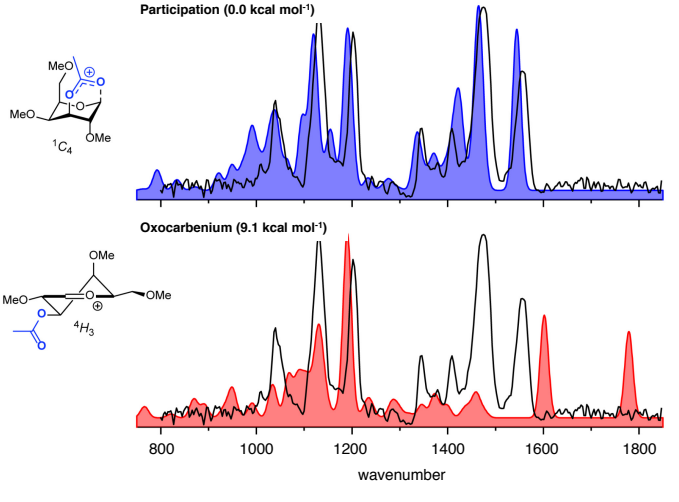


Figure S8. Comparison of the computed IR-spectra of low energy structures (filled) with the measured IR-ion spectrum (black line) of the m/z = 247 CID fragment of compound **7** (top structure). The computed IR-spectrum in blue was assigned as best match with the measured spectrum.

4-*O*-Acetyl-2,3,6-tri-*O*-methyl-galacto-D-pyranosyl cation

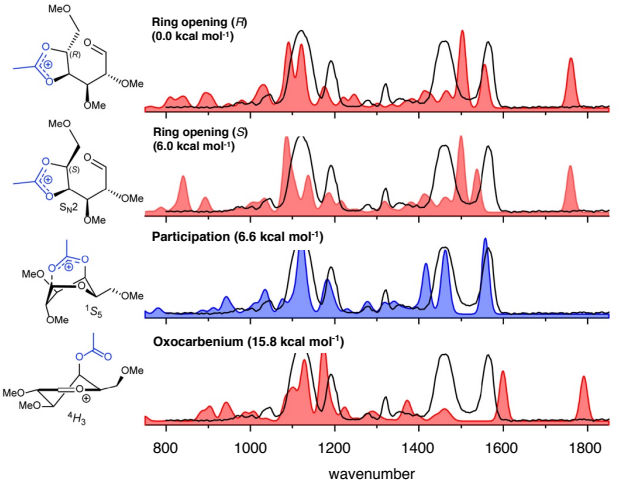


Figure S9. Comparison of the computed IR-spectra of low energy structures (filled) with the measured IR-ion spectrum (black line) of the m/z = 247 CID fragment of compound **8** (top structure). The computed IR-spectrum in blue was assigned as best match with the measured spectrum.

6-*O*-Acetyl-2,3,4-tri-*O*-methyl-galacto-D-pyranosyl cation

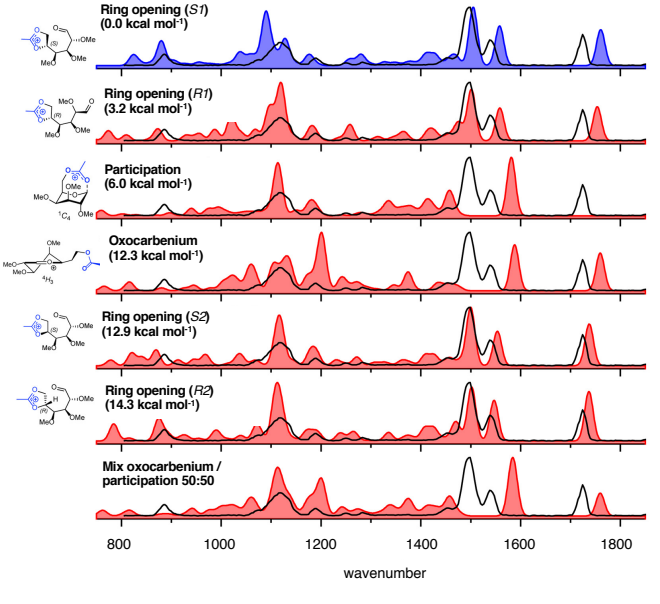


Figure S10. Comparison of the computed IR-spectra of low energy structures (filled) with the measured IR-ion spectrum (black line) of the m/z = 247 CID fragment of compound **9** (top structure). The computed IR-spectrum in blue was assigned as best match with the measured spectrum.

3-*O*-Benzoyl-2,4,6-tri-*O*-benzyl-manno-D-pyranosyl cation

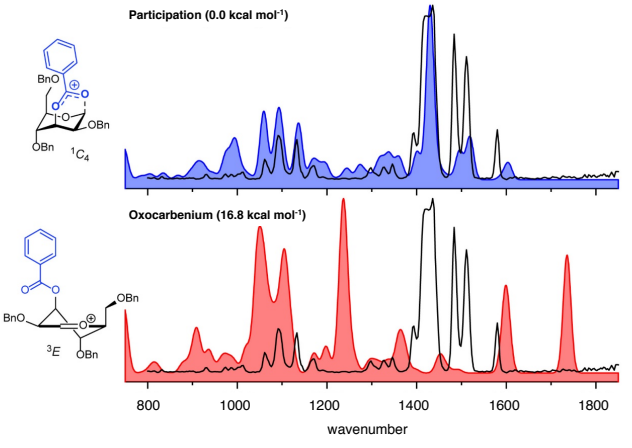


Figure S11. Comparison of the computed IR-spectra of low energy structures (filled) with the measured IR-ion spectrum (black line) of the m/z = 537 CID fragment of compound **13** (top structure). The computed IR-spectrum in blue was assigned as best match with the measured spectrum.

4-*O*-Benzoyl-2,3,6-tri-*O*-benzyl-manno-D-pyranosyl cation

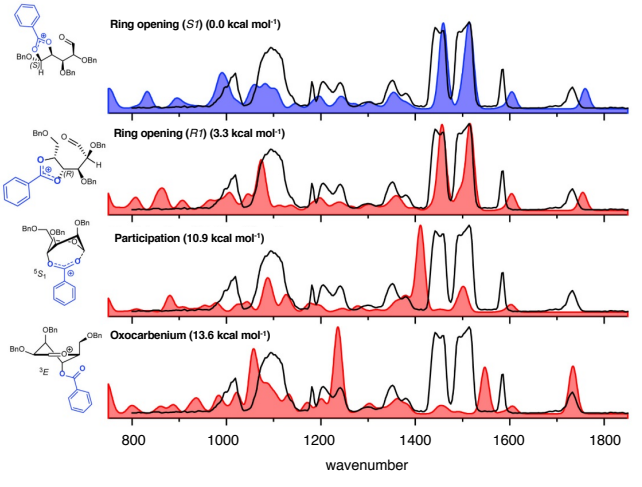


Figure S12. Comparison of the computed IR-spectra of low energy structures (filled) with the measured IR-ion spectrum (black line) of the m/z = 537 CID fragment of compound **14** (top structure). The computed IR-spectrum in blue was assigned as best match with the measured spectrum.

6-*O*-Benzoyl-2,3,4-tri-*O*-benzyl-manno-D-pyranosyl cation

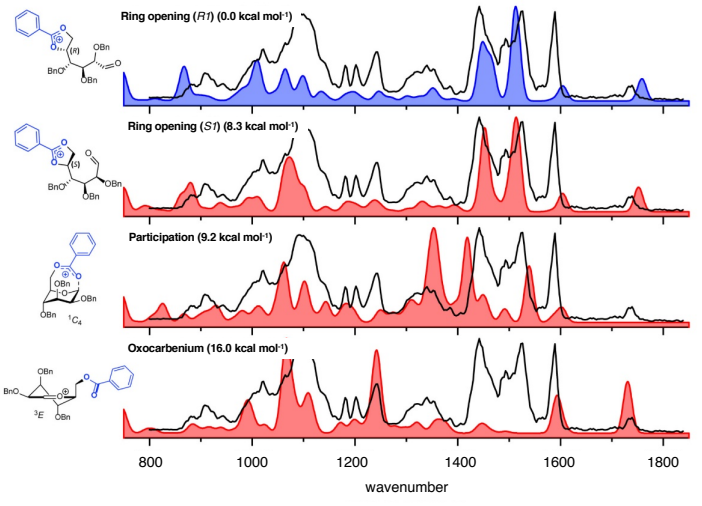


Figure S13. Comparison of the computed IR-spectra of low energy structures (filled) with the measured IR-ion spectrum (black line) of the m/z = 537 CID fragment of compound **15** (top structure). The computed IR-spectrum in blue was assigned as best match with the measured spectrum.

Organic synthesis

General experimental procedures • All chemicals (Merck, Sigma-Aldrich, Alfa Aesar, Honeywell, Boom and Merck KGaA) were of commercial grade and were used as received unless stated otherwise. Dichloromethane, tetrahydrofuran and toluene were stored over activated 4 Å molecular sieves (beads, 8-12 mesh, Sigma-Aldrich). Before use traces of water present in the donor, diphenyl sulfoxide (Ph2SO) and tri-*tert*-butylpyrimidine (TTBP) were removed by co-evaporation with dry toluene. The acceptors used in the model glycosylation reactions (ethanol, 2-fluoroethanol, 2,2-difluoroethanol and 2,2,2,-trifluoroethanol, 1,1,1,3,3,3-hexafluoro-2-propanol) were stored in stock solutions (DCM, 0.5 M) over activated 3 Å molecular rods (rods, size 1/16 in., Sigma Aldrich). Trifluoromethanesulfonic anhydride (Tf_2O) was distilled over P_2O_5 and stored at –20 °C under a nitrogen atmosphere. Deuterated chloroform was stored over activated 3 Å molecular rods (rods, size 1/16 in., Sigma Aldrich) and potassium carbonate. Flash column chromatography was performed on silica gel 60 Å (0.04 – 0.063 mm, Screening Devices B.V.). Size exclusion chromatography was performed on SephadexTM (LH-20, GE Healthcare Life Sciences) by isocratic elution with DCM:MeOH (1:1, v:v). TLC analysis was performed on TLC Silica gel 60 (Kieselgel 60 F254, Merck) with UV detection (254 nm) and by spraying with 20% H_2SO_4 in ethanol followed by charring at ± 260 °C or by spraying with a solution of $(NH_4)_6Mo_7O_{24}{\cdot}H_2O$ (25 g/L) and $(NH_4)_4Ce(SO_4)_4{\cdot}2H_2O$ (10 g/L) in 10% sulfuric acid in water followed by charring at ± 260 °C. TLC-MS analysis was performed on a Camag TLC-MS Interface coupled with an API165 (SCIEX) mass spectrometer (eluted with *tert*-butylmethylether/EtOAc/MeOH, 5/4/1, v/v/v +0.1% formic acid, flow rate 0.12 mL/min). High-resolution mass spectra (HRMS) were recorded on a Waters Synapt G2-Si (TOF) equipped with an electrospray ion source in positive mode (source voltage 3.5 kV) and an internal lock mass LeuEnk ($M+H^+$ = 556.2771) or on a Thermo Finnigan LTQ Orbitrap mass spectrometer equipped with an electrospray ion source in positive mode (source voltage 3.5 kV, sheath gas flow 10, capillary temperature 275 °C) with resolution R=60.000 at m/z=400 (mass range = 150-4000). Amberlite resin (Sigma Aldrich Amberlite IR120 H^+ form or Amberlite IRA-67 free base) was pre-washed with MeOH. ^1H and ^{13}C NMR spectra were recorded on a Bruker AV-400 NMR instrument (400 and 101 MHz respectively), a Bruker AV-500 NMR instrument (500 and 126 MHz respectively), a Bruker AV-600 NMR instrument (600 and 151 MHz respectively) or a Bruker AV-850 NMR instrument (850 and 214 MHz respectively. All samples were measured in $CDCl_3$, unless stated otherwise. Chemical shifts (δ) are given in ppm relative to tetramethylsilane as internal standard or the residual signal

of the deuterated solvent. Coupling constants (*J*) are given in Hz. To get better resolution of signals with small coupling constants or overlapping signals a gaussian window function (LB = ± –1 and GB = ± 0.5) was used on the ^{1}H NMR spectrum. All given ^{13}C APT spectra are proton decoupled. NMR peak assignment was accomplished using COSY, HSQC. If necessary, an additional NOESY, HMBC, and HMBC-gated experiment were used to further elucidate the structure. Stereochemical product ratios were based on integration of ^{1}H NMR (crude and purified). IR spectra were recorded on a Shimadzu FTIR-8300 IR spectrometer and are reported in cm^{-1}. Specific rotations were measured on an Anton Paar Polarimeter MCP 100 in $CHCl_3$ (10 mg/mL) at 589 nm, unless stated otherwise.

General procedure IV: acetylation procedure • To a solution of the glycoside in pyridine (0.10 M), Ac_2O (10 eq.) and cat. DMAP was added. The mixture was stirred to completion before being concentrated *in vacuo*. The resulting crude was dissolved in EtOAc and washed with 1 M aq. HCl solution, sat. aq. $NaHCO_3$ and brine. The organic layer was dried and the resulting solvent evaporated under reduced pressure to obtain the acetylated sugar.

General procedure V: methylation procedure • To a solution of the glycoside in DMF (0.20 M), NaH (60 wt% in mineral oil, 1.5 eq. per hydroxyl) and MeI (1.1 eq. per hydroxyl group) were added at room temperature under inert atmosphere. The mixture was allowed to stir to completion after which it was quenched by dropwise addition of methanol. The resulting suspension was taken up in diethyl ether and washed once with 5% aq. LiCl solution and brine. The resulting aqueous layer was extracted once with DCM. The combined organic layers were dried ($MgSO_4$), filtered and conc. *in vacuo*. The resulting residue was purified by crystallization or silica column chromatography.

General procedure VI: *S*-oxidation procedure • Based on the protocol by Gómez *et al.*[55], a solution of the thioglycoside in DCM (0.05 mM) was cooled to –78 °C under inert atmosphere and then *m*-CPBA (1.1 eq., 75 wt%) was added. The reaction was stirred for 3 h, diluted with DCM (30 mL) and washed with 10% aq. $Na_2S_2O_3$ solution, sat. aq. $NaHCO_3$ and brine. The organic layer was dried ($MgSO_4$), filtered, concentrated *in vacuo*. The resulting crude mixture was used directly for IRMPD experiments.

General procedure VII: pre-activation Tf_2O/Ph_2SO based *O*-glycosylation • A solution of the donor (100 µmol), Ph_2SO (26 mg, 130 µmol, 1.3 eq.) and TTBP (62 mg, 250 µmol, 2.5 eq.) in DCM (2 mL, 0.05 M) was stirred over activated 3 Å molecular sieves (rods, size 1/16 in., Sigma-Aldrich) for 30 min under an atmosphere of N_2. The solution was cooled to –80 °C and Tf_2O (22 µl, 130 µmol, 1.3 eq.) was slowly added to the reaction mixture. The reaction mixture was allowed to warm to –60 °C in approximately 45 min, followed by cooling to –80 °C and the addition of the acceptor (200 µmol, 2 eq.) in DCM (0.4 mL, 0.5 M). The reaction was allowed to warm up to –60 °C and stirred for an additional 4-18 h at this temperature till full reaction completion was observed. The reaction was quenched with sat. aq. $NaHCO_3$ at –60 °C and diluted with DCM (5 mL). The resulting solution was washed with H_2O and brine, dried over $MgSO_4$, filtered and concentrated under reduced pressure. Purification by column chromatography yielded the corresponding *O*-coupled glycoside.

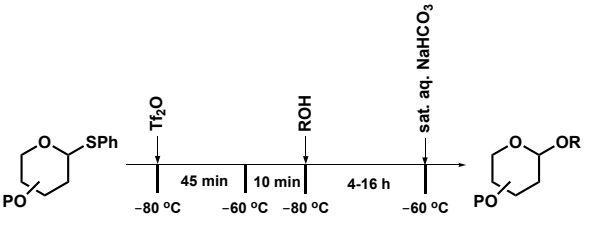
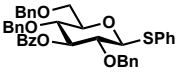
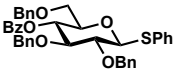


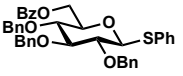
Figure S14. Schematic representation of the reaction procedure during pre-activation Ph_2SO/Tf_2O mediated glycosylation.



Phenyl 3-*O*-benzoyl-2,4,6-tri-*O*-benzyl-1-thio-β-D-glucopyranoside (10). The title compound was prepared according to literature procedure.[15] ^{1}H NMR (400 MHz, $CDCl_3$, HH-COSY, HSQC): δ 8.00 – 7.91 (m, 2H, CH_{arom}), 7.62 – 7.57 (m, 2H, CH_{arom}), 7.57 – 7.52 (m, 1H, CH_{arom}), 7.44 – 7.24 (m, 10H, CH_{arom}), 7.14 – 7.07 (m, 8H, CH_{arom}), 7.02 (m, 2H, CH_{arom}), 5.58 (t, *J* = 9.2 Hz, 1H, H-3), 4.81 – 4.74 (m, 2H, H-1, C*H*H Bn), 4.64 (d, *J* = 12.0 Hz, 1H, C*H*H Bn), 4.58 – 4.51 (m, 2H, CH*H* Bn, CH*H* Bn), 4.51 – 4.45 (m, 2H, CH_2 Bn), 3.83 (t, *J* = 9.6 Hz, 1H, H-4), 3.80 – 3.73 (m, 2H, H-6, H-6), 3.64 – 3.58 (m, 2H, H-2, H-5); ^{13}C NMR (101 MHz, $CDCl_3$, HSQC): δ 165.6 (C=O Bz), 138.2, 137.5, 137.4, 133.7 ($C_{q\text{-}arom}$), 133.2, 132.2, 129.9, 129.1, 128.5, 128.5, 128.4, 128.4, 128.3, 128.2, 127.9, 127.9, 127.8, 127.8, 127.7 (CH_{arom}), 87.6 (C-1), 79.0 (C-2/C-5), 78.7 (C-2/C-5), 78.1 (C-3), 75.9 (C-4), 74.9, 74.6, 73.6 (CH_2 Bn), 68.8 (C-6); HRMS: $[M+Na]^+$ calcd for $C_{40}H_{38}NaO_6S$ 669.22813, found 669.22756.

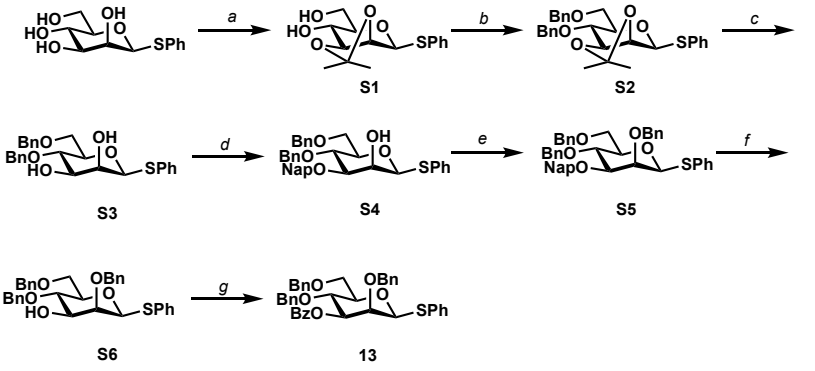


Phenyl 4-*O*-benzoyl-2,3,6-tri-*O*-benzyl-1-thio-β-D-glucopyranoside (11). The title compound was prepared according to literature procedure.[15] ^{1}H NMR (400 MHz, $CDCl_3$, HH-COSY, HSQC): δ 8.23 – 8.18 (m, 1H, CH_{arom}), 8.03 – 7.95 (m, 2H, CH_{arom}), 7.76 – 7.70 (m, 1H, CH_{arom}), 7.67 – 7.63 (m, 2H, CH_{arom}), 7.62 – 7.55 (m, 2H, CH_{arom}), 7.47 (ddd, *J* = 8.1, 6.2, 1.6 Hz, 4H, CH_{arom}), 7.43 – 7.34 (m, 3H, CH_{arom}), 7.33 – 7.23 (m, 8H, CH_{arom}), 7.19 – 7.08 (m, 4H, CH_{arom}), 5.38 – 5.31 (m, 1H, H-4), 4.96 (d, *J* = 10.3 Hz, 1H, C*H*H Bn), 4.85 – 4.76 (m, 3H, H-1, C*H*H Bn, CH*H* Bn), 4.68 (d, *J* = 11.0 Hz, 1H, CH*H* Bn), 4.53 (s, 2H, CH_2 Bn), 3.88 (t, *J* = 9.0 Hz, 1H, H-3), 3.82 (dt, *J* = 10.1, 4.5 Hz, 1H, H-5), 3.72 – 3.61 (m, 3H, H-2, 2x H-6); ^{13}C NMR (101 MHz, $CDCl_3$, HSQC): δ 165.5 (C=O Bz), 138.0, 138.0, 137.8 ($C_{q\text{-}arom}$), 134.7 (CH_{arom}), 133.7 ($C_{q\text{-}arom}$), 133.4, 132.0, 130.7, 129.9 (CH_{arom}), 129.7 ($C_{q\text{-}arom}$), 129.1, 129.0, 128.6, 128.6, 128.4, 128.4, 128.1, 128.1, 127.8, 127.7, 127.6 (CH_{arom}), 87.7 (C-1), 83.9 (C-3), 80.8 (C-2), 78.0 (C-5), 75.7, 75.6, 73.7 (CH_2 Bn), 71.4 (C-4), 69.9 (C-6); HRMS: $[M+Na]^+$ calcd for $C_{40}H_{38}NaO_6S$ 669.22813, found 669.22815.

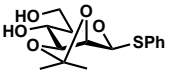


Phenyl 6-*O*-benzoyl-2,3,4-tri-*O*-benzyl-1-thio-β-D-glucopyranoside (12). The title compound was prepared according to literature procedure.[56] ^{1}H NMR (400 MHz, $CDCl_3$, HH-COSY, HSQC): δ 8.07 – 8.00 (m, 2H, CH_{arom}), 7.65 – 7.56 (m, 1H, CH_{arom}), 7.58 – 7.51 (m, 2H, CH_{arom}), 7.51 – 7.42 (m, 2H, CH_{arom}), 7.45 – 7.38 (m, 2H, CH_{arom}), 7.40 – 7.22 (m, 13H, CH_{arom}), 7.25 – 7.16 (m, 1H, CH_{arom}), 7.16 – 7.10 (m, 2H, CH_{arom}), 4.97 – 4.83 (m, 4H, 2x C*H*H Bn, CH_2 Bn), 4.75 (d, *J* = 10.2 Hz, 1H, CH*H* Bn), 4.72 – 4.64 (m, 2H, H-1, H-6), 4.62 (d, *J* = 10.8 Hz, 1H, CH*H* Bn), 4.44 (dd, *J* = 11.9, 4.9 Hz, 1H, H-6), 3.77 (t, *J* = 8.6 Hz, 1H, H-3), 3.73 – 3.60 (m, 2H, H-4, H-5), 3.53 (dd, *J* = 9.8, 8.7 Hz, 1H, H-2); ^{13}C NMR (101 MHz, $CDCl_3$, HSQC): δ 166.2 (C=O Bz), 138.2, 138.0, 137.6, 133.3 ($C_{q\text{-}arom}$), 133.3, 132.4 (CH_{arom}), 130.0 ($C_{q\text{-}arom}$), 129.9, 129.0, 128.7, 128.6, 128.5, 128.3, 128.2, 128.2, 128.1, 128.1, 128.0, 127.8 (CH_{arom}), 87.4 (C-1), 86.9 (C-3), 80.8 (C-2), 77.7 (C-4), 77.2 (C-5), 76.1, 75.6, 75.3 (CH_2 Bn), 63.7 (C-6); HRMS: $[M+Na]^+$ calcd for $C_{40}H_{38}NaO_6S$ 669.22813, found 669.22788.

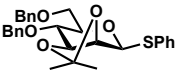
Preparation of donor 13



Scheme S1. Synthesis of donor **13**. *Reagents and conditions:* a) *i.* 2,2-dimethoxypropane, acetone, $Sc(OTf)_3$, *ii.* AcOH, MeOH, DCM, reflux, **S1**: 56%; b) BnBr, NaH, DMF, **S2**: 92%; c) *p*TsOH, MeOH, 50 °C, **S3**: 99%; d) *i.* di-*n*-butyltin(IV) oxide, toluene reflux, *ii.* NapBr, CsF, DMF, **S4**: 79%; e) BnBr, NaH, DMF, **S5**: 76%; f) DDQ, DCM, H_2O, **S6**: 62%; g) BzCl, pyridine, **13**: *quant.*

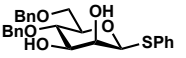


Phenyl 2,3-*O*-isopropylidene-1-thio-β-D-mannopyranoside (S1). According to a modified literature procedure.[57] Phenyl 1-thio-β-D-mannopyranoside[42] (4.6 g, 17.0 mmol) was suspended in 80 mL 2,2-dimethoxypropane and 25 mL acetone. 50 mg $Sc(OTf)_3$ was added, and the suspension was stirred until everything was dissolved. The solution was concentrated to 25% of the original volume, 50 mL acetone was added and the reaction was stirred for 1 h, before being quenched with 0.3 mL triethylamine and concentrated under reduced pressure. The residue was dissolved in DCM and washed with water. The organic phase was dried with $MgSO_4$ and concentrated to give the crude diisopropylidene as yellowish powder, which was used without further purification. The crude product was dissolved in 5:13:7 DCM/MeOH/AcOH and heated to a vigorous reflux until the title compound was the major product together with a few percent unreacted starting material. The reaction mixture was diluted with toluene, concentrated under reduced pressure and co-evaporated with toluene two more times. The residue was purified over silica (30% → 50% acetone in pentane) yielding the title compound (2.9 g, 9.5 mmol, 56%) as off-white powder. TLC: R_f 0.35 (pentane:acetone, 60:40, v:v); $[\alpha]_D^{25}$ –114.1° (*c* 0.27, $CHCl_3$); IR (thin film, cm^{-1}): 733, 1066, 1090, 1217, 1483, 3449; ^{1}H NMR (400 MHz, $CDCl_3$, HH-COSY, HSQC): δ 7.53 – 7.48 (m, 2H, CH_{arom}), 7.35 – 7.26 (m, 3H, CH_{arom}), 5.11 (d, *J* = 2.2 Hz, 1H, H-1), 4.45 (dd, *J* = 5.5, 2.2 Hz, 1H, H-2), 4.10 (dd, *J* = 7.2, 5.5 Hz, 1H, H-3), 3.96 – 3.89 (m, 1H, H-6), 3.86 – 3.78 (m, 2H, H-4, H-6), 3.32 (ddd, *J* = 9.7, 5.1, 3.6 Hz, 1H, H-5), 2.89 (d, *J* = 3.7 Hz, 1H, 4-OH), 2.31 (t, *J* = 6.6 Hz, 1H, 6-OH), 1.59 (s, 3H, CH_3 isoprop), 1.42 (s, 3H, CH_3 isopropylidene); ^{13}C NMR (101 MHz, $CDCl_3$, HSQC): δ 134.7 ($C_{q\text{-}arom}$), 130.9, 129.3, 127.7 (CH_{arom}), 111.0 (C_q isoprop), 84.2 (C-1), 80.3 (C-3), 78.5 (C-5), 76.1 (C-2), 70.1 (C-4), 62.8 (C-6), 28.2, 26.5 (CH_3 isoprop); HRMS: $[M+Na]^+$ calcd for $C_{15}H_{20}NaO_5S$ 335.09237, found 335.09217.

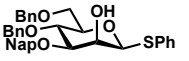


Phenyl 4,6-di-*O*-benzyl-2,3-*O*-isopropylidene-1-thio-β-D-mannopyranoside (S2). S1 (2.94 g, 9.41 mmol) was dissolved in DMF, and benzyl bromide (3.4 mL, 28.2 mmol, 3 eq.) and sodium hydride (60% dispersion in mineral oil, 1.1 g, 28.2 mmol, 3 eq) were added. When TLC shows full conversion, the reaction mixture was quenched with water and extracted twice with diethyl ether. Combined organic phases were dried with $MgSO_4$ and concentrated under reduced pressure. The residue was purified over silica (5% → 10% acetone in pentane) yielding the title compound (4.3 g, 8.6 mmol, 92%) as white powder. TLC: R_f 0.25 (pentane:acetone, 90:10, v:v); $[\alpha]_D^{25}$ –84.0° (*c* 0.43, $CHCl_3$); IR (thin film, cm^{-1}): 695, 736, 1059, 1216, 1380; ^{1}H NMR (400 MHz, $CDCl_3$, HH-COSY, HSQC): δ 7.58 – 7.53 (m, 2H, CH_{arom}), 7.35 – 7.18 (m, 13H, CH_{arom}), 5.07 (d, *J* = 2.1 Hz, 1H, H-1), 4.81 (d, *J* = 11.6 Hz, 1H, C*H*H Bn), 4.58 (d, *J* = 11.6 Hz, 1H, CH*H* Bn), 4.55

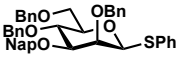
(s, 2H, CH_2 Bn), 4.46 (dd, *J* = 5.8, 2.1 Hz, 1H, H-2), 4.35 – 4.28 (m, 1H, H-3), 3.85 (dd, *J* = 10.2, 1.8 Hz, 1H, H-6), 3.70 – 3.63 (m, 1H, H-6), 3.63 – 3.56 (m, 2H, H-4, H-5), 1.57 (s, 3H, CH_3 isopropylidene), 1.42 (s, 3H, CH_3 isopropylidene); ^{13}C NMR (101 MHz, $CDCl_3$, HSQC): δ 138.5, 138.0, 135.5 ($C_{q\text{-}arom}$), 130.5, 129.1, 128.5, 128.4, 128.1, 127.9, 127.8, 127.6, 127.2 (CH_{arom}), 110.7 ($C_{q\text{-}arom}$ isopropylidene), 84.4 (C-1), 79.8 (C-3), 78.5 (C-4), 76.1 (C-2), 75.4 (C-5), 73.6, 72.7 (CH_2 Bn), 70.4 (C-6), 27.9, 26.4 (CH_3 isopropylidene); HRMS: $[M+NH_4]^+$ calcd for $C_{29}H_{36}NO_5S$ 515.23087, found 515.23058.



Phenyl 4,6-di-*O*-benzyl-1-thio-β-D-mannopyranoside (S3). S2 (4.2 g, 8.5 mmol) and *p*TsOH (162 mg, 0.853 mmol, 0.1 eq) were dissolved in 75 mL methanol and heated to 50 °C. When the reaction was complete, the title compound was precipitated from the solution. Triethylamine (0.24 mL, 1.71 mmol, 0.2 eq.) was added and the mixture was cooled to –30 °C. The product was collected by filtration and washed with a few mL of very cold methanol, yielding the title compound (2.7 g, 6.0 mmol, 71%) as fluffy white solid (mp: 146 °C). The concentrated mother liquor contained ca. 1.1 g (28%) of slightly impure product of sufficient quality to use in subsequent reactions. TLC: R_f 0.15 (pentane:EtOAc, 60:40, v:v); $[\alpha]_D^{25}$ –114.1° (*c* 0.27, $CHCl_3$); IR (thin film, cm^{-1}): 733, 1066, 1217, 3449 ; ^{1}H NMR (400 MHz, $CDCl_3$, HH-COSY, HSQC): δ 7.61 – 7.46 (m, 2H, CH_{arom}), 7.38 – 7.16 (m, 13H, CH_{arom}), 4.84 (d, *J* = 1.1 Hz, 1H, H-1), 4.78 (d, *J* = 11.3 Hz, 1H, C*H*H Bn), 4.66 – 4.60 (m, 2H, C*H*H Bn, CH*H* Bn), 4.56 (d, *J* = 11.9 Hz, 1H, CH*H* Bn), 4.17 – 4.10 (m, 1H, H-2), 3.82 (dd, *J* = 10.9, 2.0 Hz, 1H, H-6), 3.75 (dd, *J* = 10.9, 5.1 Hz, 1H, H-6), 3.72 – 3.65 (m, 2H, H-3, H-4), 3.47 (dq, *J* = 7.4, 3.1, 2.5 Hz, 1H, H-5), 2.72 (d, *J* = 5.8 Hz, 1H, 2-OH), 2.61 – 2.53 (m, 1H, 3-OH); ^{13}C NMR (101 MHz, $CDCl_3$, HSQC): δ 138.2, 138.2, 134.4 ($C_{q\text{-}arom}$), 131.3, 129.2, 128.7, 128.5, 128.2, 128.1, 128.0, 127.8, 127.6 (CH_{arom}), 87.1 (C-1), 79.6 (C-5), 75.8, 75.4 (C-3/C-4), 75.0, 73.7 (CH_2 Bn), 72.7 (C-2), 69.3 (C-5); HRMS: $[M+NH_4]^+$ calcd for $C_{26}H_{32}NO_5S$ 470.19957, found 470.19932.

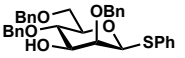


Phenyl 3-*O*-(2-naphthyl)methyl-4,6-di-*O*-benzyl-1-thio-β-D-mannopyranoside (S4). Diol **S3** (3.82 g, 8.44 mmol) and di-*n*-butyltin oxide (2.7 g, 11.0 mmol, 1.3 eq.) were refluxed in toluene for 2 h, while removing water using a Dean-Stark setup. The mixture was cooled to room temperature and concentrated under reduced pressure. The residue was dissolved in DMF, CsF (1.67 g, 11.0 mmol, 1.3 eq) and napthyl bromide (2.43 g, 11.0 mmol, 1.3 eq) were added. After overnight reaction, water and diethyl ether were added, causing the product to precipitate as white solid (3.36 g) Silica chromatography of the concentrated organic phase yielded an additional 590 mg product, bringing the total yield to 3.95 g (6.7 mmol, 79%). TLC: R_f 0.40 ($CHCl_3$:acetone, 90:10, v:v); $[\alpha]_D^{25}$ –32.2° (*c* 1.12, $CHCl_3$); IR (thin film, cm^{-1}):698, 738, 1027, 1074, 1089, 1120; ^{1}H NMR (400 MHz, $CDCl_3$, HH-COSY, HSQC): δ 7.85 – 7.72 (m, 4H, CH_{arom}), 7.55 – 7.43 (m, 5H, CH_{arom}), 7.35 – 7.18 (m, 13H, CH_{arom}), 4.93 – 4.87 (m, 2H, 2x C*H*H Bn/Nap), 4.82 (d, *J* = 11.8 Hz, 1H, CH*H* Bn/Nap), 4.79 – 4.78 (m, 1H, H-1), 4.62 – 4.57 (m, 2H, C*H*H Bn/Nap, CH*H* Bn/Nap), 4.54 (d, *J* = 11.9 Hz, 1H, CH*H* Bn/Nap), 4.30 (t, *J* = 2.9 Hz, 1H, H-2), 3.90 – 3.79 (m, 2H, H-4, H-6), 3.72 (dd, *J* = 10.9, 5.9 Hz, 1H, H-6), 3.66 (dd, *J* = 9.0, 3.3 Hz, 1H, H-3), 3.50 (ddd, *J* = 9.8, 5.9, 1.9 Hz, 1H, H-5), 2.72 (d, *J* = 3.0 Hz, 1H, OH); ^{13}C NMR (101 MHz, $CDCl_3$, HSQC): δ 138.4, 138.2, 135.0, 135.0, 133.3, 133.2 ($C_{q\text{-}arom}$), 131.0, 129.1, 128.6, 128.5, 128.4, 128.1, 128.1, 127.9, 127.9, 127.9, 127.7, 127.4, 127.0, 126.4, 126.3, 125.9 (CH_{arom}), 86.8 (C-1), 82.6 (C-3), 79.8 (C-5), 75.4 (CH_2 Bn/Nap), 74.4 (C-4), 73.6, 72.1 (CH_2 Bn/Nap), 70.2 (C-4), 69.5 (C-6); HRMS: $[M+NH_4]^+$ calcd for $C_{37}H_{40}NO_5S$ 610.26217, found 610.26172.

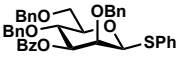


Phenyl 3-*O*-(2-naphthyl)methyl-2,4,6-tri-*O*-benzyl-1-thio-β-D-mannopyranoside (S5). S4 (3.30 g, 5.57 mmol) was dissolved in DMF at 0 °C. Benzyl bromide (0.99 mL, 8.35 mmol, 1.5 eq) and NaH (60% in mineral oil, 334 mg, 8.35 mmol, 1.5 eq) were added and the reaction mixture was allowed to warm to rt. When TLC showed full conversion, the reaction was quenched with water and extracted with diethyl ether. The organic phase was dried with $MgSO_4$ and concentrated under reduced pressure. The residue was purified over silica (15% diethyl ether in pentane) yielding the title compound (2.89 g, 4.2 mmol, 76%) as white solid. TLC: R_f 0.30 (pentane:Et_2O), 80:20, v:v); $[\alpha]_D^{25}$ –40.2° (*c* 0.59, $CHCl_3$); IR (thin film, cm^{-1}): 696, 738, 1026, 1072, 1122; ^{1}H NMR (400 MHz, $CDCl_3$, HH-COSY, HSQC): δ 7.85 – 7.76 (m, 3H, CH_{arom}), 7.73 – 7.67 (m, 1H, CH_{arom}), 7.54 – 7.41 (m, 8H, CH_{arom}), 7.38 – 7.15 (m, 17H, CH_{arom}), 5.09 (d, *J* = 11.5 Hz, 1H,

C*H*H Bn/Nap), 4.96 – 4.89 (m, 2H, C*H*H Bn/Nap, CH*H* Bn/Nap), 4.87 (d, *J* = 12.0 Hz, 1H, C*H*H Bn/Nap), 4.82 (d, *J* = 12.0 Hz, 1H, CH*H* Bn/Nap), 4.77 (d, *J* = 1.1 Hz, 1H, H-1), 4.64 – 4.58 (m, 2H, C*H*H Bn/Nap, CH*H* Bn/Nap), 4.55 (d, *J* = 11.7 Hz, 1H, CH*H* Bn/Nap), 4.17 (dd, *J* = 3.0, 1.1 Hz, 1H, H-2), 3.98 (t, *J* = 9.6 Hz, 1H, H-4), 3.86 (dd, *J* = 11.0, 1.9 Hz, 1H, H-6), 3.76 (dd, *J* = 10.9, 6.5 Hz, 1H, H-6), 3.68 (dd, *J* = 9.4, 2.9 Hz, 1H, H-3), 3.54 (ddd, *J* = 9.8, 6.5, 1.9 Hz, 1H, H-5); ^{13}C NMR (101 MHz, $CDCl_3$, HSQC): δ 138.6, 138.4, 138.3, 135.8, 135.6, 133.3, 133.1 ($C_{q\text{-arom}}$), 130.6, 129.0, 128.5, 128.4, 128.4, 128.3, 128.1, 128.0, 127.9, 127.8, 127.7, 127.5, 127.1, 126.5, 126.3, 126.1, 125.7 (CH_{arom}), 87.7 (C-1), 84.3 (C-3), 80.2 (C-5), 77.7 (C-2), 75.3, 75.2 (CH_2 Bn/Nap), 75.1 (C-4), 73.6, 72.7 (CH_2 Bn/Nap), 69.9 (C-6); HRMS: $[M+NH_4]^+$ calcd for $C_{44}H_{46}NO_5S$ 700.30967, found 700.30861.

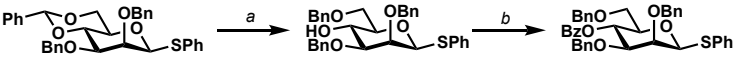


Phenyl 2,4,6-tri-*O*-benzyl-1-thio-β-D-mannopyranoside (S6). S5 (2.86 g, 4.19 mmol) was dissolved in 25mL 9:1 DCM/H_2O. DDQ (1.90 g, 8.38 mmol, 2 eq.) was added and the reaction was stirred at room temperature until TLC showed full conversion. The mixture was diluted with DCM and washed twice with sat. aq. $NaHCO_3$. The organic phase was dried with $MgSO_4$ and concentrated under reduced pressure. The residue was purified over silica (15% acetone in pentane), yielding the title compound (1.40 g, 2.58 mmol, 62%) as white solid. TLC: R_f 0.32 (pentane:acetone, 80:20, v:v); $[\alpha]_D^{25}$ –95.6° (*c* 0.95, $CHCl_3$); IR (thin film, cm^{-1}): 695, 732, 1027, 1062, 1073, 1089, 1452; ^{1}H NMR (400 MHz, $CDCl_3$, HH-COSY, HSQC): δ 7.57 – 7.51 (m, 2H, CH_{arom}), 7.48 – 7.44 (m, 2H, CH_{arom}), 7.41 – 7.20 (m, 16H, CH_{arom}), 5.03 (d, *J* = 11.5 Hz, 1H, C*H*H Bn), 4.82 (d, *J* = 1.1 Hz, 1H, H-1), 4.80 – 4.74 (m, 2H, C*H*H Bn, CH*H* Bn), 4.63 (d, *J* = 11.7 Hz, 1H, C*H*H Bn), 4.60 – 4.53 (m, 2H, 2x CH*H* Bn), 4.05 (dd, *J* = 3.5, 1.1 Hz, 1H, H-2), 3.86 (dd, *J* = 10.9, 2.0 Hz, 1H, H-6), 3.76 (dd, *J* = 11.0, 6.3 Hz, 1H, H-6), 3.73 – 3.69 (m, 1H, H-3), 3.65 (t, *J* = 9.3 Hz, 1H, H-4), 3.49 (ddd, *J* = 9.4, 6.1, 2.0 Hz, 1H, H-5), 2.18 (d, *J* = 7.8 Hz, 1H, OH); ^{13}C NMR (101 MHz, $CDCl_3$, HSQC): δ 138.5, 138.2, 138.1, 135.4 ($C_{q\text{-arom}}$), 130.7, 129.1, 128.7, 128.6, 128.4, 128.4, 128.2, 128.2, 128.0, 128.0, 127.6, 127.3 (CH_{arom}), 87.8 (C-1), 80.7 (C-2), 79.8 (C-5), 76.5 (C-4), 76.3 (CH_2 Bn), 75.8 (C-3), 74.9, 73.6 (CH_2 Bn), 69.8 (C-6); HRMS: $[M+NH_4]^+$ calcd for $C_{33}H_{38}NO_5S$ 560.24652, found 560.24624.



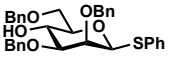
Phenyl 3-*O*-benzoyl-2,4,6-tri-*O*-benzyl-1-thio-β-D-mannopyranoside (13). S6 (1.4 g, 2.5 mmol) and benzoyl chloride (0.44 mL, 3.75 mmol, 1.5 eq) were dissolved in 5 mL pyridine. When TLC shows full conversion, the reaction mixture was diluted with ethyl acetate and washed twice with 1 M aq. HCl and once with sat. aq. $NaHCO_3$. The organic phase was dried with $MgSO_4$ and concentrated under reduced pressure. The residue was purified over silica (5% → 10% acetone in pentane), yielding the title compound in *quantitative* yield as colorless oil. TLC: R_f 0.28 (pentane:acetone, 90:10, v:v); $[\alpha]_D^{25}$ –74.7° (*c* 1.33, $CHCl_3$); IR (thin film, cm^{-1}): 695, 713, 733, 1025, 1062, 1089, 1266, 1452, 17165, 1718; ^{1}H NMR (400 MHz, $CDCl_3$, HH-COSY, HSQC): δ 8.03 – 7.97 (m, 2H, CH_{arom}), 7.61 – 7.52 (m, 3H, CH_{arom}), 7.46 – 7.41 (m, 2H, CH_{arom}), 7.35 (ddt, *J* = 8.0, 4.2, 2.3 Hz, 4H, CH_{arom}), 7.33 – 7.28 (m, 3H, CH_{arom}), 7.27 – 7.20 (m, 7H, CH_{arom}), 7.16 (dd, *J* = 5.0, 1.9 Hz, 3H, CH_{arom}), 7.10 – 7.05 (m, 2H, CH_{arom}), 5.26 (dd, *J* = 9.9, 3.2 Hz, 1H, H-3), 4.96 (d, *J* = 1.1 Hz, 1H, H-1), 4.82 (d, *J* = 11.4 Hz, 1H, C*H*H Bn), 4.74 (d, *J* = 11.4 Hz, 1H, CH*H* Bn), 4.71 – 4.64 (m, 2H, 2x C*H*H Bn), 4.60 – 4.54 (m, 2H, 2x CH*H* Bn), 4.37 (dd, *J* = 3.3, 1.1 Hz, 1H, H-2), 4.19 (t, *J* = 9.8 Hz, 1H, H-4), 3.89 – 3.78 (m, 2H, 2x H-6), 3.64 (ddd, *J* = 9.7, 5.4, 2.2 Hz, 1H, H-5); ^{13}C NMR (101 MHz, $CDCl_3$, HSQC): δ 165.9 (C=O Bz), 138.5, 137.8, 137.7, 135.2 ($C_{q\text{-arom}}$), 133.5, 131.2, 129.9 (CH_{arom}), 129.6 ($C_{q\text{-arom}}$), 129.1, 128.7, 128.4, 128.4, 128.3, 128.2, 128.1, 128.0, 127.9, 127.8, 127.6, 127.4 (CH_{arom}), 87.8 (C-1), 80.1 (C-5), 78.6 (C-2), 77.9 (C-3), 75.9, 75.2, 73.7 (CH_2 Bn), 73.4 (C-4), 69.6 (C-6); HRMS: $[M+NH_4]^+$ calcd for $C_{40}H_{42}NO_6S$ 664.27274, found 669.27257.

Preparation of donor 14

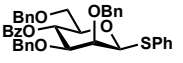


S7 **14**

Scheme S2. Synthesis of donor **14**. *Reagents and conditions:* a) TES-H, TFA, DCM, 0 °C, **S7**: 71%; b) BzCl, pyridine, **14**: 97%.

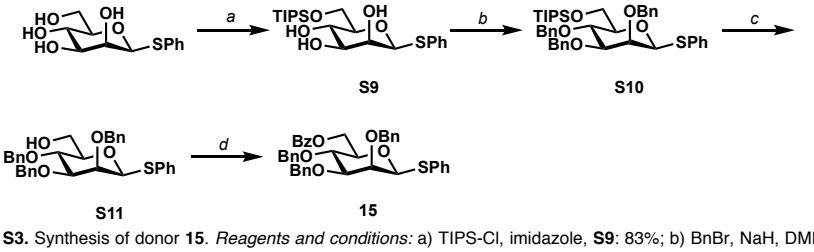


Phenyl 2,3,6-tri-*O*-benzyl-1-thio-β-D-mannopyranoside (S7). Phenyl 2,3-di-O-benzyl-4,6-O-benzylidene-1-thio-β-D-mannopyranoside[42] (2.00 g, 3.70 mmol) was dissolved in dichloromethane and cooled to 0 °C, after which TES-H (5.9 mL, 37.0 mmol, 10 eq) and TFA (2.8 mL, 37.0 mmol, 10 eq) were added. When TLC shows full conversion, the reaction is quenched with sat. aq. $NaHCO_3$ and diluted with DCM. Phases were separated and the aquatic phase was extracted with DCM. Combined organic phases were dried with $MgSO_4$ and concentrated under reduced pressure. The residue was purified over silica (15% acetone in pentane), yielding the title compound (1.42 g, 2.62 mmol, 71%) as waxy white solid. TLC: R_f 0.20 (pentane:EtOAc, 85:15, v:v); $[\alpha]_D^{25}$ –71.6° (*c* 0.83, $CHCl_3$); IR (thin film, cm^{-1}): 695, 732, 1026, 1064, 1128; ^1H NMR (400 MHz, $CDCl_3$, HH-COSY, HSQC): δ 7.53 – 7.44 (m, 4H, CH_{arom}), 7.38 – 7.25 (m, 13H, CH_{arom}), 7.25 – 7.18 (m, 3H, CH_{arom}), 4.98 (d, *J* = 11.4 Hz, 1H, C*H*H Bn), 4.86 (d, *J* = 11.4 Hz, 1H, CH*H* Bn), 4.80 (d, *J* = 1.1 Hz, 1H, H-1), 4.73 (d, *J* = 11.8 Hz, 1H, C*H*H Bn), 4.59 (d, *J* = 11.8 Hz, 1H, CH*H* Bn), 4.57 (s, 2H, CH_2 Bn), 4.15 (dd, *J* = 3.0, 1.1 Hz, 1H, H-2), 4.06 (td, *J* = 9.5, 1.9 Hz, 1H, H-4), 3.90 (dd, *J* = 10.4, 4.1 Hz, 1H, H-6), 3.80 (dd, *J* = 10.4, 6.4 Hz, 1H, H-6), 3.51 (ddd, *J* = 9.4, 6.3, 4.0 Hz, 1H, H-5), 3.44 (dd, *J* = 9.4, 3.0 Hz, 1H, H-3), 2.71 (d, *J* = 2.0 Hz, 1H, 4-OH); ^{13}C NMR (101 MHz, $CDCl_3$, HSQC): δ 138.2, 137.9, 135.6 ($C_{q\text{-}arom}$), 130.8, 129.0, 128.7, 128.5, 128.5, 128.3, 128.1, 127.9, 127.9, 127.8, 127.7, 127.3 (CH_{arom}), 87.9 (C-1), 83.6 (C-3), 79.2 (C-5), 76.8 (C-2), 75.2, 73.8, 72.4 (CH_2 Bn), 71.2 (C-6), 68.7 (C-4); HRMS: $[M+NH_4]^+$ calcd for $C_{33}H_{38}NO_5S$ 560.24652, found 560.24596

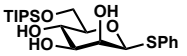


Phenyl 4-*O*-benzoyl-2,3,6-tri-*O*-benzyl-1-thio-β-D-mannopyranoside (14). S7 (1.40 g, 2.58 mmol) was dissolved in 5 mL pyridine with benzoyl chloride (0.45 mL, 3.87 mmol, 1.5 eq.) When TLC shows full conversion, the reaction mixture was diluted with ethyl acetate and washed with 1 M aq. HCl and sat. aq. $NaHCO_3$. The organic phase was dried and concentrated. The residue was purified over silica (10 → 15% EA in pentane) yielding the title compound (1.62 g, 2.51 mmol, 97%) as white amorphous solid. TLC: R_f 0.22 (pentane:EtOAc, 85:15, v:v); $[\alpha]_D^{25}$ –69.1° (*c* 1.01, $CHCl_3$); IR (thin film, cm^{-1}): 695, 711, 1027, 1068, 1109, 1266, 1452, 1724; ^1H NMR (400 MHz, $CDCl_3$, HH-COSY, HSQC): δ 8.00 – 7.91 (m, 2H, CH_{arom}), 7.61 – 7.47 (m, 6H, CH_{arom}), 7.43 (t, *J* = 7.8 Hz, 2H, CH_{arom}), 7.38 – 7.33 (m, 2H, CH_{arom}), 7.32 – 7.28 (m, 1H, CH_{arom}), 7.23 – 7.12 (m, 13H, CH_{arom}), 5.66 (t, *J* = 9.6 Hz, 1H, H-4), 5.08 (d, *J* = 11.5 Hz, 1H, C*H*H Bn), 4.87 (d, *J* = 11.6 Hz, 1H, CH*H* Bn), 4.84 (d, *J* = 1.1 Hz, 1H, H-1), 4.63 (d, *J* = 12.2 Hz, 1H, C*H*H Bn), 4.52 – 4.48 (m, 2H, C*H*H Bn, CH*H* Bn), 4.43 (d, *J* = 11.4 Hz, 1H, CH*H* Bn), 4.22 (dd, *J* = 3.0, 1.1 Hz, 1H, H-2), 3.83 – 3.75 (m, 2H, H-5, H-6), 3.74 – 3.66 (m, 2H, H-3, H-6); ^{13}C NMR (101 MHz, $CDCl_3$, HSQC): δ 165.7 (C=O Bz), 138.3, 138.0, 137.5, 135.5 ($C_{q\text{-}arom}$), 133.3 , 130.8, 129.9 (CH_{arom}), 129.8 ($C_{q\text{-}arom}$), 129.0, 128.7, 128.5, 128.5, 128.4, 128.3, 128.0, 127.9, 127.9, 127.7, 127.5, 127.3 (CH_{arom}), 87.9 (C-1), 80.9 (C-3), 78.9 (C-5), 76.5 (C-2), 75.1, 73.7, 72.2 (CH_2 Bn), 70.6 (C-6), 69.5 (C-4); HRMS: $[M+NH_4]^+$ calcd for $C_{40}H_{42}NO_6S$ 664.27274, found 669.27235.

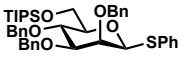
Preparation of donor 15



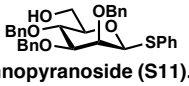
Scheme S3. Synthesis of donor **15**. *Reagents and conditions:* a) TIPS-Cl, imidazole, **S9**: 83%; b) BnBr, NaH, DMF, **S10**: 81%; c) TFA, THF, water, **S11**: 93%; d) BzCl, pyridine, **15**: 78%.



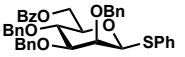
Phenyl 6-*O*-triisopropylsilyl-1-thio-β-D-mannopyranoside (S9). Phenyl 1-thio-β-D-mannopyranoside[42] (5.45 g, 20 mmol) was dissolved in DMF after which imidazole (3.4 g, 50 mmol, 2.5 eq) and triisopropylsilyl chloride (5.4 mL, 25 mmol, 1.25 eq) were added. After reacting overnight, excess reagent was destroyed by the addition of 7.5 mL methanol. After stirring for an additional 30 min, the reaction mixture was concentrated under reduced pressure, dissolved in diethyl ether and washed with water. The organic phase was dried with $MgSO_4$ and concentrated, the residue was purified over silica (20% acetone in pentane) yielding the title compound (6.3 g, 14.7 mmol, 73%) as colorless oil. TLC: R_f 0.40 (pentane:acetone, 60:40, v:v); $[\alpha]_D^{25}$ –83.6° (*c* 0.73, $CHCl_3$); IR (thin film, cm^{-1}): 688, 734, 882, 946, 1264, 2865; ^1H NMR (400 MHz, $CDCl_3$, HH-COSY, HSQC): δ 7.55 – 7.40 (m, 2H, CH_{arom}), 7.30 – 7.22 (m, 3H, CH_{arom}), 4.87 (d, *J* = 1.1 Hz, 1H, H-1), 4.21 (t, *J* = 4.3 Hz, 1H, H-2), 4.07 – 3.98 (m, 2H, 2x H-6), 3.96 (d, *J* = 2.0 Hz, 1H, 3-OH), 3.91 – 3.81 (m, 2H, H-4, 4-OH), 3.65 (ddd, *J* = 9.1, 5.5, 3.3 Hz, 1H, H-3), 3.45 – 3.35 (m, 2H, H-5, 2-OH), 1.15 – 1.02 (m, 21H, 3x CH TIPS, 6x CH_3 TIPS); ^{13}C NMR (101 MHz, $CDCl_3$, HSQC): δ 134.8 ($C_{q\text{-}arom}$), 131.0, 129.1, 127.4 (CH_{arom}), 87.3 (C-1), 78.7 (C-5), 75.1 (C-3), 72.2 (C-2), 70.8 (C-4), 65.5 (C-6), 18.0 (CH_3 TIPS), 11.8 (CH TIPS); HRMS: $[M+Na]^+$ calcd for $C_{21}H_{36}NaO_5SSi$ 451.19449, found 451.19430.



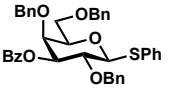
Phenyl 6-*O*-triisopropylsilyl-2,3,4-tri-*O*-benzyl-1-thio-β-D-mannopyranoside (S10). S9 (4.07 g, 9.50 mmol) was dissolved in DMF and cooled to 0 °C, after which benzyl bromide (4.2 mL, 35.6 mmol, 3.75 eq) and NaH (60% dispersion in mineral oil, 1.43 g, 35.6 mmol, 3.75 eq) were added after which the reaction mixture was slowly allowed to warm to RT. When TLC showed full conversion, the reaction was quenched with water. The aqueous phase was extracted twice with diethyl ether, combined organic phases were dried with sodium sulfate and concentrated under reduced pressure. The residue was purified over silica (10% diethyl ether in pentane) to yield the title compound (5.40 g, 7.7 mmol, 81%) as waxy white solid. TLC: R_f 0.40 (pentane:Et_2O, 85:15, v:v); $[\alpha]_D^{25}$ –30.8° (*c* 0.59, $CHCl_3$); IR (thin film, cm^{-1}): 695, 732, 1062, 1088, 1134, 1453; ^1H NMR (400 MHz, $CDCl_3$, HH-COSY, HSQC): δ 7.54 – 7.46 (m, 4H, CH_{arom}), 7.38 – 7.24 (m, 13H, CH_{arom}), 7.24 – 7.16 (m, 3H, CH_{arom}), 5.05 (d, *J* = 11.4 Hz, 1H, C*H*H Bn), 4.90 (d, *J* = 11.0 Hz, 1H, C*H*H Bn), 4.84 (d, *J* = 11.4 Hz, 1H, CH*H* Bn), 4.78 – 4.72 (m, 2H, H-1, C*H*H Bn), 4.69 (d, *J* = 11.8 Hz, 1H, CH*H* Bn), 4.65 (d, *J* = 11.0 Hz, 1H, CH*H* Bn), 4.13 (dd, *J* = 3.0, 1.1 Hz, 1H, H-2), 3.99 (dd, *J* = 10.9, 1.8 Hz, 1H, H-6), 3.92 (t, *J* = 8.2 Hz, 1H, H-4), 3.88 (dd, *J* = 9.6, 4.9 Hz, 1H, H-6), 3.63 (dd, *J* = 9.5, 3.0 Hz, 1H, H-3), 3.38 (ddd, *J* = 9.7, 6.2, 1.8 Hz, 1H, H-5), 1.44 – 0.80 (m, 21H, 6x CH_3 TIPS, 3x CH TIPS); ^{13}C NMR (101 MHz, $CDCl_3$, HSQC): δ 138.6, 138.4, 138.3, 136.5 ($C_{q\text{-}arom}$), 130.4, 128.9, 128.6, 128.5, 128.5, 128.3, 128.2, 128.1, 127.9, 127.9, 127.7, 127.6, 126.9 (CH_{arom}), 87.9 (C-1), 84.4 (C-3), 81.8 (C-5), 78.0 (C-2), 75.4, 75.1 (CH_2 Bn), 74.9 (C-4), 72.7 (CH_2 Bn), 63.4 (C-6), 18.2, 18.1 (CH_3 TIPS), 12.1 (CH TIPS); HRMS: $[M+NH_4]^+$ calcd for $C_{42}H_{58}NO_5SSi$ 716.37995, found 716.37934.



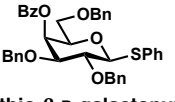
Phenyl 2,3,4-tri-*O*-benzyl-1-thio-β-D-mannopyranoside (S11). S10 (5.24 g, 7.50 mmol) was dissolved in 30 mL THF, to which 10 mL and 10 mL TFA were added. The reaction mixture was stirred at room temperature until TLC showed full conversion. The solution was diluted with water, neutralized with 20 g K_2CO_3, partially concentrated to remove organic solvents and extracted twice with ethyl acetate. Combined organic phases were dried and concentrated under reduced pressure. The residue was purified over silica (15% acetone in pentane), yielding the title compound (3.77 g, 7.0 mmol, 93%) as colorless oil. TLC: R_f 0.35 (pentane:acetone, 80:20, v:v); $[\alpha]_D^{25}$ –19.7° (*c* 0.67, $CHCl_3$); IR (thin film, cm^{-1}): 695, 732, 1026, 1072, 1452; ^1H NMR (400 MHz, $CDCl_3$, HH-COSY, HSQC): δ 7.50 – 7.23 (m, 20H, CH_{arom}), 5.05 (d, *J* = 11.3 Hz, 1H, C*H*H Bn), 4.91 (d, *J* = 10.9 Hz, 1H, C*H*H Bn), 4.83 (d, *J* = 11.3 Hz, 1H, CH*H* Bn), 4.80 (d, *J* = 1.1 Hz, 1H, H-1), 4.78 – 4.68 (m, 2H, CH_2 Bn), 4.66 (d, *J* = 10.9 Hz, 1H, CH*H* Bn), 4.14 (dd, *J* = 2.9, 1.2 Hz, 1H, H-2), 3.99 (t, *J* = 9.5 Hz, 1H, H-4), 3.87 (ddd, *J* = 12.0, 6.9, 2.9 Hz, 1H, H-6), 3.74 (ddd, *J* = 12.1, 7.0, 5.7 Hz, 1H, H-6), 3.65 (dd, *J* = 9.5, 2.9 Hz, 1H, H-3), 3.37 (ddd, *J* = 9.6, 5.7, 2.9 Hz, 1H, H-5), 2.22 (t, *J* = 6.9 Hz, 1H, OH); ^{13}C NMR (101 MHz, $CDCl_3$, HSQC): δ 138.2, 138.1, 138.1, 135.2 ($C_{q\text{-}arom}$), 130.6, 129.1, 128.6, 128.5, 128.4, 128.3, 128.3, 128.0, 127.9, 127.8, 127.7, 127.4 (CH_{arom}), 87.8 (C-1), 84.2 (C-3), 80.1 (C-5), 77.7 (C-2), 75.4, 75.4 (CH_2 Bn), 74.8 (C-4), 72.7 (CH_2 Bn), 62.6 (C-6); HRMS: $[M+Na]^+$ calcd for $C_{33}H_{34}NaO_5S$ 565.20192, found 565.20152.



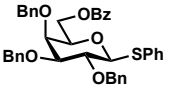
Phenyl 6-benzoyl-2,3,4-tri-O-benzyl-1-thio-β-D-mannopyranoside (15). S11 (2.98 g, 5.50 mmol) was dissolved in 10 mL pyridine, to which benzoyl chloride (0.96 mL, 8.25 mmol, 1.5 eq) was added. When TLC showed full conversion of the starting material, the reaction mixture was diluted with ethyl acetate and washed twice with 1 M aq. HCl and with sat. aq. $NaHCO_3$. The organic phase was dried and concentrated under reduced pressure. The residue was purified by recrystallization from ethyl acetate/pentane, obtaining the title compound (2.79 g, 4.3 mmol, 78%) as fluffy white solid (melting point: 137 ºC); TLC: R_f 0.20, (pentane:EtOAc, 90:10, v:v); $[\alpha]_D^{25}$ –44.1° (*c* 0.85, $CHCl_3$); IR (thin film, cm^{-1}): 697, 713, 1027, 1070, 1090, 1120, 1274, 1720; ^{1}H NMR (400 MHz, $CDCl_3$, HH-COSY, HSQC): δ 8.05 – 8.00 (m, 2H, CH_{arom}), 7.59 – 7.53 (m, 1H, CH_{arom}), 7.52 – 7.47 (m, 4H, CH_{arom}), 7.42 – 7.26 (m, 14H, CH_{arom}), 7.21 – 7.08 (m, 3H, CH_{arom}), 5.07 (d, *J* = 11.4 Hz, 1H, C*H*H Bn), 4.95 (d, *J* = 10.9 Hz, 1H, C*H*H Bn), 4.87 (d, *J* = 11.3 Hz, 1H, CH*H* Bn), 4.79 (d, *J* = 1.1 Hz, 1H, H-1), 4.77 (d, *J* = 12.0 Hz, 1H, C*H*H Bn), 4.75 – 4.69 (m, 2H, H-6, CH*H* Bn), 4.66 (d, *J* = 10.9 Hz, 1H, CH*H* Bn), 4.39 (dd, *J* = 11.7, 7.5 Hz, 1H, H-6), 4.19 (dd, *J* = 2.9, 1.1 Hz, 1H, H-2), 4.00 (t, *J* = 9.5 Hz, 1H, H-4), 3.74 – 3.67 (m, 2H, H-3, H-5); ^{13}C NMR (101 MHz, $CDCl_3$, HSQC): δ 166.4 (C=O Bz), 138.3, 137.9, 137.9, 135.6 ($C_{q\text{-}arom}$), 133.1, 130.8 CH_{arom}), 130.2 ($C_{q\text{-}arom}$), 129.9, 128.9, 128.7, 128.6, 128.4, 128.4, 128.3, 128.1, 128.0, 127.8, 127.8, 127.2 (CH_{arom}), 87.8 (C-1), 84.3 (C-3), 77.9 (C-5), 77.6 (C-2), 75.5, 75.3 (CH_2 Bn), 74.8 (C-4), 72.7 (CH_2 Bn), 64.5 (C-6); HRMS: $[M+Na]^+$ calcd for $C_{40}H_{38}NaO_6S$ 669.22813, found 669.22749.



Phenyl 3-*O*-benzoyl-2,4,6-tri-*O*-benzyl-1-thio-β-D-galactopyranoside (16). Compound was prepared according to literature procedure.[15] ^{1}H NMR (400 MHz, $CDCl_3$, HH-COSY, HSQC): δ 7.99 – 7.92 (m, 2H, CH_{arom}), 7.62 – 7.57 (m, 2H, CH_{arom}), 7.57 – 7.53 (m, 1H, CH_{arom}), 7.43 – 7.38 (m, 2H, CH_{arom}), 7.34 – 7.19 (m, 13H, CH_{arom}), 7.16 – 7.13 (m, 5H, CH_{arom}), 5.28 (dd, *J* = 9.6, 3.0 Hz, 1H, H-3), 4.80 (d, *J* = 10.6 Hz, 1H, C*H*H Bn), 4.77 (d, *J* = 9.6 Hz, 1H, H-1), 4.67 (d, *J* = 11.5 Hz, 1H, C*H*H Bn), 4.59 (d, *J* = 10.5 Hz, 1H, CH*H* Bn), 4.54 – 4.46 (m, 2H, C*H*H Bn, CH*H* Bn), 4.43 (d, *J* = 11.7 Hz, 1H, CH*H* Bn), 4.16 (dd, *J* = 3.1, 1.0 Hz, 1H, H-4), 4.11 (t, *J* = 9.7 Hz, 1H, H-2), 3.84 (ddd, *J* = 7.0, 5.7, 1.0 Hz, 1H, H-5), 3.72 – 3.63 (m, 2H, 2x H-6); ^{13}C NMR (101 MHz, $CDCl_3$): δ 165.8 (C=O Bz), 138.2, 137.9, 137.8, 134.0 ($C_{q\text{-}arom}$), 133.4, 131.6, 129.9 (CH_{arom}), 129.7 ($C_{q\text{-}arom}$), 129.0, 128.6, 128.5, 128.3, 128.3, 128.3, 127.9, 127.9, 127.8, 127.7, 127.3 (CH_{arom}), 87.8 (C-1), 77.6 (C-3), 77.1 (C-5), 75.5 (C-2), 75.5 (CH_2 Bn), 75.0 (CH_2 Bn), 74.7 (C-4), 73.6 (CH_2 Bn), 68.4 (C-6); HRMS: $[M+NH_4]^+$ calcd for $C_{40}H_{42}NO_6S$ 664.27274, found 664.27236.

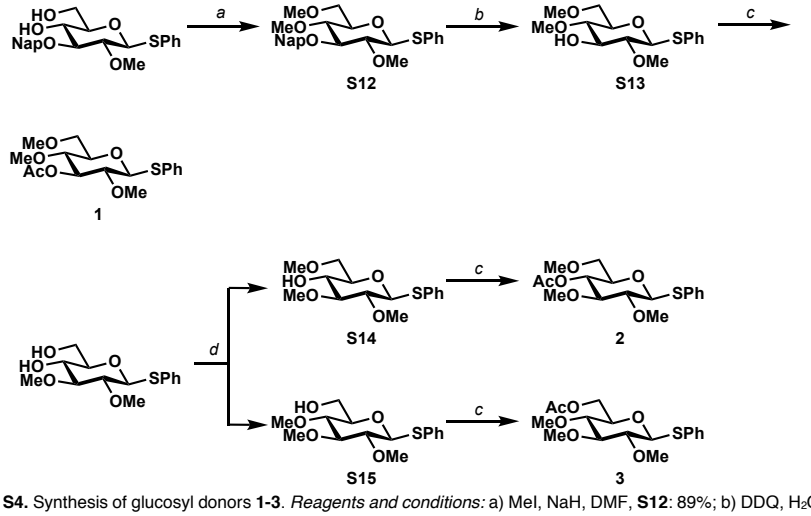


Phenyl 4-*O*-benzoyl-2,3,6-tri-*O*-benzyl-1-thio-β-D-galactopyranoside (17). The title compound was prepared according to literature procedure.[15] ^{1}H NMR (400 MHz, $CDCl_3$, HH-COSY, HSQC): δ 8.02 – 7.96 (m, 2H, CH_{arom}), 7.66 – 7.63 (m, 2H, CH_{arom}), 7.62 – 7.56 (m, 1H, CH_{arom}), 7.49 – 7.42 (m, 2H, CH_{arom}), 7.41 – 7.25 (m, 15H, CH_{arom}), 7.23 – 7.20 (m, 4H, CH_{arom}), 5.89 (dd, *J* = 3.1, 1.0 Hz, 1H, H-4), 4.85 (d, *J* = 11.1 Hz, 1H, C*H*H Bn), 4.73 (s, 2H, CH_2 Bn), 4.70 (d, *J* = 9.4 Hz, 1H, H-1), 4.55 – 4.49 (m, 2H, C*H*H Bn, CH*H* Bn), 4.44 (d, *J* = 11.7 Hz, 1H, CH*H* Bn), 3.89 (td, *J* = 6.4, 5.9, 1.0 Hz, 1H, H-5), 3.76 (dd, *J* = 9.1, 3.1 Hz, 1H, H-3), 3.72 – 3.66 (m, 2H, H-2, H-6), 3.58 (dd, *J* = 9.6, 6.8 Hz, 1H, H-6); ^{13}C NMR (101 MHz, $CDCl_3$, HSQC): δ 165.8 (C=O Bz), 138.4, 137.7 ($C_{q\text{-}arom}$), 133.3, 133.0 (CH_{arom}), 130.1 ($C_{q\text{-}arom}$), 129.9, 129.0, 128.5, 128.5, 128.5, 128.4, 128.3, 128.0, 127.9, 127.9, 127.8 (CH_{arom}), 87.3 (C-1), 81.6 (C-3), 76.6 (C-2), 76.4 (C-5), 75.8, 73.8, 71.9 (CH_2 Bn), 68.5 (C-6), 67.4 (C-4); HRMS: $[M+NH_4]^+$ calcd for $C_{40}H_{42}NO_6S$ 664.27274, found 664.27250.

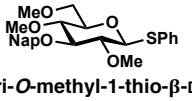


Phenyl 6-*O*-benzoyl-2,3,4-tri-*O*-benzyl-1-thio-β-D-galactopyranoside (18). Phenyl 2,3,4-tri-*O*-benzyl-1-thio-β-D-galactopyranoside[58] (1.45 g, 2.67 mmol) was dissolved in 10 mL pyridine after which benzoyl chloride (0.47 mL, 4.01 mmol, 1.5 eq) was added. When TLC shows full conversion, the reaction mixture was diluted with ethyl acetate and washed with 1M aq. HCl and sat. aq. $NaHCO_3$. The organic phase was dried and concentrated. The residue was purified over silica (10% ethyl acetate in pentane) yielding the title compound (1.28 g, 2.0 mmol, 74%) as white amorphous solid. TLC: R_f 0.30, (pentane:EtOAc, 90:10, v:v); $[\alpha]_D^{25}$ -18.1° (*c* 0.42, $CHCl_3$); IR (thin film, cm^{-1}): 698, 713, 736, 1026, 1070, 1271, 1452, 1718 ; ^{1}H NMR (400 MHz, $CDCl_3$, HH-COSY, HSQC) δ 8.00 – 7.92 (m, 2H, CH_{arom}), 7.56 (ddt, *J* = 6.7, 3.7, 1.7 Hz, 3H, CH_{arom}), 7.47 – 7.22 (m, 17H, CH_{arom}), 7.19 – 7.05 (m, 3H, CH_{arom}), 5.02 (d, *J* = 11.6 Hz, 1H, C*H*H Bn), 4.86 (d, *J* = 10.2 Hz, 1H, C*H*H Bn), 4.82 – 4.72 (m, 3H, C*H*H Bn, 2x CH*H* Bn), 4.71 – 4.63 (m, 2H, H-1, CH*H* Bn) 4.51 (dd, *J* = 11.3, 7.3 Hz, 1H, H-6), 4.37 (dd, *J* = 11.3, 5.2 Hz, 1H, H-6), 3.98 (t, *J* = 9.5 Hz, 1H, H-2), 3.90 (d, *J* = 2.8 Hz, 1H, H-4), 3.74 (dd, *J* = 7.2, 5.4 Hz, 1H, H-5), 3.63 (dd, *J* = 9.2, 2.8 Hz, 1H, H-3); ^{13}C NMR (101 MHz, $CDCl_3$, HSQC) δ 166.2 (C=O), 138.3, 138.2, 134.4 ($C_{q\text{-}arom}$), 133.2, 131.5 (CH_{arom}), 129.8 ($C_{q\text{-}arom}$), 128.8, 128.6, 128.5, 128.4, 128.4, 128.2, 127.9, 127.8, 127.7, 127.2 (CH_{arom}), 88.1 (C-1), 84.2 (C-3), 77.6 (C-2), 76.2 (C-5), 75.8, 74.5 (CH_2 Bn), 73.6 (C-4), 73.3 (CH_2 Bn), 64.0 (C-6); HRMS: $[M+NH_4]^+$ calcd for $C_{40}H_{42}NO_6S$ 664.27274, found 664.27231.

Preparation of donors 1-3

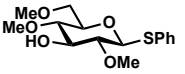


Scheme S4. Synthesis of glucosyl donors **1-3**. *Reagents and conditions:* a) MeI, NaH, DMF, **S12**: 89%; b) DDQ, H_2O/DCM, **S13**: 81%; c) Ac_2O, pyridine, **1**: 97%, **2**: 57%. **3**: 97%; d) MeI, NaH, DMF, **S14**: 21%, **S15**: 32%.

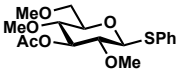


Phenyl 3-*O*-(2-methylnaphthyl)-2,4,6-tri-*O*-methyl-1-thio-β-D-glucopyranose (S12). *Via* general methylation protocol starting with phenyl 3-*O*-(2-methylnaphthyl)-2-*O*-methyl-1-thio-β-D-glucopyranose[33] (85 mg, 0.21 mmol). The residue was purified by crystallization in MeOH to afford the product **S12** (83 mg, 89%) as white solid; TLC: R_f = 0.23 (EtOAc:*n*-heptane, 20:80, v:v); 1H NMR (400 MHz, $CDCl_3$): δ 7.83 (dd, *J* = 6.0, 3.5 Hz, 4H, CH_{arom}), 7.65 – 7.38 (m, 5H, CH_{arom}), 7.36 – 7.15 (m, 3H, CH_{arom}), 5.03 (d, *J* = 11.2 Hz, 1H, C*H*H Nap), 4.99 (d, *J* = 11.2 Hz, 1H, C*H*H Nap), 4.53 (d, *J* = 9.8 Hz, 1H, H-1), 3.66 (dd, *J* = 10.9, 1.8 Hz, 1H, H-6), 3.63 (s, 3H, CH_3 Me), 3.62 – 3.50 (m, 5H, H-6, H-3, CH_3 Me), 3.40 (s, 3H, CH_3 Me), 3.37 – 3.26 (m, 2H, H-5, H-4), 3.18 (dd, *J* = 9.8, 8.8 Hz, 1H, H-2); ^{13}C NMR (101 MHz, $CDCl_3$): δ 136.2, 134.1, 133.5, 133.1, 131.9, 129.0, 128.2, 128.1, 127.8, 127.5, 126.7, 126.2, 126.2, 126.0, 87.7 (C-1), 86.8 (C-3),

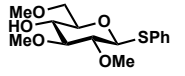
82.9 (C-2), 79.6 (C-4), 79.1 (C-5), 75.7, 71.5 (C-6), 61.2, 60.8, 59.5 (CH_3 Me); HRMS: $[M+Na]^+$ calcd for $C_{26}H_{30}O_5S$, 477.1712, found 477.1694.



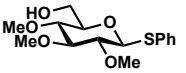
Phenyl 2,4,6-tri-*O*-methyl-1-thio-β-D-glucopyranose (S13) To a well stirred emulsion of **S12** (75 mg, 0.16 mmol) in DCM and H_2O (7/1, v/v, 1.6 mL) was added DDQ (56 mg, 0.25 mmol) and the suspension was protected from light and stirred at room temperature for 1.5 h. The mixture was diluted with DCM (20 mL) and washed (2 x 10 mL) with 10% $Na_2S_3O_3$ in H_2O w:w, to reduce the remaining DDQ. The organic layer was dried over $MgSO_4$, filtered and concentrated *in vacuo*. Silica gel column chromatography of the residue afforded **S13** as white solid (42 mg, 81%); TLC: R_f = 0.35 (EtOAc:*n*-heptane, 40:60, v:v); ^{1}H NMR (500 MHz, $CDCl_3$): δ 7.59 – 7.44 (m, 2H, CH_{arom}), 7.39 – 7.20 (m, 3H, CH_{arom}), 4.60 – 4.48 (m, 1H, H-1), 3.68 – 3.56 (m, 6H, H-6, H-6, CH_3 Me, H-3), 3.56 (s, 3H, CH_3 Me), 3.40 (s, 3H, CH_3 Me), 3.33 (ddd, *J* = 9.7, 4.5, 2.0 Hz, 1H, H-5), 3.26 – 3.20 (m, 1H, H-4), 3.08 (dd, *J* = 9.7, 8.8 Hz, 1H, H-2), 2.67 (s, 1H, 3-OH); ^{13}C NMR (126 MHz, $CDCl_3$): δ 134.1 ($C_{q\text{-}arom}$), 132.0, 131.8, 129.1, 129.0, 127.5 (CH_{arom}), 87.2 (C-1), 82.5 (C-2), 79.1 (C-4), 78.8 (C-5), 78.6 (C-3), 71.6 (C-6), 61.2, 60.7, 59.5 (CH_3 Me); HRMS: $[M+Na]^+$ calcd for $C_{15}H_{22}O_5S$, 337.1086, found 337.1086.



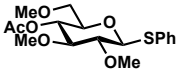
Phenyl 3-*O*-acetyl-2,4,6-tri-*O*-methyl-1-thio-β-D-glucopyranose (1). *Via* general acetylation protocol starting with **S13** (40 mg, 0.13 mmol). The product **1** (44 mg, 97%) was obtained as a pale oil; TLC: R_f = 0.49 (EtOAc:*n*-heptane, 40:60, v:v); ^{1}H NMR (500 MHz, $CDCl_3$): δ 7.60 – 7.47 (m, 2H, CH_{arom}), 7.38 – 7.20 (m, 4H, CH_{arom}), 5.13 (t, *J* = 9.0 Hz, 1H, H-3), 4.58 (d, *J* = 9.8 Hz, 1H, H-1), 3.67 – 3.57 (m, 3H, H-6, H-6), 3.50 (s, 3H, CH_3 Me), 3.42 (s, 3H, CH_3 Me), 3.40 (s, 3H, CH_3 Me), 3.38 (dd, *J* = 3.8, 1.8 Hz, 1H, H-5), 3.37 – 3.32 (m, 1H, H-4), 3.16 (t, *J* = 9.5 Hz, 1H, H-2), 2.14 (s, 3H, CH_3 Ac); ^{13}C NMR (126 MHz, $CDCl_3$): δ 170.1 (C=O), 133.7, 132.2, 129.0, 128.9, 127.7 (CH_{arom}), 87.4 (C-1), 80.6 (C-2), 78.7 (C-5), 77.5 (C-4), 77.5 (C-3), 71.2 (C-6), 60.3, 60.1, 59.5 (CH_3 Me), 21.2; (CH_3 Ac) HRMS: $[M+Na]^+$ calcd for $C_{17}H_{24}O_6S$, 379.1191, found 379.1205.



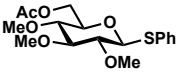
Phenyl 2,3,6-tri-*O*-methyl-1-thio-β-D-glucopyranoside (S14). To a solution of phenyl 2,3-di-*O*-methyl-1-thio-β-D-glucopyranoside[59] (100 mg, 0.33 mmol) in DMF (3.0 mL), NaH (33 mg, 0.83 mmol, 60 wt% in mineral oil) was added. The mixture was allowed to stir for 5 min before MeI (21 µL, 0.33 mmol) was added and was left at room temperature for 1 hour under argon. The reaction was quenched by addition of sat. aq. NH_4Cl (0.5 mL), diluted with EtOAc (15 mL) and washed once with water (10 mL) and once with brine. The organic layer was dried ($MgSO_4$), filtered and concentrated *in vacuo*. Silica column chromatography of the crude (30% EtOAc in *n*-heptane) afforded Phenyl 2,3,6-tri-*O*-methyl-1-thio-β-D-glucopyranoside **S14** (34 mg, 32%) as a clear oil. Phenyl 2,3,4-tri-*O*-methyl-1-thio-β-D-glucopyranoside (22 mg, 21%) was obtained as main by-product; TLC: R_f = 0.35 (EtOAc:*n*-heptane, 50:50, v:v); ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.68 – 7.40 (m, 2H, CH_{arom}), 7.40 – 7.13 (m, 3H, CH_{arom}), 4.55 (d, *J* = 9.7 Hz, 1H, H-1), 3.66 (pd, *J* = 4.1 Hz, 5H, H-6, H-6, CH_3 Me), 3.61 (s, 3H, CH_3 Me), 3.57 – 3.49 (m, 1H, H-4), 3.48 – 3.34 (m, 4H, CH_3 Me, H-5), 3.18 (t, *J* = 8.8 Hz, 1H, H-3), 3.08 (dd, *J* = 9.7, 8.7 Hz, 1H, H-2), 2.83 (d, *J* = 2.1 Hz, 1H, 4-OH); ^{13}C NMR (101 MHz, $CDCl_3$): δ 133.9, 132.0, 129.0, 128.6 (CH_{arom}), 88.0 (C-3), 87.7 (C-1), 82.5 (C-2), 77.8 (C-5), 73.0 (C-6), 71.7 (C-4), 61.2, 60.8, 59.7 (CH_3 Me); HRMS: $[M+Na]^+$ calcd for $C_{15}H_{22}O_5S$, 337.1086, found 337.1084.



Phenyl 2,3,4-tri-*O*-methyl-1-thio-β-D-glucopyranoside (S15). Afforded as main by-product in the synthesis of phenyl 2,3,6-tri-*O*-methyl-1-thio-β-D-glucopyranoside. TLC: R_f = 0.44 (EtOAc:*n*-heptane, 50:50, v:v); ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.53 – 7.46 (m, 2H, CH_{arom}), 7.35 – 7.24 (m, 3H, CH_{arom}), 4.55 (d, *J* = 9.8 Hz, 1H, H-1), 3.92 – 3.78 (m, 1H, H-6), 3.74 – 3.64 (m, 4H, H-6, CH_3 Me), 3.62 (s, 3H, CH_3 Me), 3.55 (s, 3H, CH_3 Me), 3.29 – 3.20 (m, 2H, H-5, H-3), 3.17 – 3.08 (m, 1H, H-4), 3.03 (dd, *J* = 9.8, 8.6 Hz, 1H, H-4), 1.92 (t, *J* = 6.7 Hz, 1H, 6-OH); ^{13}C NMR (101 MHz, $CDCl_3$): δ 132.0, 129.1, 127.8 (CH_{arom}), 88.6 (C-3), 87.2 (C-1), 82.8 (C-2), 79.7 (C-4), 79.2 (C-5), 62.4 (C-6), 61.1, 61.0, 60.7 (CH_3 Me); HRMS: $[M+Na]^+$ calcd for $C_{15}H_{22}O_5S$, 337.1086, found 337.1083.

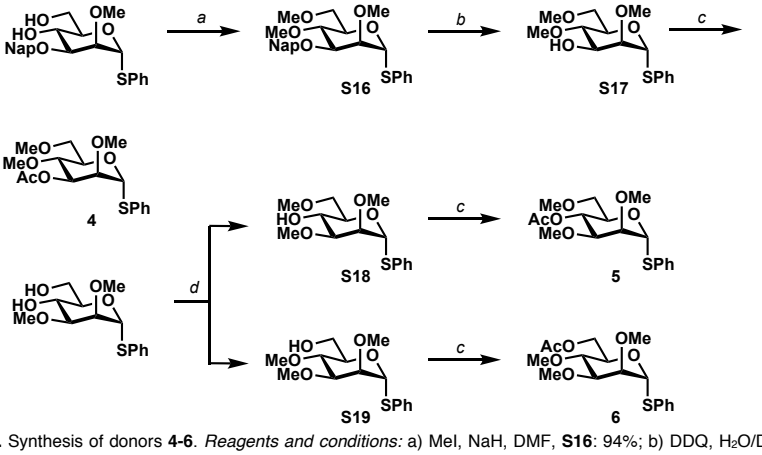


Phenyl 4-*O*-acetyl-2,3,6-tri-*O*-methyl-1-thio-β-D-glucopyranoside (2). *Via* general acetylation protocol starting with **S14** (20 mg, 0.064 mmol). **2** (13 mg, 57%) was obtained as a white amorphous solid. TLC: R_f = 0.49 (EtOAc:*n*-heptane, 40:60, v:v); ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.65 – 7.47 (m, 1H), 7.41 – 7.19 (m, 2H, CH_{arom}), 4.85 (t, *J* = 9.6 Hz, 1H, H-4), 4.53 (d, *J* = 9.8 Hz, 1H, H-1), 3.59 (s, 3H, CH_3 Me), 3.54 (s, 3H, CH_3 Me), 3.50 (ddd, *J* = 9.8, 5.9, 3.2 Hz, 1H, H-5), 3.46 – 3.42 (m, 2H, H-6, H-6), 3.35 – 3.26 (m, 4H, H-3, CH_3 Me), 3.13 (dd, *J* = 9.8, 8.7 Hz, 1H, H-2), 2.09 (s, 1H, CH_3 Ac); ^{13}C NMR (101 MHz, $CDCl_3$): δ 170.0, 132.2, 129.0, 127.7 (CH_{arom}), 87.4 (C-1), 86.0 (C-3), 82.2 (C-2), 77.5 (C-5), 72.2 (C-6), 70.9 (C-4), 61.0, 60.9, 59.6 (CH_3 Me), 21.1 (CH_3 Ac); HRMS: $[M+Na]^+$ calcd for $C_{17}H_{24}O_6S$, 379.1191, found 379.1193.

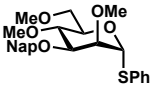


Phenyl 6-*O*-acetyl-2,3,4-tri-*O*-methyl-1-thio-β-D-glucopyranoside (3). *Via* general acetylation protocol starting with **S15** (33 mg, 0.10 mmol). **3** (36 mg, 96%) was obtained as a white amorphous solid. TLC: R_f = 0.50 (EtOAc:*n*-heptane, 40:60, v:v); ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.66 – 7.50 (m, 2H, CH_{arom}), 7.41 – 7.20 (m, 3H, CH_{arom}), 4.49 (d, *J* = 9.8 Hz, 1H, H-1), 4.35 (dd, *J* = 11.8, 2.2 Hz, 1H, H-6), 4.20 (dd, *J* = 11.8, 6.2 Hz, 1H, H-6), 3.65 (s, 3H, CH_3 Me), 3.61 (s, 3H, CH_3 Me), 3.52 (s, 3H, CH_3 Me), 3.41 (ddd, *J* = 9.9, 6.2, 2.1 Hz, 1H, H-5), 3.24 (t, *J* = 8.8 Hz, 1H, H-3), 3.06 (pddd, *J* = 9.9, 8.8, 7.9 Hz, 2H, H-4, H-2), 2.08 (s, 3H, CH_3 Ac); ^{13}C NMR (101 MHz, $CDCl_3$): δ 170.9, 133.7, 132.1, 128.9, 127.7 (CH_{arom}), 88.7 (C-3), 87.2 (C-1), 82.7 (C-2), 79.9 (C-4), 76.9 (C-5), 63.7 (C-6), 61.2, 61.0, 60.8 (CH_3 Me), 21.0 (CH_3 Ac); HRMS: $[M+Na]^+$ calcd for $C_{17}H_{24}O_6S$, 379.1191, found 379.1198.

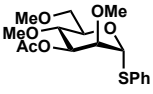
Preparation of donor 4-6



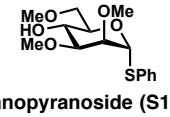
Scheme S5. Synthesis of donors **4-6**. *Reagents and conditions:* a) MeI, NaH, DMF, **S16**: 94%; b) DDQ, H_2O/DCM, **S17**: 86%; c) Ac_2O, pyridine, **4**: 98%, **5**: 97%, **6**: *quant.*; d) MeI, NaH, DMF, **S18**: 11%, **S19**: 43%.



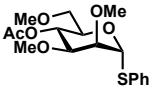
Phenyl 3-*O*-(2-methylnaphthyl)-2,4,6-tri-*O*-methyl-1-thio-α-D-mannoyranose (S16). *Via* general methylation protocol starting with phenyl 3-*O*-(2-methylnaphthyl)-2-*O*-methyl-1-thio-α-D-mannopyranose[33] (350 mg, 0.82 mmol). The residue was purified by silica column chromatography (20% EtOAc in toluene) to afford the product **S19** (352 mg, 94%) as a white amorphous solid. TLC: R_f = 0.19 (EtOAc:*n*-heptane, 20:80, v:v); ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.97 – 7.78 (m, 4H, CH_{arom}), 7.63 – 7.38 (m, 5H, CH_{arom}), 7.35 – 7.12 (m, 3H, CH_{arom}), 5.59 (d, *J* = 1.5 Hz, 1H, H-1), 4.92 (d, *J* = 12.2 Hz, 1H, C*H*H Nap), 4.87 (d, *J* = 12.2 Hz, 1H, C*H*H Nap), 4.09 (ddd, *J* = 9.7, 4.6, 1.9 Hz, 1H, H-5), 3.80 (dd, *J* = 9.4, 3.1 Hz, 1H, H-3), 3.76 – 3.63 (m, 3H, H-2, H-4, H-6), 3.62 – 3.59 (m, 4H, CH_3 Me, H-6), 3.43 (s, 3H, CH_3 Me), 3.38 (s, 1H, CH_3 Me); ^{13}C NMR (101 MHz, $CDCl_3$): δ 135.9, 134.7, 133.5, 133.2, 131.2, 129.1, 128.3, 128.1, 127.9, 127.4, 126.7, 126.3, 126.1, 126.0 (CH_{arom}), 85.1 (C-1), 80.0 (C-3), 79.8 (C-2), 76.5 (C-4), 72.7, 72.6 (C-5), 71.5 (C-6), 61.0, 59.3, 58.6 (CH_3 Me); HRMS: $[M+Na]^+$ calcd for $C_{26}H_{30}O_5S$, 477.1712, found 477.1694.



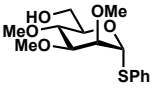
Phenyl 3-*O*-acetyl-2,4,6-tri-*O*-methyl-1-thio-α-D-mannopyranoside (4). To a well stirred emulsion of **S16** (330 mg, 0.73 mmol) in DCM and H_2O (7/1, v/v, 7.3 mL) was added DDQ (247 mg, 1.1 mmol) and the suspension was protected from light and stirred at room temperature for 1.5 h. The mixture was diluted with DCM (100 mL) and washed (2 x 20 mL) with 10% $Na_2S_3O_3$ in H_2O w/w, to reduce the remaining DDQ. The organic layer was dried over $MgSO_4$, filtered and concentrated *in vacuo*. Silica gel column chromatography (30% EtOAc in *n*-heptane) of the residue afforded **S17** as a clear oil (0.196 mg, 86%). TLC: (EtOAc:*n*-heptane, 40:60, v:v): R_f = 0.13; HRMS: $[M+Na]^+$ calcd for $C_{15}H_{22}O_5S$, 337.1086, found 337.1106. **S17** was directly acetylated *via* general acetylation protocol starting with **S17** (189 mg, 0.60 mmol). The product **4** (210 mg, 98%) was obtained as a pale oil. TLC: R_f = 0.67 (EtOAc:*n*-heptane, 50:50, v:v); ^{1}H NMR (500 MHz, $CDCl_3$): δ 7.55 – 7.45 (m, 2H, CH_{arom}), 7.33 – 7.28 (m, 3H, CH_{arom}), 5.60 (d, *J* = 1.9 Hz, 1H, H-1), 5.11 (dd, *J* = 9.6, 3.3 Hz, 1H, H-3), 4.16 (ddd, *J* = 9.8, 4.3, 2.0 Hz, 1H, H-5), 3.88 (dd, *J* = 3.3, 1.9 Hz, 1H, H-2), 3.75 (t, *J* = 9.7 Hz, 1H, H-4), 3.67 (dd, *J* = 10.8, 4.2 Hz, 1H, H-6), 3.58 (dd, *J* = 10.7, 2.0 Hz, 1H, H-6), 3.49 (s, 3H, CH_3 Me), 3.42 (s, 3H, CH_3 Me), 3.39 (s, 3H, CH_3 Me), 2.16 (s, 3H, CH_3 Ac); ^{13}C NMR (126 MHz, $CDCl_3$): δ 170.5 (C=O), 134.6, 131.3, 129.2, 127.4 (CH_{arom}), 84.9 (C-1), 79.9 (C-2), 74.7 (C-4), 74.0 (C-3), 72.3 (C-5), 71.2 (C-6), 60.6, 59.4, 58.6 (CH_3 Me), 21.3 (CH_3 Ac); HRMS: $[M+Na]^+$ calcd for $C_{17}H_{24}O_6S$, 379.1191, found 379.1199.



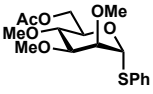
Phenyl 2,3,6-tri-*O*-methyl-1-thio-α-D-mannopyranoside (S18). To a solution of phenyl 2,3-di-*O*-methyl-1-thio-α-D-mannopyranoside[32] (196 mg, 0.653 mmol) in DMF (6.5 mL), NaH (78 mg, 1.96 mmol, 60 wt% in mineral oil) was added. The mixture was allowed to stir for 5 min before MeI (41 µL, 0.653 mmol) was added and was left at room temperature for 1 hour under argon. The reaction was quenched by addition of sat. aq. NH_4Cl (0.5 mL), diluted with EtOAc (15 mL) and washed once with water (10 mL) and once with brine. The organic layer was dried ($MgSO_4$), filtered and concentrated *in vacuo*. Silica column chromatography of the crude (40% Et_2O in toluene) afforded phenyl 2,3,6-tri-*O*-methyl-1-thio-α-D-mannopyranoside **S22** (88 mg, 43%) as a clear oil. Phenyl 2,3,4-tri-*O*-methyl-1-thio-β-D-glucopyranoside (22 mg, 11%) was obtained as by-product; TLC: R_f = 0.28 (Et_2O:toluene, 40:60, v:v); ^{1}H NMR (500 MHz, $CDCl_3$): δ 7.60 – 7.51 (m, 2H, CH_{arom}), 7.39 – 7.21 (m, 3H, CH_{arom}), 5.69 (d, *J* = 1.5 Hz, 1H, H-1), 4.24 (dt, *J* = 9.2, 4.3 Hz, 1H, H-5), 3.97 (t, *J* = 9.6 Hz, 1H, H-4), 3.91 (dd, *J* = 3.1, 1.6 Hz, 1H, H-2), 3.80 – 3.67 (m, 2H, H-6, H-6), 3.53 (s, 3H, CH_3 Me), 3.49 – 3.44 (m, 4H, CH_3 Me, H-3), 3.41 (s, 3H, CH_3 Me), 2.71 (s, 1H, 4-OH); ^{13}C NMR (126 MHz, $CDCl_3$): δ 134.6, 131.4, 129.2, 127.6 (CH_{arom}), 85.2 (C-1), 81.4 (C-3), 77.7 (C-2), 72.4 (C-5), 71.9 (C-6), 67.8 (C-4), 59.6, 58.3, 57.3 (CH_3 Me); HRMS: $[M+Na]^+$ calcd for $C_{15}H_{22}O_5S$, 337.1086, found 337.1090.



Phenyl 4-*O*-acetyl-2,3,6-tri-*O*-methyl-1-thio-α-D-mannopyranoside (5). *Via* general acetylation protocol starting with **S18** (80 mg, 0.25 mmoL). The title compound (88 mg, 97%) was obtained as a pale oil. TLC: R_f = 0.63 (EtOAc:*n*-heptane, 50:50, v:v); ^{1}H NMR (500 MHz, $CDCl_3$): δ 7.63 – 7.49 (m, 2H, CH_{arom}), 7.46 – 7.15 (m, 3H, CH_{arom}), 5.63 (d, *J* = 1.9 Hz, 1H, H-1), 5.26 (t, *J* = 9.7 Hz, 1H, H-4), 4.30 (dt, *J* = 9.5, 4.5 Hz, 1H, H-5), 3.89 (dd, *J* = 3.1, 1.9 Hz, 1H, H-2), 3.56 (dd, *J* = 9.5, 3.1 Hz, 1H, H-3), 3.52 – 3.46 (m, 5H, H-6, H-6, CH_3 Me), 3.45 (s, 3H, CH_3 Me), 3.33 (s, 3H, CH_3 Me), 2.10 (s, 3H, CH_3 Ac); ^{13}C NMR (126 MHz, $CDCl_3$): δ 170.0 (C=O), 134.3, 131.7, 129.2, 127.8 (CH_{arom}), 85.3 (C-1), 79.2 (C-3), 78.3 (C-2), 72.0 (C-6), 71.0 (C-5), 68.9 (C-4), 59.5, 58.5, 57.9 (CH_3 Me), 21.1 (CH_3 Ac); HRMS: $[M+Na]^+$ calcd for $C_{17}H_{24}O_6S$, 379.1191, found 379.1201.

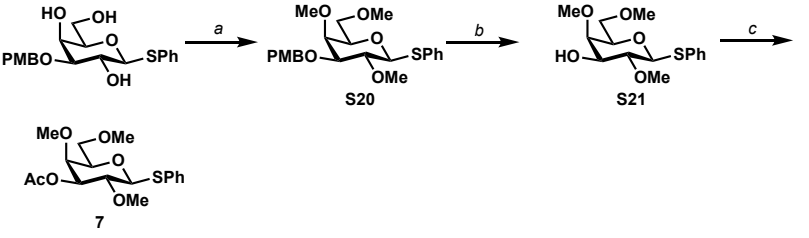


Phenyl 2,3,4-tri-*O*-methyl-1-thio-α-D-mannopyranoside (S19). Isolated as main by-product in the synthesis of Phenyl 2,4,6-tri-*O*-methyl-1-thio-α-D-mannopyranoside.[60] TLC: R_f = 0.25 (Et_2O:toluene, 40:60, v:v); ^{1}H NMR (500 MHz, $CDCl_3$): δ 7.51 – 7.40 (m, 2H, CH_{arom}), 7.40 – 7.16 (m, 3H, CH_{arom}), 5.61 (d, *J* = 1.8 Hz, 1H, H-1), 4.04 (ddd, *J* = 9.5, 4.7, 2.9 Hz, 1H, H-5), 3.88 – 3.73 (m, 3H, H-2, H-6, H-6), 3.57 (s, 3H, H-4, CH_3 Me), 3.55 – 3.49 (m, 4H, H-3, CH_3 Me), 3.48 (s, 3H, CH_3 Me), 1.98 (s, 1H, 6-OH); ^{13}C NMR (126 MHz, $CDCl_3$): δ 134.2, 131.8, 129.3, 127.8 (CH_{arom}), 85.0 (C-1), 81.7 (C-3), 78.8 (C-2), 76.6 (C-4), 73.1 (C-5), 62.3 (C-6), 61.0, 58.4, 57.9 (CH_3 Me).



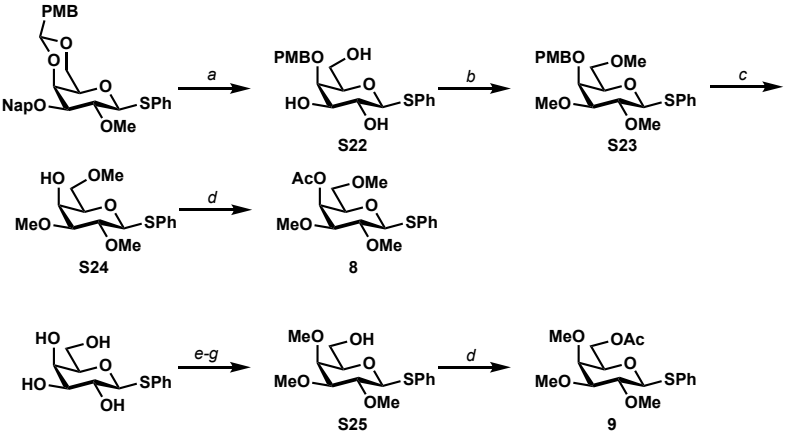
Phenyl 6-*O*-acetyl-2,3,4-tri-*O*-methyl-1-thio-α-D-mannopyranoside (6). *Via* general acetylation protocol starting with **S19** (22 mg, 70 µmol). Obtained **6** (25 mg, *quant.*) as a clear oil. TLC: R_f = 0.63 (EtOAc:*n*-heptane, 50:50, v:v); ^{1}H NMR (500 MHz, $CDCl_3$): δ 7.60 – 7.38 (m, 2H, CH_{arom}), 7.40 – 7.16 (m, 3H, CH_{arom}), 5.64 (d, *J* = 1.6 Hz, 1H, H-1), 4.37 – 4.28 (m, 2H, H-6, H-6), 4.23 (ddd, *J* = 8.5, 5.1, 3.1 Hz, 1H, H-5), 3.86 (dd, *J* = 3.0, 1.7 Hz, 1H, H-2), 3.54 (s, 3H, CH_3 Me), 3.53 – 3.49 (m, 4H, H-3, CH_3 Me), 3.47 (s, 4H, H-4, CH_3 Me), 2.06 (s, 3H, CH_3 Ac); ^{13}C NMR (126 MHz, $CDCl_3$): δ 170.9 (C=O), 134.2, 131.6, 129.2, 127.7 (CH_{arom}), 84.6 (C-1), 81.7 (C-3), 78.5 (C-2), 76.7 (C-4) 70.8 (C-5), 63.6 (C-6), 61.0, 58.2, 57.8 (CH_3 Me), 21.0 (CH_3 Ac); HRMS: $[M+Na]^+$ calcd for $C_{17}H_{24}O_6S$, 379.1191, found 379.1202.

Preparation of donors 7

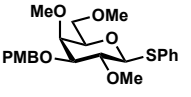


Scheme S6. Synthesis of donor **7**. *Reagents and conditions:* a) MeI, NaH, DMF, **S20**: 99%; b) *p*TsOH, MeOH, **S21**: 81%; c) Ac_2O, pyridine, **7**: *quant.*

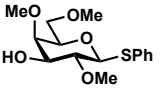
Preparation of donors 8 and 9



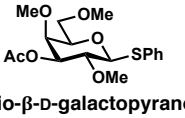
Scheme S7. Synthesis of donors **8** and **9**. *Reagents and conditions:* a) BH_3, TMSOTf, THF, **S22**: 75%; b) MeI, NaH, DMF, **S23**: 97%; c) *p*TsOH, MeOH, **S24**: 81%; d) Ac_2O, pyridine, **8**: *quant.*, **9**: *quant.*; e) TBS-Cl, imidazole, DMF; f) MeI, NaH, DMF; g) TBAF, THF, **S25**: 27% over three steps.



Phenyl 2,4,6-tri-*O*-methyl-3-*O*-*p*-methoxybenzyl-1-thio-β-D-galactopyranoside (S20). *Via* general methylation protocol starting with phenyl 3-*O*-*p*-methoxybenzyl-1-thio-β-D-galactopyranoside (327 mg, 0.833 mmol). The residue was purified by silica column chromatography (30% EtOAc in *n*-heptane) to obtain the product **S25** (359 mg, 99%) as a white amorphous solid. TLC: R_f = 0.31 (EtOAc:*n*-heptane, 30:70, v:v); ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.62 – 7.46 (m, 2H, CH_{arom}), 7.40 – 7.13 (m, 5H, CH_{arom}), 6.97 – 6.81 (m, 2H, CH_{arom}), 4.70 – 4.63 (m, 2H, 2 x C*H*H PMB), 4.49 (d, *J* = 9.3 Hz, 1H, H-1), 3.81 (s, 3H, CH_3 Me), 3.62 – 3.58 (m, 4H, H-4, CH_3 Me), 3.58 – 3.55 (m, 4H, H-6, CH_3 Me), 3.55 – 3.45 (m, 4H, H-6, H-2, H-5), 3.42 (dd, *J* = 9.2, 2.9 Hz, 1H, H-3), 3.36 (s, 3H, CH_3 Me); ^{13}C NMR (101 MHz, $CDCl_3$): δ 134.3, 131.6, 130.4, 129.3, 128.7, 127.1, 113.9 (CH_{arom}), 87.9 (C-1), 83.2 (C-3), 79.4 (C-2), 77.0 (C-5), 76.0 (C-4), 72.3, 70.7 (C-6), 61.3, 61.3, 59.2 (CH_3 Me); HRMS: $[M+Na]^+$ calcd for $C_{23}H_{30}O_6S$, 457.1661, found 457.1658.

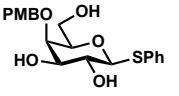


Phenyl 2,4,6-tri-*O*-methyl-1-thio-β-D-galactopyranoside (S21). S20 (359 mg, 0.826 mmol) was suspended in methanol (4.13 mL) and heated to 50 °C before *p*TsOH (157 mg, 0.826 mmol) was added. The suspension stirred for 18 h before being neutralized by addition of TEA. The mixture was concentrated in *vacuo*. Silica column chromatography (50% ethyl acetate in *n*-heptane) of the residue obtained the product **S21** (210 mg, 81%) as a clear oil; TLC: R_f = 0.23 (EtOAc:*n*-heptane, 50:50, v:v); ^{1}H NMR (500 MHz, $CDCl_3$): δ 7.59 – 7.47 (m, 1H, CH_{arom}), 7.37 – 7.14 (m, 3H, CH_{arom}), 4.50 (d, *J* = 9.6 Hz, 1H, H-1), 3.71 – 3.50 (m, 11H, 2 x CH_3 Me, H-3, H-4, H-5, H-6, H-6), 3.37 (s, 3H, CH_3 Me), 3.29 (ddd, *J* = 9.7, 7.2, 3.1 Hz, 1H, H-2), 2.47 (d, *J* = 6.9 Hz, 1H, 4-OH); ^{13}C NMR (126 MHz, $CDCl_3$): δ 134.3, 131.7, 128.9, 127.4 (CH_{arom}), 87.7 (C-1), 80.8 (C-2), 78.4 (C-5), 77.3 (C-3), 75.8 (C-4), 70.7 (C-6), 61.9, 61.5, 59.3 (CH_3 Me); HRMS: $[M+Na]^+$ calcd for $C_{15}H_{22}O_5S$, 337.1086, found 337.1104.

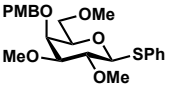


Phenyl 3-*O*-acetyl-2,4,6-tri-O-methyl-1-thio-β-D-galactopyranoside (7). *Via* general acetylation protocol starting with **S21** (150 mg, 0.477 mmol). **7** (170 mg, *quant.*) was obtained as a pale oil. TLC: R_f = 0.64

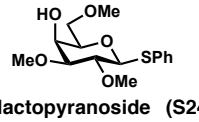
(EtOAc:*n*-heptane, 50:50, v:v); ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.60 – 7.48 (m, 2H, CH_{arom}), 7.40 – 7.11 (m, 3H, CH_{arom}), 4.87 (dd, *J* = 9.7, 3.1 Hz, 1H, H-3), 4.57 (d, *J* = 9.8 Hz, 1H, H-1), 3.71 (dd, *J* = 3.2, 1.0 Hz, 1H, H-4), 3.68 – 3.45 (m, 10H, 2 x CH_3 Me, H-2, H-5, H-6, H-6), 3.34 (s, 3H, CH_3 Me), 2.15 (s, 3H, CH_3 Ac); ^{13}C NMR (101 MHz, $CDCl_3$): δ 170.4 (C=O), 134.0, 131.8, 128.9, 128.9, 127.4 (CH_{arom}), 87.9 (C-1), 77.4 (C-2), 77.3 (C-3), 76.7 (C-5), 76.6 (C-4), 70.5 (C-6), 61.4, 61.1, 59.3 (CH_3 Me), 21.2 (CH_3 Ac); HRMS: $[M+Na]^+$ calcd for $C_{17}H_{24}O_6S$, 379.1191, found 379.1211.



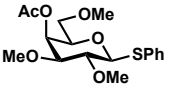
Phenyl 4-*O*-*p*-methoxybenzyl-1-thio-β-D-galactopyranoside (S22). Phenyl 4,6-*O*-*p*-methoxybenzylidene-1-thio-β-D-galactopyranoside (1.0 g, 2.56 mmol) was dissolved in DCM (26 mL) after which 1 M BH_3 in THF (18 mL, 18 mmol) was added at 0 °C. The mixture was allowed to warm up to room temperature in 20 min before TMSOTf (46 µL, 0.26 mmol) was added. After full conversion was observed after 3 h, the reaction was cooled to 0 °C and triethylamine (0.5 mL) was added. The mixture was quenched by careful addition of methanol and subsequently concentrated *in vacuo*. Silica column chromatography (70% ethyl acetate in *n*-heptane) of the residue gave the product **S22** (756 mg, 75%) as a white amorphous solid; TLC: R_f = 0.15 (EtOAc:*n*-heptane, 80:20, v:v); ^{1}H NMR (400 MHz, Acetone-d_6) δ 7.71 – 7.46 (m, 2H, CH_{arom}), 7.40 – 7.10 (m, 5H, CH_{arom}), 7.01 – 6.81 (m, 2H, CH_{arom}), 4.89 (d, *J* = 11.0 Hz, 1H, C*H*H PMB), 4.70 – 4.46 (m, 2H, H-1, C*H*H PMB), 4.24 (dd, *J* = 4.5, 1.3 Hz, 1H, H-4), 4.11 – 4.04 (m, 1H, 2-OH), 3.92 (dd, *J* = 2.8, 0.8 Hz, 1H, 3-OH), 3.79 (s, 3H, CH_3 Me), 3.78 – 3.60 (m, 5H, H-2, H-3, H-5, H-6, H-6); ^{13}C NMR (101 MHz, Acetone-d_6) δ 160.1, 135.8, 132.5, 131.6, 131.6, 130.0, 129.5, 127.4, 114.3 (CH_{arom}), 89.0 (C-1), 89.0, 80.3, 80.3, 77.3, 77.2, 77.1, 77.0, 75.2, 71.0, 70.9, 70.9, 62.0, 61.8, 55.5, 55.0; HRMS: $[M+Na]^+$ calcd for $C_{20}H_{24}O_6S$, 415.1191, found 415.1187.



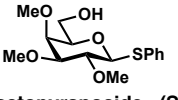
Phenyl 2,3,6-tri-*O*-methyl-4-*O*-*p*-methoxybenzyl-1-thio-β-D-galactopyranoside (S23). *Via* general methylation protocol starting with **S22** (316 mg, 0.81 mmol). Crystallization of the residue from methanol gave **S23** (340 mg, 97%) as a white solid. TLC: R_f = 0.60 (EtOAc:*n*-heptane, 50:50, v:v); ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.63 – 7.42 (m, 2H, CH_{arom}), 7.33 – 7.25 (m, 2H, CH_{arom}), 7.24 – 7.18 (m, 3H, CH_{arom}), 6.93 – 6.83 (m, 2H, CH_{arom}), 4.83 (d, *J* = 11.3 Hz, 1H, C*H*H PMB), 4.55 (d, *J* = 11.3 Hz, 1H, C*H*H PMB), 4.50 (d, *J* = 9.6 Hz, 1H, H-1), 3.91 (d, *J* = 2.8 Hz, 1H, H-4), 3.82 (s, 3H, CH_3 Me), 3.57 (s, 3H, CH_3 Me), 3.55 – 3.41 (m, 7H, CH_3 Me, H-6, H-6, H-2, H-5), 3.28 (s, 3H, CH_3 Me), 3.22 (dd, *J* = 9.2, 2.8 Hz, 1H, H-3); ^{13}C NMR (101 MHz, $CDCl_3$): δ 159.3, 134.3, 131.7, 131.1, 129.6, 128.8, 127.1, 113.7 CH_{arom}), 87.7 (C-1), 86.6 (C-3), 79.0 (C-2), 77.3 (C-5), 74.1, 72.2 (C-4), 71.1 (C-6), 61.2, 59.3, 58.4 (CH_3 Me); HRMS: $[M+Na]^+$ calcd for $C_{23}H_{30}O_6S$, 457.1661, found 457.1661.



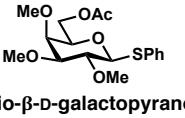
Phenyl 2,3,6-tri-*O*-methyl-1-thio-β-D-galactopyranoside (S24). S23 (315 mg, 0.725 mmol) was suspended in methanol (3.62 mL) and heated to 50 °C before *p*TsOH (138 mg, 0.725 mmol) was added. The suspension stirred for 18 h before being neutralized by addition of triethylamine. The mixture was concentrated in *vacuo*. Silica column chromatography (50% ethyl acetate in *n*-heptane) of the residue obtained the product **S24** (171 mg, 75%) as a clear oil. TLC: R_f = 0.31 (EtOAc:*n*-heptane, 50:50, v:v); ^{1}H NMR (500 MHz, $CDCl_3$): δ 7.65 – 7.41 (m, 2H, CH_{arom}), 7.38 – 7.13 (m, 3H, CH_{arom}), 4.51 (d, *J* = 9.7 Hz, 1H, H-1), 4.12 (s, 1H, H-4), 3.72 (dd, *J* = 10.0, 5.8 Hz, 1H, H-6), 3.64 (dd, *J* = 10.0, 5.6 Hz, 1H, H-6), 3.57 (s, 3H, CH_3 Me), 3.54 (t, *J* = 5.4 Hz, 1H, H-5), 3.51 (s, 3H, CH_3 Me), 3.39 (s, 3H, CH_3 Me), 3.35 (t, *J* = 9.3 Hz, 1H, H-2), 3.23 (dd, *J* = 8.9, 3.2 Hz, 1H, H-3), 2.61 – 2.39 (m, 1H, 4-OH); ^{13}C NMR (126 MHz, $CDCl_3$): δ 133.9, 132.0, 128.9, 127.5 (CH_{arom}), 87.6 (C-1), 84.8 (C-3), 78.6 (C-2), 76.9 (C-5), 71.9 (C-6), 66.2 (C-4), 61.3, 59.6, 57.7 (CH_3 Me); HRMS: $[M+Na]^+$ calcd for $C_{15}H_{22}O_5S$, 337.1086, found 337.1092.



Phenyl 4-*O*-acetyl-2,3,6-tri-O-methyl-1-thio-β-D-galactopyranoside (8). *Via* general acetylation protocol starting with **S24** (171 mg, 0.54 mmol). The product **8** (193 mg, *quant.*) was obtained as a pale oil. TLC: R_f = 0.50 (EtOAc:*n*-heptane, 50:50, v:v); ^{1}H NMR (500 MHz, $CDCl_3$): δ 7.57 (dt, *J* = 8.6, 2.1 Hz, 2H, CH_{arom}), 7.36 – 7.16 (m, 3H, CH_{arom}), 5.48 (d, *J* = 1.6 Hz, 1H, H-4), 4.64 – 4.48 (m, 1H, H-1), 3.70 – 3.64 (m, 1H, H-5), 3.57 (s, 3H, CH_3 Me), 3.50 (dd, *J* = 9.9, 6.1 Hz, 1H, H-6), 3.42 (s, 3H, CH_3 Me), 3.41 – 3.38 (m, 1H, H-6), 3.33 (s, 3H, CH_3 Me), 3.28 (dd, *J* = 5.5, 1.5 Hz, 2H, H-2, H-3), 2.13 (s, 3H, CH_3 Ac); ^{13}C NMR (126 MHz, $CDCl_3$): δ 170.4, 133.8, 132.0, 128.9, 127.6 (CH_{arom}), 87.6 (C-1), 83.6 (C-3), 78.5 (C-2), 76.1 (C-5), 71.1 (C-6), 66.6 (C-4), 61.4, 59.5, 57.9 (CH_3 Me), 21.0 (CH_3 Ac); HRMS: $[M+Na]^+$ calcd for $C_{17}H_{24}O_6S$, 379.1191, found 379.1201.



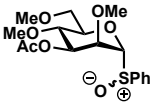
Phenyl 2,3,4-tri-*O*-methyl-1-thio-β-D-galactopyranoside (S25). To a mixture of phenyl 1-thio-β-galactopyranoside (1.00 g, 1 eq, 3.67 mmol) in DMF (18.4 mL) was added imidazole (375 mg, 5.51 mmol) and TBS-Cl (664 mg, 4.41 mmol). The reaction was stirred for 2 h before being quenched by the addition of 0.5 mL of MeOH. The mixture was partitioned between H_2O and Et_2O, and the aqueous layer was extracted. The combined organic phases were subsequently washed with aq. 1 M HCl, sat aq. $NaHCO_3$ and brine before being dried over $MgSO_4$, filtered, and conc. *in vacuo*. The crude product was dissolved in DMF (18.4 mL) and to this solution was added MeI (1.82 g, 804 µL, 3.5 eq, 12.9 mmol) and NaH (0.73 g, 18.4 mmol, 60 wt% in mineral oil) at 0 °C. The reaction stirred at ambient temperature for 18 h before being quenched by careful addition of MeOH (0.5 mL) at 0 °C. The residue was taken up in Et_2O and washed with 5% aq. LiCl and brine. The organic layer was dried over $MgSO_4$, filtered and concentrated *in vacuo*. The residue was dissolved in 4 mL of THF and treated with 7.3 mL of 1.0 M TBAF (in THF, 2 eq, 7.3 mmol). The mixture was stirred for 3 h and subsequently taken up in EtOAc and H_2O. The water layer was further extracted with EtOAc, and the combined organic layers were dried (MgSO4), filtered and concentrated *in vacuo*. Purification of the residue by Silica column chromatography (50% ethyl acetate in *n*-heptane) afforded S25 (302 mg, 26%) as a white amorphous solid. In addition, the 4-OH regio-isomer (113 mg, 10 %) was obtained. TLC: R_f = 0.13 (EtOAc:*n*-heptane, 50:50, v:v). ^{1}H NMR (500 MHz, $CDCl_3$): δ 7.52 (dt, *J* = 8.5, 2.0 Hz, 2H, CH_{arom}), 7.35 – 7.13 (m, 3H, CH_{arom}), 4.53 (d, *J* = 9.7 Hz, 1H, H-1), 3.92 (dd, *J* = 11.2, 7.6 Hz, 1H, H-6), 3.75 – 3.66 (m, 1H, H-6), 3.64 (d, *J* = 2.8 Hz, 1H, H-4), 3.60 (s, 3H, CH_3 Me), 3.55 (s, 3H, CH_3 Me), 3.54 (s, 3H, CH_3 Me), 3.48 – 3.35 (m, 2H, H-2, H-5), 3.22 (dd, *J* = 9.2, 3.0 Hz, 1H, H-3), 2.01 (d, *J* = 7.4 Hz, 1H, 6-OH); ^{13}C NMR (126 MHz, $CDCl_3$): δ 134.1, 131.8, 129.0, 127.4 (CH_{arom}), 87.7 (C-1), 86.2 (C-3), 79.4 (C-2), 79.0 (C-5), 76.0 (C-4), 62.5 (C-6), 61.4, 61.3, 58.5 (CH_3 Me); HRMS: $[M+Na]^+$ calcd for $C_{15}H_{22}O_5S$, 337.1086, found 337.1093.



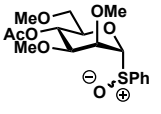
Phenyl 6-*O*-acetyl-2,3,4-tri-*O*-methyl-1-thio-β-D-galactopyranoside (9). *Via* general acetylation protocol starting with **S25** (205 mg, 0.65 mmol). Product **9** (233 mg, *quant.*) was obtained as a pale amorphous solid. TLC: R_f = 0.58 (EtOAc:*n*-heptane, 50:50, v:v). ^{1}H NMR (500 MHz, $CDCl_3$): δ 7.63 – 7.45 (m, 2H, CH_{arom}), 7.35 – 7.18 (m, 3H, CH_{arom}), 4.49 (d, *J* = 9.7 Hz, 1H, H-1), 4.31 (dd, *J* = 11.3, 7.2 Hz, 1H, H-6), 4.24 (dd, *J* = 11.3, 5.4 Hz, 1H, H-6), 3.61 (m, 1H, H-4), 3.60 (s, 3H, CH_3 Me), 3.59 – 3.56 (m, 1H, H-5), 3.56 (s, 3H, CH_3 Me), 3.54 (s, 3H), 3.46 – 3.39 (m, 1H, H-2), 3.21 (dd, *J* = 9.2, 3.0 Hz, 1H, H-3), 2.07 (s, 3H, CH_3 Ac); ^{13}C NMR (126 MHz, $CDCl_3$): δ 170.8, 134.3, 131.9, 128.8, 127.4 (CH_{arom}), 87.9 (C-1), 86.1 (C-3), 79.3 (C-2), 76.1 (C-5), 75.7 (C-4), 63.5 (C-6), 61.5, 61.3, 58.6 (CH_3 Me), 21.0 (CH_3 Ac); HRMS: $[M+Na]^+$ calcd for $C_{17}H_{24}O_6S$, 379.1191, found 379.1195.

Phenyl 3-*O*-acetyl-2,4,6-tri-*O*-methyl-1-thiosulfinyl-β-D-glucopyranoside (S26). *Via* general *S*-oxidation protocol starting with **1** (10 mg, 0.028 mmol). HRMS: $[M+Na]^+$ calcd for $C_{17}H_{17}O_7S$, 395.1140, found 395.1150.

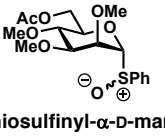
Phenyl 6-*O*-acetyl-2,3,4-tri-*O*-methyl-1-thiosulfinyl-β-D-glucopyranoside (S27). *Via* general *S*-oxidation protocol starting with **2** (10 mg, 0.028 mmol). HRMS: $[M+Na]^+$ calcd for $C_{17}H_{17}O_7S$, 395.1140, found 395.1153.



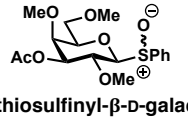
Phenyl 3-*O*-acetyl-2,4,6-tri-*O*-methyl-1-thiosulfinyl-α-D-mannopyranoside (S28). *Via* general *S*-oxidation protocol starting with **3** (17 mg, 0.048 mmol). HRMS: $[M+Na]^+$ calcd for $C_{17}H_{24}O_7S$, 395.1140, found 379.1151.



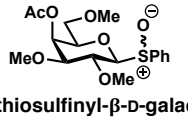
Phenyl 4-*O*-acetyl-2,3,6-tri-*O*-methyl-1-thiosulfinyl-α-D-mannopyranoside (S29). *Via* general *S*-oxidation protocol starting with **4** (10 mg, 0.028 mmol). HRMS: $[M+Na]^+$ calcd for $C_{17}H_{24}O_7S$, 395.1140, found 379.1150.



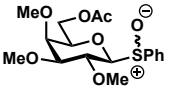
Phenyl 6-*O*-acetyl-2,3,4-tri-*O*-methyl-1-thiosulfinyl-α-D-mannopyranoside (S30). *Via* general *S*-oxidation protocol starting with **5** (25 mg, 0.070 mmol). HRMS: $[M+Na]^+$ calcd for $C_{17}H_{17}O_7S$, 395.1140, found 395.1146.



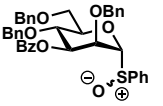
Phenyl 3-*O*-acetyl-2,4,6-tri-*O*-methyl-1-thiosulfinyl-β-D-galactopyranoside (S31). *Via* general *S*-oxidation protocol starting with **6** (10 mg, 0.028 mmol). HRMS: $[M+Na]^+$ calcd for $C_{17}H_{17}O_7S$, 395.1140, found 395.1147.



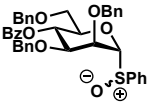
Phenyl 4-*O*-acetyl-2,3,6-tri-*O*-methyl-1-thiosulfinyl-β-D-galactopyranoside (S32). *Via* general *S*-oxidation protocol starting with **7** (13 mg, 0.035 mmol); HRMS: $[M+Na]^+$ calcd for $C_{17}H_{17}O_7S$, 395.1140, found 395.1153.



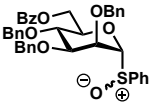
Phenyl 6-*O*-acetyl-2,3,4-tri-*O*-methyl-1-thiosulfinyl-β-D-galactopyranoside (S33). *Via* general *S*-oxidation protocol starting with **8** (12 mg, 0.033 mmol); HRMS: $[M+Na]^+$ calcd for $C_{17}H_{17}O_7S$, 395.1140, found 395.1151.



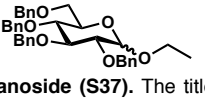
Phenyl 3-*O*-benzoyl-2,4,6-tri-*O*-benzyl-1-thiosulfinyl-β-D-mannopyranoside (S34). *Via* general *S*-oxidation protocol starting with **13** (20 mg, 0.031 mmol). HRMS: $[M+Na]^+$ calcd for $C_{40}H_{38}O_7S$, 685.2236, found 685.2208.



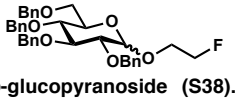
Phenyl 4-*O*-benzoyl-2,3,6-tri-*O*-benzyl-1-thiosulfinyl-β-D-mannopyranoside (S35). *Via* general *S*-oxidation protocol starting with **14** (20 mg, 0.031 mmol). HRMS: $[M+Na]^+$ calcd for $C_{40}H_{38}O_7S$, 685.2236, found 685.2206.



Phenyl 6-*O*-benzoyl-2,3,4-tri-*O*-benzyl-1-thiosulfinyl-β-D-mannopyranoside (S36). *Via* general *S*-oxidation protocol starting with **15** (20 mg, 0.031 mmol). HRMS: $[M+Na]^+$ calcd for $C_{40}H_{38}O_7S$, 685.2236, found 685.2208.

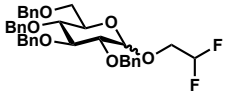


Ethyl 2,3,4,6-tetra-*O*-benzyl-D-glucopyranoside (S37). The title compound was prepared according to general procedure VII. Column chromatography (100:0 → 90:10, pentane:EtOAc) yielded the title compound (40 mg, 58 µmol, 70%, colorless oil, α:β; 15:85). TLC: R_f 0.50 (pentane:EtOAc, 90:10, v:v); IR (thin film, cm^{-1}): 733, 1026, 1065, 1358, 1452, 1497, 2864, 2901; Data of the major stereoisomer (β product): ^{1}H NMR (400 MHz, $CDCl_3$, HH-COSY, HSQC): δ 7.39 – 7.08 (m, 20H, CH_{arom}), 5.00 – 4.89 (m, 2H, C*H*H Bn, C*H*H Bn), 4.82 (d, *J* = 10.9 Hz, 1H, C*H*H Bn), 4.79 (d, *J* = 11.0 Hz, 1H, CH*H* Bn), 4.72 (d, *J* = 10.9 Hz, 1H, CH*H* Bn), 4.64 – 4.55 (m, 2H, C*H*H Bn), 4.52 (d, *J* = 10.6 Hz, 1H, CH*H* Bn), 4.40 (d, *J* = 7.8 Hz, 1H, H-1), 4.01 (dq, *J* = 9.5, 7.1 Hz, 1H, C*H*HCH$_3$ Et), 3.68 (t, *J* = 5.5 Hz, 1H, H-6), 3.63 (t, *J* = 8.7 Hz, 1H, H-3), 3.72 – 3.54 (m, 1H, CH*H*CH$_3$ Et) 3.57 (t, *J* = 9.2 Hz, 1H, H-4), 3.45 (dd, *J* = 8.9, 7.8 Hz, 1H, H-2), 3.50 – 3.41 (m, 1H, H-5), 1.29 (t, *J* = 7.1 Hz, 3H, CH_3 Et); ^{13}C NMR ($CDCl_3$, 101 MHz, HSQC): δ 138.8, 138.7, 138.3, 138.2 ($C_{q\text{-}arom}$), 128.5, 128.5, 128.5, 128.5, 128.3, 128.2, 128.1, 128.1, 128.0, 127.9, 127.9, 127.8, 127.7, 127.7 (CH_{arom}), 103.6 (C-1), 84.8 (C-3), 82.4 (C-2), 78.1 (C-4), 75.8 (CH_2 Bn), 75.1 (CH_2 Bn), 75.0 (C-5), 74.9 (CH_2 Bn), 73.6 (CH_2 Bn), 69.2 (C-6), 65.7 (*C*H$_2$CH$_3$ Et), 15.5 (CH_3 Et); Data of the minor stereoisomer (α product): ^{1}H NMR (400 MHz, $CDCl_3$, HH-COSY, HSQC): δ 5.00 (d, *J* = 10.9 Hz, 1H, C*H*H Bn), 4.76 (d, *J* = 3.7 Hz, 1H, H-1), 4.46 (d, *J* = 11.7 Hz, 1H, CH*H* Bn); ^{13}C NMR (101 MHz, $CDCl_3$, HSQC): δ 96.7 (C-1); HRMS: $[M+Na]^+$ calcd for $C_{36}H_{40}O_6$ 591.27171, found 591.27077.

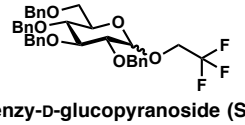


2-Fluoroethyl 2,3,4,6-tetra-*O*-benzy-D-glucopyranoside (S38). The title compound was prepared according to general procedure VII. Column chromatography (97:3 → 90:10, pentane:EtOAc) yielded the

title compound (44 mg, 75 µmol, 75%, colorless oil, α:β; 36:64). TLC: R_f 0.34, 0.46 (pentane:EtOAc, 85:15, v:v); IR (thin film, cm^{-1}): 695, 734, 1027, 1065, 1360, 1453, 1497, 2901; Data of the major stereoisomer (β product): ^{1}H NMR (400 MHz, $CDCl_3$, HH-COSY, HSQC): δ 7.41 – 7.08 (m, 20H, CH_{arom}), 5.01 – 4.90 (m, 2H, C*H*H Bn, CH*H* Bn), 4.87 – 4.42 (m, 9H, H-1, C*H*H Bn, CH*H* Bn, C*H*H Bn, CH*H* Bn, C*H*H Bn, CH*H* Bn, CH_2CHHF, CH_2CHHF), 4.12 (dddd, *J* = 33.2, 12.1, 4.5, 2.5 Hz, 1H, C*H*HCH_2F), 3.94 – 3.54 (m, 5H, H-3, H-4, H-6, H-6, CH*H*CH_2F), 3.49 (dd, *J* = 8.9, 7.8 Hz, 1H, H-2) 3.52 – 3.43 (m, 1H, H-5); ^{13}C NMR (101 MHz, $CDCl_3$, HSQC): ^{13}C NMR (101 MHz, $CDCl_3$): δ 138.9, 138.7, 138.5, 138.3, 138.2, 138.1, 138.0 ($C_{q\text{-}arom}$), 128.6, 128.5, 128.3, 128.1, 128.1, 128.0, 128.0, 128.0, 127.9, 127.8, 127.8, 127.8, 127.8, 127.7 (CH_{arom}), 103.9 (C-1), 84.7 (C-3), 82.7 (d, *J* = 169.8 Hz, CH_2F), 82.2 (C-2), 77.8 (C-4), 75.8 (C-5), 75.2 (CH_2 Bn), 75.0 (CH_2 Bn), 74.9 (CH_2 Bn), 73.6 (CH_2 Bn), 69.0 (d, *J* = 20.0 Hz, *C*H_2CH_2F), 68.9 (C-6); Data of the minor stereoisomer (α product): ^{1}H NMR (400 MHz, $CDCl_3$, HH-COSY, HSQC): ^{1}H NMR (400 MHz, $CDCl_3$, HH-COSY, HSQC): δ 4.79 (d, *J* = 3.7 Hz, 1H, H-1), 4.01 (t, *J* = 9.3 Hz, 1H, H-3); ^{13}C NMR (101 MHz, $CDCl_3$, HSQC): δ 97.5 (C-1), 82.6 (d, *J* = 169.9 Hz, CH_2F), 67.1 (d, *J* = 20.2 Hz, *C*H_2CH_2F); HRMS: $[M+Na]^+$ calcd for $C_{36}H_{39}FO_6$ 609.2628, found 609.2638.

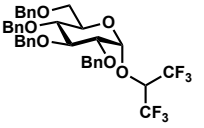


2,2-Difluoroethyl 2,3,4,6-tetra-*O*-benzy-D-glucopyranoside (S39). The title compound was prepared according to general procedure VII. Column chromatography (97:3 → 90:10, pentane:EtOAc) yielded the title compound (35 mg, 58 µmol, 58%, colorless oil, α:β; 48:52). TLC: R_f 0.31 (pentane:EtOAc, 90:10, v:v); IR (thin film, cm-1): 695, 733, 1027, 1066, 1360, 1453, 1497, 2865; Data of the major stereoisomer (β product): ^{1}H NMR (400 MHz, $CDCl_3$, HH-COSY, HSQC): δ 7.42 – 7.09 (m, 20H, CH_{arom}), 5.96 (tt, *J* = 55.1, 4.2 Hz, 1H, CHF_2), 4.93 (d, *J* = 10.9 Hz, 1H, C*H*H Bn), 4.90 (d, *J* = 11.0 Hz, 1H, C*H*H Bn), 4.84 – 4.74 (m, 2H, C*H*H Bn, CH*H* Bn), 4.70 (d, *J* = 10.8 Hz, 1H, C*H*H Bn), 4.63 (d, *J* = 12.1 Hz, 1H, C*H*H Bn), 4.60 (d, *J* = 11.1 Hz, 1H, CH*H* Bn), 4.53 (d, *J* = 12.2 Hz, 1H, CH*H* Bn), 4.43 (d, *J* = 7.6 Hz, 1H, H-1), 4.03 (dddd, *J* = 19.8, 11.8, 10.8, 3.4 Hz, 1H, CH*H*CHF_2), 3.86 – 3.55 (m, 5H, H-3, H-4, H-6, H-6, C*H*HCHF_2), 3.48 (dd, *J* = 9.0, 7.7 Hz, 1H, H-2) 3.48 – 3.44 (m, 1H, H-5); ^{13}C NMR (101 MHz, $CDCl_3$, HSQC): δ ^{13}C NMR (101 MHz, $CDCl_3$): δ 138.8, 138.6, 138.3, 138.1 ($C_{q\text{-}arom}$), 128.6, 128.5, 128.5, 128.2, 128.1, 128.0, 127.9, 127.9 (CH_{arom}), 114.2 (t, *J* = 241.3 Hz, CHF_2), 104.1 (C-1), 84.5 (C-3), 82.0 (C-2), 77.6 (C-4), 76.8 (CH_2 Bn), 75.9 (CH_2 Bn), 75.1 (CH_2 Bn), 75.0 (C-5), 73.6 (CH_2 Bn), 70.7, 68.8 (C-6), 67.3 (t, *J* = 28.8 Hz, *C*H_2CHF_2); Data of the minor stereoisomer (α product): ^{1}H NMR (400 MHz, $CDCl_3$, HH-COSY, HSQC): δ 4.75 (d, *J* = 3.6 Hz, 1H, H-1), 3.96 (t, *J* = 9.0 Hz, 1H, H-3); ^{13}C NMR (101 MHz, $CDCl_3$, HSQC): δ 98.0 (C-1), 73.6 (CH_2 Bn), 68.8 (t, *J* = 28.9 Hz, *C*H_2CHF_2) 68.3 (C-6); HRMS: $[M+Na]^+$ calcd for $C_{36}H_{38}F_2O_6$ 627.2534, found 627.2538.

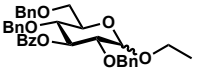


2,2,2-Trifluoroethyl 2,3,4,6-tetra-*O*-benzy-D-glucopyranoside (S40). The title compound was prepared according to general procedure VII. Column chromatography (97:3 → 90:10, pentane:EtOAc) yielded the title compound (50 mg, 80 µmol, 80%, colorless oil, α:β; 72:28). TLC: R_f 0.36 (pentane:EtOAc, 90:10, v:v); IR (thin film, cm^{-1}): 695, 734, 1027, 1047, 1070, 1154, 1277, 1361, 1453, 1497, 2899; Data of the major stereoisomer (α product): ^{1}H NMR (400 MHz, $CDCl_3$, HH-COSY, HSQC): δ 7.61 – 6.74 (m, 20H, CH_{arom}), 4.98 (d, *J* = 12.0 Hz, 1H, C*H*H Bn), 4.83 (d, *J* = 11.9 Hz, 1H, C*H*H Bn), 4.82 – 4.76 (m, 2H, C*H*H Bn, CH*H* Bn), 4.80 (d, *J* = 2.2 Hz, 1H, H-1), 4.63 (d, *J* = 12.0 Hz, 1H, CH*H* Bn), 4.59 (d, *J* = 12.1 Hz, 1H C*H*H Bn), 4.47 (d, *J* = 11.7 Hz, 1H, CH*H* Bn), 4.46 (d, *J* = 12.1 Hz, 1H, CH*H* Bn), 3.98 (dd, *J* = 9.7, 8.9 Hz, 1H, H-3), 3.88 (q, *J* = 8.7 Hz, 2H, C*H*$_2CF_3$), 3.81 – 3.61 (m, 3H, H-4, H-6, H-6), 3.59 (dd, *J* = 9.6, 3.6 Hz, 1H, H-2); ^{13}C NMR (101 MHz, $CDCl_3$, HSQC): δ 138.8, 138.6, 138.2, 138.1, 138.0, 137.8 ($C_{q\text{-}arom}$), 128.6, 128.6, 128.6, 128.5, 128.2, 128.1, 128.1, 128.0, 127.9, 127.9, 127.8, 127.8 (CH_{arom}), 128.2 (q, *J* = 279.5 Hz, CH_2*C*F_3), 97.9 (C-1), 81.7 (C-3), 79.8 (C-2), 77.3 (C-4), 75.9 (CH_2 Bn), 75.3 (CH_2 Bn), 73.6 (CH_2 Bn), 73.5 (CH_2 Bn), 71.0 (C-5), 68.2 (C-6), 64.8 (q, *J* = 34.9 Hz, *C*H_2CF_3); ^{13}C-GATED NMR (101 MHz, $CDCl_3$): δ 97.9 ($J_{H1\text{-}C1}$ = 171 Hz, α); Data of the minor stereoisomer (β product): ^{1}H NMR (400 MHz, $CDCl_3$, HH-COSY, HSQC): δ 4.93 (d, *J* = 10.9 Hz, 1H), 4.92 (d, *J* = 10.6 Hz, 1H, CHH Bn), 4.68 (d, *J* = 10.7 Hz, 1H, CHH Bn), 4.50 (d, *J* = 7.7 Hz, 1H, H-1), 4.22 (dq, *J* = 12.4, 8.7 Hz, 1H, C*H*$_2CF_3$), 3.50 (dd, *J* = 9.0, 7.6 Hz, 1H, H-2); ^{13}C NMR (101 MHz, $CDCl_3$, HSQC): δ 103.8 (C-1), 81.8 (C-3), 75.2 (CH_2 Bn), 75.1 (CH_2 Bn), 68.7 (C-6),

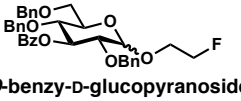
66.2 (q, *J* = 34.9 Hz, *C*H$_2$CF$_3$);^{13}C-GATED NMR (101 MHz, CDCl$_3$): δ 103.8 (J_{H1-C1} = 159 Hz, β); HRMS: [M+Na]$^+$ calcd for $C_{36}H_{37}F_3O_6$ 645.2440, found 645.2455.



1,1,1,3,3,3-Hexafluoro-2-propyl 2,3,4,6-tetra-*O*-benzyl-α-D-glucopyranoside (S41). The title compound was prepared according to general procedure VII. Column chromatography (100:0 → 80:20, pentane:Et$_2$O) yielded the title compound (29 mg, 41 µmol, 41%, colorless oil, α:β; >98:2). TLC: R$_f$ 0.13 (pentane:EtOAc, 95:5, v:v); $[\alpha]_D^{20}$ 20.5° (*c* 1, CHCl$_3$); IR (thin film, cm^{-1}): 687, 696, 736, 1103, 1219, 1287, 1369, 1454, 1498, 2917; ^{1}H NMR (500 MHz, CDCl$_3$, HH-COSY, HSQC, HMBC-Gated, ^{1}H-^{19}F decoupled): δ 7.36 – 7.25 (m, 20H, CH$_{arom}$), 5.14 (d, *J* = 3.8 Hz, 1H, H-1), 4.96 (d, *J* = 10.8 Hz, 1H, C*H*H Bn), 4.82 (dd, *J* = 10.7, 5.5 Hz, 2H, C*H*H Bn, CH*H* Bn), 4.70 (s, 2H, CH$_2$ Bn), 4.60 (d, *J* = 12.1 Hz, 1H, C*H*H Bn), 4.50 – 4.39 (m, 3H, CH*H* Bn, CH*H* Bn, C*H*(CF$_3$)$_2$), 3.96 (t, *J* = 9.5 Hz, 1H, H-3), 3.86 (dt, *J* = 10.1, 2.6 Hz, 1H, H-5), 3.76 (dd, *J* = 10.8, 3.1 Hz, 1H, H-6), 3.63 (dd, *J* = 9.8, 3.8 Hz, 1H, H-2), 3.60 (dd, *J* = 10.8, 2.1 Hz, 1H, H-6); ^{13}C NMR (126 MHz, CDCl$_3$, HSQC, HMBC-Gated): δ 138.7, 138.1, 137.8, 137.7 (C$_{q\text{-}arom}$), 128.6, 128.6, 128.5, 128.2, 128.1, 128.1, 128.0, 128.0, 127.8 (CH$_{arom}$), 99.6 (C-1), 81.3 (C-3), 79.0 (C-2), 77.1 (C-4), 75.9, 75.4, 73.7, 73.5 (CH$_2$ Bn), 72.9 (p, *J* = 33.2, *C*H(CF$_3$)$_2$), 72.0 (C-5), 67.9 (C-6); ^{13}C-GATED NMR (126 MHz, CDCl$_3$): δ 99.6 (J_{H1-C1} = 172 Hz, α); HRMS: [M+Na]$^+$ calcd for $C_{37}H_{36}F_6O_6$ 713.2314, found 713.2329.

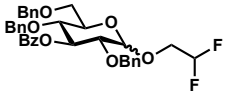


Ethyl 3-*O*-benzoyl-2,4,6-tri-*O*-benzy-D-glucopyranoside (S42). The title compound was prepared according to general procedure VII. Column chromatography (95:5 → 75:25, pentane:Et$_2$O) yielded the title compound (51 mg, 88 µmol, 88%, colorless oil, α:β; 40:60). TLC: R$_f$ 0.15 (pentane:Et$_2$O, 80:20, v:v); IR (thin film, cm^{-1}): 696, 711, 740, 1027, 1047, 1070, 1267, 1452, 1720, 2916, 3031; Data of the major stereoisomer (β product): ^{1}H NMR (500 MHz, CDCl$_3$, HH-COSY, HSQC): δ 7.95 – 6.93 (m, 20H, CH$_{arom}$), 5.49 (t, *J* = 9.5 Hz, 1H, H-4), 4.79 (d, *J* = 11.8 Hz, 1H, C*H*H Bn), 4.58 – 4.34 (m, 6H, H-1, CH*H* Bn, C*H*H Bn, CH*H* Bn, C*H*H Bn, CH*H* Bn), 4.03 (dq, *J* = 9.5, 7.1 Hz, 1H, C*H*HCH$_3$ Et), 3.87 – 3.53 (m, 4H, H-4, H-5, H-6, CH*H*CH$_3$ Et), 3.45 (dd, *J* = 9.6, 7.8 Hz, 1H, H-2), 1.31 (t, *J* = 7.1 Hz, 3H, CH$_3$ Et); ^{13}C NMR (126 MHz, CDCl$_3$, HSQC): δ 165.7 (C=O Bz), 138.1, 138.0, 137.6 (C$_{q\text{-}arom}$), 133.1, 131.2, 130.2, 129.9, 129.4, 128.5, 128.5, 128.4, 128.2, 128.2, 127.8, 127.5, 124.9 (CH$_{arom}$), 103.6 (C-1), 78.7 (C-2), 76.4 (C-3), 76.2 (C-4), 74.7 (C-5), 74.6 (CH$_2$ Bn), 73.9 (CH$_2$ Bn), 73.7 (CH$_2$ Bn), 68.7 (C-6), 65.8 (*C*H$_2$CH$_3$ Et), 15.5 (CH$_3$ Et); Data of the minor stereoisomer (α product): ^{1}H NMR (500 MHz, CDCl$_3$, HH-COSY, HSQC): δ 8.03 (dd, *J* = 8.4, 1.4 Hz, 2H, CH$_{arom}$ Bz), 5.82 (dd, *J* = 10.0, 9.1 Hz, 1H, H-3), 4.87 (d, *J* = 3.5 Hz, 1H, H-1), 1.25 (t, *J* = 7.1 Hz, 3H, CH$_3$ Et); ^{13}C NMR (126 MHz, CDCl$_3$, HSQC): δ 165.6 (C=O Bz), 96.5 (C-1), 68.3 (CH$_2$ Bn), 63.7 (C-5), 15.1 (CH$_3$ Et); HRMS: [M+NH$_4$]$^+$ calcd for $C_{36}H_{38}O_7$ 600.29558, found 600.29556.

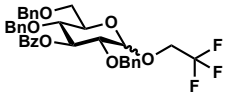


2-Fluoroethyl 3-*O*-benzoyl-2,4,6-tri-*O*-benzy-D-glucopyranoside (S43). The title compound was prepared according to general procedure VII. Column chromatography (95:5 → 75:25, pentane:Et$_2$O) yielded the title compound (57 mg, 95 µmol, 95%, colorless oil, α:β; 44:56). TLC: R$_f$ 0.15 (pentane:Et$_2$O, 70:30, v:v); IR (thin film, cm^{-1}): 697, 711, 742, 1026, 1046, 1070, 1090, 1269, 1452, 1724, 2869, 3030; Data of the major stereoisomer (β product): ^{1}H NMR (500 MHz, CDCl$_3$, HH-COSY, HSQC): δ 8.09 – 6.85 (m, 20H, CH$_{arom}$), 5.50 (t, *J* = 9.4 Hz, 1H, H-3), 4.80 (d, *J* = 11.7 Hz, 1H, C*H*H Bn), 4.57 (d, *J* = 7.6 Hz, 1H, H-1), 4.74 – 4.33 (m, 7H, CH*H* Bn, C*H*H Bn, CH*H* Bn, C*H*H Bn, CH*H* Bn, CH$_2$C*H*HF, CH$_2$CH*H*F), 4.14 (dddd, *J* = 32.2, 12.1, 4.8, 2.5 Hz, 1H, C*H*HCH$_2$F), 4.00 – 3.69 (m, 4H, CH*H*CH$_2$F, H-4, H-6, H-6), 3.56 (dt, *J* = 9.8, 3.1 Hz, 1H, H-5), 3.50 (dd, *J* = 9.6, 7.7 Hz, 1H, H-2); ^{13}C NMR (126 MHz, CDCl$_3$, HSQC): δ 165.7 (C=O Bz), 138.0, 137.9, 137.9, 137.8, 137.6, 137.5, 133.1, 133.0, 129.9, 129.9, 129.4, 128.5, 128.5, 128.4, 128.4, 128.3, 128.3, 128.3, 128.2, 128.1, 128.0, 128.0, 128.0, 127.9, 127.9, 127.8, 127.8, 127.6 (CH$_{arom}$), 103.9 (C-1), 82.7 (d, *J* = 170.1 Hz, CH$_2$F), 78.4 (C-2), 76.3 (C-3), 76.0 (C-4), 74.8 (C-5), 74.6 (CH$_2$ Bn), 74.6 (CH$_2$ Bn), 73.7 (CH$_2$ Bn), 69.1 (CH$_2$ Bn), 69.0 (d, *J* = 20.1 Hz, CH$_2$*C*H$_2$F), 68.5 (C-6); Data of the minor

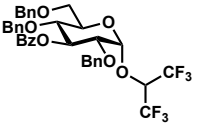
stereoisomer (α product): ^{1}H NMR (500 MHz, $CDCl_3$, HH-COSY, HSQC): δ 5.82 (dd, *J* = 10.0, 9.2 Hz, 1H, H-3), 4.92 (d, *J* = 3.5 Hz, 1H, H-1); ^{13}C NMR (126 MHz, $CDCl_3$, HSQC): δ 165.6 (C=O Bz), 97.2 (C-1), 82.7 (d, *J* = 169.9 Hz, CH_2F), 68.2 (C-6), 67.3 (d, *J* = 20.2 Hz, *C*H_2CH_2F); HRMS: $[M+NH_4]^+$ calcd for $C_{36}H_{37}FO_7$ 618.28616, found 618.28601.



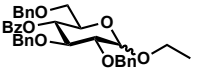
2,2-Difluoroethyl 3-*O*-benzoyl-2,4,6-tri-*O*-benzy-D-glucopyranoside (S44). The title compound was prepared according to general procedure VII. Column chromatography (95:5 → 70:30, pentane:Et_2O) yielded the title compound (60 mg, 97 µmol, 97%, colorless oil, α:β; 58:42). TLC: R_f 0.10 (pentane:Et_2O, 80:20, v:v); IR (thin film, cm^{-1}): 696, 711, 743, 1027, 1070, 1090, 1268, 1452, 1720, 2871, 3031; Data of the major stereoisomer (α product): ^{1}H NMR (500 MHz, $CDCl_3$, HH-COSY, HSQC): δ 8.17 – 6.80 (m, 20H, CH_{arom}), 5.97 (tt, *J* = 55.5, 4.3 Hz, 1H, CHF_2), 5.78 (dd, *J* = 10.0, 9.1 Hz, 1H, H-3), 4.87 (d, *J* = 3.6 Hz, 1H, H-1), 4.69 – 4.35 (m, 6H, C*H*H Bn, CH*H* Bn, C*H*H Bn, CH*H* Bn, C*H*H Bn, CH*H* Bn), 3.93 – 3.65 (m, 6H, H-4, H-5, H-6, H-6, C*H*HCHF$_2$, CH*H*CHF$_2$), 3.63 (dd, *J* = 6.5, 3.5 Hz, 1H, H-2); ^{13}C NMR (126 MHz, $CDCl_3$, HSQC): δ 165.6 (C=O, Bz), 137.9, 137.7, 137.7, 137.4 ($C_{q\text{-}arom}$), 133.1, 131.2, 130.3, 129.9, 129.4, 128.6, 128.6, 128.4, 128.3, 128.2, 128.1, 128.1, 128.0, 127.9, 127.9, 127.7 (CH_{arom}), 114.2 (t, *J* = 242.0 Hz, CHF_2), 97.7 (C-1), 77.0 (C-2), 76.1 (C-3), 75.8 (C-4), 74.7, 73.8, 72.8 (CH_2 Bn), 70.5 (C-5), 68.1, (C-6) 67.5 (t, *J* = 29.1 Hz, *C*H_2CHF_2); Data of the minor stereoisomer (β product): ^{1}H NMR (500 MHz, $CDCl_3$, HH-COSY, HSQC): δ 5.49 (t, *J* = 9.4 Hz, 1H, H-3), 4.76 (d, *J* = 11.7 Hz, 1H, C*H*H Bn), 4.69 – 4.35 (m, 6H, CH*H* Bn, C*H*H Bn, CH*H* Bn, C*H*H Bn, CH*H* Bn, H-1), 4.05 (dtd, *J* = 18.6, 11.5, 3.3 Hz, 1H, C*H*HCHF$_2$), 3.50 (dd, *J* = 9.5, 7.6 Hz, 1H, H-2); ^{13}C NMR (126 MHz, $CDCl_3$, HSQC): δ 165.6 (C=O Bz), 114.2 (t, *J* = 242.0 Hz, CHF_2), 104.1 (C-1), 78.4 (C-2), 76.1 (C-3), 68.8 (dd, *J* = 29.8, 27.4 Hz, *C*H_2CHF_2), 68.3 (C-6); HRMS: $[M+NH_4]^+$ calcd for $C_{36}H_{36}F_2O_7$ 636.27674, found 636.27659.



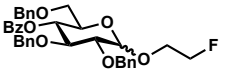
2,2,2-Trifluoroethyl 3-*O*-benzoyl-2,4,6-tri-*O*-benzy-D-glucopyranoside (S45). The title compound was prepared according to general procedure VII. Column chromatography (95:5 → 70:30, pentane:Et_2O) yielded the title compound (58 mg, 91 µmol, 91%, colorless oil, α:β; 76:24). TLC: R_f 0.2 (pentane:Et_2O, 80:20, v:v); IR (thin film, cm^{-1}): 696, 711, 745, 1027, 1072, 1093, 1161, 1270, 1452, 1720, 2926, 3032; Data of the major stereoisomer (α product): ^{1}H NMR (500 MHz, $CDCl_3$, HH-COSY, HSQC): δ 8.11 – 6.77 (m, 20H, CH_{arom}), 5.79 (dd, *J* = 10.0, 8.8 Hz, 1H, H-3), 4.89 (d, *J* = 3.6 Hz, 1H, H-1), 4.68 – 4.42 (m, 5H, C*H*H Bn, CH*H* Bn, C*H*H Bn, CH*H* Bn, C*H*H Bn), 4.38 (d, *J* = 10.8 Hz, 1H, CH*H* Bn), 3.90 (q, *J* = 8.7 Hz, 2H, C*H*$_2$CF$_3$), 3.88 – 3.86 (m, 1H, H-5), 3.84 (dd, *J* = 10.1, 8.9 Hz, 1H, H-4), 3.77 (dd, *J* = 10.8, 3.0 Hz, 1H, H-6), 3.65 (dd, *J* = 10.1, 3.6 Hz, 1H, H-2), 3.64 (dd, *J* = 9.0, 5.4 Hz, 1H, H-6); ^{13}C NMR (126 MHz, $CDCl_3$, HSQC): δ 165.6 (C=O Bz), 137.9, 137.8, 137.7, 137.5 ($C_{q\text{-}arom}$), 130.3, 130.0, 128.6, 128.6, 128.5, 128.4, 128.3, 128.2, 128.2, 128.2, 128.1, 128.0, 128.0, 127.9, 127.9 (CH_{arom}), 123.7 (q, *J* = 279.0 Hz, CF_3) 97.8 (C-1), 76.8 (C-2), 75.7 (C-4), 74.7 (CH_2 Bn), 73.9 (C-3), 73.8 (CH_2 Bn), 72.7 (CH_2 Bn), 70.8 (C-5), 68.0 (C-6), 65.2 (q, *J* = 35.0 Hz, *C*H_2CF_3); Data of the minor stereoisomer (β product): ^{1}H NMR (500 MHz, $CDCl_3$, HH-COSY, HSQC): δ 5.49 (t, *J* = 9.4 Hz, 1H, H-3), 4.77 (d, *J* = 11.7 Hz, 1H, C*H*H Bn), 4.68 – 4.42 (m, 5H, C*H*H Bn, CH*H* Bn, C*H*H Bn, CH*H* Bn, C*H*H Bn), 4.60 (d, *J* = 7.6 Hz, 1H, H-1), 4.41 (d, *J* = 10.8 Hz, 1H, CH*H* Bn), 4.24 (dt, *J* = 12.1, 8.7 Hz, 1H, C*H*$_2$CF$_3$), 3.97 (dq, *J* = 12.1, 8.4 Hz, 1H, C*H*$_2$CF$_3$), 3.51 (dd, *J* = 9.5, 7.6 Hz, 1H, H-2); ^{13}C NMR (126 MHz, $CDCl_3$, HSQC): δ 165.6 (C=O Bz), 103.7 (C-1), 76.0 (C-3), 74.6 (CH_2 Bn), 73.9 (CH_2 Bn), 73.7 (CH_2 Bn), 68.3 (C-6), 66.3 (q, *J* = 35.1 Hz, *C*H_2CF_3); HRMS: $[M+NH_4]^+$ calcd for $C_{36}H_{35}F_3O_7$ 654.26731, found 654.26721.



1,1,1,3,3,3-Hexafluoro-2-propyl 3-*O*-benzoyl-2,4,6-tri-*O*-benzyl-α-D-glucopyranoside (S46). The title compound was prepared according to general procedure VII. Column chromatography (100:0 → 80:20, pentane:Et_2O) yielded the title compound (20 mg, 28 µmol, 28%, colorless oil, α:β; >98:2). TLC: R_f 0.1 (pentane:Et_2O, 90:10, v:v); $[\alpha]_D^{25}$ 7.6° (*c* 1, $CHCl_3$); IR (thin film, cm^{-1}): 590, 867, 697, 710, 736, 1027, 1070, 1195, 1219, 1266, 1285, 1368, 1452, 1720, 2921, 3032; ^1H NMR (500 MHz, $CDCl_3$, HH-COSY, HSQC): δ 8.14 – 6.82 (m, 20H, CH_{arom}), 5.75 (t, *J* = 9.7 Hz, 1H, H-3), 5.21 (d, *J* = 3.8 Hz, 1H, H-1), 4.63 (d, *J* = 12.0 Hz, 1H, C*H*H Bn), 4.61 (d, *J* = 12.4 Hz, 1H, C*H*H Bn), 4.51 – 4.42 (m, 4H, C*H*H Bn, CH*H* Bn, CH*H* Bn, C*H*(CF_3)$_2$), 4.39 (d, *J* = 10.8 Hz, 1H, CH*H* Bn), 3.98 (dt, *J* = 10.0, 2.3 Hz, 1H, H-5), 3.85 (t, *J* = 9.7 Hz, 1H, H-4), 3.80 (dd, *J* = 10.9, 2.8 Hz, 1H, H-6), 3.71 (dd, *J* = 10.1, 3.8 Hz, 1H, H-2), 3.62 (dd, *J* = 10.9, 2.1 Hz, 1H, H-6); ^{13}C NMR (126 MHz, $CDCl_3$, HSQC): δ 137.6, 137.4 ($C_{q\text{-}arom}$), 133.3, 133.2, 130.0, 128.7, 128.5, 128.4, 128.3, 128.2, 128.2, 128.1, 127.9 (CH_{arom}), 99.3 (C-1), 75.8 (C-2), 75.4 (C-4), 74.9, 73.9 (CH_2 Bn), 73.6 (C-3), 72.5 (CH_2 Bn), 71.7 (C-5), 67.7 (C-6); HRMS: $[M+NH_4]^+$ calcd for $C_{37}H_{34}F_6O_7$ 722.25470, found 722.25415.

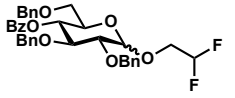


Ethyl 4-*O*-benzoyl-2,3,6-tri-*O*-benzy-D-glucopyranoside (S47). The title compound was prepared according to general procedure VII. Column chromatography 95:5 → 80:20, pentane:Et_2O) yielded the title compound (44 mg, 76 µmol, 76%, colorless oil, α:β; 15:85). TLC: R_f 0.30 (pentane:Et_2O, 80:20, v:v); IR (thin film, cm^{-1}): 696, 711, 735, 1027, 1043, 1266, 1452, 1720, 2869, 3031; Data of the major stereoisomer (β product): ^1H NMR (500 MHz, $CDCl_3$, HH-COSY, HSQC): δ 8.00 – 7.00 (m, 20H, CH_{arom}), 5.24 (dd, *J* = 10.0, 9.3 Hz, 1H, H-4), 4.96 (d, *J* = 10.9 Hz, 1H, C*H*H Bn), 4.77 (d, *J* = 11.2 Hz, 1H, C*H*H Bn), 4.74 (d, *J* = 10.9 Hz, 1H, CH*H* Bn), 4.61 (d, *J* = 11.2 Hz, 1H, CH*H* Bn), 4.50 (d, *J* = 7.8 Hz, 1H, H-1), 4.47 (m, 2H, C*H*H Bn, CH*H* Bn), 4.11 – 3.98 (m, 1H, C*H*HCH$_3$ Et), 3.75 (t, *J* = 9.3 Hz, 1H, H-3), 3.72 – 3.59 (m, 4H, H-5, CH*H*CH$_3$ Et, H-6, H-6), 3.56 (dd, *J* = 9.2, 7.8 Hz, 1H, H-2), 1.31 (t, *J* = 7.1 Hz, 3H, CH_3 Et); ^{13}C NMR (126 MHz, $CDCl_3$, HSQC): δ 165.5 (C=O Bz), 138.5, 138.4, 138.3, 138.1, 138.0, 137.9 ($C_{q\text{-}arom}$), 133.3, 129.9, 129.8, 128.5, 128.5, 128.3, 128.3, 128.3, 128.3, 128.2, 128.1, 127.9, 127.8, 127.6, 127.6, 127.5 (CH_{arom}), 103.5 (C-1), 82.2 (C-2), 81.6 (C-3), 75.2, 75.1 (CH_2 Bn), 73.8 (C-5), 73.8 (CH_2 Bn), 71.6 (C-4), 70.0 (C-6), 65.9 (*C*H$_2$CH$_3$ Et), 15.5 (CH_3 Et); Data of the minor stereoisomer (α product): ^1H NMR (500 MHz, $CDCl_3$, HH-COSY, HSQC): δ 5.32 (dd, *J* = 10.3, 9.3 Hz, 1H, H-4), 4.85 (d, *J* = 11.2 Hz, 1H, C*H*H Bn), 4.79 (d, *J* = 3.6 Hz, 1H, H-1), 4.66 (d, *J* = 12.1 Hz, 1H, CH*H* Bn); ^{13}C NMR (126 MHz, $CDCl_3$, HSQC): δ 165.4 (C=O Bz), 96.7 (C-1), 79.8, 79.5 (CH_2 Bn), 71.3 (C-4), 69.2 (C-6), 63.7 (*C*H$_2$CH$_3$ Et), 15.1 (CH_3 Et); HRMS: $[M+NH_4]^+$ calcd for $C_{36}H_{38}O_7$ 600.29558, found 600.29548.

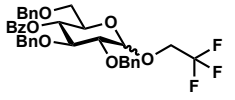


2-Fluoroethyl 4-*O*-benzoyl-2,3,6-tri-*O*-benzy-D-glucopyranoside (S48). The title compound was prepared according to general procedure VII. Column chromatography (90:10 → 60:40, pentane:Et_2O) yielded the title compound (49 mg, 82 µmol, 82%, colorless oil, α:β; 34:66). TLC: R_f 0.2 (pentane:Et_2O, 70:30, v:v); IR (thin film, cm^{-1}): 696, 711, 740, 1027, 1042, 1090, 1268, 1452, 1720, 2867, 3030; Data of the major stereoisomer (β product): ^1H NMR (500 MHz, $CDCl_3$, HH-COSY, HSQC): 7.97 – 7.12 (m, 20H, CH_{arom}), 5.25 (dd, *J* = 10.0, 9.3 Hz, 1H, H-4), 4.98 (d, *J* = 11.8 Hz, 1H, C*H*H Bn), 4.87 – 4.81 (m, 1H, CH*H* Bn), 4.78 (d, *J* = 11.2 Hz, 1H, C*H*H Bn), 4.73 (d, *J* = 11.8 Hz, 1H, CH*H* Bn), 4.71 – 4.57 (m, 4H, C*H*H Bn, CH*H* Bn, CH$_2$C*H*HF, CH$_2$CH*H*F), 4.55 (d, *J* = 7.8 Hz, 1H, H-1), 4.22 – 3.78 (m, 2H, C*H*HCH$_2$F, CH*H*CH$_2$F), 3.76 (t, *J* = 9.2 Hz, 1H, H-3), 3.75 – 3.65 (m, 1H, H-5), 3.64 – 3.57 (m, 3H, H-6, H-6, H-2); ^{13}C NMR (126 MHz, $CDCl_3$, HSQC): δ 165.5 (C=O Bz), 138.3, 138.0, 137.9 ($C_{q\text{-}arom}$), 133.3, 133.2, 131.2, 129.9, 129.7, 129.4, 128.6, 128.5, 128.4, 128.3, 128.1, 128.0, 127.9, 127.8, 127.8, 127.8, 127.7, 127.6, 127.6, 127.5 (CH_{arom}), 103.8 (C-1), 81.7 (d, *J* = 73.4 Hz, CH_2F), 81.5 (C-2), 75.2, 75.1 (CH_2 Bn), 73.8 (C-5), 73.7 (CH_2 Bn), 71.3 (C-4), 69.8 (C-6), 67.0 (d, *J* = 15.2 Hz, *C*H$_2$CH$_2$F); Data of the minor stereoisomer (α product): ^1H NMR (500 MHz, $CDCl_3$, HH-COSY, HSQC): δ 5.35 (dd, *J* = 10.3, 9.3 Hz, 1H, H-4), 4.09 (t, *J* = 9.4 Hz, 1H,

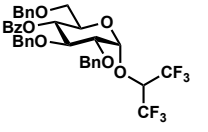
H-3), 4.84 – 4.80 (m, 2H, CH*H* Bn, H-1), 3.51 (dd, *J* = 10.9, 5.0 Hz, 1H, H-2); ^{13}C NMR (126 MHz, $CDCl_3$, HSQC): δ 165.4 (C=O Bz), 97.5 (C-1), 79.5 (d, *J* = 56.2 Hz, CH_2F), 71.0 (C-4), 67.4 (d, *J* = 19.9 Hz, *C*H_2CH_2F); HRMS: $[M+NH_4]^+$ calcd for $C_{36}H_{37}FO_7$ 618.28616, found 618.28582.



2,2-Difluoroethyl 4-*O*-benzoyl-2,3,6-tri-*O*-benzy-D-glucopyranoside (S49). The title compound was prepared according to general procedure VII. Column chromatography (95:5 →70:30, pentane:Et_2O) yielded the title compound (43 mg, 70 µmol, 70%, colorless oil, α:β; 48:52). TLC: R_f 0.25 (pentane:Et_2O, 80:20, v:v); IR (thin film, cm^{-1}): 697, 711, 738, 1027, 1093, 1268, 1452, 1720, 2869, 3032; Data of the major stereoisomer (β product): ^{1}H NMR (500 MHz, $CDCl_3$, HH-COSY, HSQC): δ 8.20 – 7.03 (m, 20H, CH_{arom}), 6.04 (tt, *J* = 55.5, 4.5 Hz, 1H, CHF_2), 5.33 (dd, *J* = 10.3, 9.3 Hz, 1H, H-4), 4.86 – 4.59 (m, 6H, CH_2 Bn, CH_2 Bn, CH_2 Bn, CH_2 Bn, CH_2 Bn, CH_2 Bn), 4.53 (d, *J* = 7.8 Hz, 1H, H-1), 4.13 – 3.96 (m, 1H, C*H*HCHF$_2$), 3.91 – 3.65 (m, 2H, CH*H*CHF$_2$, H-5), 3.75 (t, *J* = 9.2 Hz, 1H, H-3), 3.64 – 3.53 (m, 3H, H-6, H-6, H-2); ^{13}C NMR (126 MHz, $CDCl_3$, HSQC): δ 165.4 (C=O Bz), 138.2, 138.2, 138.0, 137.9, 137.8, 137.7 ($C_{q\text{-}arom}$), 129.8, 129.7, 128.6, 128.5, 128.5, 128.4, 128.4, 128.4, 128.4, 128.3, 128.3, 128.3, , 128.0, 127.7, 127.6 (CH_{arom}), 114.2 (t, *J* = 241.3 Hz, CHF_2), 104.0 (C-1), 81.9 (C-2), 81.4 (C-3), 75.6 (CH_2 Bn), 75.3 (CH_2 Bn), 73.9 (C-5), 73.8 (CH_2 Bn), 71.2 (C-4), 68.8 (C-6), 67.7 (t, *J* = 28.8 Hz, *C*H_2CHF$_2$); Data of the minor stereoisomer (α product): ^{1}H NMR (500 MHz, $CDCl_3$, HH-COSY, HSQC): δ 6.0 (dddd, *J* = 56.0, 54.8, 5.3, 3.0 Hz, 1H, CHF_2), 5.3 (dd, *J* = 10.0, 9.3 Hz, 1H, H-4), 4.91 (d, *J* = 11.8 Hz, 1H, C*H*H Bn), 4.78 (d, *J* = 3.7 Hz, 1H, H-1), 4.04 (t, *J* = 9.5 Hz, 1H, H-3); ^{13}C NMR (126 MHz, $CDCl_3$, HSQC): δ 165.4 (C=O Bz), 114.2 (dd, *J* = 242.2, 239.9 Hz, CHF_2), 98.3 (C-1), 70.8 (C-4), 69.6 (C-6), 68.9 (dd, *J* = 30.4, 26.6 Hz, *C*H_2CHF$_2$); HRMS: $[M+NH_4]^+$ calcd for $C_{36}H_{36}F_2O_7$ 636.27674, found 636.27675.

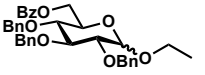


2,2,2-Trifluoroethyl 4-*O*-benzoyl-2,3,6-tri-*O*-benzy-D-glucopyranoside (S50). The title compound was prepared according to general procedure VII. Column chromatography (95:5 → 80:20, pentane:Et_2O) yielded the title compound (49 mg, 76 µmol, 76%, colorless oil, α:β; 79:21). TLC: R_f 0.4 (pentane:Et_2O, 80:20, v:v); IR (thin film, cm^{-1}): 697, 711, 738, 1027, 1070, 1093, 1161, 1270, 1452, 1720, 2959, 2910, 3032; Data of the major stereoisomer (α product): ^{1}H NMR (500 MHz, $CDCl_3$, HH-COSY, HSQC): δ 8.07 – 6.88 (m, 20H, CH_{arom}), 5.35 (dd, *J* = 10.3, 9.3 Hz, 1H, H-4), 4.87 – 4.78 (m, 3H, C*H*H Bn, CH*H* Bn, H-1), 4.67 – 4.60 (m, 2H, C*H*H Bn, CH*H* Bn), 4.50 – 4.41 (m, 2H, C*H*H Bn, CH*H* Bn), 4.06 (t, *J* = 9.5 Hz, 1H, H-3), 4.00 – 3.87 (m, 3H, CH_2CF$_3$, H-5), 3.70 (dd, *J* = 9.6, 3.6 Hz, 1H, H-2), 3.55 (dd, *J* = 10.9, 2.7 Hz, 1H, H-6), 3.50 (dd, *J* = 10.9, 5.0 Hz, 1H, H-6); ^{13}C NMR (126 MHz, $CDCl_3$, HSQC): δ 165.3 (C=O Bz), 138.2, 138.0, 137.7 ($C_{q\text{-}arom}$), 129.7, 128.6, 128.5, 128.4, 128.3, 128.2, 128.2, 128.0, 127.8, 127.7, 127.6, 127.2, 123.9 (q, *J* = 278.7 Hz, CF_3), 97.9 (C-1), 79.5 (C-2), 78.9 (C-3), 75.6, 73.8, 73.6 (CH_2 Bn), 70.6 (C-4), 69.9 (C-5), 68.7 (C-6), 64.9 (q, *J* = 34.9 Hz, *C*H_2CF$_3$); Data of the minor stereoisomer (β product): ^{1}H NMR (500 MHz, $CDCl_3$, HH-COSY, HSQC): δ 5.26 (dd, *J* = 10.0, 9.3 Hz, 1H, H-4), 4.93 (d, *J* = 10.6 Hz, 1H, C*H*H Bn), 4.60 (d, *J* = 7.1 Hz, 1H, H-1), 3.75 (t, *J* = 9.2 Hz, 1H, H-3); ^{13}C NMR (126 MHz, $CDCl_3$, HSQC): δ 103.6 (C-1), 81.7 (C-2), 81.2 (C-3), 71.0 (C-4) 69.4 (C-6); HRMS: $[M+NH_4]^+$ calcd for $C_{36}H_{35}F_3O_7$ 654.26731, found 654.26708.

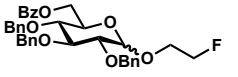


1,1,1,3,3,3-Hexafluoro-2-propyl 4-*O*-benzoyl-2,3,6-tri-*O*-benzyl-α-D-glucopyranoside (S51). The title compound was prepared according to general procedure VII. Column chromatography (100:0 → 80:20, pentane:Et_2O) yielded the title compound (13 mg, 19 µmol, 19%, colorless oil, α:β; >98:2). TLC: R_f 0.1 (pentane:Et_2O, 90:10, v:v); $[\alpha]_D^{25}$ 0.7° (*c* 1, $CHCl_3$); IR (thin film, cm^{-1}): 538, 688, 696, 711, 741, 1027, 1068, 1104, 1196, 1219, 1264, 1286, 1452, 1720, 2924, 3032; ^{1}H NMR (500 MHz, CDCl3, HH-COSY, HSQC): δ

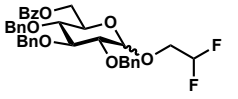
8.42 – 6.93 (m, 20H, CH_{arom}), 5.42 (dd, *J* = 10.3, 9.4 Hz, 1H, H-4), 5.16 (d, *J* = 3.7 Hz, 1H, H-1), 4.82 (d, *J* = 11.1 Hz, 1H, C*H*H Bn), 4.74 (d, *J* = 11.6 Hz, 1H, C*H*H Bn), 4.70 (d, *J* = 11.6 Hz, 1H, CH*H* Bn), 4.61 (d, *J* = 11.1 Hz, 1H, CH*H* Bn), 4.55 – 4.47 (m, 2H, CH*H* Bn, C*H*(CF_3)$_2$), 4.42 (d, *J* = 12.0 Hz, 1H, CH*H* Bn), 4.13 – 4.05 (m, 1H, H-5), 4.04 (t, *J* = 9.6 Hz, 1H, H-3), 3.75 (dd, *J* = 9.8, 3.8 Hz, 1H, H-2), 3.55 (dd, *J* = 11.0, 2.6 Hz, 1H, H-6), 3.50 (dd, *J* = 11.0, 4.4 Hz, 1H, H-6); ^{13}C NMR (126 MHz, $CDCl_3$, HSQC): δ 165.3 (C=O Bz), 133.4, 131.2 ($C_{q\text{-}arom}$), 129.9, 129.5, 128.6, 128.6, 128.4, 128.3, 128.2, 128.2, 128.1, 127.9, 127.7, 127.7 (CH_{arom}), 99.5 (C-1), 77.2 (C-2), 76.9 (C-3), 75.6, 73.8, 73.7 (CH_2 Bn), 70.8 (C-5), 70.1 (C-4), 68.2 (C-6); HRMS: $[M+NH_4]^+$ calcd for $C_{37}H_{34}F_6O_7$ 722.25470, found 722.25434.



Ethyl 6-*O*-benzoyl-2,3,4-tri-*O*-benzy-D-glucopyranoside (S52). The title compound was prepared according to general procedure VII. Column chromatography (95:5 → 75:25, pentane:Et_2O) yielded the title compound (55 mg, 94 µmol, 94%, colorless oil, α:β; 17:83). TLC: R_f 0.30 (pentane:Et_2O, 80:20, v:v); IR (thin film, cm^{-1}): 695, 711, 735, 1026, 1066, 1272, 1720, 2904, 3030; Data of the major stereoisomer (β product): ^{1}H NMR (500 MHz, $CDCl_3$, HH-COSY, HSQC): δ 8.27 – 7.12 (m, 20H, CH_{arom}), 4.98 (d, *J* = 11.0 Hz, 1H, C*H*H Bn), 4.97 (d, *J* = 10.8 Hz, 1H, C*H*H Bn), 4.89 (d, *J* = 10.7 Hz, 1H, C*H*H Bn), 4.82 (d, *J* = 10.7 Hz, 1H, CH*H* Bn), 4.75 (d, *J* = 10.8 Hz, 1H, CH*H* Bn), 4.60 (m, 2H, CH*H* Bn, H-6), 4.54 – 4.42 (m, 2H, H-6, H-1), 3.98 (dq, *J* = 9.3, 7.2 Hz, 1H, C*H*$_2$CH$_3$ Et), 3.71 (t, *J* = 8.6 Hz, 1H, H-3), 3.71 – 3.55 (m, 3H, C*H*$_2$CH$_3$ Et, H-4, H-5), 3.49 (t, *J* = 8.3 Hz, 1H, H-2), 1.28 (t, *J* = 7.2 Hz, 3H, CH$_2$C*H*$_3$ Et); ^{13}C NMR (126 MHz, $CDCl_3$, HSQC): δ 166.4 (C=O Bz), 133.2, 133.1, 130.2 ($C_{q\text{-}arom}$), 129.8, 129.8, 128.6, 128.6, 128.6, 128.5, 128.5, 128.3, 128.2, 128.2, 128.2, 128.1, 128.1, 127.9, 127.9 (CH_{arom}), 103.7 (C-1), 84.8 (C-3), 82.4 (C-2), 77.8 (C-4), 76.0, 75.3, 75.0 (CH_2 Bn), 73.1 (C-5), 65.9 (*C*H$_2$CH$_3$ Et), 63.7 (C-6), 15.5 (CH$_3$ Et); Data of the minor stereoisomer (α product): ^{1}H NMR (500 MHz, $CDCl_3$, HH-COSY, HSQC): δ 5.04 (d, *J* = 10.6 Hz, 1H, C*H*H Bn), 4.92 (d, *J* = 10.7 Hz, 1H, C*H*H Bn), 4.85 (d, *J* = 10.5 Hz, 1H, CH*H* Bn), 4.77 (signal overlaps with major isomer, 1H, H-1), 4.67 (d, *J* = 12.1 Hz, 1H, CH*H* Bn), 4.08 (t, *J* = 9.2 Hz, 1H, H-3); ^{13}C NMR (126 MHz, $CDCl_3$, HSQC): δ 96.5 (C-1), 82.3 (C-3), 80.3 (C-2), 77.8 (C-4), 76.1, 75.4, 73.4 (CH_2 Bn), 68.9 (C-5), 63.6 (*C*H$_2$CH$_3$ Et), 63.6 (C-6), 15.1 (CH$_3$ Et); HRMS: $[M+NH_4]^+$ calcd for $C_{36}H_{38}O_7$ 600.29558, found 600.29595.

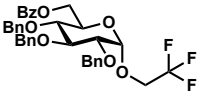


2-Fluoroethyl 6-*O*-benzoyl-2,3,4-tri-*O*-benzy-D-glucopyranoside (S53). The title compound was prepared according to general procedure VII. Column chromatography (90:10 → 60:40, pentane:Et_2O) yielded the title compound (50 mg, 83 µmol, 83%, colorless oil, α:β; 35:65). TLC: R_f 0.2 (pentane:Et_2O, 70:30, v:v); IR (thin film, cm^{-1}): 696, 712, 736, 1026, 1067, 1154, 1273, 1452, 1720; Data of the major stereoisomer (β product): ^{1}H NMR (500 MHz, $CDCl_3$, HH-COSY, HSQC): δ 8.12 – 6.99 (m, 20H, CH_{arom}), 4.98 (m, 2H, C*H*H Bn, C*H*H Bn), 4.87 (m, 1H, CH*H* Bn), 4.85 – 4.78 (m, 3H, C*H*H Bn, CH*H* Bn, CH*H* Bn), 4.69 – 4.48 (m, 4H, H-6, H-6, CH$_2$C*H*HF, CH$_2$CH*H*F), 4.50 (d, *J* = 7.7 Hz, 1H, H-1), 4.13 – 4.00 (m, 1H, C*H*HCH$_2$F), 3.92 – 3.75 (m, 1H, CH*H*CH$_2$F), 3.72 (t, *J* = 8.8 Hz, 1H, H-3), 3.69 – 3.58 (m, 2H, H-4, H-5), 3.53 (dd, *J* = 8.9, 7.8 Hz, 1H, H-2); ^{13}C NMR (126 MHz, $CDCl_3$, HSQC): δ 166.3 (C=O Bz), 138.5, 138.4, 137.7 ($C_{q\text{-}arom}$), 129.8, 128.6, 128.6, 128.6, 128.5, 128.5, 128.5, 128.3, 128.1, 128.1, 127.9 (CH_{arom}), 104.0 (C-1), 84.7 (C-3), 82.7 (d, *J* = 169.9 Hz, CH$_2$F) 82.2 (C-2), 77.6 (C-4), 76.0, 75.3, 73.2 (CH_2 Bn), 69.1 (d, *J* = 19.8 Hz, *C*H$_2$CH$_2$F), 63.5 (C-6); Data of the minor stereoisomer (α product): ^{1}H NMR (500 MHz, $CDCl_3$, HH-COSY, HSQC): δ 5.03 (d, *J* = 10.6 Hz, 1H, C*H*H Bn), 4.81 (d, *J* = 2.0 Hz, 1H, H-1), 4.08 (t, *J* = 9.4 Hz, 1H, H-3); ^{13}C NMR (126 MHz, $CDCl_3$, HSQC): 97.3 (C-1), 82.6 (d, *J* = 170.2 Hz, CH$_2$F), 67.2 (d, *J* = 20.2 Hz, *C*H$_2$CH$_2$F), 63.5 (C-6); HRMS: $[M+NH_4]^+$ calcd for $C_{36}H_{37}FO_7$ 618.28616, found 618.28612.

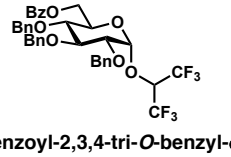


2,2-Difluoroethyl 6-*O*-benzoyl-2,3,4-tri-*O*-benzy-D-glucopyranoside (S54). The title compound was prepared according to general procedure VII. Column chromatography (95:5 → 75:25, pentane:Et_2O) yielded the title compound (51 mg, 82 µmol, 82%, colorless oil, α:β; 77:23). TLC: R_f 0.30 (pentane:Et_2O, 80:20, v:v); IR (thin film, cm^{-1}): 696, 711, 737, 1274, 1452, 1720, 2917, 3032; Data of the major stereoisomer

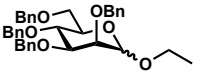
(α product): ^{1}H NMR (500 MHz, $CDCl_3$, HH-COSY, HSQC): δ 8.07 – 7.04 (m, 20H, CH_{arom}), 5.97 (tt, *J* = 55.5, 4.3 Hz, 1H, CHF_2), 5.01 (d, *J* = 10.6 Hz, 1H, C*H*H Bn), 4.92 (d, *J* = 10.8 Hz, 1H, C*H*H Bn), 4.85 (d, *J* = 10.6 Hz, 1H, CH*H* Bn), 4.81 (d, *J* = 11.9 Hz, 1H CH*H* Bn), 4.75 (d, *J* = 3.6 Hz, 1H, H-1), 4.68 – 4.59 (m, 2H, C*H*H Bn, CH*H* Bn), 4.54 (dd, *J* = 12.0, 2.2 Hz, 1H, H-6), 4.52 – 4.43 (m, 1H, H-6), 4.04 (t, *J* = 9.3 Hz, 1H, H-3), 4.00 (ddd, *J* = 10.2, 4.7, 2.1 Hz, 1H, H-5), 3.86 – 3.56 (m, 4H, H-2, H-4, C*H*HCHF$_2$, CH*H*CHF$_2$); ^{13}C NMR (126 MHz, $CDCl_3$, HSQC): δ 166.3 (C=O Bz), 138.6, 138.1, 137.7 ($C_{q\text{-}arom}$), 129.7, 128.7, 128.6, 128.6, 128.5, 128.4, 128.2, 128.2, 128.2, 127.9 (CH_{arom}), 114.1 (t, *J* = 241.4 Hz, CHF_2), 97.8 (C-1), 81.9 (C-3), 80.1 (C-2), 77.5 (C-4), 76.1, 75.4, 73.7 (CH_2 Bn), 69.5 (C-5), 67.3 (t, *J* = 28.8 Hz, *C*H$_2$CHF$_2$), 63.4 (C-6); Data of the minor stereoisomer (β product): ^{1}H NMR (500 MHz, $CDCl_3$, HH-COSY, HSQC): δ 6.12 – 5.64 (m, 1H CHF_2), 4.97 (d, *J* = 10.8 Hz, 1H, C*H*H Bn), 4.73 (d, *J* = 10.9 Hz, 1H, CH*H* Bn), 4.49 (d, *J* = 7.8 Hz, 1H, H-1), 3.51 (dd, *J* = 9.0, 7.7 Hz, 1H, H-2); ^{13}C NMR (126 MHz, $CDCl_3$, HSQC): δ 104.2 (C-1), 84.6 (C-3), 82.1 (C-2), 76.0, 75.3, 75.1 (CH_2 Bn), 68.9 (dd, *J* = 29.8, 27.3 Hz, *C*H$_2$CHF$_2$), 63.3 (C-6); HRMS: $[M+NH_4]^+$ calcd for $C_{36}H_{36}F_2O_7$ 636.27674, found 636.27645.



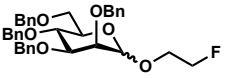
2,2,2-Trifluoroethyl 3-*O*-benzoyl-2,3,4-tri-*O*-benzyl-α-D-glucopyranoside (S55). The title compound was prepared according to general procedure VII. Column chromatography (95:5 → 80:20, pentane:Et_2O) yielded the title compound (52 mg, 82 µmol, 82%, colorless oil, α:β; 95:5). TLC: R_f 0.45 (pentane:Et_2O, 80:20, v:v); $[\alpha]_D^{25}$ 40.2° (*c* 1, $CHCl_3$); IR (thin film, cm^{-1}): 696, 711, 736, 1027, 1070, 1273, 1452, 1720, 2920, 3032; Data of the major stereoisomer (α product): ^{1}H NMR (500 MHz, $CDCl_3$, HH-COSY, HSQC): δ 8.71 – 6.95 (m, 20H, CH_{arom}), 5.02 (d, *J* = 10.6 Hz, 1H, C*H*H Bn), 4.92 (d, *J* = 10.8 Hz, 1H, C*H*H Bn), 4.85 (d, *J* = 10.6 Hz, 1H, CH*H* Bn), 4.85 (d, *J* = 3.6 Hz, 1H, H-1) 4.82 (m, 1H, CH*H* Bn), 4.64 (m, 1H, C*H*H Bn, CH*H* Bn) 4.54 (dd, *J* = 12.0, 2.2 Hz, 1H, H-6), 4.47 (dd, *J* = 12.1, 4.5 Hz, 1H, H-6), 4.05 (dd, *J* = 9.7, 8.9 Hz, 1H, H-3), 3.97 (ddd, *J* = 10.1, 4.5, 2.2 Hz, 1H, H-5), 3.89 (qd, *J* = 8.7, 7.0 Hz, 2H, C*H*$_2$CF$_3$), 3.63 (t, *J* = 10.0 Hz, 1H, H-4), 3.60 (dd, *J* = 9.6, 3.7 Hz, 1H, H-2); ^{13}C NMR (126 MHz, $CDCl_3$, HSQC): δ 166.2 (C=O Bz), 138.6, 138.1, 137.7 ($C_{q\text{-}arom}$), 129.9, 129.7, 128.7, 128.7, 128.6, 128.6, 128.6, 128.5, 128.3, 128.2, 128.2, 128.2, 128.2, 128.1, 128.1, 128.0, 127.1 (CH_{arom}), 123.8 (q, *J* = 278.8 Hz, CF_3), 97.7 (C-1), 81.7 (C-3), 80.0 (C-2), 77.3 (C-4), 76.1, 75.4, 73.5 (CH_2 Bn), 65.3 (C-5), 64.9 (q, *J* = 35.0 Hz, *C*H$_2$CF$_3$), 63.2 (C-6); Data of the minor stereoisomer (β product): ^{1}H NMR (500 MHz, $CDCl_3$, HH-COSY, HSQC): 1H NMR (500 MHz, $CDCl_3$): δ 5.06 (d, *J* = 10.7 Hz, 1H, C*H*H Bn), 4.70 (d, *J* = 10.6 Hz, 1H, CH*H* Bn), 4.18 (dq, *J* = 12.3, 8.8 Hz, 1H, C*H*$_2$CF$_3$), 3.53 (dd, *J* = 8.7, 7.7 Hz, 1H, H-2); ^{13}C NMR (126 MHz, $CDCl_3$, HSQC): 103.8 (C-1), 84.5 (C-3), 81.9 (C-2); HRMS: $[M+NH_4]^+$ calcd for $C_{36}H_{35}F_3O_7$ 654.26731, found 654.26723.



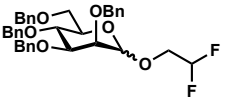
1,1,1,3,3,3-Hexafluoro-2-propyl 6-*O*-benzoyl-2,3,4-tri-*O*-benzyl-α-D-glucopyranoside (S56). The title compound was prepared according to general procedure VII. Column chromatography (100:0 → 80:20, pentane:Et_2O) yielded the title compound (21 mg, 30 µmol, 30%, colorless oil, α:β; >98:2). TLC: R_f 0.1 (pentane:Et_2O, 90:10, v:v); $[\alpha]_D^{25}$ 49.0° (*c* 1, $CHCl_3$); IR (thin film, cm^{-1}): 595, 698, 712, 750, 1027, 1105, 1198, 1278, 1454, 1720, 2933, 3035; ^{1}H NMR (500 MHz, $CDCl_3$, HH-COSY, HSQC): δ 8.07 – 7.16 (m, 20H, CH_{arom}), 5.15 (d, *J* = 3.8 Hz, 1H, H-1), 5.00 (d, *J* = 10.6 Hz, 1H, C*H*H Bn), 4.93 (d, *J* = 10.7 Hz, 1H, C*H*H Bn), 4.85 (d, *J* = 10.6 Hz, 1H, CH*H* Bn), 4.76 – 4.66 (m, 2H, C*H*H Bn, CH*H* Bn), 4.63 (d, *J* = 10.7 Hz, 1H, CH*H* Bn), 4.56 (dd, *J* = 12.1, 2.1 Hz, 1H, H-6), 4.46 (m, 2H, H-6, C*H*(CF$_3$)$_2$), 4.09 (ddd, *J* = 10.2, 4.3, 2.1 Hz, 1H, H-5), 4.04 (dd, *J* = 9.8, 9.0 Hz, 1H, H-3), 3.78 – 3.59 (m, 2H, H-4, H-2); ^{13}C NMR (126 MHz, $CDCl_3$, HSQC): δ 166.2 (C=O Bz), 138.4, 137.6, 137.5 ($C_{q\text{-}arom}$), 133.4, 129.8, 129.7, 128.7, 128.6, 128.6, 128.3, 128.3, 128.3, 128.2, 128.2, 128.2, 128.0, 127.7 (CH_{arom}), 99.2 (C-1), 81.2 (C-3), 79.2 (C-2), 77.4 (C-4), 76.9, 76.1, 73.7 (CH_2 Bn), 72.9 (p, *J* = 33.6 Hz, *C*H(CF$_3$)$_2$), 62.9 (C-6); HRMS: $[M+NH_4]^+$ calcd for C37H34F6O7 722.25470, found 722.25454.



Ethyl 2,3,4,6-tetra-*O*-benzy-D-mannopyranoside (S57). The title compound was prepared according to general procedure VII. Column chromatography (100:0 → 90:10, pentane:EtOAc) yielded the title compound (40 mg, 70 µmol, 70%, colorless oil, α:β; 33:67). TLC: R_f 0.25 (pentane:EtOAc, 90:10, v:v); Data of the major stereoisomer (β product): ^{1}H NMR (400 MHz, $CDCl_3$, HH-COSY, HSQC): δ 7.50 – 7.14 (m, 20H, CH_{arom}), 4.99 (d, *J* = 12.5 Hz, 1H, C*H*H Bn), 4.93 – 4.84 (m, 2H, C*H*H Bn, CH*H* Bn), 4.69 – 4.58 (m, 4H, C*H*H Bn, CH*H* Bn, C*H*H Bn, CH*H* Bn), 4.44 (d, J = 11.8 Hz, 1H, CH*H* Bn), 4.38 (s, 1H, H-1), 4.07 – 3.97 (m, 1H, C*H*HCH$_3$ Et), 3.97 – 3.67 (m, 5H, CH*H*CH$_3$ Et, H-2, H-4, H-6, H-6), 3.57 – 3.36 (m, 3H, CH*H*CH$_3$ Et, H-5, H-3), 1.27 (t, *J* = 7.0 Hz, 3H, CH$_3$ Et); ^{13}C NMR (101 MHz, $CDCl_3$, HSQC): δ 139.0, 138.6, 138.5, 138.3 ($C_{q\text{-}arom}$), 128.6, 128.5, 128.4, 128.4, 128.2, 128.2, 128.0, 127.9, 127.9, 127.8, 127.7, 127.7, 127.6, 127.6, 127.6, 127.5 (CH_{arom}), 101.6 (C-1), 82.5 (C-3), 76.1 (C-5), 75.3 (CH_2 Bn), 75.1 (C-4), 73.9 (CH_2 Bn), 73.9 (H-2), 73.6 (CH_2 Bn), 71.5 (CH_2 Bn), 69.9 (C-6), 65.4 (*C*H$_2$CH$_3$ Et), 15.4 (CH$_3$ Et); ^{13}C-GATED NMR (101 MHz, $CDCl_3$): δ 101.6 ($J_{H1\text{-}C1}$ = 153 Hz, β); Data of the minor stereoisomer (α product): ^{1}H NMR (400 MHz, $CDCl_3$, HH-COSY, HSQC): δ 4.93 – 4.84 (signals overlap with major isomer, 1H, H-1), 4.76 (d, *J* = 12.5 Hz, 1H, C*H*H Bn), 4.72 (d, *J* = 12.5 Hz, 1H, CH*H* Bn), 1.15 (t, *J* = 7.1 Hz, 3H, CH$_3$ Et); ^{13}C NMR (101 MHz, $CDCl_3$, HSQC): 97.8 (C-1), 80.5 (C-3), 69.5 (C-6), 63.0 (*C*H$_2$CH$_3$ Et), 15.1 (CH$_3$ Et); ^{13}C-GATED NMR (101 MHz, $CDCl_3$): δ 97.8 ($J_{H1\text{-}C1}$ = 168 Hz, α); HRMS: $[M+Na]^+$ calcd for $C_{36}H_{40}O_6Na$ 591.27171, found 591.27096.

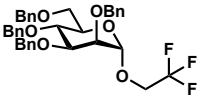


2-Fluoroethyl 2,3,4,6-tetra-*O*-benzy-D-mannopyranoside (S58). The title compound was prepared according to general procedure VII. Column chromatography (97:3 → 90:10, pentane:EtOAc) yielded the title compound (44 mg, 75 µmol, 75%, colorless oil, α:β; 60:40). TLC: R_f 0.24, 0.34 (pentane:EtOAc, 85:15, v:v); IR (thin film, cm^{-1}): 695, 734, 1026, 1073, 1362, 1453, 1496, 2910; Data of the major stereoisomer (α product): ^{1}H NMR (400 MHz, $CDCl_3$, HH-COSY, HSQC): 7.57 – 7.07 (m, 20H, CH_{arom}), 4.98 – 4.83 (m, 2H, C*H*H Bn, CH*H* Bn), 4.93 (d, *J* = 1.9 Hz, 1H, H-1), 4.76 (d, *J* = 12.4 Hz, 1H, C*H*H Bn), 4.72 (d, *J* = 12.5 Hz, 1H, CH*H* Bn), 4.68 – 4.39 (m, 6H, C*H*H Bn, CH*H* Bn, C*H*H Bn, CH*H* Bn, CH$_2$C*H*HF, CH$_2$CH*H*F), 4.04 – 3.59 (m, 12H, H-2, H-3, H-4, H-5, H-6, H-6, C*H*HCH$_2$F, CH*H*CH$_2$F); ^{13}C NMR (101 MHz, $CDCl_3$, HSQC): δ 138.7, 138.6, 138.4, 138.4 ($C_{q\text{-}arom}$), 128.5, 128.4, 128.4, 128.1, 127.7, 127.6, 127.6, 127.6, 127.6, 127.5 (CH_{arom}), 98.2 (C-1), 82.6 (d, *J* = 169.8 Hz, CH_2F), 80.2 (C-3), 75.3 (CH_2 Bn), 74.9 (C-2), 74.6 (C-4), 73.5, 72.8, 72.2 (CH_2 Bn), 71.9 (C-5), 69.2 (C-6), 66.6 (d, *J* = 19.8 Hz, *C*H$_2$CH$_2$F); ^{13}C-HMBC-GATED NMR (101 MHz, $CDCl_3$): δ 98.2 ($J_{H1\text{-}C1}$ = 170 Hz, α); Data of the minor stereoisomer (β product): ^{1}H NMR (400 MHz, $CDCl_3$, HH-COSY, HSQC): δ 4.98 (d, *J* = 12.4 Hz, 1H, C*H*H Bn), 4.45 (s, 1H, H-1), 4.11 (dddd, *J* = 35.8, 12.1, 3.9, 2.3 Hz, 1H, C*H*HCH$_2$F), 3.50 (dd, *J* = 9.4, 3.0 Hz, 1H, H-3), 3.46 (ddd, *J* = 9.7, 5.8, 2.1 Hz, 1H, H-5); ^{13}C NMR (101 MHz, $CDCl_3$, HSQC): δ 101.7 (C-1), 83.0 (d, *J* = 169.3 Hz, CH_2F), 82.2 (C-3), 69.7 (C-6), 68.7 (d, *J* = 19.7 Hz, *C*H$_2$CH$_2$F); ^{13}C-HMBC-GATED NMR (101 MHz, $CDCl_3$): δ 98.2 ($J_{H1\text{-}C1}$ = 153 Hz, β); HRMS: $[M+Na]^+$ calcd for $C_{36}H_{39}FO_6$ 609.2628, found 609.2635.

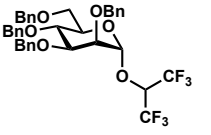


2,2-Difluoroethyl 2,3,4,6-tetra-*O*-benzy-D-mannopyranoside (S59). The title compound was prepared according to general procedure VII. Column chromatography (97:3 → 90:10, pentane:EtOAc) yielded the title compound (39 mg, 65 µmol, 65%, colorless oil, α:β; 80:20). TLC: R_f 0.19, 0.31 (pentane:EtOAc, 90:10, v:v); IR (thin film, cm^{-1}): 695, 734, 1027, 1064, 1363, 1453, 1496, 2916; Data of the major stereoisomer (α product): ^{1}H NMR (400 MHz, $CDCl_3$, HH-COSY, HSQC): δ 7.71 – 7.10 (m, 20H, CH_{arom}), 5.86 (tdd, *J* = 55.3, 4.8, 3.4 Hz, 1H, CHF_2), 4.95 – 4.80 (m, 3H, C*H*H Bn, CH*H* Bn, C*H*H Bn), 4.90 (d, *J* = 2.0 Hz, 1H, H-1), 4.76 (d, *J* = 12.4 Hz, 1H, CH*H* Bn), 4.70 (d, *J* = 12.4 Hz, 1H, C*H*H Bn), 4.68 – 4.38 (m, 4H, C*H*H Bn, CH*H* Bn, C*H*H Bn, CH*H* Bn), 3.98 (t, *J* = 9.1 Hz, 1H, H-4), 4.13 – 3.61 (m, 7H, H-2, H-3, H-5, H-6, H-6, C*H*HCHF$_2$, CH*H*CHF$_2$); ^{13}C NMR (101 MHz, $CDCl_3$, HSQC): δ 138.6, 138.5, 138.4, 138.3 ($C_{q\text{-}arom}$), 129.5, 128.5, 128.5, 128.0, 127.9, 127.8, 127.8, 127.8, 127.7, 127.7, 127.6 (CH_{arom}), 114.1 (t, *J* = 241.1 Hz, CHF_2), 99.0 (C-1), 80.0 (C-3), 75.3 (C-4), 74.8 (C-2), 74.5, 73.5, 72.9, 72.4 (CH_2 Bn), 72.4 (C-5), 69.2 (C-6), 66.8 (t, *J* = 28.2

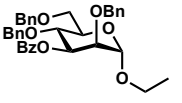
Hz, *C*H$_2$CHF$_2$); ^{13}C-HMBC-GATED NMR (101 MHz, CDCl$_3$): δ 99.0 ($J_{H1\text{-}C1}$ = 171 Hz, α); Data of the minor stereoisomer (β product): ^{1}H NMR (400 MHz, CDCl$_3$, HH-COSY, HSQC): δ 5.94 (dddd, *J* = 56.3, 54.7, 5.6, 2.7 Hz, 1H, CHF$_2$), 4.94 (d, *J* = 12.4 Hz, 1H, C*H*H Bn), 4.68 – 4.38 (signals overlap with major isomer, 1H, H-1), 3.50 (dd, *J* = 9.3, 3.0 Hz, 1H, H-3), 3.45 (ddd, *J* = 9.8, 5.8, 2.2 Hz, 1H, H-5); ^{13}C NMR (101 MHz, CDCl$_3$, HSQC): δ 114.4 (dd, *J* = 242.1, 240.0 Hz, CHF$_2$), 101.8 (C-1), 82.1, 68.5 (dd, *J* = 30.6, 26.2 Hz, *C*H$_2$CHF$_2$); ^{13}C-HMBC-GATED NMR (101 MHz, CDCl$_3$): δ 101.8 ($J_{H1\text{-}C1}$ = 153 Hz, β); HRMS: [M+Na]$^+$ calcd for $C_{36}H_{38}F_2O_6$ 627.2534, found 627.2541.



2,2,2-Trifluoroethyl 2,3,4,6-tetra-*O*-benzyl-α-D-mannopyranoside (S60). The title compound was prepared according to general procedure VII. Column chromatography (97:3 → 90:10, pentane:EtOAc) yielded the title compound (52 mg, 84 µmol, 84%, colorless oil, α:β; >98:2). TLC: R_f 0.45 (pentane:EtOAc, 90:10, v:v); $[\alpha]_D^{20}$ –16.6° (*c* 1, CHCl$_3$); IR (thin film, cm^{-1}): 667, 695, 985, 1069, 1165, 1279, 1362, 1454, 2867; ^{1}H NMR (400 MHz, CDCl$_3$, HH-COSY, HSQC): δ 8.07 – 5.74 (m, 20H, CH$_{arom}$), 4.94 (d, *J* = 1.9 Hz, 1H, H-1), 4.86 (d, *J* = 10.7 Hz, 1H, C*H*H Bn), 4.76 (d, *J* = 12.4 Hz, 1H, C*H*H Bn), 4.69 (d, *J* = 12.3 Hz, 1H, CH*H* Bn), 4.69 – 4.59 (m, 3H, CH*H* Bn, C*H*H Bn, C*H*H Bn), 4.53 (d, *J* = 12.2 Hz, 1H, CH*H* Bn), 4.49 (d, *J* = 10.7 Hz, 1H, CH*H* Bn), 4.00 (t, *J* = 9.1 Hz, 1H, H-4), 3.96 – 3.64 (m, 7H, H-2, H-3, H-5, H-6, H-6, C*H*HCF$_3$, CH*H*CF$_3$); ^{13}C NMR (101 MHz, CDCl$_3$, HSQC): δ 138.4, 138.3, 138.3, 138.1 (C$_{q\text{-}arom}$), 128.5, 128.5, 128.5, 128.1, 128.1, 127.9, 127.8, 127.8, 127.8, 127.8, 127.7, 127.7, 127.7 (CH$_{arom}$), 122.4 (q, *J* = 277.6 Hz, CF$_3$), 98.7 (C-1), 79.8 (C-3), 75.3 (CH$_2$ Bn), 74.6 (C-4), 74.4 (C-2), 73.6, 73.5 (CH$_2$ Bn), 73.1 (C-5), 72.7 (CH$_2$ Bn), 72.5 (C-6), 64.1 (q, *J* = 34.8 Hz, *C*H$_2$CF$_3$); HRMS: [M+Na]$^+$ calcd for $C_{36}H_{37}F_3O_6$ 645.2440, found 645.2452.

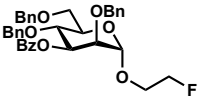


1,1,1,3,3,3-Hexafluoro-2-propyl 2,3,4,6-tetra-*O*-benzyl-α-D-mannopyranoside (S61). The title compound was prepared according to general procedure VII. Column chromatography (100:0 → 80:20, pentane:Et$_2$O) yielded the title compound (26 mg, 39 µmol, 39%, colorless oil, α:β; >98:2). TLC: R_f 0.23 (pentane:EtOAc, 95:5, v:v); $[\alpha]_D^{20}$ 35.7° (*c* 1, CHCl$_3$); IR (thin film, cm^{-1}): 695, 734, 900, 964, 1027, 1101, 1195, 1219, 1288, 1367, 1454, 2917; ^{1}H NMR (500 MHz, CDCl$_3$, HH-COSY, HSQC, HMBC-Gated, ^{1}H-^{19}F Decoupled) δ 7.38 – 7.12 (m, 20H, CH$_{arom}$), 5.07 (d, *J* = 1.8 Hz, 1H, H-1), 4.81 (d, *J* = 10.7 Hz, 1H, C*H*H Bn), 4.75 (d, *J* = 12.3 Hz, 1H, C*H*H Bn), 4.69 – 4.60 (m, 4H, C*H*H Bn, CH*H* Bn, C*H*H Bn, CH*H* Bn), 4.50 – 4.39 (m, 3H, CH*H* Bn, CH*H* Bn, C*H*(CF$_3$)$_2$), 4.05 (td, *J* = 9.8, 1.4 Hz, 1H, H-4), 3.87 – 3.79 (m, 3H, H-2, H-3, H-5), 3.77 (dd, *J* = 10.9, 4.5 Hz, 1H, H-6), 3.65 (dd, *J* = 10.9, 1.9 Hz, 1H, H-6); ^{13}C NMR (126 MHz, CDCl$_3$, HSQC, HMBC-Gated) δ 138.3, 138.3, 138.2, 137.8 (C$_{q\text{-}arom}$), 128.6, 128.6, 128.5, 128.5, 128.2, 128.1, 128.0, 127.9, 127.9, 127.7 (CH$_{arom}$), 100.7 (C-1), 79.2 (C-3), 75.1 (CH$_2$ Bn), 74.5 (C-2), 74.3 (C-4), 73.5 (C-5), 73.5, 73.3, 72.8 (CH$_2$ Bn), 72.1 (p, *J* = 32.7 Hz, *C*H(CF$_3$)$_2$), 68.7 (C-6); ^{13}C-GATED NMR (126 MHz, CDCl$_3$): δ 100.7 ($J_{H1\text{-}C1}$ = 174 Hz, α); HRMS: [M+Na]$^+$ calcd for $C_{37}H_{36}F_6O_6$ 713.2314, found 713.2335.

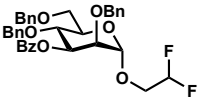


Ethyl 2,3,4,6-tetra-*O*-benzyl-α-D-mannopyranoside (S62). The title compound was prepared according to general procedure VII. Column chromatography (95:5 → 75:25, pentane:Et$_2$O) yielded the title compound (55 mg, 94 µmol, 94%, colorless oil, α:β; >98:2). TLC: R_f 0.30 (pentane:Et$_2$O, 80:20, v:v); $[\alpha]_D^{25}$ –3.6° (*c* 1, CHCl$_3$); IR (thin film, cm^{-1}): 695, 735, 1026, 1059, 1093, 1268, 1452, 1720, 2867, 3030; ^{1}H NMR (500 MHz, CDCl$_3$, HH-COSY, HSQC): δ 8.67 – 6.65 (m, 20H, CH$_{arom}$), 5.55 (dd, *J* = 9.6, 3.3 Hz, 1H, H-3), 4.93 (d, *J* = 1.9 Hz, 1H, H-1), 4.72 (d, *J* = 12.1 Hz, 1H, C*H*H Bn), 4.69 – 4.64 (m, 2H, C*H*H Bn, C*H*H Bn), 4.59 (d, *J* = 12.3 Hz, 1H, CH*H* Bn), 4.54 (d, *J* = 12.1 Hz, 1H, CH*H* Bn), 4.50 (d, *J* = 10.8 Hz, 1H, CH*H* Bn), 4.22 (t, *J* = 9.7 Hz, 1H, H-4), 3.97 (dd, *J* = 3.4, 1.9 Hz, 1H, H-2), 3.91 (ddd, *J* = 9.8, 4.5, 1.9 Hz, 1H, H-5), 3.83 (dd, *J* =

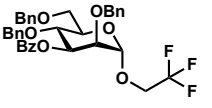
10.8, 4.5 Hz, 1H, H-6), 3.81 – 3.70 (m, 2H, H-6, C*H*HCH$_3$ Et), 3.49 (dq, *J* = 9.7, 7.1 Hz, 1H, CH*H*CH$_3$ Et), 1.20 (t, *J* = 7.1 Hz, 3H, CH$_3$ Et); ^{13}C NMR (126 MHz, CDCl$_3$, HSQC): δ 165.8 (C=O Bz), 138.4, 138.1, 138.0 (C$_{q\text{-arom}}$), 130.2, 128.5, 128.4, 128.4, 128.0, 127.8, 127.8, 127.7, 127.7, 127.7, 127.7 (CH$_{arom}$), 97.8 (C-1), 76.4 (C-2), 75.0 (CH$_2$ Bn), 74.8 (C-3), 73.8 (C-4), 73.6, 73.1 (CH$_2$ Bn), 71.6 (C-5), 69.2 (C-6), 63.3 (*C*H$_2$CH$_3$ Et), 15.1 (CH$_3$ Et); HRMS: [M+NH$_4$]$^+$ calcd for C$_{36}$H$_{38}$O$_7$ 600.29558, found 600.29561.



2-Fluoroethyl 3-*O*-benzoyl-2,4,6-tri-*O*-benzyl-α-D-mannopyranoside (S63). The title compound was prepared according to general procedure VII. Column chromatography (90:10 → 60:40, pentane:Et$_2$O) yielded the title compound (52 mg, 87 µmol, 87%, colorless oil, α:β; >98:2). TLC: R$_f$ 0.20 (pentane:Et$_2$O, 70:30, v:v); $[\alpha]_D^{25}$ –2.6° (*c* 1, CHCl$_3$); IR (thin film, cm^{-1}): 539, 697, 714, 738, 1026, 2046, 170, 1270, 1452 1496, 1601, 1720, 2914, 3031; ^{1}H NMR (500 MHz, CDCl$_3$, HH-COSY, HSQC): 8.28 – 6.76 (m, 20H, CH$_{arom}$), 5.54 (dd, *J* = 9.4, 3.3 Hz, 1H, H-3), 4.98 (d, *J* = 2.0 Hz, 1H, H-1), 4.74 (d, *J* = 11.0 Hz, 1H, C*H*H Bn), 4.67 (d, *J* = 10.8 Hz, 1H, C*H*H Bn), 4.67 (d, *J* = 12.2 Hz, 1H, C*H*H Bn), 4.60 (d, *J* = 12.3 Hz, 1H, CH*H* Bn), 4.62 – 4.46 (m, 2H, C*H*HF, CH*H*F), 4.53 (d, *J* = 12.1 Hz, 1H, CH*H* Bn), 4.50 (d, *J* = 10.7 Hz, 1H, CH*H* Bn), 4.22 (t, *J* = 9.6 Hz, 1H, H-4), 4.04 (dd, *J* = 3.4, 2.0 Hz, 1H, H-2), 3.93 (ddt, *J* = 11.8, 6.7, 2.5 Hz, 2H, H-5), 3.82 (dd, *J* = 10.9, 4.5 Hz, 1H, H-6), 3.91 – 3.67 (m, 2H, C*H*HCH$_2$F, CH*H*CH$_2$F), 3.73 (dd, *J* = 10.9, 1.9 Hz, 1H, H-6); ^{13}C NMR (126 MHz, CDCl$_3$, HSQC): δ 165.7 (C=O Bz), 138.3, 137.9, 133.2, 131.2 (C$_{q\text{-arom}}$), 129.9, 129.4, 128.5, 128.4, 128.4, 128.4, 128.4, 128.0, 128.0, 127.8, 127.8, 127.8, 127.7, 127.7, (CH$_{arom}$) 98.4 (C-1), 82.6 (d, *J* = 169.9 Hz, CH$_2$F), 76.1 (C-2), 74.9 (CH$_2$ Bn), 74.4 (C-3), 73.6 (CH$_2$ Bn), 73.6 (C-4), 73.2 (CH$_2$ Bn), 71.7 (C-5), 69.0 (C-6), 66.8 (d, *J* = 20.2 Hz, *C*H$_2$CH$_2$F); HRMS: [M+NH$_4$]$^+$ calcd for C$_{36}$H$_{37}$FO$_7$ 618.28616, found 618.28583.

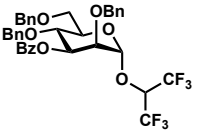


2,2-Difluoroethyl 3-*O*-benzoyl-2,4,6-tri-*O*-benzyl-α-D-mannopyranoside (S64). The title compound was prepared according to general procedure VII. Column chromatography (95:5 → 75:25, pentane:Et$_2$O) yielded the title compound (54 mg, 87 µmol, 87%, colorless oil, α:β; >98:2). TLC: R$_f$ 0.3 (pentane:Et$_2$O, 80:20, v:v); $[\alpha]_D^{25}$ 1.1° (*c* 1, CHCl$_3$); IR (thin film, cm^{-1}): 696, 737, 1269, 1452, 1720, 2926, 3032; ^{1}H NMR (500 MHz, CDCl$_3$, HH-COSY, HSQC): δ 8.40 – 6.70 (m, 20H, CH$_{arom}$), 5.92 (tdd, *J* = 55.5, 4.8, 3.7 Hz, 1H, CHF$_2$), 5.49 (dd, *J* = 9.2, 3.3 Hz, 1H, H-3), 4.96 (d, *J* = 2.1 Hz, 1H, H-1), 4.69 (d, *J* = 12.3 Hz, 1H, C*H*H Bn), 4.69 (d, *J* = 11.2 Hz, 1H, C*H*H Bn), 4.65 (d, *J* = 12.2 Hz, 1H, C*H*H Bn), 4.59 (d, *J* = 12.2 Hz, 1H, CH*H* Bn), 4.53 (d, *J* = 12.0 Hz, 1H, CH*H* Bn), 4.50 (d, *J* = 10.9 Hz, 1H, CH*H* Bn), 4.20 (t, *J* = 9.5 Hz, 1H, H-4), 4.03 (dd, *J* = 3.4, 2.1 Hz, 1H, H-2), 3.93 – 3.68 (m, 5H, H-6, H-6, H-5, C*H*HCH$_2$F, CH*H*CH$_2$F); ^{13}C NMR (126 MHz, CDCl$_3$, HSQC): ^{13}C NMR (126 MHz, CDCl$_3$): δ 165.8 (C=O Bz), 138.2, 137.8, 137.7, 133.3, 130.0, 129.9, 128.6, 128.5, 128.4, 128.4, 128.0, 127.8, 127.8 (CH$_{arom}$), 114.1 (t, *J* = 241.2 Hz, CHF$_2$), 98.9 (C-1), 75.8 (C-2), 74.9 (CH$_2$ Bn), 74.1 (C-3), 73.6 (CH$_2$ Bn), 73.4 (C-4), 73.3 (CH$_2$ Bn), 72.1 (C-5), 68.9 (C-6), 66.9 (t, *J* = 28.7 Hz, *C*H$_2$CHF$_2$); HRMS: [M+NH$_4$]$^+$ calcd for C$_{36}$H$_{36}$F$_2$O$_7$ 636.27674, found 636.27663.

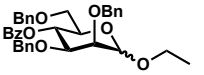


2,2,2-Trifluoroethyl 3-*O*-benzoyl-2,4,6-tri-*O*-benzyl-α-D-mannopyranoside (S65). The title compound was prepared according to general procedure VII. Column chromatography (95:5 → 80:20, pentane:Et$_2$O) yielded the title compound (51 mg, 79 µmol, 79%, colorless oil, α:β; >98:2). TLC: R$_f$ 0.40 (pentane:Et$_2$O, 80:20, v:v); $[\alpha]_D^{25}$ 5.6° (*c* 1, CHCl$_3$); IR (thin film, cm^{-1}): 698, 738, 1027, 1035, 1166, 1253, 1452, 1720, 2866, 3030; ^{1}H NMR (500 MHz, CDCl$_3$, HH-COSY, HSQC): δ 8.53 – 6.76 (m, 20H, CH$_{arom}$), 5.50 (dd, *J* = 9.1, 3.3 Hz, 1H, H-3), 5.00 (d, *J* = 2.1 Hz, 1H, H-1), 4.69 (d, *J* = 12.1 Hz, 1H, C*H*H Bn), 4.68 (d, *J* = 10.9 Hz, 1H, C*H*H Bn), 4.65 (d, *J* = 12.1 Hz, 1H, C*H*H Bn), 4.61 (d, *J* = 12.1 Hz, 1H, CH*H* Bn), 4.52 (d, *J* = 12.1 Hz, 1H, CH*H* Bn), 4.50 (d, *J* = 10.9 Hz, 1H, CH*H* Bn), 4.21 (t, *J* = 9.4 Hz, 1H, H-4), 4.07 (dd, *J* = 3.4, 2.2 Hz, 1H, H-2), 4.06 – 3.83 (m, 3H, C*H*HCF$_3$, CH*H*CF$_3$, H-5), 3.80 (dd, *J* = 10.9, 4.5 Hz, 1H, H-6), 3.71 (dd, *J* = 10.9,

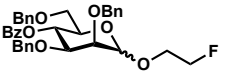
1.9 Hz, 1H, H-6); ^{13}C NMR (126 MHz, $CDCl_3$, HSQC): δ 165.7 (C=O Bz), 138.2, 137.8, 137.6 ($C_{q\text{-arom}}$), 130.0, 128.6, 128.5, 128.4, 128.1, 128.0, 128.0, 128.0, 127.9, 127.8, 127.8, 127.1 (CH_{arom}), 123.8 (q, *J* = 278.4 Hz, CF_3), 98.8 (C-1), 75.6 (C-2), 74.9 (CH_2 Bn), 73.9 (C-3), 73.7 (CH_2 Bn), 73.4 (C-4), 73.4 (CH_2 Bn), 72.3 (C-5), 68.8 (C-6), 64.3 (q, *J* = 35.0 Hz, *C*H_2CF_3); HRMS: $[M+NH_4]^+$ calcd for $C_{36}H_{35}F_3O_7$ 654.26731, found 654.26711.



1,1,1,3,3,3-Hexafluoro-2-propyl 3-*O*-benzoyl-2,4,6-tri-*O*-benzyl-α-D-mannopyranoside (S66). The title compound was prepared according to general procedure VII. Column chromatography (100:0 → 80:20, pentane:Et_2O) yielded the title compound (43 mg, 61 µmol, 61%, colorless oil, α:β; >98:2). TLC: R_f 0.20 (pentane:Et_2O, 90:10, v:v); $[\alpha]_D^{25}$ 19.2° (*c* 1, $CHCl_3$); IR (thin film, cm^{-1}): 688, 696, 712, 738, 974, 1027, 1101, 1195, 1220, 1315, 1367, 1452, 1720, 2926, 3032; ^{1}H NMR (500 MHz, $CDCl_3$, HH-COSY, HSQC): δ 8.22 – 7.03 (m, 20H, CH_{arom}), 5.47 (dd, *J* = 7.9, 3.3 Hz, 1H, H-3), 5.15 (d, *J* = 2.7 Hz, 1H, H-1), 4.71 (d, *J* = 11.0 Hz, 1H, C*H*H Bn), 4.66 (d, *J* = 12.0 Hz, 1H, C*H*H Bn), 4.63 (s, 2H, CH_2 Bn), 4.50 (d, *J* = 10.8 Hz, 1H CH*H* Bn), 4.56 – 4.47 (m, 1H, $CH(CF_3)_2$), 4.44 (d, *J* = 12.0 Hz, 1H, CH*H* Bn), 4.22 (dd, *J* = 9.6, 7.9 Hz, 1H, H-4), 4.10 (dd, *J* = 3.3, 2.7 Hz, 1H, H-2), 3.92 (ddd, *J* = 9.6, 3.9, 2.1 Hz, 1H, H-5), 3.76 (dd, *J* = 11.0, 3.8 Hz, 1H, H-6), 3.66 (dd, *J* = 11.0, 2.1 Hz, 1H, H-6); ^{13}C NMR (126 MHz, $CDCl_3$, HSQC): δ 165.8 (C=O Bz), 138.0, 137.6, 137.2 ($C_{q\text{-arom}}$), 129.9, 128.6, 128.6, 128.5, 128.2, 128.1, 128.1, 128.0, 127.9, 127.8 (CH_{arom}), 100.9 (C-1), 75.1 (C-2), 74.5, 73.6, 73.4 (CH_2 Bn), 73.3 (C-4), 72.9 (C-5), 72.9 (C-3), 72.0 (p, *J* = 34.2 Hz, *C*$H(CF_3)_2$), 68.4 (C-6); ^{13}C-GATED NMR (126 MHz, $CDCl_3$): δ 100.9 ($J_{H1\text{-}C1}$ = 178 Hz, □); HRMS: $[M+NH_4]^+$ calcd for $C_{37}H_{34}F_6O_7$ 722.25470, found 722.25433.

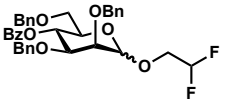


Ethyl 4-*O*-benzoyl-2,3,6-tri-*O*-benzy-D-mannopyranoside (S67). The title compound was prepared according to general procedure VII. Column chromatography (95:5 → 70:30, pentane:Et_2O) yielded the title compound (51 mg, 88 µmol, 88%, colorless oil, α:β; 31:69). TLC: R_f 0.20 (pentane:Et_2O, 80:20, v:v); IR (thin film, cm^{-1}): 595, 695, 735, 1026, 1105, 1266, 1452, 1720, 2869, 3030; Data of the major stereoisomer (β product): ^{1}H NMR (500 MHz, $CDCl_3$, HH-COSY, HSQC): δ 7.61 – 7.06 (m, 20H, CH_{arom}), 5.55 (t, *J* = 9.7 Hz, 1H, H-4), 4.99 (d, *J* = 12.7 Hz, 1H, C*H*H Bn), 4.90 (d, *J* = 12.6 Hz, 1H, CH*H* Bn), 4.58 – 4.41 (m, 4H, C*H*H Bn, CH*H* Bn, CH*H* Bn, H-1), 4.24 (d, *J* = 12.5 Hz, 1H, CH*H* Bn), 4.05 (dq, *J* = 9.3, 7.1 Hz, 1H, C*H*HCH$_3$ Et), 3.94 (dd, *J* = 3.0, 0.8 Hz, 1H, H-2), 3.81 – 3.60 (m, 3H, H-5, H-6, H-6), 3.56 (dd, *J* = 9.8, 2.9 Hz, 1H, H-3), 3.59 – 3.44 (m, 1H, CH*H*CH$_3$ Et), 1.30 (t, *J* = 7.0 Hz, 3H, CH_3 Et); ^{13}C NMR (126 MHz, $CDCl_3$, HSQC): δ 165.7 (C=O Bz), 138.6, 138.2, 137.7 ($C_{q\text{-arom}}$), 129.9, 128.6, 128.4, 128.4, 128.4, 128.2, 127.7, 127.7, 127.6 (CH_{arom}), 101.3 (C-1), 78.8 (C-3), 74.8 (C-5), 74.0, 73.8 (CH_2 Bn), 73.2 (C-2), 71.0 (CH_2 Bn), 70.7 (C-6), 69.8 (C-4), 65.6 (*C*H_2CH$_3$ Et), 15.3 (CH$_3$ Et); Data of the minor stereoisomer (α product): ^{1}H NMR (500 MHz, $CDCl_3$, HH-COSY, HSQC): δ 5.64 (t, *J* = 9.8 Hz, 1H, H-4), 4.92 (d, *J* = 2.0 Hz, 1H, H-1), 4.80 (d, *J* = 12.5 Hz, 1H, C*H*H Bn), 4.73 (d, *J* = 12.5 Hz, 1H, CH*H* Bn), 3.84 (dd, *J* = 3.1, 2.0 Hz, 1H, H-2); ^{13}C NMR (126 MHz, $CDCl_3$, HSQC): δ 98.2 (C-1), 77.5 (C-3), 74.4 (C-2), 73.6, 73.0, 71.9 (CH_2 Bn), 63.4 (*C*H_2CH$_3$ Et), 15.1 (CH$_3$ Et); HRMS: $[M+NH_4]^+$ calcd for $C_{36}H_{38}O_7$ 600.29558, found 600.29575.

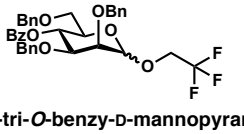


2-Fluoroethyl 4-*O*-benzoyl-2,3,6-tri-*O*-benzy-D-mannopyranoside (S68). The title compound was prepared according to general procedure VII. Column chromatography (90:10 → 60:40, pentane:Et_2O) yielded the title compound (50 mg, 83 µmol, 83%, colorless oil, α:β; 60:40). TLC: R_f 0.20 (pentane:Et_2O, 70:30, v:v); IR (thin film, cm^{-1}): 537, 695, 711, 738, 1027, 1043, 1069, 1088, 1266, 1452, 1724, 2867, 3030; Data of the major stereoisomer (α product): ^{1}H NMR (600 MHz, $CDCl_3$, HH-COSY, HSQC): δ 8.05 – 6.98 (m, 20H, CH_{arom}), 5.65 (t, *J* = 9.8 Hz, 1H, H-4), 4.96 (d, *J* = 2.0 Hz, 1H, H-1), 4.80 (d, *J* = 12.4 Hz, 1H, C*H*H Bn), 4.72 (d, *J* = 12.5 Hz, 1H, CH*H* Bn), 4.67 – 4.42 (m, 6H, C*H*H Bn, CH*H* Bn, C*H*H Bn, CH*H* Bn, C*H*HF,

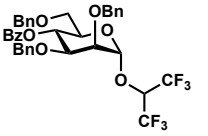
CH*H*F), 4.01 – 3.79 (m, 2H, C*H*HCH$_2$F, CH*H*CH$_2$F), 3.90 (dd, *J* = 3.0, 2.0 Hz, 1H, H-2), 3.79 – 3.64 (m, 3H, H-5, H-6, H-6), 3.62 (dd, *J* = 10.8, 2.8 Hz, 1H, H-2); ^{13}C NMR (151 MHz, $CDCl_3$, HSQC): δ 165.7 (C=O Bz), 138.5, 138.3, 138.2, 138.1, 137.7 ($C_{q\text{-}arom}$), 131.2, 130.0, 129.9, 128.6, 128.4, 128.4, 128.4, 128.4, 128.3, 127.7, 127.5 (CH_{arom}), 98.8 (C-1), 82.6 (d, *J* = 169.6 Hz, *C*H$_2$F), 77.3 (C-3), 74.3 (C-2), 73.6, 73.1, 72.1 (CH$_2$ Bn), 70.9 (C-5), 70.1 (C-6), 69.5 (C-4), 66.9 (d, *J* = 19.7 Hz, *C*H$_2$CH$_2$F); Data of the minor stereoisomer (β product): ^{1}H NMR (600 MHz, $CDCl_3$, HH-COSY, HSQC): δ 5.56 (t, *J* = 9.7 Hz, 1H, H-4), 4.98 (d, *J* = 12.5 Hz, 1H, C*H*H Bn), 4.89 (d, *J* = 12.5 Hz, 1H, CH*H* Bn), 4.67 – 4.42 (signals overlap with major isomer, 1H, H-1), 4.26 (d, *J* = 12.5 Hz, 1H, CH*H* Bn), 4.13 (dddd, *J* = 35.8, 12.2, 3.9, 2.3 Hz, 1H, C*H*HCH$_2$F), 3.58 (dd, *J* = 9.7, 3.0 Hz, 1H, H-2); ^{13}C NMR (151 MHz, $CDCl_3$, HSQC): δ 101.5 (C-1), 82.9 (d, *J* = 169.4 Hz, *C*H$_2$F), 74.2, 73.7, 71.1 (CH$_2$ Bn), 70.5 (C-6), 69.6 (C-4), 68.7 (d, *J* = 19.7 Hz, *C*H$_2$CH$_2$F); HRMS: $[M+NH_4]^+$ calcd for $C_{36}H_{37}FO_7$ 618.28616, found 618.28620.



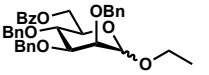
2,2-Difluoroethyl 4-*O*-benzoyl-2,3,6-tri-*O*-benzy-D-mannopyranoside (S69). The title compound was prepared according to general procedure VII. Column chromatography (95:5 → 70:30, pentane:Et$_2$O) yielded the title compound (50 mg, 81 µmol, 81%, colorless oil, α:β; 71:29). TLC: R_f 0.20 (pentane:Et$_2$O, 80:20, v:v); IR (thin film, cm^{-1}): 697, 711, 738, 1027, 1066, 1105, 1266, 1452, 1720, 2870, 3030; Data of the major stereoisomer (α product): ^{1}H NMR (600 MHz, $CDCl_3$, HH-COSY, HSQC): δ 8.22 – 6.63 (m, 20H, CH_{arom}), 5.94 (tdd, *J* = 55.3, 4.8, 3.4 Hz, 1H, C*H*F$_2$), 5.63 (t, *J* = 9.7 Hz, 1H, H-4), 4.93 (d, *J* = 2.1 Hz, 1H, H-1), 4.79 (d, *J* = 12.3 Hz, 1H, C*H*H Bn), 4.70 (d, *J* = 12.4 Hz, 1H, CH*H* Bn), 4.60 – 4.42 (m, 4H, C*H*H Bn, CH*H* Bn, C*H*H Bn, CH*H* Bn), 3.99 (ddd, *J* = 9.7, 6.5, 2.7 Hz, 1H, H-5), 3.94 (dd, *J* = 9.3, 3.0 Hz, 1H, H-3), 3.87 (t, *J* = 2.6 Hz, 1H, H-2), 3.85 – 3.64 (m, 3H, H-6, C*H*HCHF$_2$, CH*H*CHF$_2$), 3.61 (dd, *J* = 10.8, 2.8 Hz, 1H, H-6); ^{13}C NMR (151 MHz, $CDCl_3$, HSQC): δ 165.7 (C=O Bz), 138.4, 138.2, 138.1, 138.1, 138.0, 137.7 ($C_{q\text{-}arom}$), 130.0, 128.6, 128.5, 128.5, 128.5, 128.5, 128.4, 128.4, 128.4, 127.9, 127.9, 127.8, 127.8, 127.8, 127.8, 127.8, 127.7 (CH_{arom}), 114.1 (t, *J* = 241.1 Hz, *C*HF$_2$), 99.6 (C-1), 77.2 (C-3), 74.3 (C-2), 73.7, 73.3, 72.2 (CH$_2$ Bn), 71.4 (C-5), 70.0 (C-6), 69.3 (C-4), 67.1 (t, *J* = 28.1 Hz, *C*H$_2$CHF$_2$); Data of the minor stereoisomer (β product): ^{1}H NMR (600 MHz, $CDCl_3$, HH-COSY, HSQC): δ 5.55 (t, *J* = 9.5 Hz, 1H, H-4), 4.85 (d, *J* = 12.5 Hz, 1H, CH*H* Bn), 4.53 (s, 1H, H-1), 4.28 (d, *J* = 12.5 Hz, 1H, CH*H* Bn), 4.07 (dddd, *J* = 21.7, 12.1, 9.5, 2.7 Hz, 1H, C*H*HCHF$_2$), 3.58 (dd, *J* = 9.6, 3.0 Hz, 1H, H-3); ^{13}C NMR (151 MHz, $CDCl_3$, HSQC): δ 114.5 (dd, *J* = 242.2, 239.7 Hz, *C*HF$_2$), 101.6 (C-1), 74.3, 73.8, 71.3 (CH$_2$ Bn), 70.4 (C-6), 69.5 (C-4), 68.6 (dd, *J* = 31.0, 25.9 Hz, *C*H$_2$CHF$_2$); HRMS: $[M+NH_4]^+$ calcd for $C_{36}H_{36}F_2O_7$ 636.27674, found 636.27674.



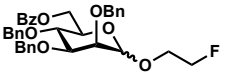
2,2,2-Trifluoroethyl 4-*O*-benzoyl-2,3,6-tri-*O*-benzy-D-mannopyranoside (S70). The title compound was prepared according to general procedure VII. Column chromatography (95:5 → 85:15, pentane:Et$_2$O) yielded the title compound (49 mg, 77 µmol, 77%, colorless oil, α:β; 88:12). TLC: R_f 0.40 (pentane:Et$_2$O, 80:20, v:v); IR (thin film, cm^{-1}): 697, 735, 1027, 1081, 1266, 1452, 1720, 2870, 3031; Data of the major stereoisomer (α product): ^{1}H NMR (400 MHz, $CDCl_3$, HH-COSY, HSQC): δ 8.47 – 6.78 (m, 20H, CH_{arom}), 5.65 (t, *J* = 9.6 Hz, 1H, H-4), 4.97 (d, *J* = 2.1 Hz, 1H, H-1), 4.80 (d, *J* = 12.3 Hz, 1H, C*H*H Bn), 4.69 (d, *J* = 12.3 Hz, 1H, CH*H* Bn), 4.6 (d, *J* = 12.0 Hz, 1H, C*H*H Bn), 4.53 – 4.41 (m, 3H, C*H*H Bn, CH*H* Bn, CH*H* Bn), 4.09 – 3.83 (m, 5H, H-3, H-4, H-5, C*H*HCF$_3$, CH*H*CF$_3$), 3.67 (dd, *J* = 10.8, 6.2 Hz, 1H, H-6), 3.60 (dd, *J* = 10.8, 2.9 Hz, 1H, H-6); ^{13}C NMR (101 MHz, $CDCl_3$, HSQC): δ 165.6 (C=O Bz), 138.1, 138.0, 137.9, 137.5 ($C_{q\text{-}arom}$), 128.4, 127.9, 127.8, 127.8, 127.7, 127.6 (CH_{arom}), 122.5 (q, *J* = 280.0 Hz, *C*F$_3$), 99.1 (C-1), 76.9 (C-3), 74.0 (C-2), 73.6, 73.3, 72.2 (CH$_2$ Bn), 71.6 (C-5), 69.8 (C-6), 69.1 (C-4), 64.3 (q, *J* = 34.9 Hz, *C*H$_2$CF$_3$); Data of the minor stereoisomer (β product): ^{1}H NMR (400 MHz, $CDCl_3$, HH-COSY, HSQC): δ 5.56 (t, *J* = 9.5 Hz, 1H, H-4), 4.87 (d, *J* = 12.5 Hz, 1H, CH*H* Bn), 4.61 – 4.53 (signals overlap with major isomer, 1H, H-1); ^{13}C NMR (126 MHz, $CDCl_3$, HSQC): 101.1 (C-1), 78.5 (C-3), 70.3 (C-6), 69.3 (C-4), 64.3 (q, *J* = 34.9 Hz, *C*H$_2$CF$_3$); HRMS: $[M+NH_4]^+$ calcd for $C_{36}H_{35}F_3O_7$ 654.26731, found 654.26732.



1,1,1,3,3,3-Hexafluoro-2-propyl 4-*O*-benzoyl-2,3,6-tri-*O*-benzyl-α-D-mannopyranoside (S71). The title compound was prepared according to general procedure VII. Column chromatography (100:0 → 80:20, pentane:Et_2O) yielded the title compound (35 mg, 50 µmol, 50%, colorless oil, α:β; >98:2). TLC: R_f 0.10 (pentane:Et_2O, 90:10, v:v); $[\alpha]_D^{25}$ 17.0° (*c* 1, $CHCl_3$); IR (thin film, cm^{-1}): 689, 711, 1027, 1068, 1452, 1727, 2861, 3032; ^1H NMR (500 MHz, $CDCl_3$, HH-COSY, HSQC): δ 8.08 – 7.09 (m, 20H, CH_{arom}), 5.69 (dd, *J* = 9.9, 8.1 Hz, 1H, H-4), 5.12 (d, *J* = 2.1 Hz, 1H, H-1), 4.77 (d, *J* = 12.3 Hz, 1H, C*H*H Bn), 4.65 (d, *J* = 12.2 Hz, 1H, CH*H* Bn), 4.59 (d, *J* = 12.0 Hz, 1H, C*H*H Bn), 4.53 (d, *J* = 12.0 Hz, 1H, CH*H* Bn), 4.52 – 4.45 (m, 3H, C*H*H Bn, CH*H* Bn, C*H*$(CF_3)_2$), 4.03 (ddd, *J* = 10.0, 5.6, 2.8 Hz, 1H, H-5), 3.93 – 3.84 (m, 2H, H-2, H-3), 3.64 (dd, *J* = 11.0, 5.6 Hz, 1H, H-6), 3.59 (dd, *J* = 11.0, 2.9 Hz, 1H, H-6); ^{13}C NMR (126 MHz, $CDCl_3$, HSQC): δ 165.5 (C=O Bz), 137.9, 137.7, 137.6 ($C_{q\text{-}arom}$), 129.8, 128.5, 128.5, 128.4, 128.4, 128.2, 128.1, 127.9, 127.8, 127.6, 127.6 (CH_{arom}), 100.8 (C-1), 76.5 (C-3), 74.0 (C-2), 73.6, 73.5, 72.4 (CH_2 Bn), 72.3 (C-5), 71.9 (p, *J* = 32.5 Hz, H-1, *C*H$(CF_3)_2$), 69.3 (C-6), 68.6 (C-4); ^{13}C-GATED NMR (126 MHz, $CDCl_3$): δ 100.8 ($J_{H1\text{-}C1}$ = 176 Hz, α); HRMS: $[M+NH_4]^+$ calcd for $C_{37}H_{34}F_6O_7$ 722.25470, found 722.25449.

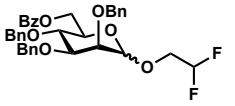


Ethyl 6-*O*-benzoyl-2,3,4-tri-*O*-benzy-D-mannopyranoside (S72). The title compound was prepared according to general procedure VII. Column chromatography (95:5 → 75:25, pentane:Et_2O) yielded the title compound (40 mg, 69 µmol, 69%, colorless oil, α:β; 35:65). TLC: R_f 0.30 (pentane:Et_2O, 80:20, v:v); IR (thin film, cm^{-1}): 696, 712, 737, 1027, 1066, 1104, 1274, 1452, 1496, 1720, 2869, 3030; Data of the major stereoisomer (β product): ^1H NMR (500 MHz, $CDCl_3$, HH-COSY, HSQC): δ 8.41 – 7.08 (m, 20H, CH_{arom}), 5.04 (d, *J* = 12.3 Hz, 1H, C*H*H Bn), 5.00 (d, *J* = 10.7 Hz, 1H, C*H*H Bn), 4.91 (d, *J* = 12.3 Hz, 1H, CH*H* Bn), 4.73 – 4.51 (m, 5H, H-6, H-6, C*H*H Bn, CH*H* Bn, CH*H* Bn), 4.47 (s, 1H, H-1), 4.07 (t, *J* = 9.4 Hz, 1H, H-4), 4.05 – 3.99 (m, 1H, C*H*HCH$_3$), 3.97 (d, *J* = 3.1 Hz, 1H, H-2), 3.66 – 3.62 (m, 1H, H-5), 3.61 (dd, *J* = 9.3, 3.0 Hz, 1H, H-3), 3.54 (dq, *J* = 9.8, 7.2 Hz, 1H, CH*H*CH$_3$), 1.28 (t, *J* = 7.1 Hz, 3H, C*H*$_3$); ^{13}C NMR (126 MHz, $CDCl_3$, HSQC): δ 166.5 (C=O Bz), 139.0, 138.6, 138.2, 138.2 ($C_{q\text{-}arom}$), 130.3, 130.2, 128.5, 128.5, 128.4, 128.4, 128.4, 127.9, 127.9, 127.8, 127.7, 127.7, 127.5 (CH_{arom}), 101.7 (C-1), 82.4 (C-3), 75.4 (CH_2 Bn), 74.8 (C-4), 74.0 (C-2), 73.9 (CH_2 Bn), 73.9 (C-5), 71.6 (CH_2 Bn), 65.6 (*C*H_2CH$_3$), 64.3 (C-6), 15.3 (*C*H$_3$); ^{13}C-GATED NMR (126 MHz, $CDCl_3$): δ 101.7 ($J_{H1\text{-}C1}$ = 153 Hz, β); Data of the minor stereoisomer (α product): ^1H NMR (500 MHz, $CDCl_3$, HH-COSY, HSQC): δ 4.94 (d, *J* = 1.9 Hz, 1H, H-1), 4.82 (d, *J* = 12.2 Hz, 1H, C*H*H Bn), 4.14 (t, *J* = 9.6 Hz, 1H, H-4), 3.87 (dd, *J* = 3.1, 1.9 Hz, 1H, H-2), 3.76 (dq, *J* = 9.8, 7.1 Hz, 1H, C*H*HCH$_3$), 3.53 – 3.45 (m, 1H, CH*H*CH$_3$), 1.21 (t, *J* = 7.1 Hz, 3H, C*H*$_3$); ^{13}C NMR (126 MHz, $CDCl_3$, HSQC): δ 97.7 (C-1), 80.5 (C-3), 75.2 (C-2), 73.9, 72.8, 72.3 (CH_2 Bn), 64.0 (*C*H_2CH$_3$), 63.3 (C-6), 15.1 (*C*H$_3$); ^{13}C-GATED NMR (126 MHz, $CDCl_3$): δ 97.7 ($J_{H1\text{-}C1}$ = 171 Hz, α); HRMS: $[M+NH_4]^+$ calcd for $C_{36}H_{38}O_7$ 600.29558, found 600.29587.

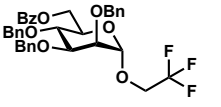


2-Fluoroethyl 6-*O*-benzoyl-2,3,4-tri-*O*-benzy-D-mannopyranoside (S73). The title compound was prepared according to general procedure VII. Column chromatography (90:10 → 60:40, pentane:Et_2O) yielded the title compound (59 mg, 99 µmol, 99%, colorless oil, α:β; 51:49). TLC: R_f 0.20 (pentane:Et_2O, 70:30, v:v); IR (thin film, cm^{-1}): 538, 712, 1027, 1209, 1274, 1720, 2871, 3032; Data of the major stereoisomer (α product): ^1H NMR (500 MHz, $CDCl_3$, HH-COSY, HSQC): δ 8.39 – 6.92 (m, 20H, CH_{arom}), 4.99 (d, *J* = 12.2 Hz, 1H, C*H*H Bn), 4.94 (d, *J* = 1.9 Hz, 1H, H-1), 4.87 (d, *J* = 12.2 Hz, 1H, CH*H* Bn), 4.73 – 4.44 (m, 8H, C*H*H Bn, CH*H* Bn, C*H*H Bn, CH*H* Bn, H-6, H-6, C*H*HF, CH*H*F), 4.12 (t, *J* = 9.6 Hz, 1H, H-4), 4.02 (dd, *J* = 9.2, 3.0 Hz, 3H, H-3), 3.90 (dd, *J* = 3.1, 1.9 Hz, 1H, H-2), 3.86 – 3.63 (m, 2H, C*H*HCH$_2$F, CH*H*CH$_2$F); ^{13}C NMR (126 MHz, $CDCl_3$, HSQC): δ 166.4 (C=O Bz), 138.4, 138.1, 138.1, 138.0 ($C_{q\text{-}arom}$), 131.2, 130.2, 129.8, 128.5, 128.5, 128.4, 128.3, 128.3, 128.2, 127.9, 127.9, 127.8, 127.7, 127.7, 127.5 (CH_{arom}), 98.3 (C-1), 82.9 (d, *J* = 169.3 Hz, *C*H_2F), 80.3 (C-3), 75.4 (CH_2 Bn), 75.0 (C-2), 74.5 (C-4), 74.1,

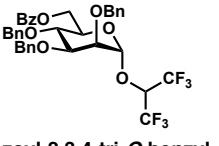
74.0, 72.9 (CH_2 Bn), 70.5 (C-5), 66.8 (d, J = 20.0 Hz, CH_2CH_2F), 64.1 (C-6); ^{13}C-GATED NMR (126 MHz, $CDCl_3$): δ 98.3 ($J_{H1\text{-}C1}$ = 171 Hz, α); Data of the minor stereoisomer (β product): ^{1}H NMR (500 MHz, $CDCl_3$, HH-COSY, HSQC): δ 4.95 (Signal overlaps with major isomer, 1H, H-1), 4.87 (d, J = 12.2 Hz, 1H, CH*H* Bn), 4.80 (d, J = 3.2 Hz, 1H, H), 4.05 (t, J = 9.5 Hz, 1H, H-4); ^{13}C NMR (126 MHz, $CDCl_3$, HSQC): 101.9 (C-1), 82.5 (d, J = 170.2 Hz, CH_2F), 68.7 (d, J = 19.8 Hz, CH_2CH_2); ^{13}C-GATED NMR (126 MHz, $CDCl_3$): δ 101.9 ($J_{H1\text{-}C1}$ = 155 Hz, β); HRMS: $[M+NH_4]^+$ calcd for $C_{36}H_{37}FO_7$ 618.28616, found 618.28604.



2,2-Difluoroethyl 6-*O*-benzoyl-2,3,4-tri-*O*-benzy-D-mannopyranoside (S74). The title compound was prepared according to general procedure VII. Column chromatography (95:5 → 80:20, pentane:Et_2O) yielded the title compound (55 mg, 89 µmol, 89%, colorless oil, α:β; 78:22). TLC: R_f 0.30 (pentane:Et_2O, 80:20, v:v); IR (thin film, cm^{-1}): 696, 1027, 1069, 1273, 1452, 1720, 2924, 3031; Data of the major stereoisomer (α product): ^{1}H NMR (500 MHz, $CDCl_3$, HH-COSY, HSQC): δ 8.32 – 6.85 (m, 20H, CH_{arom}), 5.87 (tdd, J = 55.3, 4.6, 3.6 Hz, 1H, C*H*F_2), 4.93 (d, J = 10.7 Hz, 1H, C*H*H Bn), 4.91 (d, J = 2.0 Hz, 1H, H-1), 4.79 (d, J = 12.1 Hz, 1H, C*H*H Bn), 4.72 – 4.46 (m, 5H, C*H*H Bn, CH*H* Bn, CH*H* Bn, H-6, H-6), 4.10 (t, J = 9.5 Hz, 1H, H-4), 3.96 (dd, J = 9.3, 3.1 Hz, 1H, H-3), 3.93 (ddd, J = 9.8, 4.3, 2.5 Hz, 1H, H-5), 3.86 (dd, J = 3.1, 2.0 Hz, 1H, H-2), 3.80 (dddd, J = 15.3, 14.1, 11.8, 3.6 Hz, 1H, C*H*HCF$_2$), 3.68 (tdd, J = 13.2, 11.8, 4.6 Hz, 1H, CH*H*CF$_2$); ^{13}C NMR (126 MHz, $CDCl_3$, HSQC): δ 166.4 (C=O Bz), 138.6, 138.3, 138.2, 137.9 ($C_{q\text{-}arom}$), 130.1, 128.6, 128.5, 128.5, 128.4, 128.3, 128.3, 128.3, 128.0, 128.0, 127.9, 127.9, 127.7, 127.6 (CH_{arom}), 114.0 (t, J = 241.2 Hz, CF_2), 98.8 (C-1), 80.0 (C-3), 75.4 (CH_2 Bn), 74.8 (C-2), 74.3 (C-4), 73.1, 72.5 (CH_2 Bn), 70.9 (C-5), 66.8 (t, J = 28.1 Hz, CH_2CHF_2), 63.7 (C-6); ^{13}C-GATED NMR (126 MHz, $CDCl_3$): δ 98.8 ($J_{H1\text{-}C1}$ = 170 Hz, α); Data of the minor stereoisomer (β product): ^{1}H NMR (500 MHz, $CDCl_3$, HH-COSY, HSQC): δ 6.04 – 5.77 (m, 1H, C*H*F_2), 4.84 (d, J = 12.1 Hz, 1H, CH*H* Bn), 4.50 (signal overlaps with major isomer, 1H, H-1), 4.03 (t, J = 9.4 Hz, 1H, H-4); ^{13}C NMR (126 MHz, $CDCl_3$, HSQC): δ 101.9 (C-1), 74.4, 74.1, 73.7 (CH_2 Bn), 68.5 (dd, J = 31.1, 25.9 Hz, CH_2CHF_2), 63.9 (C-6); HRMS: $[M+NH_4]^+$ calcd for $C_{36}H_{36}F_2O_7$ 636.27674, found 636.27662.

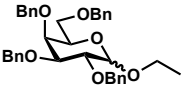


2,2,2-Trifluoroethyl 3-*O*-benzoyl-2,3,4-tri-*O*-benzy-α-D-mannopyranoside (S75). The title compound was prepared according to general procedure VII. Column chromatography (95:5 → 80:20, pentane:Et_2O) yielded the title compound (36 mg, 56 µmol, 56%, colorless oil, α:β; >98:2). TLC: R_f 0.40 (pentane:Et_2O, 80:20, v:v); $[\alpha]_D^{25}$ 34.6° (*c* 1, $CHCl_3$); IR (thin film, cm^{-1}): 697, 712, 1027, 1070, 1166, 1274, 1452, 1720, 2867, 3032; ^{1}H NMR (500 MHz, $CDCl_3$, HH-COSY, HSQC): δ 8.45 – 6.83 (m, 20H, CH_{arom}), 4.93 (s, 1H, H-1), 4.93 (d, J = 10.5 Hz, 1H, C*H*H Bn), 4.79 (d, J = 12.1 Hz, 1H, C*H*H Bn), 4.73 – 4.64 (m, 3H, C*H*H Bn, CH*H* Bn, CH*H* Bn), 4.61 (d, J = 10.8 Hz, 1H, CH*H* Bn), 4.58 – 4.51 (m, 2H, H-6, H-6), 4.11 (t, J = 9.5 Hz, 1H, H-4), 4.01 – 3.80 (m, 5H, H-2, H-3, H-5, C*H*HCF$_3$, CH*H*CF$_3$); ^{13}C NMR (126 MHz, $CDCl_3$, HSQC): δ 166.4 (C=O Bz), 138.3, 138.1, 138.0 ($C_{q\text{-}arom}$), 130.1, 129.8, 128.6, 128.6, 128.5, 128.3, 128.0, 127.9, 127.9, 127.8, 127.1 (CH_{arom}), 123.8 (q, J = 278.3 Hz, CF_3), 98.7 (C-1), 79.8 (C-3), 75.4 (CH_2 Bn), 74.8 (C-2), 74.2 (C-4), 73.3, 72.6 (CH_2 Bn), 71.2 (C-5), 64.4 (q, J = 35.0 Hz, CH_2CF_3), 63.6 (C-6); HRMS: $[M+NH_4]^+$ calcd for $C_{36}H_{35}F_3O_7$ 654.26731, found 654.26715.

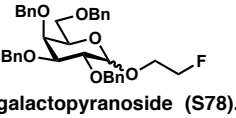


1,1,1,3,3,3-Hexafluoro-2-propyl 6-*O*-benzoyl-2,3,4-tri-*O*-benzyl-α-D-mannopyranoside (S76). The title compound was prepared according to general procedure VII. Column chromatography (100:0 → 85:15, pentane:Et_2O) yielded the title compound (45 mg, 64 µmol, 64%, colorless oil, α:β; >98:2). TLC: R_f 0.25 (pentane:Et_2O, 90:10, v:v); $[\alpha]_D^{25}$ 39.9° (*c* 1, $CHCl_3$); IR (thin film, cm^{-1}): 595, 698, 1027, 1103, 1274, 1720,

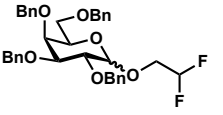
2937, 3034; ^{1}H NMR (500 MHz, $CDCl_3$, HH-COSY, HSQC): δ 8.37 – 6.41 (m, 20H, CH_{arom}), 5.04 (d, *J* = 2.1 Hz, 1H, H-1), 4.90 (d, *J* = 10.7 Hz, 1H, C*H*H Bn), 4.78 (d, *J* = 12.1 Hz, 1H, C*H*H Bn), 4.72 (d, *J* = 11.5 Hz, 1H, C*H*H Bn), 4.68 (d, *J* = 11.6 Hz, 1H, CH*H* Bn), 4.64 – 4.58 (m, 2H, CH*H* Bn, CH*H* Bn), 4.55 (dd, *J* = 12.0, 2.3 Hz, 1H, H-6), 4.51 (dd, *J* = 12.0, 4.3 Hz, 1H, H-6), 4.41 (p, *J* = 5.9 Hz, 1H, C*H*$(CF_3)_2$), 4.11 (t, *J* = 9.3 Hz, 1H, H-4), 3.99 (ddd, *J* = 9.8, 4.1, 2.4 Hz, 1H, H-5), 3.92 (dd, *J* = 8.9, 3.0 Hz, 1H, H-3), 3.86 (dd, *J* = 3.0, 2.1 Hz, 1H, H-2); ^{13}C NMR (126 MHz, $CDCl_3$, HSQC): δ 166.1 (C=O Bz), 137.8, 137.5, 137.5 ($C_{q\text{-}arom}$), 129.8, 129.5, 128.4, 128.4, 128.4, 127.9, 127.8, 127.7, 127.7, 127.5 (CH_{arom}), 100.3 (C-1), 79.0 (C-3), 77.2 (CH_2 Bn), 76.9 (C-2), 76.7 (C-4), 75.1, 74.4 (CH_2 Bn), 72.2 (p, *J* = 32.7 Hz, *C*H$(CF_3)_2$) 71.9 (C-5), 63.1 (C-6); HRMS: $[M+NH_4]^+$ calcd for $C_{37}H_{34}F_6O_7$ 722.25470, found 722.25433.



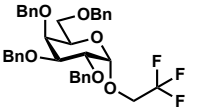
Ethyl 2,3,4,6-tetra-*O*-benzy-D-galactopyranoside (S77). The title compound was prepared according to general procedure VII. Column chromatography (100:0 → 90:10, pentane:EtOAc) yielded the title compound (42 mg, 73 µmol, 73%, colorless oil, α:β; 17:83). TLC: R_f 0.46 (pentane:EtOAc, 90:10, v:v); IR (thin film, cm^{-1}): 731, 1026, 1067, 1092, 1360, 1452, 1497, 2868, 2914; Data of the major stereoisomer (β product): ^{1}H NMR (400 MHz, $CDCl_3$, HH-COSY, HSQC): δ 7.39 – 7.22 (m, 20H, CH_{arom}), 4.97 – 4.90 (m, 2H, C*H*H Bn, C*H*H Bn), 4.76 (m, 2H, CH*H* Bn, C*H*H Bn), 4.73 – 4.67 (m, 1H, C*H*H Bn), 4.62 (d, *J* = 11.7 Hz, 1H, CH*H* Bn), 4.49 – 4.34 (m, 2H, C*H*H Bn, CH*H* Bn), 4.36 (d, *J* = 7.7 Hz, 1H, H-1), 4.03 – 3.92 (m, 1H, C*H*HCH$_3$), 3.88 (d, *J* = 2.7 Hz, 1H, H-4), 3.81 (t, *J* = 8.7 Hz, 1H, H-2), 3.62 – 3.55 (m, 3H, H-6, H-6, C*H*HCH$_3$), 3.56 – 3.46 (m, 2H, H-3, H-5), 1.26 (t, *J* = 7.1 Hz, 3H, C*H*$_3$); ^{13}C-APT NMR ($CDCl_3$, 101 MHz, HSQC): δ 139.0, 138.8, 138.7, 138.1 ($C_{q\text{-}arom}$), 128.5, 128.5, 128.5, 128.4, 128.4, 128.4, 128.3, 128.3, 128.2, 128.0, 127.9, 127.7, 127.6, 127.6 (CH_{arom}), 103.9 (C-1), 82.3 (C-3), 79.8 (C-2), 75.3 (CH_2 Bn), 74.6 (CH_2 Bn), 73.7 (CH_2 Bn), 73.6 (C-4), 73.5 (C-5), 73.2 (CH_2 Bn), 69.1 (C-6), 65.6 (*C*H$_2$CH$_3$), 15.4 (*C*H$_3$); Data of the minor stereoisomer (α product): δ 4.86 (d, *J* = 11.9 Hz, 1H, C*H*H Bn), 4.82 (d, *J* = 4.6 Hz, 1H, H-1), 3.70 (dqd, *J* = 10.1, 7.2, 1.0 Hz, 1H, C*H*HCH$_3$); ^{13}C-APT NMR ($CDCl_3$, 101 MHz, HSQC): δ 97.3 (C-1), 76.7 (C-2), 74.9, 73.4, 69.2 (CH_2 Bn), 63.4 (C-6), 15.1 (CH_3); HRMS: $[M+Na]^+$ calcd for $C_{36}H_{40}O_6Na$ 591.27171, found 591.2710.



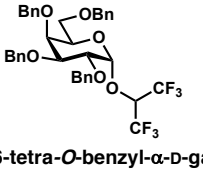
2-Fluoroethyl 2,3,4,6-tetra-*O*-benzy-D-galactopyranoside (S78). The title compound was prepared according to general procedure VII. Column chromatography (97:3 → 85:15, pentane:EtOAc) yielded the title compound (49 mg, 84 µmol, 84%, colorless oil, α:β; 31:69). TLC: R_f 0.36 (pentane:EtOAc, 85:15, v:v); IR (thin film, cm^{-1}): 696, 734, 1027, 1079, 1095, 1347, 1453, 1496, 2914; Data of the major stereoisomer (β product): ^{1}H NMR (500 MHz, $CDCl_3$, HH-COSY, HSQC, HMBC-Gated): δ 7.67 – 7.17 (m, 20H, CH_{arom}), 4.98 – 4.36 (m, 11H, CH_2 Bn, CH_2 Bn, CH_2 Bn, CH_2 Bn, H-1, CH_2C*H*HF, CH_2CH*H*F), 4.13 – 4.01 (m, 1H, C*H*HCH$_2$F), 3.60 – 3.55 (m, 3H, H-2, H-4, CH*H*CH$_2$F), 3.55 – 3.49 (m, 3H, H-6, H-6, H-3); ^{13}C NMR (126 MHz, $CDCl_3$, HSQC, HMBC-Gated): δ 138.8, 138.7, 138.6, 138.0 ($C_{q\text{-}arom}$), 131.1, 129.4, 128.5, 128.5, 128.5, 128.5, 128.4, 128.3, 128.0, 127.7, 127.7, 127.6, 124.9 (CH_{arom}), 104.2 (C-1), 82.7 (d, *J* = 169.8 Hz, *C*H$_2$F), 82.2 (C-3), 79.5 (C-2), 75.3, 74.6, 73.7 (CH_2 Bn), 73.6 (C-4), 73.6 (C-4), 73.5, 73.2 (CH_2 Bn), 69.0 (C-6), 68.8 (d, *J* = 20.2 Hz, *C*H$_2$CH$_2$F); ^{13}C-GATED NMR (126 MHz, $CDCl_3$): δ 104.2 ($J_{H1\text{-}C1}$ = 159 Hz, β); Data of the minor stereoisomer (α product): ^{1}H NMR (500 MHz, $CDCl_3$, HH-COSY, HSQC, HMBC-Gated): 4.86 (d, *J* = 3.6 Hz, 1H, H-1), 4.11 (ddd, *J* = 12.1, 4.4, 2.5, 1H, C*H*HCH$_2$F); ^{13}C NMR (126 MHz, $CDCl_3$, HSQC, HMBC-Gated): δ 98.1 (C-1), 82.7 (d, *J* = 169.8 Hz, *C*H$_2$F), 76.6 (C-2), 75.3, 74.9, 73.4 (CH_2 Bn), 69.5 (C-5), 69.1 (C-6), 67.1 (d, *J* = 20.3 Hz, *C*H$_2$CH$_2$F); ^{13}C-GATED NMR (126 MHz, $CDCl_3$): δ 98.1 ($J_{H1\text{-}C1}$ = 171 Hz, α); HRMS: $[M+Na]^+$ calcd for $C_{36}H_{39}FO_6$ 609.2628, found 609.2637.



2,2-Difluoroethyl 2,3,4,6-tetra-*O*-benzy-D-galactopyranoside (S79). The title compound was prepared according to general procedure VII. Column chromatography (97:3 → 85:15, pentane:EtOAc) yielded the title compound (42 mg, 69 µmol, 69%, colorless oil, α:β; 66:34). TLC: R_f 0.21, 0.31 (pentane:EtOAc, 90:10, v:v); IR (thin film, cm^{-1}): 696, 736, 1028, 1056, 1094, 1361, 1453, 1497, 2917; Data of the major stereoisomer (α product): ^{1}H NMR (500 MHz, $CDCl_3$, HH-COSY, HSQC, HMBC-Gated): δ 7.40 – 7.24 (m, 20H, CH_{arom}), 5.97 (tt, *J* = 55.6, 4.4 Hz, 1H, C*H*F$_2$), 4.94 (dd, *J* = 11.5, 1.3 Hz, 1H, C*H*H Bn), 4.86 – 4.79 (m, 3H, C*H*H Bn, CH*H* Bn, H-1), 4.73 (d, *J* = 11.6 Hz, 1H, C*H*H Bn), 4.65 (d, *J* = 11.9 Hz, 1H, CH*H* Bn), 4.56 (d, *J* = 11.4 Hz, 1H, CH*H* Bn), 4.46 (d, *J* = 11.8 Hz, 1H, C*H*H Bn), 4.43 – 4.37 (m, 1H, CH*H* Bn), 4.05 (dd, *J* = 10.0, 3.7 Hz, 1H, H-2), 3.98 – 3.90 (m, 3H, H-3, H-4, H-5), 3.73 (ddd, *J* = 14.7, 13.0, 4.4 Hz, 1H, C*H*HCHF$_2$), 3.80 – 3.66 (m, 1H, CH*H*CHF$_2$), 3.60 – 3.46 (m, 2H, H-6, H-6); ^{13}C NMR (126 MHz, $CDCl_3$, HSQC, HMBC-Gated): δ 138.8, 138.6, 138.6, 138.0 ($C_{q\text{-}arom}$), 128.5, 128.4, 128.4, 128.2, 127.8, 127.8, 127.7, 127.6 (CH_{arom}), 114.3 (t, *J* = 241.2 Hz, *C*HF$_2$), 98.9 (C-1), 78.9 (C-3), 76.5 (C-2), 75.1 (C-4), 74.9, 73.7, 73.6, 73.4 (CH_2 Bn), 69.9 (C-5), 69.1 (C-6), 67.5 (t, *J* = 28.9 Hz, *C*H$_2$CHF$_2$); ^{13}C-GATED NMR (126 MHz, $CDCl_3$): δ 98.9 ($J_{H1\text{-}C1}$ = 169 Hz, α); Data of the minor stereoisomer (β product): ^{1}H NMR (500 MHz, $CDCl_3$, HH-COSY, HSQC, HMBC-Gated): δ 5.91 (dddd, *J* = 56.3, 54.7, 5.4, 3.1 Hz, *C*HF$_2$), 4.88 (d, *J* = 10.8 Hz, 1H, C*H*H Bn), 4.61 (d, *J* = 11.6 Hz, 1H, CH*H* Bn), 4.39 (d, *J* = 7.6 Hz, 1H, H-1), 3.83 (dd, *J* = 9.7, 7.6 Hz, 1H, H-2); ^{13}C NMR (126 MHz, $CDCl_3$, HSQC, HMBC-Gated): δ 114.4 (dd, *J* = 242.1, 239.7 Hz, *C*HF$_2$), 104.3 (C-1), 79.3 (C-2), 75.4, 74.7 (CH_2 Bn), 73.8 (C-3), 73.7, 73.3 (CH_2 Bn), 68.9 (C-6); ^{13}C-GATED NMR (126 MHz, $CDCl_3$): δ 104.3 ($J_{H1\text{-}C1}$ = 159 Hz, β); HRMS: $[M+Na]^+$ calcd for $C_{36}H_{38}F_2O_6$ 627.2534, found 627.2542.

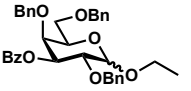


2,2,2-Trifluoroethyl 2,3,4,6-tetra-*O*-benzy-α-D-galactopyranoside (S80). The title compound was prepared according to general procedure VII. Column chromatography (97:3 → 90:10, pentane:EtOAc) yielded the title compound (49 mg, 79 µmol, 79%, colorless oil, α:β; 87:13). TLC: R_f 0.28, 0.47 (pentane:EtOAc, 90:10, v:v); $[\alpha]_D^{20}$ –27.5° (*c* 1, $CHCl_3$); IR (thin film, cm^{-1}): 696, 735, 1079, 1153, 1278, 1351, 1453, 1497, 2915; Data of the major stereoisomer (α product): ^{1}H NMR (400 MHz, $CDCl_3$, HH-COSY, HSQC, ^{13}C-HMBC-Gated): δ 7.52 – 7.05 (m, 20H, CH_{arom}), 4.94 (d, *J* = 11.4 Hz, 1H, C*H*H Bn), 4.88 (d, *J* = 3.7 Hz, 1H, H-1), 4.87 – 4.79 (m, 2H, C*H*H Bn, CH*H* Bn), 4.73 (d, *J* = 11.6 Hz, 1H, CH*H* Bn), 4.65 (d, *J* = 11.9 Hz, 1H, CH*H* Bn), 4.56 (d, *J* = 11.4 Hz, 1H, C*H*H Bn), 4.46 (d, *J* = 11.9 Hz, 1H, C*H*H Bn), 4.39 (d, *J* = 11.8 Hz, 1H, CH*H* Bn), 4.07 (dd, *J* = 10.0, 3.7 Hz, 1H, H-2), 4.00 – 3.87 (m, 5H, C*H*HCF$_3$, CH*H*CF$_3$, H-3, H-4, H-5), 3.55 – 3.48 (m, 2H, H-6, H-6); ^{13}C NMR (101 MHz, $CDCl_3$, HSQC, ^{13}C-HMBC-Gated): δ 138.8, 138.6, 138.5, 138.0 ($C_{q\text{-}arom}$), 128.6, 128.6, 128.0, 128.0, 127.9, 127.9, 127.8, 127.8, 127.7, 127.6 (CH_{arom}), 122.6 (q, *J* = 281.9 Hz, *C*F$_3$), 98.3 (C-1), 78.7 (C-3), 76.3 (C-2), 75.0 (CH_2 Bn), 74.9 (C-4), 73.6, 73.5, 73.5 (CH_2 Bn), 70.2 (C-5), 68.9 (C-6), 64.6 (q, *J* = 34.7 Hz, *C*H$_2$CF$_3$); ^{13}C-GATED NMR (101 MHz, $CDCl_3$): δ 98.3 ($J_{H1\text{-}C1}$ = 172 Hz, α); Data of the minor stereoisomer (β product): ^{1}H NMR (400 MHz, $CDCl_3$, HH-COSY, HSQC, ^{13}C-HMBC-Gated): 4.17 (dq, *J* = 12.4, 8.8 Hz, 1H, C*H*HCF$_3$); ^{13}C NMR (101 MHz, $CDCl_3$, HSQC, ^{13}C-HMBC-Gated): 104.1 (C-1), 66.0 (q, *J* = 34.8 Hz, *C*H$_2$CF$_3$); HRMS: $[M+Na]^+$ calcd for $C_{36}H_{37}F_3O_6$ 645.2440, found 645.2445.

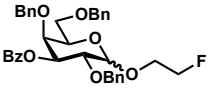


1,1,1,3,3,3-Hexafluoro-2-propyl 2,3,4,6-tetra-*O*-benzyl-α-D-galactopyranoside (S81). The title compound was prepared according to general procedure VII. Column chromatography (100:0 → 80:20, pentane:Et_2O) yielded the title compound (23 mg, 33 µmol, 33%, colorless oil, α:β; >98:2). TLC: R_f 0.38

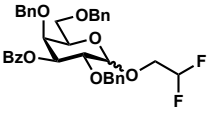
(pentane:EtOAc, 95:5, v:v); $[\alpha]_D^{20}$ 58.8° (*c* 1, $CHCl_3$); IR (thin film, cm^{-1}): 689, 696, 734, 1028, 1051, 1102, 1195, 1218, 1287, 1169, 1454, 1497, 2926; ^1H NMR (500 MHz, $CDCl_3$, HH-COSY, HSQC, HMBC-Gated, ^1H-^{19}F Decoupled): δ 7.39 – 7.23 (m, 20H, CH_{arom}), 5.15 (d, *J* = 3.8 Hz, 1H, H-1), 4.94 (d, *J* = 11.3 Hz, 1H, C*H*H Bn), 4.84 (d, *J* = 11.5 Hz, 1H, C*H*H Bn), 4.79 – 4.66 (m, 3H, CH*H* Bn, CH*H* Bn, C*H*H Bn), 4.56 (d, *J* = 11.3 Hz, 1H, CH*H* Bn), 4.50 – 4.39 (m, 3H, C*H*H Bn, CH*H* Bn, C*H*$(CF_3)_2$), 4.13 (dd, *J* = 10.2, 3.8 Hz, 1H, H-2), 4.07 – 4.00 (m, 2H, H-4, H-5), 3.94 (dd, *J* = 10.2, 2.7 Hz, 1H, H-3), 3.57 – 3.46 (m, 2H, H-6, H-6); ^{13}C NMR (126 MHz, $CDCl_3$, HSQC, HMBC-Gated): δ 138.7, 138.5, 138.2, 138.0 ($C_{q\text{-}arom}$), 128.6, 128.5, 128.5, 128.4, 128.3, 128.0, 127.9, 127.9, 127.8, 127.8, 127.7, 127.6 (CH_{arom}), 99.9 (C-1), 78.4 (C-3), 75.5 (C-2), 75.0 (CH_2 Bn), 74.7 (C-4), 73.6, 73.6, 73.4 (CH_2 Bn), 72.5 (p, *J* = 33.3 Hz, C*H*$(CF_3)_2$), 70.9 (C-5), 68.4 (C-6); ^{13}C-GATED NMR (126 MHz, $CDCl_3$): δ 99.9 ($J_{H1\text{-}C1}$ = 174 Hz, α); HRMS: $[M+Na]^+$ calcd for $C_{37}H_{36}F_6O_6$ 713.2314, found 713.2319.



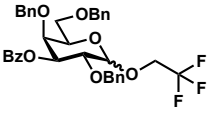
Ethyl 3-*O*-benzoyl-2,4,6-tri-*O*-benzy-D-galactopyranoside (S82). The title compound was prepared according to general procedure VII. Column chromatography (100:0 → 85:15, pentane:Et_2O) yielded the title compound (46 mg, 79 µmol, 79%, colorless oil, α:β; 41:59). TLC: R_f 0.25 (pentane:Et_2O, 80:20, v:v); IR (thin film, cm^{-1}): 695, 735, 1026, 1069, 1270, 1720, 2869, 3063; Data of the major stereoisomer (β product): ^1H NMR (400 MHz, $CDCl_3$, HH-COSY, HSQC): δ 8.24 – 6.93 (m, 20H, CH_{arom}), 5.19 (dd, *J* = 10.2, 3.1 Hz, 1H, H-3), 4.86 (d, *J* = 11.5 Hz, 1H, C*H*H Bn), 4.70 (d, *J* = 11.4 Hz, 1H, CH*H* Bn), 4.66 – 4.60 (m, 2H, C*H*H Bn, CH*H* Bn), 4.54 – 4.39 (m, 3H, H-1, C*H*H Bn, CH*H* Bn), 4.22 – 4.12 (m, 1H, H-5), 4.07 (dd, *J* = 3.2, 1.0 Hz, 1H, H-4), 4.02 (dq, *J* = 9.5, 7.1 Hz, 1H, C*H*HCH$_3$), 3.93 (dd, *J* = 10.2, 7.7 Hz, 1H, H-2), 3.69 – 3.58 (m, 2H, H-6, CH*H*CH$_3$), 3.58 – 3.49 (m, 1H, H-6), 1.29 (t, *J* = 7.1 Hz, 3H, CH_3); ^{13}C NMR (101 MHz, $CDCl_3$, HSQC): δ 166.0 (C=O Bz), 138.4, 138.2, 138.0, 138.0 ($C_{q\text{-}arom}$), 130.1, 129.9, 128.5, 128.4, 128.4, 128.3, 128.1, 128.1, 127.9, 127.9, 127.9, 127.8, 127.8, 127.8, 127.8, 127.8, 127.7, 127.6 (CH_{arom}), 103.9 (C-1), 76.7 (C-2), 75.7 (C-3), 75.0, 74.7 (CH_2 Bn), 74.5 (C-4), 73.6 (CH_2 Bn), 68.8 (C-5), 68.6 (C-6), 65.8 (*C*H$_2$CH$_3$), 15.4 (*C*H$_3$); Data of the minor stereoisomer (α product): ^1H NMR (400 MHz, $CDCl_3$, HH-COSY, HSQC): δ 5.57 (dd, *J* = 10.5, 3.1 Hz, 1H, H-3), 4.90 (d, *J* = 3.6 Hz, 1H, H-1), 1.27 (t, *J* = 7.1 Hz, 3H, CH_3); ^{13}C NMR (101 MHz, $CDCl_3$, HSQC): δ 97.2 (C-1), 75.3 (CH_2 Bn), 74.3 (C-2), 73.5, 73.0 (CH_2 Bn), 68.8 (C-3), 68.7 (C-6), 63.7 (*C*H$_2$CH$_3$), 15.2 (*C*H$_3$); HRMS: $[M+NH_4]^+$ calcd for $C_{36}H_{38}O_7$ 600.29558, found 600.29551.



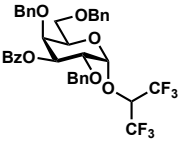
2-Fluoroethyl 3-*O*-benzoyl-2,4,6-tri-*O*-benzy-D-galactopyranoside (S83). The title compound was prepared according to general procedure VII. Column chromatography (90:10 → 60:40, pentane:Et_2O) yielded the title compound (49 mg, 82 µmol, 82%, colorless oil, α:β; 40:60). TLC: R_f 0.20 (pentane:Et_2O, 70:30, v:v); IR (thin film, cm^{-1}): 538, 696, 711, 735, 1026, 1043, 1070, 1077, 1270, 1452, 1720, 1870, 3030; Data of the major stereoisomer (β product): ^1H NMR (400 MHz, $CDCl_3$, HH-COSY, HSQC): δ 8.26 – 6.97 (m, 20H, CH_{arom}), 5.19 (dd, *J* = 10.2, 3.1 Hz, 1H, H-3), 4.87 (d, *J* = 11.4 Hz, 1H, C*H*H Bn), 4.76 – 4.58 (m, 3H, C*H*H Bn, C*H*H Bn, C*H*HCH$_2$F), 4.55 (d, *J* = 7.7 Hz, 1H, H-1), 4.59 – 4.39 (m, 4H, CH*H* Bn, CH*H* Bn, CH*H* Bn, CH*H*CH$_2$F), 4.19 – 4.05 (m, 1H, C*H*HF), 4.08 (d, *J* = 2.7 Hz, 1H, H-4), 3.96 (dd, *J* = 10.2, 7.6 Hz, 1H, H-2), 3.94 – 3.81 (m, 1H, CH*H*F), 3.77 (dd, *J* = 7.4, 6.1 Hz, 1H, H-5), 3.60 (t, *J* = 6.3 Hz, 2H, H-6), 3.55 (dd, *J* = 6.6, 1.3 Hz, 1H, H-6); ^{13}C NMR (101 MHz, $CDCl_3$, HSQC): δ 165.9 (C=O Bz), 138.2, 138.1, 138.0, 137.9 ($C_{q\text{-}arom}$), 130.0, 129.9, 129.7, 129.4, 128.5, 128.4, 128.4, 128.4, 128.3, 128.3, 128.2, 128.2, 128.1, 127.6 (CH_{arom}), 104.2 (C-1), 82.7 (d, *J* = 169.8 Hz, *C*H$_2$F), 76.4 (C-2), 75.5 (C-3), 75.1, 74.7 (CH_2 Bn), 74.3 (C-4), 73.6 (CH_2 Bn), 73.4 (C-5), 69.0 (d, *J* = 20.1 Hz, *C*H$_2$CH$_2$F), 68.5 (C-6); Data of the minor stereoisomer (α product): ^1H NMR (400 MHz, $CDCl_3$, HH-COSY, HSQC): δ 5.59 (dd, *J* = 10.6, 3.1 Hz, 1H, H-3), 4.95 (d, *J* = 3.6 Hz, 1H, H-1), 4.18 (d, *J* = 3.7 Hz, 1H, H-4); ^{13}C NMR (101 MHz, $CDCl_3$, HSQC): δ 97.8 (C-1), 82.7 (d, *J* = 169.7 Hz, *C*H$_2$F), 75.3, 73.4, 73.0 (CH_2 Bn), 67.2 (d, *J* = 20.2 Hz, *C*H$_2$CH$_2$F); HRMS: $[M+NH_4]^+$ calcd for $C_{36}H_{37}FO_7$ 618.28616, found 618.28638.



2,2-Difluoroethyl 3-*O*-benzoyl-2,4,6-tri-*O*-benzy-D-galactopyranoside (S84). The title compound was prepared according to general procedure VII. Column chromatography (95:5 → 75:25, pentane:Et_2O) yielded the title compound (50 mg, 81 µmol, 81%, colorless oil, α:β; 66:34). TLC: R_f 0.20 (pentane:Et_2O, 80:20, v:v); IR (thin film, cm^{-1}): 695, 1026, 1069, 1093, 1270, 1452, 1720, 2869, 3030; Data of the major stereoisomer (α product): ^{1}H NMR (400 MHz, $CDCl_3$, HH-COSY, HSQC): δ 8.32 – 6.86 (m, 20H, CH_{arom}), 5.99 (tt, *J* = 55.5, 4.3 Hz, 1H, C*H*F_2), 5.55 (dd, *J* = 10.6, 3.0 Hz, 1H, H-3), 4.91 (d, *J* = 3.7 Hz, 1H, H-1), 4.75 – 4.58 (m, 3H, C*H*H Bn, C*H*H Bn, CH*H* Bn), 4.56 – 4.36 (m, 3H, CH*H* Bn, C*H*H Bn, CH*H* Bn), 4.23 – 4.11 (m, 3H, H-2, H-3, H-4), 3.89 – 3.68 (m, 2H, C*H*HCHF_2, CH*H*CHF_2), 3.67 – 3.49 (m, 1H, H-6), 3.53 (dd, *J* = 6.5, 5.1 Hz, 2H, H-6); ^{13}C NMR (101 MHz, $CDCl_3$, HSQC): δ 165.9 (C=O Bz), 138.1, 138.0, 137.9, 137.8 ($C_{q\text{-}arom}$), 129.9, 129.7, 128.6, 128.5, 128.4, 128.4, 128.3, 128.3, 128.1, 128.0, 128.0, 128.0, 128.0, 127.9, 127.9, 127.8, 127.8 (CH_{arom}), 114.3 (t, *J* = 241.2 Hz, *C*HF_2), 98.4 (C-1), 75.4 (C-2), 75.3 (CH_2 Bn), 74.0 (C-4), 73.5, 73.3 (CH_2 Bn), 72.7 (C-3), 69.4 (C-5), 68.6 (C-6), 67.5 (t, *J* = 29.0 Hz, *C*H_2CHF_2); Data of the minor stereoisomer (β product): ^{1}H NMR (400 MHz, $CDCl_3$, HH-COSY, HSQC): δ 5.19 (dd, *J* = 10.2, 3.2 Hz, 1H, H-3), 4.82 (d, *J* = 11.4 Hz, 1H, C*H*H Bn), 4.54 (d, *J* = 7.6 Hz, 1H, H-1), 4.08 (d, *J* = 3.2 Hz, 1H, H-4), 3.96 (dd, *J* = 10.2, 7.6 Hz, 1H, H-2); ^{13}C NMR (101 MHz, $CDCl_3$, HSQC): δ 114.3 (dd, *J* = 242.0, 240.0 Hz, *C*HF_2), 104.3 (C-1), 76.4 (C-2), 75.1, 74.8, 73.6 (CH_2 Bn), 68.8 (dd, *J* = 30.4, 27.1 Hz, *C*H_2CHF_2), 68.4 (C-6); HRMS: $[M+NH_4]^+$ calcd for $C_{36}H_{36}F_2O_7$ 636.27674, found 636.27661.

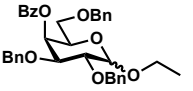


2,2,2-Trifluoroethyl 3-*O*-benzoyl-2,4,6-tri-*O*-benzy-D-galactopyranoside (S85). The title compound was prepared according to general procedure VII. Column chromatography (95:5 → 80:20, pentane:Et_2O) yielded the title compound (49 mg, 77 µmol, 77%, colorless oil, α:β; 86:14). TLC: R_f 0.35 (pentane:Et_2O, 80:20, v:v); IR (thin film, cm^{-1}): 695, 711, 735, 989, 1026, 1096, 1154, 1270, 1452, 1496, 1720, 2923, 3032; Data of the major stereoisomer (α product): ^{1}H NMR (400 MHz, $CDCl_3$, HH-COSY, HSQC): δ 8.16 – 7.12 (m, 20H, CH_{arom}), 5.53 (dd, *J* = 10.5, 3.1 Hz, 1H, H-3), 4.96 (d, *J* = 3.7 Hz, 1H, H-1), 4.71 (d, *J* = 12.3 Hz, 1H, C*H*H Bn), 4.63 (d, *J* = 11.5 Hz, 1H, C*H*H Bn), 4.62 (d, *J* = 12.2 Hz, 1H, CH*H* Bn), 4.50 (d, *J* = 11.9 Hz, 1H, C*H*H Bn), 4.43 (d, *J* = 11.4 Hz, 1H, CH*H* Bn), 4.47 – 4.39 (m, 1H, CH*H* Bn), 4.27 – 4.17 (m, 2H, H-2, H-4), 4.13 (td, *J* = 6.5, 1.2 Hz, 1H, H-5), 4.03 – 3.85 (m, 2H, C*H*HCF_3, CH*H*CF_3), 3.53 (dd, *J* = 6.6, 2.0 Hz, 2H, H-6, H-6); ^{13}C NMR (101 MHz, $CDCl_3$, HSQC): δ 165.9 (C=O Bz), 138.1, 137.9, 137.9, 137.8 ($C_{q\text{-}arom}$), 129.6, 128.6, 128.6, 128.5, 128.4, 128.4, 128.3, 128.0, 128.0, 128.0, 127.9 (CH_{arom}), 123.9 (q, *J* = 278.7 Hz, *C*F_3), 98.2 (C-1), 75.3 (CH_2 Bn), 75.3 (C-2), 73.8 (C-4), 73.5, 73.1 (CH_2 Bn), 72.7 (C-3), 69.7 (C-5), 68.4 (C-6), 64.9 (q, *J* = 34.9 Hz, *C*H_2CF_3); Data of the minor stereoisomer (β product): ^{1}H NMR (400 MHz, $CDCl_3$, HH-COSY, HSQC): δ 5.18 (dd, *J* = 10.2, 3.1 Hz, 1H, H-3), 4.84 (d, *J* = 11.3 Hz, 1H, C*H*H Bn), 4.60 (d, *J* = 7.5 Hz, 1H, H-1), 4.08 (dd, *J* = 3.2, 1.0 Hz, 1H, H-4); ^{13}C NMR (101 MHz, $CDCl_3$, HSQC): δ 104.1 (C-1), 76.1 (C-2), 75.2, 74.7, 73.6 (CH_2 Bn), 68.3 (C-6), 66.2 (d, *J* = 35.1 Hz, *C*H_2CF_3); HRMS: $[M+NH_4]^+$ calcd for $C_{36}H_{35}F_3O_7$ 654.26731, found 654.26738.

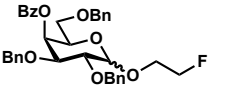


1,1,1,3,3,3-Hexafluoro-2-propyl 3-*O*-benzoyl-2,4,6-tri-*O*-benzyl-α-D-galactopyranoside (S86). The title compound was prepared according to general procedure VII. Column chromatography (100:0 → 80:20, pentane:Et_2O) yielded the title compound (38 mg, 55 µmol, 55%, colorless oil, α:β; >98:2). TLC: R_f 0.15 (pentane:Et_2O, 90:10, v:v); $[\alpha]_D^{25}$ 42.2° (*c* 1, $CHCl_3$); 687, 697, 735, 1105, 1196, 1219, 1315, 1452, 1496, 1720, 2363, 2868, 2936, 3065; ^{1}H NMR (500 MHz, $CDCl_3$, HH-COSY, HSQC): δ 8.22 – 7.13 (m, 20H, CH_{arom}), 5.51 (dd, *J* = 10.7, 3.0 Hz, 1H, H-3), 5.24 (d, *J* = 3.8 Hz, 1H, H-1), 4.69 (d, *J* = 12.1 Hz, 1H, C*H*H

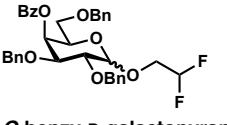
Bn), 4.63 (d, *J* = 12.0 Hz, 1H, CH*H* Bn), 4.61 (d, *J* = 11.3 Hz, 1H, C*H*H Bn), 4.50 (d, *J* = 12.1 Hz, 1H, CH*H* Bn), 4.49 – 4.41 (m, 3H, C*H*H Bn, CH*H* Bn, C*H*(CF_3)$_2$), 4.28 (dd, *J* = 10.7, 3.8 Hz, 1H, H-2), 4.26 – 4.22 (m, 2H, H-4, H-5), 3.60 – 3.48 (m, 2H, H-6, H-6); ^{13}C NMR (126 MHz, $CDCl_3$, HSQC): δ 165.9 (C=O Bz), 137.9, 137.6 ($C_{q\text{-arom}}$), 129.8, 128.6, 128.6, 128.5, 128.5, 128.2, 128.1, 128.0, 127.9, 127.9, 127.7 (CH_{arom}), 99.7 (C-1), 75.4 (CH_2 Bn), 75.0 (C-4), 73.5, 73.1 (CH_2 Bn), 72.9 (C-2), 72.4 (C-3), 70.3 (C-5), 68.0 (C-6); HRMS: $[M+NH_4]^+$ calcd for $C_{37}H_{34}F_6O_7$ 722.25470, found 722.25438.



Ethyl 4-*O*-benzoyl-2,3,6-tri-*O*-benzy-D-galactopyranoside (S87). The title compound was prepared according to general procedure VII. Column chromatography (95:5 → 70:30, pentane:Et_2O) yielded the title compound (50 mg, 86 µmol, 86%, colorless oil, α:β; 45:55). TLC: R_f 0.25 (pentane:Et_2O, 80:20x, v:v); IR (thin film, cm^{-1}): 696, 711, 1026, 1068, 1271, 1173, 1720, 2866, 3032; Data of the major stereoisomer (β product): ^{1}H NMR (500 MHz, $CDCl_3$, HH-COSY, HSQC): δ 8.29 – 7.03 (m, 20H, CH_{arom}), 5.83 (d, *J* = 1.9 Hz, 1H, H-4), 4.92 – 4.80 (m, 2H, C*H*H Bn, C*H*H Bn), 4.73 (d, *J* = 10.8 Hz, 1H, CH*H* Bn), 4.57 (d, *J* = 11.6 Hz, 1H, CH*H* Bn), 4.51 (d, *J* = 11.8 Hz, 1H, CH*H* Bn), 4.49 (d, *J* = 11.8 Hz, 1H, C*H*H Bn), 4.45 (d, *J* = 7.6 Hz, 1H, H-1), 4.04 (dq, *J* = 9.6, 7.1 Hz, 1H, C*H*HCH$_3$), 3.82 (ddd, *J* = 7.0, 5.9, 1.1 Hz, 1H, H-5), 3.71 – 3.57 (m, 3H, H-2, H-3, CH*H*CH$_3$), 3.53 (m, 2H, H-6, H-6), 1.32 (t, *J* = 7.1 Hz, 3H, C*H*$_3$); ^{13}C NMR (126 MHz, $CDCl_3$, HSQC): δ 166.0 (C=O Bz), 138.8, 138.7, 138.1, 137.8 ($C_{q\text{-arom}}$), 128.5, 128.4, 128.4, 128.4, 128.3, 128.3, 128.3, 128.2, 128.1, 128.0, 127.7, 127.7, 127.5 (CH_{arom}), 103.9 (C-1), 79.5 (C-3/C-2), 76.7 (C-2/C-3), 75.5, 73.9 (CH_2 Bn), 72.6 (C-5), 72.0 (CH_2 Bn), 68.6 (C-6), 67.6 (C-4), 66.1 (*C*H$_2$CH$_3$), 15.5 (*C*H$_3$); Data of the minor stereoisomer (α product): ^{1}H NMR (500 MHz, $CDCl_3$, HH-COSY, HSQC): δ 5.86 (dd, *J* = 3.5, 1.2 Hz, 1H, H-4), 4.92 – 4.80 (signal overlaps with major isomer, 1H, H-1), 4.65 (d, *J* = 12.1 Hz, 1H, CH*H* Bn), 4.22 (td, *J* = 6.3, 1.1 Hz, 1H, H-5), 4.10 (dd, *J* = 10.0, 3.3 Hz, 1H, H-3), 3.89 (dd, *J* = 10.0, 3.7 Hz, 1H, H-2), 3.76 (dq, *J* = 10.0, 7.1 Hz, 1H, C*H*HCH$_3$), 1.28 (t, *J* = 7.1 Hz, 3H, CH$_3$); ^{13}C NMR (126 MHz, $CDCl_3$, HSQC): δ 97.7 (C-1), 76.7 (C-3), 75.3 (C-2), 73.7, 73.6, 72.1 (CH_2 Bn), 68.9 (C-6), 68.1 (C-4), 15.1 (*C*H$_3$); HRMS: $[M+NH_4]^+$ calcd for $C_{36}H_{38}O_7$ 600.29558, found 600.29569.

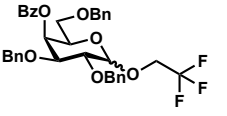


2-Fluoroethyl 4-*O*-benzoyl-2,3,6-tri-*O*-benzy-D-galactopyranoside (S88). The title compound was prepared according to general procedure VII. Column chromatography (90:10 → 60:40, pentane:Et_2O) yielded the title compound (50 mg, 84 µmol, 84%, colorless oil, α:β; 63:37). TLC: R_f 0.20 (pentane:Et_2O, 70:30, v:v); IR (thin film, cm^{-1}): 536, 712, 740, 1090, 1270, 1720, 2870, 3032; Data of the major stereoisomer (α product): ^{1}H NMR (500 MHz, $CDCl_3$, HH-COSY, HSQC): δ 8.15 – 7.02 (m, 20H, CH_{arom}), 5.87 (dd, *J* = 3.4, 1.3 Hz, 1H, H-4), 4.95 (d, *J* = 3.7 Hz, 1H, H-1), 4.87 – 4.80 (m, 2H, C*H*H Bn, C*H*H Bn), 4.69 – 4.54 (m, 4H, CH*H* Bn, CH*H* Bn, C*H*HF, CH*H*F), 4.53 – 4.38 (m, 2H, C*H*H Bn, CH*H* Bn), 4.27 (td, *J* = 6.3, 1.3 Hz, 1H, H-5), 4.11 (dd, *J* = 10.1, 3.2 Hz, 1H, H-3), 3.92 (dd, *J* = 9.9, 3.7 Hz, 1H, H-2), 3.90 – 3.74 (m, 2H, C*H*HCH$_2$F, CHHCH$_2$F), 3.60 – 3.49 (m, 2H, H-6, H-6); ^{13}C NMR (126 MHz, $CDCl_3$, HSQC): δ 165.9 (C=O Bz), 138.6, 138.5, 138.0, 137.8 ($C_{q\text{-arom}}$), 129.9, 128.5, 128.5, 128.4, 128.4, 128.4, 128.4, 128.3, 128.2, 128.1, 127.8, 127.8, 127.7, 127.6 (CH_{arom}), 98.4 (C-1), 82.8 (d, *J* = 169.8 Hz, *C*H$_2$F), 76.5 (C-3), 75.2 (C-2), 73.7, 73.6, 72.1 (CH_2 Bn), 68.8 (C-4), 68.8 (C-6), 68.2 (C-5), 67.3 (d, *J* = 20.1 Hz, *C*H$_2$CH$_2$F); Data of the minor stereoisomer (β product): ^{1}H NMR (500 MHz, $CDCl_3$, HH-COSY, HSQC): δ 5.82 (dd, *J* = 3.3, 1.1 Hz, 1H, H-4), 4.50 (d, *J* = 7.4 Hz, 1H, H-1); ^{13}C NMR (126 MHz, $CDCl_3$, HSQC): 104.2 (C-1), 69.3 (d, *J* = 20.1 Hz, *C*H$_2$CH$_2$F), 67.5 (C-4); HRMS: $[M+NH_4]^+$ calcd for $C_{36}H_{37}FO_7$ 618.28616, found 618.28617.

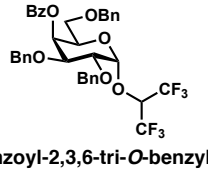


2,2-Difluoroethyl 4-*O*-benzoyl-2,3,6-tri-*O*-benzy-D-galactopyranoside (S89). The title compound was prepared according to general procedure VII. Column chromatography (95:5 → 80:20, pentane:Et_2O) yielded the title compound (40 mg, 65 µmol, 65%, colorless oil, α:β; 44:56). TLC: R_f 0.30 (pentane:Et_2O,

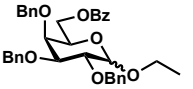
80:20, v:v); IR (thin film, cm^{-1}): 738, 1026, 1267, 1720, 2869, 3032; Data of the major stereoisomer (β product): ^{1}H NMR (400 MHz, $CDCl_3$, HH-COSY, HSQC): δ 8.44 – 7.02 (m, 20H, CH_{arom}), 6.02 (tt, *J* = 55.5, 4.3 Hz, 1H, C*H*F_2), 5.86 (dd, *J* = 3.4, 1.2 Hz, 1H, H-4), 4.91 (d, *J* = 3.7 Hz, 1H, H-1), 4.85 (d, *J* = 11.2 Hz, 1H, C*H*H Bn), 4.83 (d, *J* = 11.9 Hz, 1H, C*H*H Bn), 4.64 (d, *J* = 11.9 Hz, 1H, CH*H* Bn), 4.58 (d, *J* = 11.2 Hz, 1H, CH*H* Bn), 4.49 (d, *J* = 11.8 Hz, 1H, C*H*H Bn), 4.41 (d, *J* = 11.9 Hz, 1H, CH*H* Bn), 4.21 (td, *J* = 6.3, 1.3 Hz, 1H, H-5), 4.07 (dd, *J* = 10.1, 3.2 Hz, 1H, H-3), 3.92 (dd, *J* = 10.1, 3.6 Hz, 1H, H-2), 3.80 (m, 2H, C*H*HCHF_2, CH*H*CHF_2), 3.53 (m, 2H, H-6, H-6); ^{13}C NMR (101 MHz, $CDCl_3$, HSQC): δ 165.8 (C=O Bz), 138.3, 138.1, 137.7 ($C_{q\text{-}arom}$), 128.5, 128.5, 128.4, 128.4, 128.4, 128.2, 128.1, 128.0, 127.9, 127.8, 127.8, 127.6 (CH_{arom}), 114.3 (t, *J* = 241.3 Hz, *C*HF_2), 99.1 (C-1), 76.3 (C-3), 75.1 (C-2), 73.9, 73.7, 72.1 (CH_2 Bn), 68.7 (C-6), 68.6 (C-5), 67.7 (t, *J* = 28.9 Hz, *C*H_2CHF_2); Data of the minor stereoisomer (α product): ^{1}H NMR (400 MHz, $CDCl_3$, HH-COSY, HSQC): δ 5.82 (dd, *J* = 2.9, 1.1 Hz, 1H, H-4), 4.72 (d, *J* = 10.7 Hz, 1H, CH*H* Bn), 4.52-4.46 (signal overlaps with major isomer, 1H, H-1); ^{13}C NMR (101 MHz, $CDCl_3$, HSQC): δ 104.3 (C-1), 72.1 (CH_2 Bn); HRMS: $[M+NH_4]^+$ calcd for $C_{36}H_{36}F_2O_7$ 636.27674, found 636.27679.



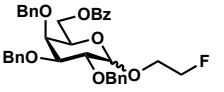
2,2,2-Trifluoroethyl 4-*O*-benzoyl-2,3,6-tri-*O*-benzy-D-galactopyranoside (S90). The title compound was prepared according to general procedure VII. Column chromatography (95:5 → 85:15, pentane:Et_2O) yielded the title compound (51 mg, 79 µmol, 79%, colorless oil, α:β; 97:3). TLC: R_f 0.40 (pentane:Et_2O, 80:20, v:v); IR (thin film, cm^{-1}): 596, 696, 735, 1054, 1267, 1720, 2873, 3032; Data of the major stereoisomer (α product): ^{1}H NMR (500 MHz, $CDCl_3$, HH-COSY, HSQC): δ 8.43 – 6.88 (m, 20H, CH_{arom}), 5.87 (dd, *J* = 3.4, 1.2 Hz, 1H, H-4), 4.97 (d, *J* = 3.7 Hz, 1H, H-1), 4.85 (d, *J* = 11.1 Hz, 1H, C*H*H Bn), 4.82 (d, *J* = 11.9 Hz, 1H, C*H*H Bn), 4.63 (d, *J* = 12.0 Hz, 1H, CH*H* Bn), 4.58 (d, *J* = 11.1 Hz, 1H, CH*H* Bn), 4.49 (d, *J* = 11.9 Hz, 1H, C*H*H Bn), 4.41 (d, *J* = 11.9 Hz, 1H, CH*H* Bn), 4.19 (td, *J* = 6.3, 1.3 Hz, 1H, H-5), 4.08 (dd, *J* = 10.1, 3.3 Hz, 1H, H-3), 4.00 – 3.91 (m, 3H, H-2, C*H*HCF_3, CH*H*CF_3), 3.60 – 3.46 (m, 2H, H-6, H-6); ^{13}C NMR (126 MHz, $CDCl_3$, HSQC): δ 165.8 (C=O Bz), 138.4, 138.2, 137.7 ($C_{q\text{-}arom}$), 130.0, 128.5, 128.5, 128.5, 128.4, 128.4, 128.3, 128.1, 128.0, 127.9, 127.9, 127.8, 127.8, 127.2 (CH_{arom}), 123.9z (q, *J* = 278.8 Hz, *C*F_3), 98.7 (C-1), 76.1 (C-3), 75.0 (C-2), 73.7, 73.7, 72.2 (CH_2 Bn), 68.9 (C-5), 68.6 (C-6), 68.5 (C-4), 64.9 (q, *J* = 34.9 Hz, *C*H_2CF_3); Data of the minor stereoisomer (β product): ^{1}H NMR (500 MHz, $CDCl_3$, HH-COSY, HSQC): δ 5.72 (d, *J* = 3.9 Hz, 1H, H-4), 4.55 (d, *J* = 7.4 Hz, 1H, H-1); ^{13}C NMR (126 MHz, $CDCl_3$, HSQC): δ 104.0 (C-1), 75.6, 73.9 (CH_2 Bn); HRMS: $[M+NH_4]^+$ calcd for $C_{36}H_{35}F_3O_7$ 654.26731, found 654.26699.



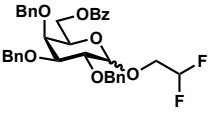
1,1,1,3,3,3-Hexafluoro-2-propyl 4-*O*-benzoyl-2,3,6-tri-*O*-benzyl-α-D-galactopyranoside (S91). The title compound was prepared according to general procedure VII. Column chromatography (100:0 → 85:15, pentane:Et_2O) yielded the title compound (39 mg, 55 µmol, 55%, colorless oil, α:β; >98:2). TLC: R_f 0.20 (pentane:Et_2O, 90:10, v:v); $[\alpha]_D^{25}$ 4.5° (*c* 1, $CHCl_3$); IR (thin film, cm^{-1}): 538, 685, 749, 1101, 1269, 1720, 2850, 3032; ^{1}H NMR (500 MHz, $CDCl_3$, HH-COSY, HSQC): δ 8.55 – 7.03 (m, 20H, CH_{arom}), 5.99 – 5.88 (m, 1H, H-4), 5.22 (d, *J* = 3.8 Hz, 1H, H-1), 4.86 (d, *J* = 10.9 Hz, 1H, C*H*H Bn), 4.78 (d, *J* = 11.8 Hz, 1H, C*H*H Bn), 4.66 (d, *J* = 11.7 Hz, 1H, CH*H* Bn), 4.58 (d, *J* = 10.9 Hz, 1H, CH*H* Bn), 4.53 – 4.46 (m, 2H, C*H*H Bn, C*H*$(CF_3)_2$), 4.41 (d, *J* = 11.9 Hz, 1H, CH*H* Bn), 4.30 (dd, *J* = 7.0, 5.7 Hz, 1H, H-5), 4.09 (dd, *J* = 10.2, 3.2 Hz, 1H, H-3), 3.98 (dd, *J* = 10.2, 3.8 Hz, 1H, H-2), 3.57 – 3.46 (m, 2H, H-6, H-6); ^{13}C NMR (126 MHz, $CDCl_3$, HSQC): δ 136.7, 133.8 ($C_{q\text{-}arom}$), 130.0, 129.6, 128.9, 128.6, 128.5, 128.5, 128.4, 128.1, 128.1, 127.9, 127.9, 127.8, 127.7, 127.7 (CH_{arom}), 100.2 (C-1), 76.0 (C-3), 74.3 (C-2), 73.9, 73.7, 72.1 (CH_2 Bn), 69.6 (C-5), 68.2 (C-4), 68.2 (C-6); HRMS: $[M+NH_4]^+$ calcd for $C_{37}H_{34}F_6O_7$ 722.25470, found 722.25409.



Ethyl 6-*O*-benzoyl-2,3,4-tri-*O*-benzy-D-galactopyranoside (S92). The title compound was prepared according to general procedure VII. Column chromatography (95:5 → 75:25, pentane:Et_2O) yielded the title compound (51 mg, 88 µmol, 88%, colorless oil, α:β; 15:85). TLC: R_f 0.25 (pentane:Et_2O, 80:20, v:v); IR (thin film, cm^{-1}): 696, 1027, 1070, 1270, 1452, 1720, 2871, 3032; Data of the major stereoisomer (β product): ^{1}H NMR (500 MHz, $CDCl_3$, HH-COSY, HSQC): δ 8.54 – 7.08 (m, 20H, CH_{arom}), 5.00 (d, *J* = 11.6 Hz, 1H, C*H*H Bn), 4.95 (d, *J* = 10.9 Hz, 1H, C*H*H Bn), 4.84 (d, *J* = 11.7 Hz, 1H, C*H*H Bn), 4.78 (d, *J* = 10.9 Hz, 1H, CH*H* Bn), 4.74 (d, *J* = 11.8 Hz, 1H, CH*H* Bn), 4.70 (d, *J* = 11.6 Hz, 1H, CH*H* Bn), 4.48 (dd, *J* = 11.0, 6.5 Hz, 1H, H-6), 4.39 (d, *J* = 7.7 Hz, 1H, H-1), 4.33 (dd, *J* = 11.0, 6.5 Hz, 1H, H-6), 3.99 (dq, *J* = 9.5, 7.0 Hz, 1H, C*H*HCH$_3$), 3.87 (dd, *J* = 9.7, 7.7 Hz, 1H, H-2), 3.85 (dd, *J* = 2.9, 1.1 Hz, 1H, H-4), 3.67 (td, *J* = 6.5, 1.1 Hz, 1H, H-5), 3.65 – 3.57 (m, 1H, CH*H*CH$_3$), 3.55 (dd, *J* = 9.8, 2.9 Hz, 1H, H-3); ^{13}C NMR (126 MHz, $CDCl_3$, HSQC): δ 166.2 (C=O Bz), 138.9, 138.6, 138.4 ($C_{q\text{-}arom}$), 130.0, 128.6, 128.6, 128.5, 128.5, 128.4, 128.4, 128.3, 128.2, 127.8, 127.8, 127.7, 127.7, 127.7 (CH_{arom}), 104.0 (C-1), 82.4 (C-3), 79.7 (C-2), 75.3, 74.5, 73.7 (CH_2 Bn), 73.3 (C-4), 72.1 (C-5), 65.7 (*C*H_2CH$_3$), 63.4 (C-6), 15.4 (CH$_3$); Data of the minor stereoisomer (α product): ^{1}H NMR (500 MHz, $CDCl_3$, HH-COSY, HSQC): δ 4.92 (d, *J* = 11.8 Hz, 1H, C*H*H Bn), 4.86 – 4.81 (signal overlaps with major isomer, 1H, H-1), 4.66 (d, *J* = 11.6 Hz, 1H, CH*H* Bn), 4.26 (dd, *J* = 11.1, 5.7 Hz, 1H, H-6); ^{13}C NMR (126 MHz, $CDCl_3$, HSQC): δ 97.3 (C-1), 74.7, 73.8, 73.6 (CH_2 Bn), 15.1 (*C*H$_3$); HRMS: $[M+NH_4]^+$ calcd for $C_{36}H_{38}O_7$ 600.29558, found 600.29557.

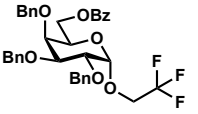


2-Fluoroethyl 6-*O*-benzoyl-2,3,4-tri-*O*-benzy-D-galactopyranoside (S93). The title compound was prepared according to general procedure VII. Column chromatography (95:5 → 60:40, pentane:Et_2O) yielded the title compound (50 mg, 81 µmol, 81%, colorless oil, α:β; 33:67). TLC: R_f 0.20 (pentane:Et_2O, 70:30, v:v); IR (thin film, cm^{-1}): 711, 734, 1026, 1270, 1452, 1720, 2900; Data of the major stereoisomer (β product): ^{1}H NMR (500 MHz, $CDCl_3$, HH-COSY, HSQC): δ 8.01 – 7.03 (m, 20H, CH_{arom}), 5.00 (d, *J* = 11.7 Hz, 1H, C*H*H Bn), 4.97 (d, *J* = 10.8 Hz, 1H, C*H*H Bn), 4.85 (d, *J* = 11.8 Hz, 1H, C*H*H Bn), 4.80 – 4.55 (m, 5H, CH*H* Bn, CH*H* Bn, CH*H* Bn, C*H*HF, CH*H*F), 4.48 (dd, *J* = 11.1, 6.5 Hz, 1H, H-6), 4.45 (d, *J* = 7.7 Hz, 1H, H-1), 4.31 (dd, *J* = 11.1, 6.4 Hz, 1H, H-6), 3.90 (dd, *J* = 9.8, 7.7 Hz, 1H, H-2), 3.89 – 3.73 (m, 2H, C*H*HCH$_2$F, CH*H*CH$_2$F), 3.85 (dd, *J* = 2.8, 0.8 Hz, 1H, H-4), 3.68 (td, *J* = 6.5, 1.1 Hz, 1H, H-5), 3.56 (dd, *J* = 9.7, 2.9 Hz, 1H, H-3); ^{13}C NMR (126 MHz, $CDCl_3$, HSQC): δ 166.2 (C=O Bz), 138.9, 138.7, 138.6, 138.5, 138.3, 138.2 ($C_{q\text{-}arom}$), 130.0, 129.9, 128.6, 128.5, 128.5, 128.5, 128.4, 128.2, 127.9, 127.8, 127.8, 127.7 (CH_{arom}), 104.3 (C-1), 82.8 (d, *J* = 169.7 Hz, *C*H$_2$F), 82.2 (C-3), 79.5 (C-2), 75.4, 74.5, 73.7 (CH_2 Bn), 73.2 (C-4), 72.3 (C-5), 68.9 (d, *J* = 20.2 Hz, *C*H$_2$CH$_2$F), 63.3 (C-6); Data of the minor stereoisomer (α product): ^{1}H NMR (500 MHz, $CDCl_3$, HH-COSY, HSQC): δ 4.92 (d, *J* = 11.7 Hz, 1H, C*H*H Bn), 4.88 (d, *J* = 3.6 Hz, 1H, H-1), 4.41 (dd, *J* = 11.2, 7.1 Hz, 1H, H-6), 4.25 (dd, *J* = 11.2, 5.5 Hz, 1H, H-6), 4.02 (dd, *J* = 10.1, 2.8 Hz, 1H, H-2), 3.96 (dd, *J* = 2.8, 1.3 Hz, 1H, H-4).; ^{13}C NMR (126 MHz, $CDCl_3$, HSQC): δ 98.1 (C-1), 82.7 (d, *J* = 169.8 Hz, *C*H$_2$F), 76.6 (C-2), 74.8, 73.8, 73.7 (CH_2 Bn), 67.2 (d, *J* = 20.2 Hz, *C*H$_2$CH$_2$F), 64.0 (C-6); HRMS: $[M+NH_4]^+$ calcd for $C_{36}H_{37}FO_7$ 618.28616, found 618.28635.

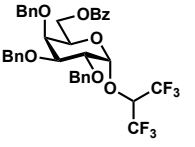


2,2-Difluoroethyl 6-*O*-benzoyl-2,3,4-tri-*O*-benzy-D-galactopyranoside (S94). The title compound was prepared according to general procedure VII. Column chromatography (95:5 → 75:25, pentane:Et_2O) yielded the title compound (50 mg, 81 µmol, 81%, colorless oil, α:β; 61:39). TLC: R_f 0.30 (pentane:Et_2O, 80:20, v:v); IR (thin film, cm^{-1}): 711, 735, 1270, 1452, 1717, 2916, 3032; Data of the major stereoisomer (α product): ^{1}H NMR (500 MHz, $CDCl_3$, HH-COSY, HSQC): δ 8.47 – 6.72 (m, 20H, CH_{arom}), 5.95 (tt, *J* = 55.4, 4.3 Hz, 1H, C*H*F$_2$), 5.00 (d, *J* = 10.9 Hz, 1H, C*H*H Bn), 4.91 (d, *J* = 11.7 Hz, 1H, C*H*H Bn), 4.85 (d, *J* = 12.1 Hz, 1H, CH*H* Bn), 4.77 (d, *J* = 11.6 Hz, 1H, C*H*H Bn), 4.67 (d, *J* = 12.0 Hz, 1H, CH*H* Bn), 4.65 (d, *J* = 11.4 Hz, 1H, CH*H* Bn), 4.43 (d, *J* = 7.7 Hz, 1H, H-1), 4.41 (dd, *J* = 11.3, 7.3 Hz, 1H, H-6), 4.24 (dd, *J* = 11.3, 5.1

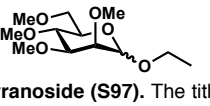
Hz, 1H, H-6), 4.14 – 4.05 (m, 2H, H-2, H-5), 4.00 – 3.94 (m, 2H, H-3, H-4), 3.80 – 3.65 (m, 2H, C*H*HCHF$_2$, CH*H*CHF$_2$); ^{13}C NMR (126 MHz, $CDCl_3$, HSQC): δ 166.3 (C=O Bz), 138.7, 138.5, 138.4, 138.1 ($C_{q\text{-arom}}$), 129.9, 129.8, 128.6, 128.6, 128.6, 128.6, 128.5, 128.5, 128.5, 128.2, 128.0, 127.9, 127.8, 127.8, 127.8, 127.7 (CH_{arom}), 114.2 (t, *J* = 241.3 Hz *C*HF$_2$), 98.7 (C-1), 78.9 (C-3), 76.4 (C-2), 74.9 (C-4), 74.8, 73.9, 73.8 (CH_2 Bn), 69.2 (C-5), 67.5 (t, *J* = 28.9 Hz, *C*H$_2$CHF$_2$), 64.1 (C-6); Data of the minor stereoisomer (β product): ^{1}H NMR (500 MHz, $CDCl_3$, HH-COSY, HSQC): δ 4.47 (dd, *J* = 11.2, 6.7 Hz, 1H, H-6), 4.43 (d, *J* = 7.7 Hz, 1H, H-1), 4.32 (dd, *J* = 11.2, 6.1 Hz, 1H, H-6), 3.90 (dd, *J* = 9.7, 7.6 Hz, 1H, H-2), 3.85 (dd, *J* = 2.9, 1.1 Hz, 1H, H-4), 3.56 (dd, *J* = 9.7, 2.8 Hz, 1H, H-3); ^{13}C NMR (126 MHz, $CDCl_3$, HSQC): δ 114.4 (dd, *J* = 241.1, 239.3 Hz, *C*HF$_2$), 104.4 (C-1), 82.2 (C-3), 79.3 (C-2), 75.5, 74.6, 73.8 (CH_2 Bn), 73.2 (C-4), 68.8 (dd, *J* = 30.8, 26.5 Hz, *C*H$_2$CHF$_2$), 63.3 (C-6); HRMS: [M+NH$_4$]$^+$ calcd for $C_{36}H_{36}F_2O_7$ 636.27674, found 636.27668.



2,2,2-Trifluoroethyl 3-*O*-benzoyl-2,3,4-tri-*O*-benzy-α-D-galactopyranoside (S95). The title compound was prepared according to general procedure VII. Column chromatography (95:5 → 80:20, pentane:Et$_2$O) yielded the title compound (47 mg, 74 µmol, 74%, colorless oil, α:β; 89:11). TLC: R_f 0.40 (pentane:Et$_2$O, 80:20, v:v); $[\alpha]_D^{25}$ 6.7° (*c* 1, $CHCl_3$); IR (thin film, cm^{-1}): 549, 711, 735, 1026, 1101, 1273, 1452, 1720, 2917, 3030; Data of the major stereoisomer (α product): ^{1}H NMR (500 MHz, $CDCl_3$, HH-COSY, HSQC): δ 8.34 – 7.02 (m, 20H, CH_{arom}), 5.00 (d, *J* = 11.4 Hz, 1H, C*H*H Bn), 4.91 (d, *J* = 11.4 Hz, 1H, C*H*H Bn), 4.89 (d, *J* = 3.7 Hz, 1H, H-1), 4.84 (d, *J* = 11.9 Hz, 1H, C*H*H Bn), 4.77 (d, *J* = 11.7 Hz, 1H, CH*H* Bn), 4.67 (d, *J* = 11.9 Hz, 1H, CH*H* Bn), 4.65 (d, *J* = 11.4 Hz, 1H, CH*H* Bn), 4.42 (dd, *J* = 11.3, 7.1 Hz, 1H, H-6), 4.24 (dd, *J* = 11.3, 5.4 Hz, 1H, H-6), 4.12 (dd, *J* = 9.8, 3.7 Hz, 1H, H-2), 4.06 (ddd, *J* = 6.8, 5.1, 1.1 Hz, 1H, H-5), 4.02 – 3.94 (m, 2H, H-3, H-4), 3.94 – 3.83 (m, 2H, C*H*HCF$_3$, CH*H*CF$_3$); ^{13}C NMR (126 MHz, $CDCl_3$, HSQC): δ 166.2 (C=O Bz), 138.7, 138.5, 138.4, 138.1 ($C_{q\text{-arom}}$), 129.8, 129.8, 129.7, 128.6, 128.6, 128.5, 128.5, 128.4, 128.1, 127.9, 127.9, 127.9, 127.7, 127.7, 127.7, 127.2 (CH_{arom}), 123.9 (q, *J* = 278.6 Hz, *C*F$_3$), 98.4 (C-1), 78.7 (C-3), 76.3 (C-2), 74.8 (CH_2 Bn), 74.8 (C-4), 73.9, 73.7 (CH_2 Bn), 64.7 (q, *J* = 34.9 Hz, *C*H$_2$CF$_3$), 63.8 (C-6); Data of the minor stereoisomer (β product): ^{1}H NMR (500 MHz, $CDCl_3$, HH-COSY, HSQC): δ 4.51 (d, *J* = 7.6 Hz, 1H, H-1), 3.56 (dd, *J* = 9.7, 2.9 Hz, 1H, H-3); ^{13}C NMR (126 MHz, $CDCl_3$, HSQC): δ 104.1 (C-1), 75.5, 74.6, 73.8 (CH_2 Bn), 66.0 (q, *J* = 35.0 Hz, CH_2CF_3), 63.2 (C-6); HRMS: [M+NH$_4$]$^+$ calcd for $C_{36}H_{35}F_3O_7$ 654.26731, found 654.26715.

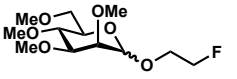


1,1,1,3,3,3-Hexafluoro-2-propyl 6-*O*-benzoyl-2,3,4-tri-*O*-benzyl-α-D-galactopyranoside (S96). The title compound was prepared according to general procedure VII. Column chromatography (100:0 → 85:15, pentane:Et$_2$O) yielded the title compound (40 mg, 57 µmol, 57%, colorless oil, α:β; >98:2). TLC: R_f 0.15 (pentane:Et$_2$O, 90:10, v:v); $[\alpha]_D^{25}$ –47.0° (*c* 1, $CHCl_3$); IR (thin film, cm^{-1}): 538, 595, 697, 1027, 1104, 1196, 1274, 1452, 1720, 2924, 3032; ^{1}H NMR (500 MHz, $CDCl_3$, HH-COSY, HSQC): δ 8.07 – 7.03 (m, 20H, CH_{arom}), 5.21 (d, *J* = 3.8 Hz, 1H, H-1), 5.00 (d, *J* = 11.3 Hz, 1H, C*H*H Bn), 4.91 (d, *J* = 11.5 Hz, 1H, C*H*H Bn), 4.79 – 4.69 (m, 3H, C*H*H Bn, CH*H* Bn, CH*H* Bn), 4.65 (d, *J* = 11.3 Hz, 1H, CH*H* Bn), 4.47 (dt, *J* = 11.9, 5.9 Hz, 1H, C*H*(CF$_3$)$_2$), 4.42 (dd, *J* = 11.4, 7.2 Hz, 1H, H-6), 4.25 (dd, *J* = 11.5, 4.9 Hz, 1H, H-6), 4.21 – 4.15 (m, 2H, H-2, H-5), 4.01 (t, *J* = 1.9 Hz, 1H, H-4), 3.99 (dd, *J* = 10.0, 2.7 Hz, 1H, H-2); ^{13}C NMR (126 MHz, $CDCl_3$, HSQC): δ 166.2 (C=O Bz), 138.5, 138.0 ($C_{q\text{-arom}}$), 129.7, 129.6, 128.9, 128.6, 128.6, 128.5, 128.1, 128.0, 127.7, 127.6 (CH_{arom}), 99.8 (C-1), 78.3 (C-3), 75.4 (C-2), 74.9 (CH_2 Bn), 74.7 (C-4), 73.8, 73.7 (CH_2 Bn), 70.5 (C-5), 64.0 (C-6); HRMS: [M+NH$_4$]$^+$ calcd for $C_{37}H_{34}F_6O_7$ 722.25470, found 722.25408.

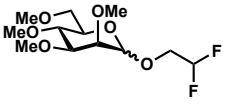


Ethyl 2,3,4,6-tetra-*O*-methyl-D-mannopyranoside (S97). The title compound was prepared according to general procedure VII. Column chromatography (80:20 → 70:30, pentane:EtOAc) yielded the title

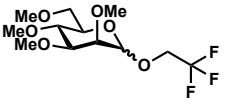
compound (18.2 mg, 69 µmol, 69%, colorless oil, α:β; 51:49). TLC: R_f 0.30, (pentane:EtOAc, 60:40, v:v); IR (thin film, cm^{-1}): 926, 1069, 1110, 1377, 2973; Data of the major stereoisomer (α product): ^{1}H NMR (400 MHz, $CDCl_3$, HH-COSY, HSQC): δ 4.92 (d, *J* = 1.6 Hz, 1H, H-1), 3.79 – 3.71 (m, 1H, C*H*H Et), 3.70 – 3.46 (m, 18H, H-2, H-3, H-4, H-5, 2x H-6, CH*H* Et, 3x CH_3 Me), 3.40 (s, 3H, CH_3 Me), 1.22 – 1.18 (m, 3H, CH_3 Et); ^{13}C NMR (101 MHz, $CDCl_3$, HSQC): δ 96.6 (C-1), 81.3 (C-3), 77.4, 77.1 (C-2/C-4), 71.9 (C-6), 71.3 (C-5), 63.1 (CH_2 Et), 60.9, 59.4, 59.3, 57.8 (CH_3 Me), 15.1 (CH_3 Et); ^{13}C-HMBC-GATED NMR (101 MHz, $CDCl_3$): δ 96.6 ($J_{H1\text{-}C1}$ = 167 Hz, α); Data of the minor stereoisomer (β product): ^{1}H NMR (400 MHz, $CDCl_3$, HH-COSY, HSQC): δ 4.39 (d, *J* = 0.8 Hz, 1H, H-1), 3.99 (dq, *J* = 9.4, 7.1 Hz, 1H, C*H*H Et), 3.64 (s, 3H, CH_3 Me), 3.19 (dd, *J* = 8.9, 3.2 Hz, 1H, H-3), 1.26 – 1.22 (m, 3H, CH_3 Et); ^{13}C NMR (101 MHz, $CDCl_3$, HSQC): δ 101.3 (C-1), 84.2 (C-3), 72.2 (C-6), 65.3 (CH_2 Et), 15.2 (CH_3 Et); ^{13}C-HMBC-GATED NMR (101 MHz, $CDCl_3$): δ 101.3 ($J_{H1\text{-}C1}$ = 154 Hz, β) ; HRMS: $[M+NH_4]^+$ calcd for $C_{13}H_{28}NO_7$ 282.19111, found 282.19093.



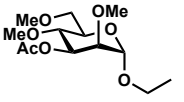
2-Fluoroethyl 2,3,4,6-tetra-*O*-methyl-D-mannopyranoside (S98). The title compound was prepared according to general procedure VII. Column chromatography (70:30 → 60:40, pentane:EtOAc) yielded the title compound (21 mg, 74 µmol, 74%, colorless oil, α:β; 64:36). TLC: R_f 0.21, (pentane:EtOAc, 60:40, v:v); IR (thin film, cm^{-1}): 730, 912, 1083, 1110, 2898; Data of the major stereoisomer (α product): ^{1}H NMR (400 MHz, $CDCl_3$, HH-COSY, HSQC): δ 4.96 (d, *J* = 1.8 Hz, 1H, H-1), 4.63 (dd, *J* = 4.9, 3.4 Hz, 1H, CH_2CHHF), 4.51 (dd, *J* = 4.8, 3.5 Hz, 1H, CH_2CHHF), 3.97 – 3.82 (m, 1H, C*H*HCH_2F), 3.81 – 3.67 (m, 2H, H-4, CH*H*CH_2F), 3.64 – 3.61 (m, 1H, H-2), 3.60 – 3.58 (m, 3H, H-5, 2x H-6), 3.58 – 3.53 (m, 1H, H-3), 3.53 (s, 3H, CH_3 Me) 3.51 (s, 3H, CH_3 Me), 3.49 (s, 3H, CH_3 Me), 3.40 (s, 3H, CH_3 Me); ^{13}C NMR (101 MHz, $CDCl_3$): δ 97.2 (C-1), 82.6 (d, *J* = 169.6 Hz, CH_2CH_2F), 81.2 (C-3), 77.1 (C-2), 76.5 (C-4), 71.8 (C-6), 71.5 (C-5), 66.7 (d, *J* = 19.7 Hz, CH_2CH_2F), 60.8, 59.4, 59.1, 57.9 (CH_3 Me); ^{13}C-HMBC-GATED NMR (101 MHz, $CDCl_3$): δ 97.2 ($J_{H1\text{-}C1}$ = 169 Hz, α); Data of the minor stereoisomer (β product): ^{1}H NMR (400 MHz, $CDCl_3$ HH-COSY, HSQC): δ 4.46 (d, *J* = 0.8 Hz, 1H, H-1), 4.10 (dddd, *J* = 36.7, 12.2, 3.7, 2.3 Hz, 1H, C*H*HCH_2F), 3.65 (s, 3H, CH_3 Me), 3.52 (s, 3H, CH_3 Me), 3.50 (s, 2H, CH_3 Me), 3.39 (s, 3H, CH_3 Me), 3.20 (dd, *J* = 8.9, 3.2 Hz, 1H, H-3); ^{13}C NMR (101 MHz, $CDCl_3$): δ 101.6 (C-1), 83.0 (d, *J* = 169.1 Hz, CH_2CH_2F), 82.2 (C-3), 68.7 (d, *J* = 19.6 Hz, CH_2CH_2F) 61.9, 60.9, 59.4, 57.5 (4x CH_3 Me); ^{13}C-HMBC-GATED NMR (101 MHz, $CDCl_3$): δ 101.6 ($J_{H1\text{-}C1}$ = 155 Hz, β); HRMS: $[M+NH_4]^+$ calcd for $C_{13}H_{27}NO_7F$ 300.18169, found 300.18153.



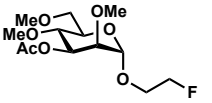
2,2-Difluoroethyl 2,3,4,6-tetra-*O*-methyl-D-mannopyranoside (S99). The title compound was prepared according to general procedure VII. Column chromatography (85:15 → 75:25, pentane:EtOAc) yielded the title compound (15.5 mg, 52 µmol, 52%, colorless oil, α:β; 76:24). TLC: R_f 0.35, (pentane:EtOAc, 60:40, v:v); IR (thin film, cm^{-1}): 730, 909, 1072, 1111; Data of the major stereoisomer (α product): ^{1}H NMR (400 MHz, $CDCl_3$, HH-COSY, HSQC): δ 5.92 (tdd, *J* = 55.3, 4.8, 3.4 Hz, 1H, CH_2CHF_2), 4.95 (d, *J* = 1.9 Hz, 1H, H-1), 3.90 – 3.64 (m, 2H, CH_2CHF_2), 3.63 – 3.57 (m, 5H, H-2, H-3, H-5, 2x H-6), 3.52 (s, 3H, CH_3 Me), 3.51 (s, 3H, CH_3 Me), 3.50 – 3.47 (m, 4H, H-4, CH_3 Me), 3.40 (s, 3H, CH_3 Me); ^{13}C NMR (101 MHz, $CDCl_3$, HSQC): δ 117.5 – 110.0 (m, CH_2CHF_2), 97.9 (C-1), 81.0 (C-4), 76.8, 76.3 (C-2/C-3), 71.9 (C-5), 71.7 (C-6), 66.8 (t, J = 28.0 Hz, CH_2CHF_2), 60.8, 59.4, 59.2, 58.0 (CH_3 Me): ^{13}C-HMBC-GATED NMR (101 MHz, $CDCl_3$): δ 97.9 ($J_{H1\text{-}C1}$ = 170 Hz, α); Data of the minor stereoisomer (β product): ^{1}H NMR (400 MHz, $CDCl_3$, HH-COSY, HSQC): δ 6.10 – 5.76 (m, 1H, CH_2CHF_2), 4.46 (d, *J* = 0.8 Hz, 1H, H-1), 4.06 (dddd, *J* = 22.5, 11.7, 9.9, 2.7 Hz, 1H, C*H*HCHF_2), 3.50 (s, 3H, CH_3 Me), 3.19 (dd, *J* = 9.1, 3.1 Hz, 1H, H-3); ^{13}C NMR (101 MHz, $CDCl_3$): δ 101.8 (C-1), 83.9 (C-3), 68.8 – 68.0 (m, CH_2CHF_2), 61.9, 60.9, 59.4, 57.7 (4x CH_3 Me); ^{13}C-HMBC-GATED NMR (101 MHz, $CDCl_3$): δ 101.8 ($J_{H1\text{-}C1}$ = 156 Hz, β); HRMS: $[M+Na]^+$ calcd for $C_{13}H_{22}NaO_7F_2$ 323.12767, found 323.12723.



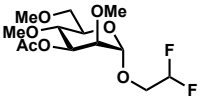
2,2,2-Trifluoroethyl 2,3,4,6-tetra-*O*-methyl-D-mannopyranoside (S100). The title compound was prepared according to general procedure VII. Column chromatography (85:15 pentane:EtOAc) yielded the title compound (18 mg, 57 µmol, 57%, colorless oil, α:β; 93:7). TLC: R_f 0.40, (pentane:EtOAc, 60:40, v:v); IR (thin film, cm^{-1}): 732, 985, 1081, 1164, 1280; Data of the major stereoisomer (α product): ^{1}H NMR (400 MHz, $CDCl_3$, HH-COSY, HSQC): δ 4.99 (d, *J* = 1.8 Hz, 1H, H-1), 4.04 – 3.94 (m, 1H, C*H*HCF$_3$), 3.94 – 3.84 (m, 1H, CH*H*CF$_3$), 3.66 – 3.62 (m, 1H, H-2), 3.63 – 3.53 (m, 3H, H-5, H-6, H-6), 3.53 (s, 3H, CH_3 Me), 3.52 (s, 3H, CH_3 Me), 3.51 – 3.45 (m, 5H, H-2, H-4, CH_3 Me), 3.40 (s, 3H, CH_3 Me); ^{13}C NMR (101 MHz, $CDCl_3$, HSQC): δ 123.9 (q, *J* = 278.2 Hz, CH_2CF_3), 97.7 (C-1), 80.9 (C-4), 76.8 (C-2), 76.2 (C-3), 72.2 (C-5), 71.6 (C-6), 64.2 (q, *J* = 34.8 Hz, CH_2CF_3), 60.8, 59.4, 59.3, 58.1 (CH_3 Me); HMBC-GATED NMR (101 MHz, $CDCl_3$): δ 97.7 ($J_{H1\text{-}C1}$ = 170 Hz, α); Data of the minor stereoisomer (β product): ^{1}H NMR (500 MHz, $CDCl_3$, HH-COSY, HSQC): δ 4.52 (s, 1H, H-1), 4.21 (dq, *J* = 12.6, 8.9 Hz, 1H, C*H*HCF$_3$), 3.76 (dd, *J* = 3.1, 0.8 Hz, 1H, H-2), 3.19 (dd, *J* = 9.1, 3.2 Hz, 1H, H-3) ^{13}C NMR (101 MHz, $CDCl_3$, HSQC): δ 101.4 (C-1), 61.9, 59.4, 57.7 (3x CH_3 Me); HRMS: $[M+Na]^+$ calcd for $C_{13}H_{21}NaO_7F_3$ 341.11824, found 341.11811.



Ethyl 3-*O*-acetyl-2,4,6-tri-*O*-methyl-α-D-mannopyranoside (S101). The title compound was prepared according to general procedure VII. Column chromatography (85:15 → 75:25, pentane:EtOAc) yielded the title compound (19.1 mg, 65 µmol, 65%, colorless oil, α:β; >98:2). TLC: R_f 0.29, (pentane:EtOAc, 60:40, v:v); $[\alpha]_D^{25}$ 69.0° (*c* 0.10 $CHCl_3$); IR (thin film, cm^{-1}): 730, 909,1067, 1101, 1238, 1733; ^{1}H NMR (400 MHz, $CDCl_3$, HH-COSY, HSQC): δ 5.17 (dd, *J* = 9.5, 3.4 Hz, 1H, H-3), 4.87 (d, *J* = 1.9 Hz, 1H, H-1), 3.75 (dt, *J* = 9.8, 7.1 Hz, 1H, C*H*H Et), 3.71 – 3.66 (m, 1H, H-6), 3.64 – 3.56 (m, 4H, H-2, H-4, H-5 ,CH*H* Et), 3.52 – 3.47 (m, 1H, H-6), 3.46 (s, 3H, CH_3 Me), 3.44 (s, 3H, CH_3 Me), 3.41 (s, 3H, CH_3 Me), 2.15 (s, 3H, CH_3 Ac), 1.20 (t, *J* = 7.1 Hz, 3H, CH_3 Et); ^{13}C NMR (101 MHz, $CDCl_3$, HSQC): δ 170.5 (C=O), 97.0 (C-1), 78.7 (C-2), 74.9 (C-4), 74.0 (C-3), 71.5 (CH_2 Et), 71.1 (C-5), 63.3 (C-6), 60.5, 59.4, 59.3 (CH_3 Me), 21.4 (CH_3 Ac), 15.1 (CH_3 Et); HMBC-GATED NMR (101 MHz, $CDCl_3$): δ 97.0 ($J_{H1\text{-}C1}$ = 169 Hz, α); HRMS: $[M+Na]^+$ calcd for $C_{13}H_{24}NaO_7$ 315.14142, found 315.14126.

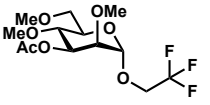


2-Fluoroethyl 3-*O*-acetyl-2,4,6-tri-*O*-methyl-α-D-mannopyranoside (S102). The title compound was prepared according to general procedure VII. Column chromatography (80:20 → 60:40, pentane:EtOAc) yielded the title compound (24.7 mg, 80 µmol, 80%, colorless oil, α:β; >98:2). TLC: R_f 0.23, (pentane:EtOAc, 60:40, v:v); $[\alpha]_D^{25}$ 52.4° (*c* 0.29 $CHCl_3$); IR (thin film, cm^{-1}): 1047, 1101, 1123, 1238, 1369, 1739; ^{1}H NMR (400 MHz, $CDCl_3$, HH-COSY, HSQC): δ 5.17 (dd, *J* = 9.5, 3.4 Hz, 1H, H-3), 4.92 (d, *J* = 1.9 Hz, 1H, H-1), 4.65 – 4.60 (m, 1H, CH_2CHHF), 4.54 – 4.48 (m, 1H, CH_2CHHF), 3.97 – 3.82 (m, 1H, C*H*HCH$_2$F), 3.81 – 3.69 (m, 2H, H-6, CH*H*CH$_2$F), 3.68 – 3.56 (m, 4H, H-2, H-4, H-5, H-6), 3.46 (s, 3H, CH_3 Me), 3.44 (s, 3H, CH_3 Me), 3.41 (s, 3H, CH_3 Me), 2.15 (s, 3H, CH_3 Ac); ^{13}C NMR (101 MHz, $CDCl_3$, HSQC): δ 170.4 (C=O), 97.6 (C-1) 82.6 (d, *J* = 169.9 Hz, CH_2CH_2F), 78.4 (H-2), 74.7 (C-4), 73.7 (C-3), 71.4 (C-6), 71.3 (C-5), 66.8 (d, *J* = 20.0 Hz, CH_2CH_2F), 60.5, 59.4, 59.4 (CH_3 Me), 21.4 (CH_3 Ac); HMBC-GATED NMR (101 MHz, $CDCl_3$): δ 97.6 ($J_{H1\text{-}C1}$ = 170 Hz, α); HRMS: $[M+Na]^+$ calcd for $C_{13}H_{23}NaO_7F$ 333.13200, found 333.13176.



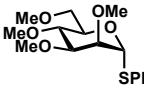
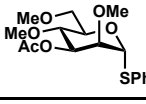
2,2-Difluoroethyl 3-*O*-acetyl-2,4,6-tri-*O*-methyl-α-D-mannopyranoside (S103). The title compound was prepared according to general procedure VII. Column chromatography (90:10 → 75:25, pentane:EtOAc)

yielded the title compound (18.6 mg, 57 µmol, 57%, colorless oil, α:β; >98:2). TLC: R_f 0.35, (pentane:EtOAc, 60:40, v:v); $[\alpha]_D^{25}$ 59.3° (*c* 0.14 $CHCl_3$); IR (thin film, cm^{-1}): 731, 909, 1070, 1100, 1240, 1739; ^1H NMR (400 MHz, $CDCl_3$, HH-COSY, HSQC): δ 5.93 (tdd, *J* = 55.4, 4.8, 3.6 Hz, 1H, CH_2CHF_2), 5.12 (dd, *J* = 8.9, 3.3 Hz, 1H, H-3), 4.91 (d, *J* = 2.0 Hz, 1H, H-1), 3.90 – 3.78 (m, 1H, $CHHCHF_2$), 3.78 – 3.70 (m, 1H, $CHHCHF_2$), 3.69 – 3.57 (m, 5H, H-2, H-4, H-5, H-6, H-6), 3.46 (s, 3H, CH_3 Me), 3.44 (s, 3H, CH_3 Me), 3.41 (s, 3H, CH_3 Me), 2.15 (s, 3H, CH_3 Ac) ^{13}C NMR (101 MHz, $CDCl_3$, HSQC): δ 170.4 (C=O), 114.1 (t, *J* = 241.1 Hz, CH_2CHF_2), 98.2 (C-1), 78.1 (C-2), 74.6 (C-4), 73.5 (C-3), 71.7 (C-5), 71.3 (C-6), 66.9 (t, *J* = 28.6 Hz, CH_2CHF_2), 60.5, 59.5, 59.4 (CH_3 Me), 21.3 (CH_3 Ac); HMBC-GATED NMR (101 MHz, $CDCl_3$): δ 98.2 ($J_{H1\text{-}C1}$ = 170 Hz, α); HRMS: $[M+Na]^+$ calcd for $C_{13}H_{22}NaO_7F_2$ 351.12258, found 351.12233.



2,2,2-Trifluoroethyl 3-*O*-acetyl-2,4,6-tri-*O*-methyl-α-D-mannopyranoside (S104). The title compound was prepared according to general procedure VII. Column chromatography (85:15, pentane:EtOAc) yielded the title compound (15.5 mg, 45 µmol, 45%, colorless oil, α:β; >98:2). TLC: R_f 0.39, (pentane:EtOAc, 60:40, v:v); $[\alpha]_D^{25}$ 59.0° (*c* 0.5 $CHCl_3$); IR (thin film, cm^{-1}): 730, 910, 1083, 1103, 1238, 1745, 2933; ^1H NMR (400 MHz, $CDCl_3$, HH-COSY, $HSC_{q\text{-}arom}$): δ 5.17 – 5.11 (m, 1H, H-3), 4.95 (d, *J* = 2.1 Hz, 1H, H-1), 3.95 (qq, *J* = 12.4, 8.6 Hz, 2H, CH_2CF_3), 3.69 (dd, *J* = 3.4, 2.1 Hz, 1H, H-2), 3.67 – 3.63 (m, 2H, H-4, H-5), 3.63 – 3.56 (m, 2H, H-6, H-6), 3.47 (s, 3H, CH_3 Me), 3.45 (s, 3H, CH_3 Me), 3.41 (s, 3H, CH_3 Me), 2.15 (s, 3H, CH_3 Ac); ^{13}C NMR (101 MHz, $CDCl_3$, HSQC): δ 170.4 (C=O), 98.1 (C-1), 77.9 (C-2), 74.5 (C-4), 73.2 (C-3), 71.9 (C-5), 71.2 (C-6), 64.3 (q, *J* = 35.0 Hz, CH_2CF_3), 60.5, 59.6, 59.4 (CH_3 Me), 21.3 (CH_3 Ac); HMBC-GATED NMR (101 MHz, $CDCl_3$): δ 98.1 ($J_{H1\text{-}C1}$ = 170 Hz, α); HRMS: $[M+Na]^+$ calcd for $C_{13}H_{21}NaO_7F_3$ 369.11316, found 369.11324.

Table S1. Experimentally found stereoselectivity for glycosylation reactions for Ac-Me-protected donors with model acceptors. The stereoselectivity is expressed as α:β ratios and were established by ^1H-NMR spectroscopy of the crude and purified reaction mixtures.

Entry	donor	HO–CF_3	HO–CH(F)–CHF$_2$	HO–CH$_2$–CH$_2$F	HO–Et
1		93:7 (57%)	76:24 (52%)	64:36 (74%)	51:49 (69%)
2		>98:2 (45%)	>98:2 (57%)	>98:2 (80%)	>98:2 (65%)

>90:10	>80:20	>60:40	>50:50	<50:50	<40:60	<20:80	<10:90	(α:β)

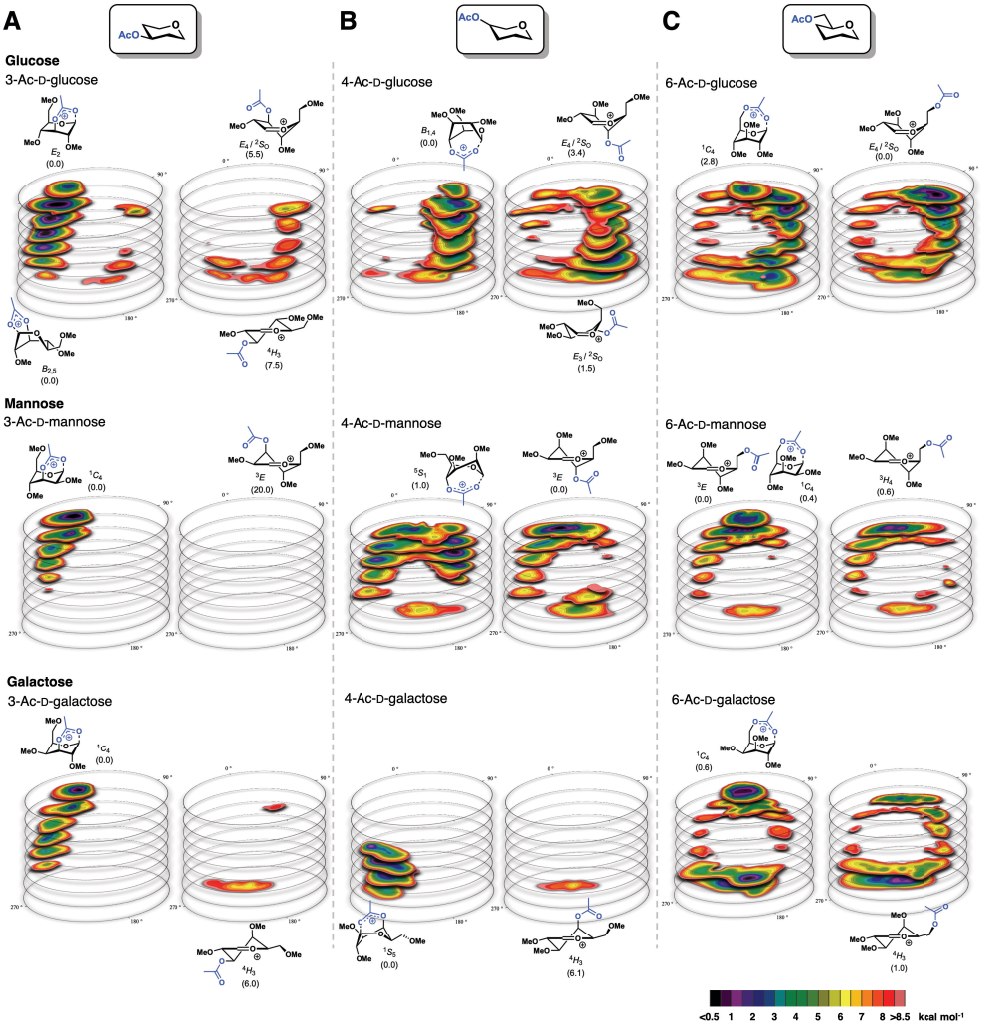


Figure S14. Gas-phase CEL maps of selected pyranosyl oxocarbenium ions in which the found local minima are shown and indicated with their respective energy. Two acetyl ester rotamers (R1 = left and R2 = right) were considered for all computed oxocarbenium ions generating two CEL maps. All energies are as calculated in the gas-phase at B3LYP/6-311G(d,p) at *T*=293.15 K and expressed as Gibbs free energy. (A) CEL maps for the C3-acetyl pyranosyl ions; (B) CEL maps for the C4-acetyl pyranosyl ions; (C) CEL maps for the C6-acetyl pyranosyl ions.

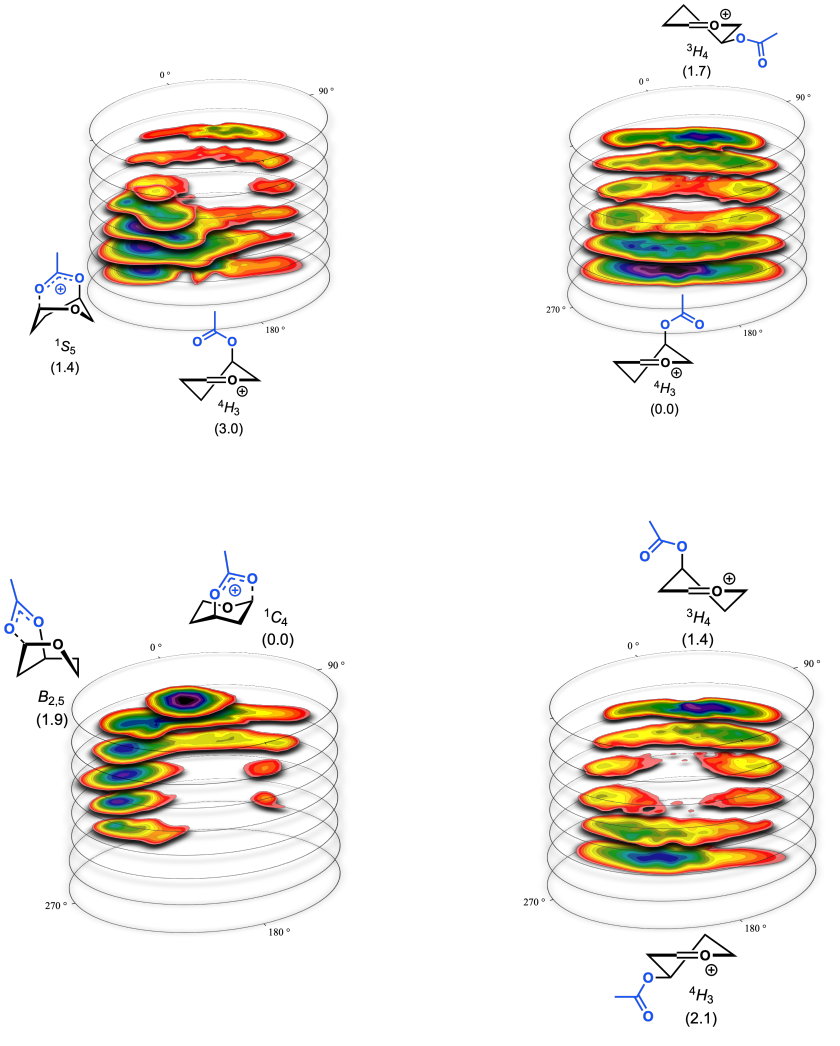


Figure S15. CEL maps of **S105** and **S106**. Two acetyl ester rotamers (R1 = left and R2 = right) were considered for all computed oxocarbenium ions generating two CEL maps. All energies are as calculated in the gas-phase at B3LYP/6-311G(d,p) at *T*=293.15 K and expressed as Gibbs free energy.

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