Reactivity and selectivity in glycosylation reactions

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Chapter 3

The influence of acceptor nucleophilicity on the glycosylation reaction mechanism

Introduction

The connection of two carbohydrate building blocks to construct a glycosidic linkage in a glycosylation reaction is one of the most important and one of the most difficult steps in the assembly of an oligosaccharide.[1–3] The stereoselective formation of 1,2-*cis*-glycosidic linkages remains a major synthetic challenge and often requires careful tuning of reaction conditions for a profitable outcome.[4] The variation in stereochemical outcome of a chemical glycosylation reaction originates from the different mechanistic pathways that can be followed for the union of an activated donor glycoside and an acceptor. Figure 1 depicts the current understanding of the continuum of mechanisms operational during a glycosylation reaction. The activation of a donor glycoside leads to an array of reactive intermediates, formed from the donor glycoside and the activator derived counterion. α- and β-configured covalent reactive intermediates can be formed and these are in equilibrium with less stable and more reactive oxocarbenium ion based species. These can be either closely associated with the counterion providing close (or

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contact) ion pairs (CIPs), or further separated from their counterion in solvent separated ion pairs (SSIPs). These reactive intermediates can be attacked by an incoming nucleophile following a reaction mechanism with both S_N1 and S_N2 features. The covalent species are displaced in a reaction mechanism having an associative S_N2-character, while the oxocarbenium ion-like intermediates are engaged in an S_N1-like reaction. The exact position(s) on the continuum where a given glycosylation reaction

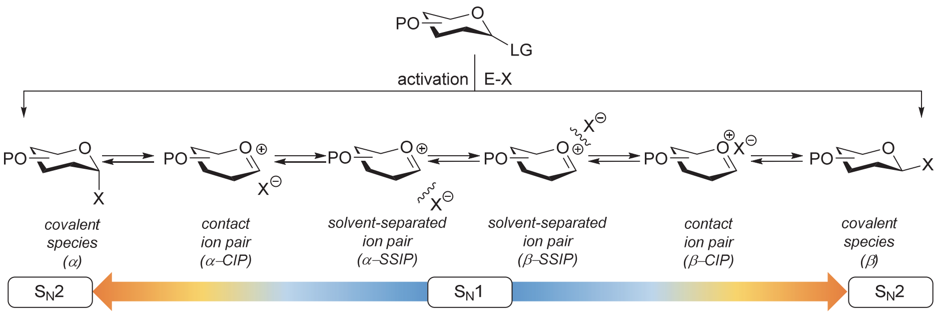


Figure 1. The reaction mechanism manifold operational during glycosylation reactions.

takes place, and hence the stereoselectivity of the process, depends critically on the reactivity of both reaction partners: the donor and the acceptor glycoside. The impact of the reactivity of the donor glycoside on the stereochemical outcome has been studied extensively, and the effect of functional and protecting groups on glycosyl donor reactivity is well documented.[5–10] In contrast, the influence of the reactivity of the nucleophile (the acceptor) on the outcome of a glycosylation reaction remains poorly understood.[11–18] This chapter presents a systematic study to determine the effect of acceptor nucleophilicity on the stereochemical course of a glycosylation reaction. It is shown how a simple “toolset” of partially fluorinated alcohols[13] can be used to dissect reaction mechanisms that are operational during a glycosylation reaction. It is revealed that the stereoselectivity of some glycosylation systems varies more with changing acceptor nucleophilicity than others, and these differences are related to changes in reaction pathways that are followed. A panel of model carbohydrate acceptors is scrutinized to place the reactivity of these building blocks in the context of the nucleophilicity scale set by the series of fluorinated ethanols.

Results and discussion

In this study the effect of acceptor nucleophilicity on the glycosylation selectivity is systematically investigated by the hand of a set of model *O*-nucleophiles, encompassing ethanol, monofluoroethanol (MFE), difluoroethanol (DFE), trifluoroethanol (TFE), hexafluoro-*iso*-propanol (HFIP) and cyclohexanol, as well as a *C*-nucleophile, allyltrimethylsilane (allyl-TMS), and a deuterium nucleophile, deuterated triethylsilane (TES-*d*).[12,13] Next a series of carbohydrate acceptors is used to put the reactivity of these alcohols in the context of the reactivity of the ethanol model acceptors (See Figure 2B and C). Three glycosylation systems have been investigated with these acceptors: the benzylidene mannose and analogous benzylidene glucose system as well as the mannuronic acid system (See Figure 2A). These systems have been selected because they have previously been studied in depth to provide insight into the major reaction pathways that operate during glycosylation reactions of these donors (*vide infra*). Although these three glycosylation systems all selectively provide 1,2-*cis*-products, the major product-forming pathways significantly differ.

The benzylidene mannose system, introduced by Crich and co-workers for the stereoselective construction of β-mannosidic linkages, represents the best studied

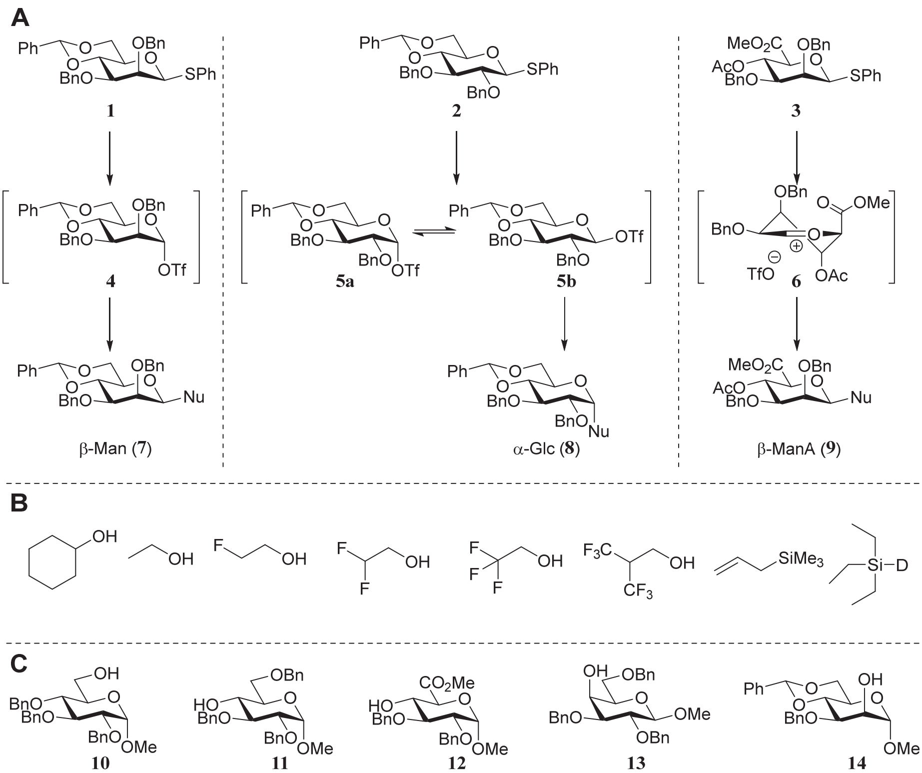


Figure 2. (A) The benzylidene mannose, benzylidene glucose and mannuronic acid glycosylation systems studied and the major glycosylation pathways of these donors. (B) Set of model nucleophiles used in this study. (C) Set of carbohydrate alcohols used.

glycosylation system to date.[19,20] It has been found that benzylidene mannose donors can be transformed into the corresponding α-anomeric triflate **4** upon activation. These triflates have been extensively characterized in variable temperature NMR studies.[21–24] A significant body of evidence has been gathered through a vast amount of glycosylation reactions[19–23,25–33], the establishment of kinetic isotope effects in combination with computational methods[34,35], and the application of cation clock methodology[36–38], to indicate that these triflates can be substituted in an S_N2-manner to provide β-mannosides. However, an alternative hypothesis to account for the β-selectivity of benzylidene mannose glycosylations has also been forwarded. This hypothesis is based on a $B_{2,5}$-oxocarbenium ion as product forming intermediate.[39–42]

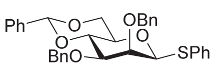
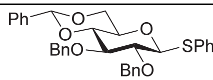
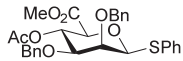
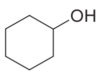
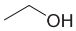
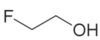
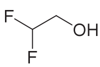
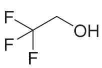
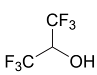
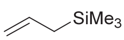
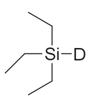
The closely related benzylidene glucose system provides α-selective glycosylation reactions.[21,22,29,40,43–47] It has been proposed that this selectivity originates from an *in situ* anomerization kinetic scheme, in which the initially formed α-triflate **5α** anomerizes into its more reactive β-counterpart **5β**.[21] Substitution of this species provides the α-glucosyl products. Mechanistic studies, amongst others kinetic isotope effect and cation-clock experiments, using the reactive nucleophile *iso*-propanol have provided support for this pathway.[34,37,38]

Glycosylations of mannuronic acids have been shown to proceed in a highly selective manner to provide α-mannuronic acid products. Based on the conformational behavior of the donors and the intermediate α-triflates **18α**, adopting an $^1C_4$ conformation[48,49], the high reactivity of these donors[50,51] and a large variety of glycosylation reactions, both in solution[50,52–55], and on fluorous[56] and solid supports[57], it has been postulated that the selectivity in these glycosylation reactions can be related to the intermediacy of an $^4H_3$ oxocarbenium ion-like intermediate.[53,54,58]

The experimental setup that was used in this study is based on preactivation of the thioglycoside donors **1**[59], **2**[21] and **3** using a slight excess of diphenyl sulfoxide and triflic anhydride (Ph_2SO/Tf_2O) at low temperature. This transforms all three donors into the corresponding anomeric triflates[21–24,48,60], prior to addition of the acceptor nucleophiles. The preactivation set-up generates a pool of reactive intermediates in the absence of the acceptor, thereby eliminating product forming pathways that originate from direct displacement reactions on the activated parent donor species. Table 1 summarizes the results obtained with the three donor systems and the set of model acceptors. As a measure for the reactivity of the used acceptors, Mayr's nucleophilicity parameters have been tabularized where available.[61–63] The field inductive parameters for the -CH_3, -CH_2F, -CHF_2 and -CF_3 groups have also been shown, to indicate the gradual increase of electron-withdrawing character of these groups.[64]

From the results depicted in Table 1 it becomes immediately apparent that the stereoselectivity of the benzylidene mannose and mannuronic acid systems shows relatively little variation with changing nucleophilicity, where the stereoselectivity of the glycosylations involving the benzylidene glucose donor changes significantly depending on the reactivity of the used nucleophile. Reactive nucleophiles such as ethanol,

Table 1. Model acceptor glycosylations.

			 **1**	 **2**	 **3**
Acceptor	*N*[a]	*F*[b]	Product α:β (yield)[c]	Product α:β (yield)	Product α:β (yield)
	-	-	**1A** 1 : 6 (96%)	**2A** 1 : 5 (71 %)	**3A** 1 : 8 (83%)
	7.44	0.01	**1B** 1 : 5 (70 %)	**2B** 1 : 10 (68 %)	**3B** 1 : 8 (95 %)
	-	0.15	**1C** 1 : 5 (86 %)	**2C** 1 : 3 (70 %)	**3C** 1 : 6 (70 %)
	-	0.29	**1D** 1 : 5 (90 %)	**2D** 5 : 1 (70 %)	**3D** 1 : 5 (87 %)
	1.11	0.38	**1E** 1 : 4 (78 %)	**2E** > 20 : 1 (64 %)	**3E** 1 : 2.5 (85 %)
	-1.93	-	**1F** 3 : 1 (56 %)	**2F** > 20 : 1 (65 %)	**3F** 1 : 1 (52 %)
	3.58	-	**1G** < 1 : 20 (60 %)	**2G** > 20 : 1 (79 %)	**3G** < 1 : 20 (95 %)
	1.68	-	**1H** < 1 : 20 (44 %)[d]	**2H** > 20 : 1 (42 %)[d]	**3H** < 1 : 20 (40%)[d]

[a]Mayr's nucleophilicity parameters. [b]Field inductive parameters. [c]α/β-Ratios were established by NMR spectroscopy of the crude and purified reaction mixtures. [d]Both anomers of donor glycoside were also found after the glycosylation reaction. Literature yields of **1H**[40]: 57% and **2H**[40]: 56%.

cyclohexanol and MFE predominantly provide β-linked products (**2A**,[65] **2B** and **2C**), where the use of less reactive nucleophiles such as DFE, TFE, HFIP, TES-*d* and allyl-TMS leads to the preferential formation of the α-glucosyl products (**2D**-**2H**). A clear trend becomes apparent between the reactivity of the non-fluorinated and partially fluorinated ethanols and the stereoselectivity of the glucosylations involving these acceptors. The formation of the β-linked products **2A**, **2B** and **2C** can be explained to originate from an S_N2-like substitution on the intermediate α-triflate **5α** (See Figure 3). The α-products in these glucosylations (**α-2A**, **α-2B**, **α-2C**) may be formed from the corresponding β-glucosyl triflate **5β**, as postulated by Crich and co-workers and as supported by kinetic isotope effect and cation clock studies.[34,35,37,66] It is however less likely that the unreactive *O*-nucleophiles, such as TFE and HFIP, and the weak *C*- and *D*-nucleophiles, are capable of displacing the anomeric triflate **5** in an S_N2-manner. Woerpel and co-workers have previously shown that TFE requires a glycosylating agent bearing significant oxocarbenium ion character.[13] An explanation for the observed α-selectivity in the glucosylations of these nucleophiles may be found in the S_N1-like substitution on the benzylidene glucose oxocarbenium ion **15**. This ion preferentially adopts a $^4H_3/^4E$-structure, as verified by several computational studies[67,68], that is attacked in a diastereoselective fashion from the bottom face, leading *via* a chair-like transition state to the α-linked products. As the reactivity of the nucleophile diminishes, it is likely that the amount of S_N2-character in the substitution of the β-triflate **5β** gradually

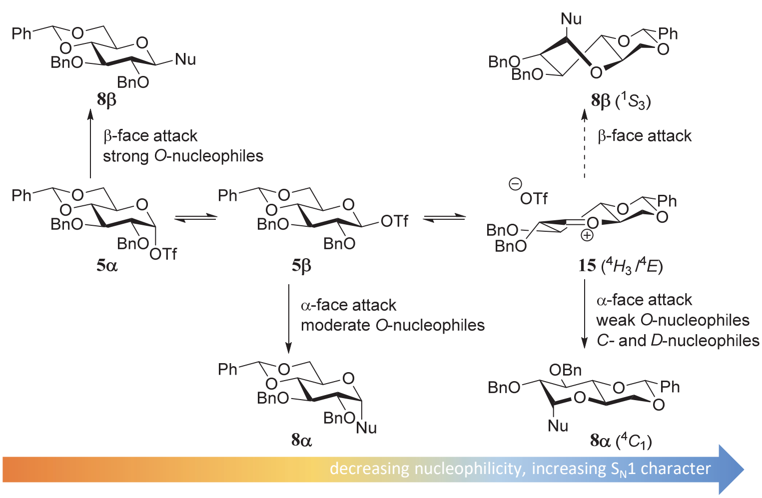


Figure 3. Mechanistic pathways to account for the selectivity in glycosylations of benzylidene glucose donors.

decreases and the amount of S_N1-character with the intermediacy of the corresponding CIP and SSIP (**15**) increases.[13] The least reactive nucleophiles require the most "naked" oxocarbenium ions, with the triflate counterions significantly, if not completely, dissociated from the carbohydrate ring.

The stereoselectivity of the benzylidene mannose system seems to be less sensitive to variation in nucleophilicity of the acceptor. Donor **1** provides β-selective glycosylations with the range of acceptors studied. There is a slight decrease in selectivity going from the reactive *O*-nucleophiles to the weak *O*-nucleophiles and the condensation of benzylidene mannose **1** with HFIP proceeds with moderate α-selectivity. The most likely explanation for the β-selectivity observed with the reactive *O*-nucleophiles is an associative S_N2-type substitution of the intermediate α-triflate **4** (See Figure 4). As discussed above, it is unlikely that unreactive acceptors such as TFE and HFIP react in an S_N2-type reaction, directly displacing the α-mannosyl triflate **4**. Formation of the β-linked products formed from the unreactive acceptors and donor **1** may be better explained with an oxocarbenium ion-like product forming intermediate. Various theoretical studies have indicated that the $B_{2,5}$-oxocarbenium ion **16** is the most stable benzylidene mannose oxocarbenium ion conformer.[67,68] This oxocarbenium ion is preferentially attacked from the convex top face, as attack from the bottom face would lead to unfavorable interactions with the *pseudo*-axial H-2 and to an eclipsed C-1–C-2 configuration upon rehybridization.[36,40,69,70]

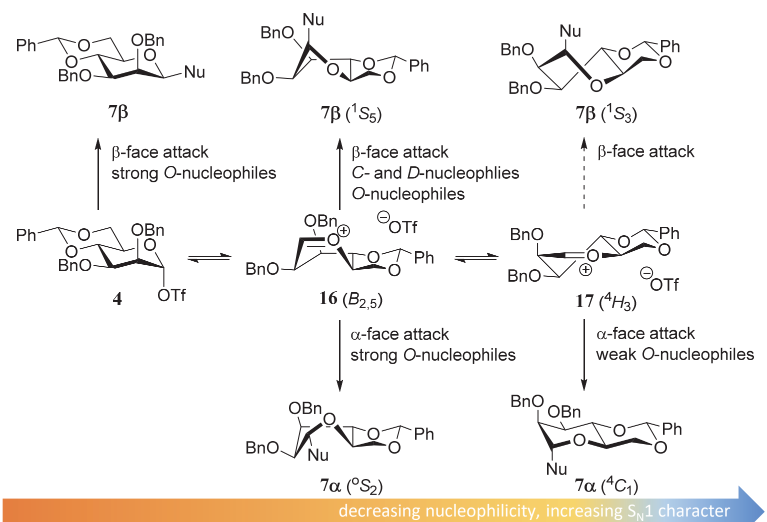


Figure 4. Mechanistic pathways to account for the selectivity in glycosylations of benzylidene mannose donors.

The α-products formed in the condensations of donors **1** likely originate from an oxocarbenium ion intermediate. Reactive *O*-nucleophiles may react with an oxocarbenium ion in a relatively indiscriminative manner leading to the formation of both α- and β-products.[11–13] Because unreactive *O*-nucleophiles are expected to react in a more diastereoselective fashion with an oxocarbenium ion, it is unlikely that the α-products derived from the weak *O*-nucleophiles, such as TFE and HFIP, originate from the $B_{2,5}$-oxocarbenium ion **16**. Instead, α-face attack on the $^4H_3$ half-chair conformer **17** may be a plausible reaction pathway to account for the α-products of the less reactive *O*-nucleophiles. In a later transition state, product development control plays a more important role, and the developing anomeric effect and the low energy chair conformation that results from the α-face attack on the $^4H_3$ half-chair **17**, make this trajectory favorable[71]. For the weak *C*- and *D*-nucleophiles, which react in a highly β-selective manner, this latter pathway does not play a major role, and these nucleophiles attack the $B_{2,5}$-oxocarbenium ion **16** selectively from the top face.[40,72]

In line with the benzylidene mannose system, the mannuronic acid donor provides β-selective condensations with all acceptors explored, except with the very unreactive *O*-nucleophile HFIP where both anomers were formed in equal amounts. Where reactions with nucleophilic *O*-nucleophiles can be expected to form from the α-triflate **18α**,[34–37] the weaker *O*-nucleophiles and allyl-TMS and TES-*d* will react preferentially with an oxocarbenium ion (Figure 5). It has been postulated that the $^3H_4$ half-chair mannuronic acid oxocarbenium ion **6** is the most stable oxocarbenium ion conformer.[51,54,55] To substantiate this hypothesis, the energy associated with a range of mannuronic acid oxocarbenium ion conformers have been calculated using DFT-calculations at the B3LYP/6-311G level.[73] From these calculations the $^3H_4$ conformer **6** appears to be significantly more stable (by > 5 kcal·mol^{-1}) than other conformers such as the alternative $^4H_3$ half-chair **19** and the $B_{2,5}$ boat conformers. The relative stability of the $^3H_4$ half-chair oxocarbenium ion can be explained by favorable interaction of the ring substituents with the electron depleted carbocation. Hyperconjugative stabilization of the C-2–H bond and through space stabilization of the *pseudo*-axial C-3, C-4 oxygen atoms and the axial C-5 carboxylate each contribute to the stability of the half-chair oxocarbenium ion.[51,54,74–76] This oxocarbenium ion is preferentially attacked from the top face to provide the β-linked products *via* a chair-like transition state. For the weaker *O*-nucleophiles, a later transition state leads to significant steric interactions with the axial substituents in the $^3H_4$ half-chair oxocarbenium **6** and a reaction pathway, involving attack of the nucleophiles on the higher energy $^4H_3$ half-chair oxocarbenium ion **19** becomes relevant. In line with the discussion above, product development control is favorable for the formation of α-*O*-mannuronic acids.

Next, the set of carbohydrate acceptors depicted in Figure 2C was explored. The results of these condensation reactions are summarized in Table 2. Where it can be reasoned that the secondary carbohydrate acceptors **11**[77], **12**[78], **13**[77] and **14**[79] electronically resemble DFE and TFE, because of the amount of electron-withdrawing β- and/or γ- and δ-substituents, the size of the carbohydrate acceptors obviously differs significantly from the small ethanol based acceptors. The picture that emerges from Table 2 follows in broad lines the results described in Table 1 and corroborates this analysis. The benzylidene glucose donor system **2** shows most variation in stereoselectivity, where both the benzylidene mannose and mannuronic acid donors **1** and **3** provide β-selective reactions with all carbohydrate acceptors studied. The series of benzylidene glucose condensations again reveals that reactive *O*-nucleophiles can provide β-selective glycosylations, while less reactive *O*-nucleophiles give the α-linked products. The electron-withdrawing effect of the C-5 carboxylate in acceptor **12**, makes this acceptor less reactive and more α-selective than its C-5-benzyloxymethylene counterpart **11**. In line with the discussion above, formation of the β-linked products can be explained with triflate **5α** as product forming intermediate. Less reactive acceptors require a glycosylating species that is more electrophilic and react in a more dissociative substitution reaction, with a substantial

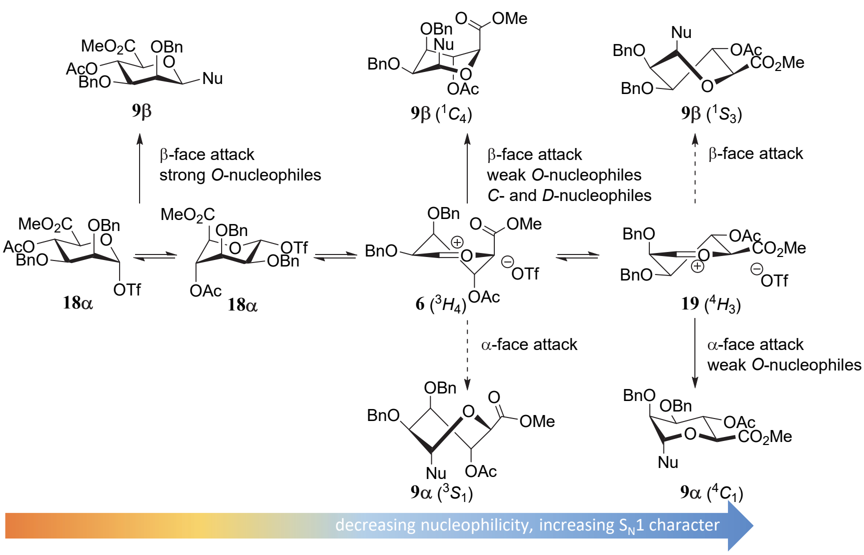
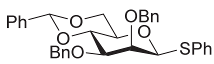
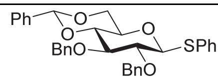
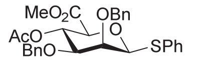
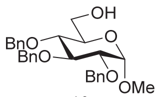
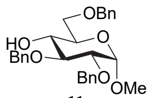
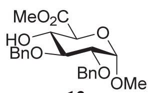
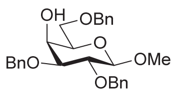
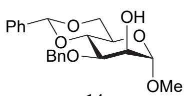


Figure 5. Mechanistic pathways to account for the selectivity in glycosylations of mannuronic acid donors.

Table 2. Glycosylation of donors **1-3** with carbohydrate acceptors **10-14**.

	 **1**	 **2**	 **3**
Acceptor	Product α:β (yield)	Product α:β (yield)	Product α:β (yield)
 **10**	**20** 1 : 10 (97 %)	**25** 1 : 3 (81 %)	**30** < 1 : 20 (71 %)
 **11**	**21** 1 : 9 (75 %)	**26** 1 : 1 (79 %)	**31** < 1 : 20 (61 %)
 **12**	**22** 1 : 10 (87 %)	**27** 5 : 1 (90 %)	**32** 1 : 10 (71 %)
 **13**	**23** < 1 : 20 (70%)	**28** > 20 : 1 (83 %)	**33** < 1 : 20 (76%)
 **14**	**24** < 1 : 20 (87 %)	**29** > 20 : 1 (80 %)	**34** 1 : 7 (80 %)

amount of oxocarbenium ion character and the glucose ring taking up a $^{4}H_{3}$-like structure (**15**).

The benzylidene mannose and mannuronic acid donors **1** and **3** provide very β-selective condensation reactions, in line with the vast amount of previously reported glycosylations of these two donors. Based on the results presented here and in previous work the following picture emerges. Reactive carbohydrate acceptors react in a reaction with significant S_N2-character, displacing the anomeric α-triflate (**4** and **18α**). Weaker nucleophiles, such as most secondary carbohydrate acceptors, will react with a species that bears more carbocation character. For the benzylidene mannose donor, this species will resemble $B_{2,5}$ boat oxocarbenium ion **16**, whereas the mannuronic acid reactive intermediate will be structurally close to $^{3}H_{4}$ oxocarbenium ion **6**. The minor α-products in these condensations likely arise from a higher energy $^{4}H_{3}$ oxocarbenium ion **19**, through a transition state that benefits from a developing anomeric effect and favorable conformational properties.

Conclusions

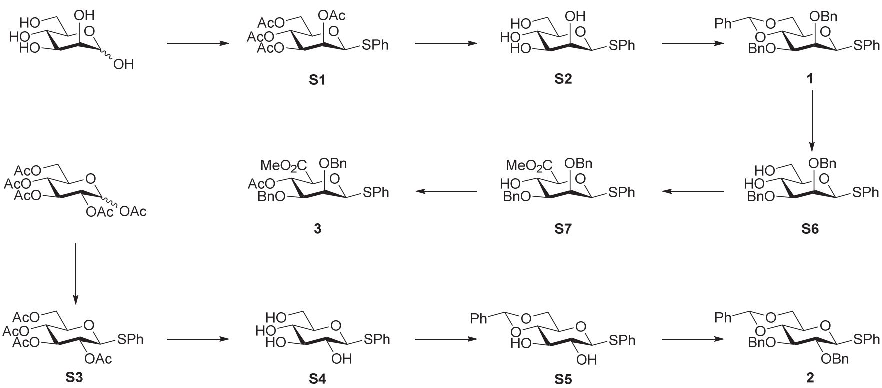
The influence of structural changes in a glycosyl donor on the outcome of a glycosylation reaction, in terms of yield and stereoselectivity, has received considerable attention over the years and many ingenious donor systems have been developed for the stereoselective construction of glycosidic bonds. The influence of the reactivity of the acceptor in glycosylation reactions, on the other hand, is less well understood. Here we have investigated in a systematic manner how the outcome of a glycosylation system can change depending on the gradually changing reactivity of the nucleophile. We have shown that a series of partially fluorinated alcohols of gradually decreasing nucleophilicity, can be used to map how the stereoselectivity of a glycosylation system varies with changing acceptor reactivity. The simple "toolset" of partially fluorinated ethanols represents a rapid and easy means to dissect S_N2-type (for ethanol) and S_N1-type (for trifluoroethanol and hexafluoro-*iso*-propanol) glycosylation reaction mechanisms.[80] It is expected that application of this set of model nucleophiles to newly developed glycosylation methodology or re-investigation of already established methods will bring detailed insight into the complex and intriguing glycosylation reaction mechanism. This will allow for more directed optimization of glycosylation reactions, taking away the trial and error component and ill-understood reaction protocols that have plagued carbohydrate chemistry for so long.

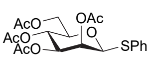
Experimental section

General procedure for Tf_2O/Ph_2SO mediated glycosylations: Donor (0.1 mmol), Ph_2SO (26 mg, 0.13 mmol, 1.3 eq.) and TTBP (62 mg, 0.25 mmol, 2.5 eq.) were coevaporated twice with dry toluene (4 Å molecular sieves) and dissolved in DCM (2 mL, 0.05 M donor). Activated 3Å molecular sieves (rods, size 1/16 in.) were added and the reaction mixture stirred for 30 min at room temperature. The solution was cooled to -78°C and Tf_2O (22 µl, 0.13 mmol, 1.3 eq.) was slowly added. The reaction mixture was allowed to warm to -60°C in approximately 45 min, followed by recooling to -78°C and addition of the acceptor (0.2 mmol, 2 eq.) in DCM (0.4 mL, 0.5 M). The reaction mixture was allowed to warm to -40°C in approximately 60 min and stirred for an additional 0-18 h depending on the acceptor. The reaction was quenched with Et_3N (0.1 mL, 0.72 mmol, 7.2 eq.) at -40°C and diluted with DCM. The solution was transferred to a separatory funnel and water was added, the layers were separated and the water phase extracted once more with DCM. The combined organic layers were dried over $MgSO_4$, filtered, and concentrated *in vacuo*. Purification by silica gel flash column chromatography and when needed, sephadex^{TM} LH-20 size exclusion chromatography yielded the glycosylation product as a mixture of anomers.

General computational procedure: Density functional theory (DFT) *ab initio* calculations were performed with the B3LYP model. Conformations were generated from a conformer distribution search option included in the Spartan 04 program[82] in the gas phase at the 6-31G* basis set level. All generated geometries were further optimized with Gaussian 03[83] at the 6-311G** level, their zero-point energy (ZPE) corrections calculated and further optimized with incorporated polarizable continuum model (PCM) to correct for solvation in dichloromethane.

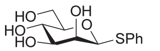
Preparation of donors **1**, **2**, and **3**.



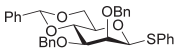


Phenyl 2,3,4,6-tetra-*O*-acetyl-1-thio-β-D-mannopyranoside (S1). To a mixture of HBr (33 wt% in AcOH, 35 mL, 200 mmol, 1 eq.) and Ac_2O (93 mL, 1020 mmol, 5.1 eq.) and 10 drops of 70% aq. $HClO_4$, D-mannose (36.0 g, 200 mmol) was added portion wise at 0 ºC. After 20 minutes an additional amount of HBr (33 wt% in AcOH, 70 mL, 400 mmol, 2 eq.) was added. After stirring for 16 h at r.t. the reaction mixture was concentrated *in vacuo* at 30 ºC. The resulting black oil was co-evaporated with toluene until neutral pH was reached and was used in the following step without further purification. To a solution of the crude product in DMF (400 mL), thiophenol (21.5 mL, 210 mmol, 1.05 eq.) was added. The reaction mixture was cooled to 0 ºC and NaH (60% dispersion in mineral oil, 8.4 g, 210 mmol, 1.05 eq.) was added portion wise. After 2 h stirring at r.t. the reaction was quenched by the addition of aq. HCl (1 M). To the resulting black suspension, 4 L of water was added and extracted 10 times with Et_2O. The combined organic layers were washed with water, dried with $MgSO_4$ and concentrated *in vacuo*. Flash column chromatography (9/1 to 7/3 pentane/EtOAc) afforded the title compound as an orange oil (57.3 g, 130 mmol, 65%). R_f: 0.70 (1/1 pentane/EtOAc). Spectroscopic data were in accord with those previously reported.[84,85] $[\alpha]_D^{26}$ = -44.4° (*c* = 0.5, $CHCl_3$); IR (neat): 1047, 1213, 1368, 1742; ^{1}H NMR (400 MHz, $CDCl_3$, HH-COSY, HSQC): δ 7.56 – 7.47 (m, 2H, CH_{arom} SPh), 7.34 – 7.30 (m, 3H, CH_{arom} SPh), 5.66 (dd, 1H, *J* = 3.5, 0.8 Hz, H-2), 5.28 (t, 1H, *J* = 10.0 Hz, H-4), 5.07 (dd, 1H, *J* = 10.1, 3.5 Hz, H-3), 4.94 (d, 1H, *J* = 1.0 Hz, H-1), 4.29 (dd, 1H, *J* = 12.2, 6.5 Hz, H-6), 4.17 (dd, 1H, *J* = 12.2, 2.4 Hz, H-6), 3.72 (ddd, 1H, *J* = 10.0, 6.4, 2.5 Hz, H-5), 2.20 (s, 3H, CH_3 OAc), 2.09 (s, 3H, CH_3 OAc), 2.04 (s, 3H, CH_3 OAc), 1.98 (s, 3H CH_3, OAc); ^{13}C-APT NMR (101 MHz, $CDCl_3$, HSQC): δ 170.5, 170.1, 167.0, 169.6

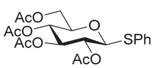
(C=O Ac), 133.2 (C_q SPh), 131.9, 129.1, 128.1 (CH_{arom} SPh), 85.5 (C-1), 76.4 (C-5), 71.8 (C-3), 70.6 (C-2), 65.8 (C-4), 62.8 (C-6), 20.7, 20.7, 20.6, 20.6 (CH_3 Ac); ^{13}C-GATED NMR (101 MHz, $CDCl_3$): δ 85.5 ($J_{C1,H1}$ = 153 Hz, C-1 β); HRMS: $[M+Na]^+$ calcd for $C_{20}H_{24}O_9SNa$ 463.10332, found 463.10305.



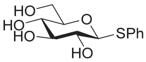
Phenyl 1-thio-β-D-mannopyranoside (S2). To a solution of **S1** (24.9 g, 56.5 mmol) in MeOH (280 mL), NaOMe (0.31 g, 5.7 mmol, 0.1 eq.) was added. The reaction mixture was stirred for 16 h. Amberlite IR120 H^+ was added until pH 6 was reached and the mixture was filtered and concentrated *in vacuo*. This afforded the title compound (15.3 g, 56.4 mmol, 99%) as a white foam. R_f: 0.20 (9/1 DCM/MeOH). Spectroscopic data were in accord with those previously reported.[86,87] IR (neat, cm^{-1}): 880, 1085, 1636, 2974, 3312; ^{1}H NMR (400 MHz, MeOD, HH-COSY, HSQC): δ 7.53 – 7.46 (m, 2H, CH_{arom} SPh), 7.34 – 7.17 (m, 3H, CH_{arom} SPh), 5.00 (s, 1H, H-1), 4.05 (dd, 1H, *J* = 3.4, 1.0 Hz, H-2), 3.88 (dd, 1H, *J* = 11.9, 2.4 Hz, H-6), 3.73 (dd, 1H, *J* = 12.1, 5.7 Hz, H-6), 3.63 (t, 1H, *J* = 9.5 Hz, H-4), 3.51 (dd, 1H, *J* = 9.5, 3.4 Hz, H-3), 3.29 (m, 1H, *J* = 5.8 Hz, H-5); ^{13}C-APT NMR (101 MHz, MeOD, HSQC): δ 131.0, 130.0, 127.7 (CH_{arom} SPh), 88.8 (C-1), 82.4 (C-5), 76.2 (C-3), 74.3 (C-2), 68.3 (C-4), 62.9 (C-6); HRMS: $[M+Na]^+$ calcd for $C_{12}H_{16}O_5SNa$ 295.06107, found 295.06107.



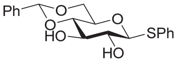
Phenyl 2,3-di-*O*-benzyl-4,6-*O*-benzylidene-1-thio-β-D-mannopyranoside (1). To a solution of **S2** (1.36 g, 5 mmol) in DMF (50 mL), benzaldehyde dimethyl acetal (3.0 mL, 20 mmol, 4 eq.) and CSA (0.25 g, 1 mmol, 0.2 eq.) were added. After the solution was stirred for 16 h, benzyl bromide (2.4 mL, 20 mmol, 4 eq.) and NaH (60% dispersion in mineral oil, 0.48 g, 20 mmol, 4 eq.) were added at 0 ºC. The suspension was allowed to warm up until r.t. and stirred for an additional 2 h. The reaction mixture was quenched with MeOH, followed by the addition of DCM (250 mL) and ice water (500 mL). The water layer was extracted once with DCM and the combined organic layers were washed with water and brine. The combined organic layers were dried over $MgSO_4$, filtered and concentrated under reduced pressure. Flash column chromatography (1/0 to 9/1 pentane/EtOAc) and subsequent recrystallization from EtOAc and pentane afforded the title compound as a white solid (1.38 g, 2.56 mmol, 51% over 2 steps). R_f: 0.27 (9/1 pentane/EtOAc). Spectroscopic data were in accord with those previously reported.[59] IR (neat): 733, 1026, 1069, 1452, 2864; ^{1}H NMR (400 MHz, $CDCl_3$, HH-COSY, HSQC, HMBC): δ 7.64 – 7.14 (m, 20H, CH_{arom}), 5.64 (s, 1H, C*H*Ph), 5.12 (d, 1H, *J* = 11.1 Hz, C*H*H Bn), 4.89 (d, 1H, *J* = 12.3 Hz, CH*H* Bn), 4.86 (d, 1H, *J* = 11.1 Hz, C*H*H Bn), 4.85 (d, 1H, *J* = 1.3 Hz, H-1), 4.74 (d, 1H, *J* = 12.3 Hz, CH*H* Bn), 4.36 – 4.26 (m, 2H, H-4, H-6), 4.18 (dd, 1H, *J* = 3.1, 1.3 Hz, H-2), 3.95 (t, 1H, *J* = 10.3 Hz, H-6), 3.74 (dd, 1H, *J* = 9.8, 3.1 Hz, H-3), 3.42 (td, 1H, *J* = 9.7, 4.9 Hz, H-5); ^{13}C-APT NMR (101 MHz, $CDCl_3$, HSQC, HMBC): δ 138.1, 137.6, 135.1 (C_q), 131.2, 129.1, 129.1, 128.8, 128.6, 128.4, 127.9, 127.9, 127.8, 127.6, 126.2 (CH_{arom}), 101.6 (CHPh), 89.2 (C-1), 79.9 (C-3), 79.1 (C-2), 78.8 (C-4), 76.0, 73.3 (CH_2 Bn), 71.8 (C-5), 68.6 (C-6); ^{13}C-GATED NMR (101 MHz, $CDCl_3$) δ 89.2 ($J_{C1,H1}$ = 152 Hz, C-1 β); HRMS: $[M+NH_4]^+$ calcd for $C_{33}H_{36}NO_5S$ 558.23087, found 558.23071.



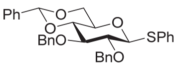
Phenyl 2,3,4,6-tetra-*O*-acetyl-1-thio-β-D-glucopyranoside (S3). To a 140°C solution of NaOAc (8.2 g, 100 mmol, 0.5 eq) in Ac_2O (190 mL, 2 mol, 10 eq.) D-glucose (36 g, 200 mmol, 1 eq.) was added portionwise and the reaction mixture was refluxed for an additional 15 min. The solution was cooled to r.t. and poured over crushed ice. The product was filtered, taken up in DCM, concentrated *in vacuo* and recrystallized from hot EtOH (750 mL) to give the pentaacetate as a white solid (69.4 g, 178 mmol, 89%). Spectroscopic data were in accord with those previously reported.[88,89] Data for the β-anomer: ^{1}H NMR ($CDCl_3$, 400 MHz, HH-COSY, HSQC): δ 5.72 (d, 1H, *J* = 8.3 Hz, H-1), 5.26 (t, 1H, *J* = 9.4 Hz, H-3), 5.19 – 5.08 (m, 2H, H-2, H-4), 4.30 (dd, 1H, *J* = 12.7, 3.8 Hz, H-6), 4.15 – 4.08 (m, 1H, H-6), 3.88 – 3.81 (m, 1H, H-5), 2.12 (s, 3H, CH_3 OAc), 2.09 (s, 3H, CH_3 OAc), 2.04 (s, 6H, 2xCH_3 OAc), 2.02 (s, 3H, CH_3 OAc); ^{13}C-APT NMR ($CDCl_3$, 101 MHz, HSQC): δ 170.7, 170.2, 169.5, 169.4, 169.1 (C_q OAc), 91.8 (C-1), 72.9, 72.8 (C-3, C-5), 70.3, 67.9 (C-2, C-4), 61.6 (C-6), 21.0, 20.8, 20.7 (CH_3 OAc).D-glucose pentaacetate (20 g, 51 mmol) was dissolved in DCM (100 mL) and cooled to 0°C. Thiophenol (7.8 mL, 76.5 mmol, 1.5 eq.) was added followed by addition of boron trifluoride diethyl etherate (10.9 mL, 76.5 mmol, 1.5 eq.) and the mixture was refluxed overnight. Sat. aq. $NaHCO_3$ (300 mL) and Et_2O (100 mL) were added and the mixture was extracted three times with Et_2O. The organic layer was washed with brine, dried with $MgSO_4$, filtered and concentrated under reduced pressure. The crude product was purified by crystallization from EtOAc/hexane (1/10) to obtain the title compound as a white solid. (16.8 g, 38.2 mmol, 75%). Spectroscopic data were in accord with those previously reported.[77,90–92] ^{1}H NMR ($CDCl_3$, 400 MHz, HH-COSY, HSQC): δ 7.50 (dd, 2H, *J* = 6.6, 3.0 Hz, CH_{arom}), 7.34 – 7.28 (m, 3H, CH_{arom}), 5.24 (t, 1H, *J* = 9.3 Hz, H-3), 5.04 (t, 1H, *J* = 9.8 Hz, H-4), 4.97 (t, 1H, *J* = 9.6 Hz, H-2), 4.75 (d, 1H, *J* = 10.0 Hz, H-1), 4.23 (dd, 1H, *J* = 12.3, 5.1 Hz, H-6), 4.17 (dd, 1H, *J* = 12.3, 2.5 Hz, H-6), 3.76 (ddd, 1H, *J* = 10.0, 5.1, 2.5 Hz, H-5), 2.07 (s, 3H, CH_3 OAc), 2.06 (s, 3H, CH_3 OAc), 2.01 (s, 3H, CH_3 OAc), 1.98 (s, 3H, CH_3 OAc); ^{13}C-APT NMR ($CDCl_3$, 101 MHz, HSQC): δ 170.2, 169.8, 169.2, 169.0 (C=O Ac), 132.8 (CH_{arom}), 131.5 (C_q), 128.8, 128.2 (CH_{arom}), 85.3 (C-1), 75.5 (C-5), 73.8 (C-3), 69.8 (C-2), 68.1 (C-4), 61.9 (C-6), 20.5, 20.5, 20.4, 20.4 (CH_3 Ac).



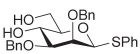
Phenyl 1-thio-β-D-glucopyranoside (S4). To a solution of **S3** (16.3 g, 37.0 mmol) in MeOH (200 mL) was added Na(s) (89 mg, 3.7 mmol, 0.1 eq) and the reaction was stirred for 18 h at r.t. The reaction mixture was neutralized with Amberlite H^+, filtered and Celite® was added to the filtrate and the mixture concentrated *in vacuo*. The residue was purified by flash column chromatography (1% to 12% EtOH in EtOAc) to obtain a white solid (8.6 g, 31.6 mmol, 85%). Spectroscopic data were in accord with those previously reported.[93] ^{1}H NMR (MeOD, 400 MHz, HH-COSY, HSQC): δ 7.61 – 7.54 (m, 2H, CH_{arom}), 7.33 – 7.24 (m, 3H, CH_{arom}), 4.60 (d, 1H, *J* = 9.8 Hz, H-1), 3.87 (dd, 1H, *J* = 12.1, 1.8 Hz, H-6), 3.67 (dd, 1H, *J* = 12.2, 5.2 Hz, H-6), 3.39 (t, 1H, *J* = 8.5 Hz, H-3), 3.35 – 3.26 (m, 2H, H-4, H-5), 3.22 (dd, 1H, *J* = 9.8, 8.6 Hz, H-2); ^{13}C-APT NMR (MeOD, 101 MHz, HSQC): δ 135.3 (C_q), 132.7, 129.9, 128.3 (CH_{arom}), 89.4 (C-1), 82.0 (C-4), 79.7 (C-3), 73.7 (C-2), 71.3 (C-5), 62.8 (C-6).



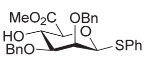
Phenyl 4,6-*O*-benzylidene-1-thio-β-D-glucopyranoside (S5). To a solution of **S4** (12.81 g, 47 mmol) and *p*-TsOH·H_2O (100 mg, 0.5 mmol, 0.01 eq.) in DMF (25 mL) and CH_3CN (100 mL) was added benzaldehyde dimethyl acetal (9.9 mL, 65.8 mmol, 1.4 eq.). The reaction was heated to 50°C at 250 mbar for 5 hours and subsequently quenched with Et_3N (2 mL) and diluted with EtOAc (250 mL). The solution was washed with H_2O (2x 100 mL) and brine (100 mL). The organic layer was dried ($MgSO_4$) and concentrated *in vacuo*. Precipitation from EtOAc/petroleum ether formed a waxy material (12.0 g, 33.3 mmol) and the remaining mother liquors were purified by column chromatography (3/1 to 1/3 pentane/EtOAc) to give another batch of product (3.86 g, 10.7 mmol). Total yield 15.9 g, 44 mmol, 94%. R_f: 0.50 (1/2 pentane/EtOAc). Spectroscopic data were in accord with those previously reported.[90–92] ^{1}H NMR ($CDCl_3$, 400 MHz, HH-COSY, HSQC): δ 7.59 – 7.51 (m, 2H, CH_{arom}), 7.51 – 7.44 (m, 2H, CH_{arom}), 7.40 – 7.31 (m, 6H, CH_{arom}), 5.54 (s, 1H, C*H*Ph), 4.64 (d, 1H, *J* = 9.8 Hz, H-1), 4.39 (dd, 1H, *J* = 10.5, 4.4 Hz, H-6), 3.91 – 3.74 (m, 2H, H-4, H-6), 3.59 – 3.43 (m, 3H, H-2, H-3, H-5); ^{13}C-APT NMR ($CDCl_3$, 101 MHz, HSQC): δ 137.0 (C_q), 133.2 (CH_{arom}), 131.4 (C_q), 129.5, 129.3, 128.7, 128.5, 126.4 (CH_{arom}), 102.1 (CHPh), 88.8 (C-1), 80.4 (C-3), 74.7 (C-4), 72.7 (C-2), 70.7 (C-5), 68.7 (C-6).



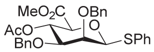
Phenyl 2,3-di-*O*-benzyl-4,6-*O*-benzylidene-1-thio-β-D-glucopyranoside (2). Diol **S5** (7.21 g, 20 mmol) was dissolved in DMF (100 mL) and cooled to 0°C. Benzyl bromide (5.75 mL, 48 mmol, 2.4 eq.) and NaH (60% dispersion in mineral oil, 2.4 g, 60 mmol, 3 eq.) were added and the reaction mixture was allowed to stir overnight. MeOH was added to quench the reaction followed by H_2O (500 mL) and EtOAc (300 mL). The organic layer was washed with brine and dried with MgSO4. After concentration of the organic layer under reduced pressure, the crude product was crystallized from EtOAc (50 mL) and hexane (100 mL) to obtain the title compound as a white solid (9.49 g, 17.4 mmol, 86%). Spectroscopic data were in accord with those previously reported.[21,90–92] ^{1}H NMR ($CDCl_3$, 400 MHz, HH-COSY, HSQC): δ 7.56 – 7.51 (m, 2H, CH_{arom}), 7.51 – 7.46 (m, 2H, CH_{arom}), 7.42 – 7.26 (m, 16H, CH_{arom}), 5.59 (s, 1H, C*H*Ph), 4.94 (d, 1H, *J* = 11.1 Hz, C*H*H Bn), 4.86 (d, 1H, *J* = 10.2 Hz, C*H*H Bn), 4.81 (d, 1H, *J* = 10.3 Hz, CH*H* Bn), 4.80 – 4.73 (m, 2H, CH*H* Bn, H-1), 4.39 (dd, 1H, *J* = 10.5, 5.0 Hz, H-6), 3.84 (dd, 1H, *J* = 9.3, 8.3 Hz, H-3), 3.80 (t, 1H, *J* = 10.3 Hz, H-6), 3.71 (t, 1H, *J* = 9.3 Hz, H-4), 3.56 – 3.42 (m, 2H, H-2, H-5); ^{13}C-APT NMR ($CDCl_3$, 101 MHz, HSQC): δ 138.4, 138.1, 137.4, 133.2 ($C_{q\text{-}arom}$), 132.5, 129.1, 129.1, 128.5, 128.5, 128.4, 128.3, 128.2, 128.0, 128.0, 127.9, 126.1 (CH_{arom}), 101.3 (CHPh), 88.4 (C-1), 83.1 (C-3), 81.6 (C-4), 80.6 (C-2), 76.0, 75.5 (CH_2 Bn), 70.4 (C-5), 68.8 (C-6); HRMS: $[M+H]^+$ calcd for $C_{33}H_{33}O_5S$ 541.20432, found 541.20392.



Phenyl 2,3-di-*O*-benzyl-1-thio-β-D-mannopyranoside (S6). To a solution of **1** (1.62 g, 3 mmol) in MeOH (30 mL), *p*-TsOH·H_2O (60 mg, 0.3 mmol, 0.1 eq.) was added. The suspension was stirred for 1 h at 50 °C and subsequently quenched with Et_3N. After concentration *in vacuo* the resulting product was purified by flash column chromatography (9/1 to 1/1 pentane/EtOAc) to yield the title compound as a colourless foam (1.26 g, 2.78 mmol, 93%). R_f: 0.10 (4/1 pentane/EtOAc). Spectroscopic data were in accord with those previously reported.[51] $[\alpha]_D^{26}$ = -62.4° (*c* = 0.5, $CHCl_3$); IR (neat): 734, 1026, 1119, 1454, 924, 3391; ^{1}H NMR (400 MHz, $CDCl_3$, HH-COSY, HSQC): δ 7.54 – 7.19 (m, 15H, CH_{arom}), 4.97 (d, 1H, *J* = 11.3 Hz, C*H*H Bn), 4.85 (s, 1H, H-1), 4.85 (d, 1H, *J* = 11.3 Hz, CH*H* Bn), 4.75 (d, 1H, *J* = 11.7 Hz, C*H*H Bn), 4.53 (d, 1H, *J* = 11.7 Hz, CH*H* Bn), 4.20 (d, 1H, *J* = 2.1 Hz, H-2), 4.05 (td, 1H, *J* = 9.5, 2.3 Hz, H-4), 3.93 (ddd, 1H, *J* = 11.0, 7.2, 3.6 Hz, H-6), 3.82 (dt, 1H, *J* = 12.1, 6.3 Hz, H-6), 3.46 (dd, 1H, *J* = 9.5, 2.8 Hz, H-3), 3.38 (ddd, 1H, *J* = 9.5, 6.0, 3.6 Hz, H-5), 2.33 (s, 1H, 4-OH), 2.14 (t, 1H, *J* = 6.4 Hz, 6-OH); ^{13}C-APT NMR (101 MHz, $CDCl_3$, HSQC): δ 138.0, 137.6, 135.1 (C_q), 130.7, 129.2, 128.8, 128.5, 128.4, 128.3, 127.9, 127.9, 127.5 (CH_{arom}), 87.9 (C-1), 83.6 (C-3), 80.1 (C-5), 76.7 (C-2), 75.3, 72.3 (CH_2 Bn), 67.5 (C-4), 63.1 (C-6); ^{13}C-GATED NMR (101 MHz, $CDCl_3$): δ 87.9 (*J* = 152 Hz, C-1 β); HRMS: $[M+Na]^+$ calcd for $C_{26}H_{28}O_5SNa$ 475.15497, found 475.15430.

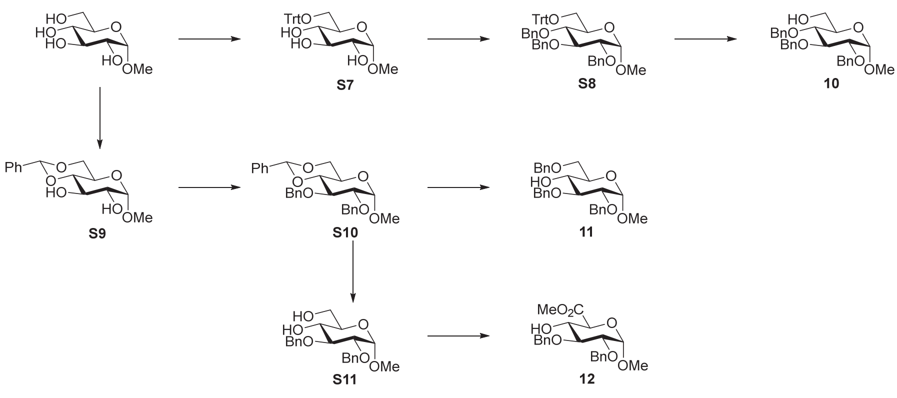


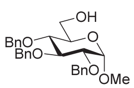
Methyl (phenyl 2,3-di-*O*-benzyl-1-thio-β-D-mannopyranosyl uronate) (S7). To a two phase system of **S6** (1.25 g, 2.76 mmol) in DCM (10 mL) and H_2O (5 mL), TEMPO (86 mg, 0.55 mmol, 0.2 eq.), BAIB (2.22 g, 6.9 mmol, 2.5 eq.) and AcOH (50 µL) were added. The reaction mixture was stirred for 6 h and was quenched with sat. aq. $Na_2S_2O_3$. The resulting suspension was concentrated under reduced pressure and co-evaporated three times with toluene. The formed solid was dissolved in DMF (15 mL), K_2CO_3 (1.14 g, 8.28 mmol, 3 eq.) and methyl iodide (0.52 mL, 8.28 mmol, 3 eq.) were added. The suspension was stirred for 16 h at r.t. and followed by the addition of H_2O (150 mL). The aqueous layer was extracted three times with Et_2O and subsequently washed with sat. aq. $NaHCO_3$ and brine. The combined organic layers were dried over $MgSO_4$, filtered and concentrated under reduced pressure. Flash column chromatography (1/0 to 3/1 pentane/EtOAc) followed by recrystallization in EtOAc and pentane afforded the title compound as a white solid (0.48 g, 1.75 mmol, 63% over 2 steps). R_f: 0.70 (1/1 pentane/EtOAc). Spectroscopic data were in accord with those previously reported.[51] $[\alpha]_D^{26}$ = -72,0° (*c* = 0.5, $CHCl_3$); IR (neat): 696, 735, 1026, 1064, 1123, 1429, 1454, 1744, 2855, 2924, 3462; ^1H NMR (400 MHz, $CDCl_3$, HH-COSY, HSQC): δ 7.51 – 7.25 (m, 20H, CH_{arom}), 5.02 (d, 1H, *J* = 11.4 Hz, C*H*H Bn), 4.86 (d, 1H, *J* = 11.3 Hz, CH*H* Bn), 4.79 – 4.74 (m, 3H, C*H*H Bn, CH*H* Bn, H-1), 4.41 (td, 1H, *J* = 9.5, 2.1 Hz, H-4), 4.12 (dd, 1H, *J* = 3.0, 1.0 Hz, H-2), 3.84 – 3.77 (m, 4H, H-5, CH_3 CO_2Me), 3.50 (dd, 1H, *J* = 9.5, 2.9 Hz, H-3), 3.11 (d, 1H, *J* = 2.3 Hz, 4-OH); ^{13}C-APT NMR (101 MHz, $CDCl_3$, HSQC): δ 138.0, 135.1 (C_q), 131.3, 129.1, 128.7, 128.6, 128.3, 128.1, 127.9, 127.9, 127.6 (CH_{arom}), 89.0 (C-1), 82.4 (C-3), 78.3 (C-5), 77.0 (C-2), 75.4, 73.1 (CH_2 Bn), 68.6 (C-4), 52.9 (CH_3 CO_2Me); ^{13}C- GATED NMR (101 MHz, $CDCl_3$): δ 89.0 ($J_{C1,H1}$ = 154 Hz, C-1 β). HRMS: $[M+H]^+$ calcd for $C_{27}H_{29}O_6S$ 481,16794, found 481,16812.



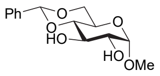
Methyl (phenyl 4-*O*-acetyl-2,3-di-*O*-benzyl-thio-β-D-mannopyranosyl uronate) (3). To a suspension of S7 (1.20 g, 2.5 mmol) in pyridine (3.0 mL, 37.5 mmol, 15 eq.), Ac_2O (0.30 mL, 3.1 mmol, 1.25 eq.) was added. After stirring for 16 h at r.t., the reaction mixture was quenched with H_2O (25 mL). To the quenched reaction mixture, EtOAc was added and the layers were separated. The water layer was extracted for an additional 2 times with EtOAc. The combined organic layers were washed with sat. aq. $NaHCO_3$ and brine. The resulting organic layer was dried over $MgSO_4$, filtered and concentrated under reduced pressure. Flash column chromatography (9/1 to 7/3 pentane/EtOAc) afforded the title compound as a white solid (1.2 g, 2.3 mmol, 92%). R_f: 0.42 (7/3 pentane/EtOAc). $[\alpha]_D^{26}$ = -84.0° (*c* = 0.5, $CHCl_3$); IR (neat): 733, 1024, 1053, 1089, 1746, 2870; ^1H NMR (400 MHz, $CDCl_3$, HH-COSY, HSQC): δ 7.50 – 7.23 (m, 15H, CH_{arom}), 5.61 (t, 1H, *J* = 9.6 Hz, H-4), 5.03 (d, 1H, *J* = 11.6 Hz, C*H*H Bn), 4.85 (d, 1H, *J* = 11.6 Hz, CH*H* Bn), 4.78 (d, 1H, *J* = 1.1 Hz, H-1), 4.67 (d, 1H, *J* = 12.2 Hz, C*H*H Bn), 4.57 (d, 1H, *J* = 12.2 Hz, CH*H* Bn), 4.15 (dd, 1H, *J* = 2.8, 1.0 Hz, H-2), 3.88 (d, 1H, *J* = 9.6 Hz, H-5), 3.74 (s, 3H, CH_3 CO_2Me), 3.61 (dd, 1H, *J* = 9.7, 2.9 Hz, H-3), 2.01 (s, 3H, CH_3 OAc); ^{13}C-APT NMR (101 MHz, $CDCl_3$, HSQC): δ 169.7, 167.8 (C=O CO_2Me, Ac), 137.9, 137.7, 135.1 (C_q), 131.3, 129.1, 128.7, 128.6, 128.3, 128.1, 127.9, 127.7, 127.7 (CH_{arom}), 88.7 (C-1), 80.4 (C-3), 77.3 (C-5), 76.4 (C-2), 75.1, 72.6 (CH_2 Bn), 68.9 (C-4), 52.8 (CH_3 CO_2Me), 21.0 (CH_3 Ac); ^{13}C-GATED NMR (101 MHz, $CDCl_3$): δ 88.7 ($J_{C1,H1}$ = 152 Hz, C-1 β); HRMS: $[M+NH_4]^+$ calcd for $C_{29}H_{34}NO_7S$ 540.20505, found 540.20515.

Preparation of acceptors 10, 11, and 12.

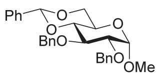




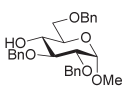
Methyl 2,3,4-tri-*O*-benzyl-α-D-glucopyranoside (10). To a solution of methyl-α-D-glucopyranoside (1.94 g, 10 mmol, 1 eq.) in DMF (50 mL), trityl chloride (3.1 g, 11 mmol, 1.1 eq.), Et_3N (2.1 mL, 15 mmol, 1.5 eq.) and DMAP (0.12 g, 1 mmol, 0.1 eq.) were added. After stirring for 6 h at 60 °C the reaction was cooled to 0 °C and followed by the addition of benzyl bromide (4.8 mL, 40 mmol, 4 eq.), NaH (2 g, 50 mmol, 5 eq.). The suspension was stirred for 16 h at r.t. and subsequently quenched with MeOH. The reaction mixture was concentrated under reduced pressure and the remaining oil was transferred to a separation funnel. Et_2O and H_2O were added and the layers were separated. The water layer was extracted three more times with Et_2O. The combined organic layers were washed with water, sat. aq. $NaHCO_3$ and brine. The resulting organic layer was dried over $MgSO_4$, filtered and concentrated under reduced pressure. The crude product **S8** was suspended in MeOH (100 mL) followed by the addition of *p*-TsOH·H_2O (0.19 g, 1 mmol, 0.1 eq.). After stirring for 1 h at 50 ^{o}C the reaction mixture was quenched with sat. aq. $NaHCO_3$ and concentrated *in vacuo*. Flash column chromatography (1/0 to 7/3 pentane/EtOAc) afforded the title compound as a waxy solid (3.6 g, 7.7 mmol, 78% over 3 steps). Spectroscopic data were in accord with those previously reported.[77,94] R*f*: 0.57 (7/3 pentane/EtOAc). IR (neat): 880, 1043, 1086, 1381, 1636, 2893, 2974, 3312; ^{1}H NMR (400 MHz, $CDCl_3$, HH-COSY, HSQC): δ 7.42 – 7.24 (m, 15H, CH_{arom}), 4.99 (d, 1H, *J* = 10.8 Hz, C*H*H Bn), 4.92 – 4.77 (m, 3H, C*H*H Bn, CH*H* Bn, C*H*H Bn), 4.72 – 4.60 (m, 2H, CH*H* Bn, CH*H* Bn), 4.56 (d, 1H, *J* = 3.5 Hz, H-1), 4.01 (t, 1H, *J* = 9.3 Hz, H-4), 3.82 – 3.73 (m, 1H, H-6), 3.73 – 3.61 (m, 2H, H-6, H-5), 3.58 – 3.45 (m, 2H, H-6, H-2, H-3), 3.37 (s, 3H, CH_3 OMe), 1.61 (dd, 1H, *J* = 7.3, 5.4 Hz, 6-OH); ^{13}C-APT NMR (101 MHz, $CDCl_3$, HSQC, HMBC): δ 138.8, 138.2 (C_q), 128.6, 128.6, 128.6, 128.3, 128.2, 128.1, 128.1, 128.0, 127.8 (CH_{arom}), 98.3 (C-1), 82.1 (C-4), 80.0 (C-2), 77.4 (C-3), 75.9, 75.2, 73.6 (CH_2 Bn), 70.7 (C-5), 62.0 (C-6), 55.3 (CH_3 OMe); ^{13}C-GATED NMR (101 MHz, $CDCl_3$): δ 98.3 ($J_{C1,H1}$ = 164 Hz, C-1 α); HRMS: $[M+Na]^+$ calcd for $C_{28}H_{32}O_6Na$ 487.20911, found 487.20851.



Methyl 4,6-*O*-benzylidene-α-D-glucopyranoside (S9). To a solution of methyl α-D-glucopyranoside (38.8 g, 200 mmol) in acetonitrile (800 mL) was added $PhCH(OMe)_2$ (36 mL, 240 mmol, 1.2 eq.) and *p*-TsOH·H_2O (3.8 g, 20 mmol, 0.1 eq.). The solution was stirred overnight at ambient temperature followed by concentration *in vacuo* (60°C, 600 mbar, 1.5 h) to a quarter of its original volume. The reaction mixture was treated with Et_3N (3 mL), diluted with EtOAc (500 mL) and subsequently washed with H_2O (2x 150 mL), sat. aq. $NaHCO_3$ (50 mL) and brine (2x 100 mL). The organic layer was dried ($MgSO_4$), filtered and concentrated in vacuo. The resulting crude residue was crystalized from EtOAc/petroleum ether to give the title product in two crops (49.2 g, 174 mmol, 87%, white solid). Spectroscopic data were in accord with those previously reported.[77,95] ^{1}H NMR ($CDCl_3$, 400 MHz, HH-COSY, HSQC): δ 7.51 – 7.45 (m, 2H, CH_{arom}), 7.36 (dd, 3H, *J* = 5.1, 2.0 Hz, CH_{arom}), 5.51 (s, 1H, C*H*Ph), 4.75 (d, 1H, *J* = 3.8 Hz, H-1), 4.28 (dd, 1H, *J* = 9.6, 4.3 Hz, H-6), 3.91 (t, 1H, *J* = 9.2 Hz, H-3), 3.84 – 3.68 (m, 2H, H-5, H-6), 3.60 (dd, 1H, *J* = 9.2, 3.9 Hz, H-2), 3.47 (t, 1H, *J* = 9.3 Hz, H-4), 3.43 (s, 3H, CH_3 OMe), 2.87 (bs, 2H, OH); ^{13}C-APT NMR ($CDCl_3$, 101 MHz, HSQC): δ 137.2 (C_q), 129.4, 128.4, 126.4 (CH_{arom}), 102.0 (CHPh), 99.9 (C-1), 81.1 (C-4), 72.9 (C-2), 71.7 (C-3), 69.0 (C-6), 62.5 (C-5), 55.7 (OMe).

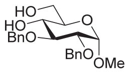


Methyl 2,3-di-*O*-benzyl-4,6-*O*-benzylidene-α-D-glucopyranoside (S10). Benzyl bromide (10.5 mL, 88 mmol, 2.2 eq.) and sodium hydride (60% dispersion, 4.16 g, 104 mmol, 2.6 eq.) were added to a 0°C solution of diol **S9** (11.29 g, 40 mmol) in DMF (200 mL) and the solution was stirred overnight. The reaction mixture was quenched by slow addition of MeOH, diluted with EtOAc (500 mL) and washed with H_2O (200 mL) and brine (200 mL). The organic layer was dried with $MgSO_4$, filtered and concentrated *in vacuo*. The solid residue was recrystallization from EtOAc/pentane to yield the title compound as a white solid (16.0 g, 34.6 mmol, 87%). R*f*: 0.57 (4/1 pentane/EtOAc). Spectroscopic data were in accord with those previously reported.[21,77] ^{1}H NMR ($CDCl_3$, 400 MHz, HH-COSY, HSQC): δ 7.52 – 7.46 (m, 2H, CH_{arom}), 7.41 – 7.25 (m, 13H, CH_{arom}), 5.55 (s, 1H, C*H*Ph), 4.92 (d, 1H, *J* = 11.3 Hz, C*H*H Bn), 4.85 (d, 1H, *J* = 12.1 Hz, C*H*H Bn), 4.84 (d, 1H, *J* = 11.3 Hz, CH*H* Bn), 4.70 (d, 1H, *J* = 12.1 Hz, CH*H* Bn), 4.59 (d, 1H, *J* = 3.7 Hz, H-1), 4.26 (dd, 1H, *J* = 10.1, 4.7 Hz H-6), 4.05 (t, 1H, *J* = 9.3 Hz, H-3), 3.83 (td, 1H, *J* = 9.9, 4.7 Hz, H-5), 3.70 (t, 1H, *J* = 10.2 Hz, H-6), 3.60 (t, 1H, *J* = 9.4 Hz, H-4), 3.56 (dd, 1H, *J* = 9.3, 3.7 Hz, H-2), 3.40 (s, 3H, CH_3 OMe); ^{13}C-APT NMR ($CDCl_3$, 101 MHz, HSQC): δ 138.8, 138.3, 137.5 (C_q), 129.0, 128.6, 128.4, 128.3, 128.2, 128.1, 128.0, 127.7, 126.1 (CH_{arom}), 101.4 (CHPh), 99.3 (C-1), 82.2 (C-4), 79.3 (C-2), 78.7 (C-3), 75.5, 73.9 (CH_2 Bn), 69.2 (C-6), 62.4 (C-5), 55.5 (OMe).

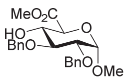


Methyl 2,3,6-tri-*O*-benzyl-α-D-glucopyranoside (11). Fully protected compound **S10** (3.24 g, 7.0 mmol) was dissolved in THF (100 mL) and $NaCNBH_3$ (4.0 g, 63 mmol, 9 eq.) was added. To this solution 4.0 M HCl in 1,4-dioxane (18 mL, 72 mmol, 10.3 eq.) was slowly added and the reaction was stirred for an additional hour. Ice cold H_2O (300 mL) was added and the mixture extracted with DCM (2x 120 mL). The combined organic layers were washed with sat. aq. $NaHCO_3$ (100 mL) and brine (100 mL), dried with $MgSO_4$ and concentrated *in vacuo*. Flash column chromatography (6/1 to 4/1 pentane/EtOAc,) gave the title compound as a colorless oil (2.7 g, 5.85 mmol, 87%). R*f*: 0.37 (4/1 pentane/EtOAc). Spectroscopic data were in accord with those previously reported.[77] IR (neat): 695, 732, 1027, 1047, 1453, 2910, 3477; ^{1}H NMR ($CDCl_3$, 400 MHz, HH-COSY, HSQC): δ 7.41 – 7.23 (m, 15H, CH_{arom}), 4.99 (d, 1H, *J* = 11.4 Hz, C*H*H Bn), 4.75 (d, 1H, *J* = 12.1 Hz, C*H*H Bn), 4.73 (d, 1H, *J* = 11.4 Hz, CH*H* Bn), 4.68 – 4.60 (m, 2H, CH*H* Bn, H-1), 4.57 (d, 1H, *J* = 12.1 Hz, C*H*H Bn), 4.52 (d, 1H, *J* = 12.2 Hz, CH*H* Bn), 3.78 (dd, 1H, *J* = 9.6, 8.8 Hz, H-3), 3.74 – 3.63 (m, 3H, H-5, H-6, H-6), 3.59 (t, 1H, *J* = 9.2 Hz, H-4), 3.52 (dd, 1H, *J* = 9.6, 3.5 Hz, H-2), 3.37 (s, 3H, CH_3 OMe), 2.44 (bs, 1H, 4-OH); ^{13}C-APT NMR ($CDCl_3$, 101 MHz, HSQC): δ 138.8, 138.1, 138.0 (C_q), 128.6, 128.5, 128.4, 128.1, 128.0, 128.0, 127.8, 127.6, 127.6 (CH_{arom}), 98.2 (C-1), 81.5 (C-3), 79.6 (C-2), 75.4, 73.6, 73.1

(CH_2 Bn), 70.7 (C-4), 69.9 (C-5), 69.5 (C-6), 55.2 (OMe); HRMS: $[M+NH_4]^+$ calcd for $C_{28}H_{36}NO_6$ 482.25371, found 482.25357.

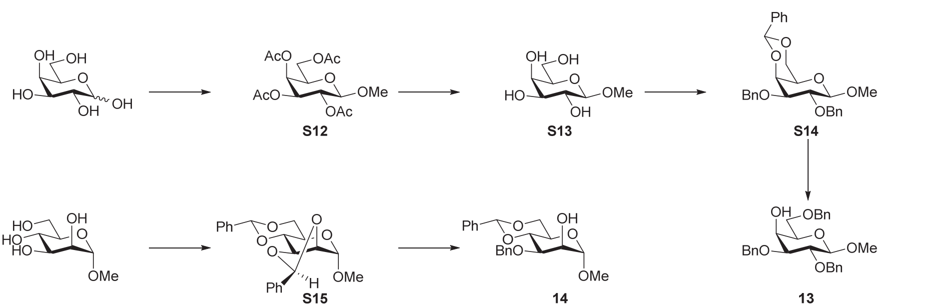


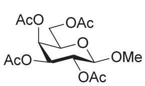
Methyl 2,3-di-*O*-benzyl-α-D-glucopyranoside (S11). Fully protected **S10** (9.25 g, 20 mmol) and *p*-TsOH·H_2O (380 mg, 2 mmol, 0.1 eq.) were added to MeOH (100 mL) and heated at 60°C for 15 min after all solids were dissolved and TLC analysis showed full conversion to a lower running spot. The reaction mixture was quenched with Et_3N (1 mL) and concentrated *in vacuo*. The crude product was purified by flash column chromatography (8/1 to 3/2 pentane/acetone) to give the tile compound as a white solid (7.4 g, 19.8 mmol, 99%) as a white solid. R_f: 0.33 (2/1 pentane/acetone). Spectroscopic data were in accord with those previously reported.[77,96] ^{1}H NMR ($CDCl_3$, 400 MHz, HH-COSY, HSQC): δ 7.37 – 7.26 (m, 10H, CH_{arom}), 5.00 (d, 1H, *J* = 11.4 Hz, C*H*H Bn), 4.75 (d, 1H, *J* = 12.2 Hz, C*H*H Bn), 4.71 (d, 1H, *J* = 11.5 Hz, CH*H* Bn), 4.64 (d, 1H, *J* = 12.1 Hz, CH*H* Bn), 4.59 (d, 1H, *J* = 3.5 Hz, H-1), 3.78 (dd, 1H, *J* = 9.6, 8.6 Hz, H-3), 3.78 – 3.69 (m, 2H, H-6), 3.61 – 3.56 (m, 1H, H-5), 3.51 (dd, 1H, *J* = 9.8, 8.6 Hz, H-4), 3.48 (dd, 1H, *J* = 9.5, 3.5 Hz, H-2), 3.36 (s, 3H, CH_3 OMe), 2.46 (bs, 2H, OH); ^{13}C-APT NMR ($CDCl_3$, 101 MHz, HSQC): δ 138.8, 138.1 ($C_{q\text{-}arom}$), 128.7, 128.6, 128.2, 128.1, 128.0, 127.9 (CH_{arom}), 98.2 (C-1), 81.4 (C-3), 79.9 (C-2), 75.5, 73.2 (CH_2 Bn), 70.8 (C-5), 70.3 (C-4), 62.3 (C-6), 55.3 (OMe).



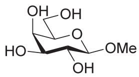
Methyl (methyl 2,3-di-*O*-benzyl-α-D-glucopyranosyl uronate) (12). To a solution of diol **S11** (6.95 g, 18.6 mmol) in DCM (70 mL) and AcOH (0.1 mL) was added BAIB (14.95 g, 46.4 mmol, 2.5 eq.), TEMPO (580 mg, 3.7 mmol, 0.2 eq.) and H_2O (30 mL). The solution was stirred vigorously for 2.5 hours at room temperature, quenched by the addition of $Na_2S_2O_3$ (10% aq.) and this suspension stirred for 15 min. The mixture was extracted two times with EtOAc and the combined organic fractions were dried ($MgSO_4$), filtered, concentrated *in vacuo* and coevaporated with toluene once. The crude carboxylic acid was dissolved in DMF (75 mL) and cooled to 0°C. K_2CO_3 (7.7 g, 55.7 mmol, 3 eq.) and MeI (3.5 mL, 55.7 mmol, 3 eq.) were added and the reaction mixture stirred overnight. H_2O was added and the reaction mixture was extracted twice with EtOAc. The combined organic layers where dried ($MgSO_4$), filtered and concentrated in vacuo. Purification by flash column chromatography (1/0 to 9/1 toluene/acetone) followed by recrystallization from DCM/EtOAc/petroleum ether (1/1/23) gave the title product as white needles (3.84 g, 9.54 mmol, 52%, 2 steps). Spectroscopic data were in accord with those previously reported.[78] $[\alpha]_D^{23}$ = +19.0° (c=1.0, $CHCl_3$), lit.: $[\alpha]_D^{30}$ = +17.9° (c=0.5, $CHCl_3$)[78] ; IR: 700, 738, 1040, 1061, 1738, 2918, 3532; ^{1}H NMR ($CDCl_3$, 400 MHz, HH-COSY, HSQC): δ 7.39 – 7.26 (m, 10H, CH_{arom}), 4.92 (d, 1H, *J* = 11.3 Hz, C*H*H Bn), 4.81 (d, 1H, *J* = 11.4 Hz, CH*H* Bn), 4.79 (d, 1H, *J* = 12.1 Hz, C*H*H Bn), 4.67 – 4.62 (m, 2H, CH*H* Bn, H-1), 4.15 (d, 1H, *J* = 8.9 Hz, H-5), 3.87 – 3.76 (m, 5H, H-3, H-4, CH_3 CO_2Me), 3.53 (dd, 1H, *J* = 8.9, 3.4 Hz, H-2), 3.42 (s, 3H, CH_3 OMe), 2.89 (bs, 1H, 4-OH); ^{13}C-APT NMR ($CDCl_3$, 101 MHz, HSQC): δ 170.8 (C=O CO_2Me), 138.7, 138.0 ($C_{q\text{-}arom}$), 128.6, 128.3, 128.1, 128.0, 127.9 (CH_{arom}), 98.8 (C-1), 80.5 (C-3), 78.6 (C-2), 75.6, 73.7 (CH_2 Bn), 71.9 (C-4), 70.6 (C-5), 56.0 (OMe), 52.8 (CO_2Me); HRMS: $[M+Na]^+$ calcd for $C_{22}H_{26}O_7Na$ 425.15707, found 425.15649.

<u>Preparation of acceptors **13** and **14**.</u>

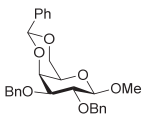




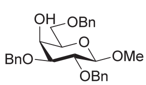
Methyl 2,3,4,6-tetra-*O*-acetyl-β-D-galactopyranoside (S12). Following the procedure of Kartha *et al*.[97] D-galactose (4.5 g, 25 mmol) was portionwise added to a mixture of 70% aq. $HClO_4$ (cat., 5 drops) and Ac_2O (14.2 mL, 150 mmol, 6 eq.). After stirring overnight a 33 wt% solution of HBr in AcOH (13.1 mL, 75 mmol, 3 eq.) was added and the reaction stirred at r.t. for 5 h. Solvents were evaporated by a water aspirator and the crude product was dissolved in EtOAc and washed with cold sat.aq. $NaHCO_3$ and brine. The organic phase was dried (Na_2SO_4) and concentrated *in vacuo*. The crude bromide was dissolved in MeOH (100 mL) and cooled to 0°C. Iodine (3.17 g, 12.5 mmol, 0.5 eq.) was added and the reaction was stirred for 2 h. The reaction mixture was quenched by sat. aq. $Na_2S_2O_3$ and extracted with Et_2O twice. The organic layer was washed with sat. aq. $NaHCO_3$ and brine, dried ($MgSO_4$), filtered, and concentrated *in vacuo*. Flash column chromatography (8/1 to 1/1 pentane/EtOAc) gave the methyl galactoside as an anomerically pure yellow oil (4.31 g, 11.9 mmol, 48% over three steps). Spectroscopic data were in accord with those previously reported.[98,99] ^{1}H NMR ($CDCl_3$, 400 MHz, HH-COSY, HSQC): δ 5.40 (dd, 1H, *J* = 3.4, 1.2 Hz, H-4), 5.20 (dd, 1H, *J* = 10.5, 7.9 Hz, H-2), 5.03 (dd, 1H, *J* = 10.5, 3.4 Hz, H-3), 4.42 (d, 1H, *J* = 7.9 Hz, H-1), 4.25 – 4.11 (m, 2H, H-6), 3.93 (td, 1H, *J* = 6.7, 1.2 Hz, H-5), 3.52 (s, 3H, CH_3 OMe), 2.16 (s, 3H, CH_3 Ac), 2.07 (s, 3H, CH_3 Ac), 2.06 (s, 3H, CH_3 Ac), 1.99 (s, 3H, CH_3 Ac); ^{13}C-APT NMR ($CDCl_3$, 101 MHz, HSQC): δ 170.4, 170.2, 170.1, 169.5 (C=O Ac), 102.0 (C-1), 71.0 (C-3), 70.6 (C-5), 68.8 (C-2), 67.1 (C-4), 61.3 (C-6), 57.0 (OMe), 20.8, 20.7, 20.7, 20.6 (CH_3 Ac).



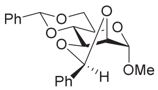
Methyl β-D-galactopyranoside (S13). Acetylated **S12** (4.31 g, 11.9 mmol) was dissolved in MeOH (50 mL) and NaOMe (325 mg, 6.0 mmol, 0.5 eq.) was added. After 30 min Amberlite H^+ was added until neutral pH was achieved and the resin was subsequently filtered off. The solution was concentrated *in vacuo* to give the crude tetra-ol. Spectroscopic data were in accord with those previously reported.[100] ^{1}H NMR (D_2O, 400 MHz, HSQC): δ 4.79 (bs, 4H, OH), 4.30 (d, 1H, *J* = 7.9 Hz, H-1), 3.90 (d, 1H, *J* = 3.5 Hz, H-4), 3.81 – 3.73 (m, 2H, H-6), 3.75 – 3.64 (m, 1H, H-5), 3.63 (dd, 1H, *J* = 9.9, 3.5 Hz, H-3), 3.55 (s, 3H, CH_3 OMe), 3.48 (dd, 1H, *J* = 9.9, 7.9 Hz, H-2); ^{13}C NMR (D_2O, 101 MHz, HSQC): δ 103.8 (C-1), 75.2 (C-5), 72.8 (C-3), 70.8 (C-2), 68.7 (C-4), 61.0 (C-6), 57.2 (OMe).



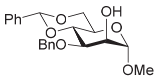
Methyl 2,3-di-*O*-benzyl-4,6-*O*-benzylidene-β-D-galactopyranoside (S14). Crude **S13** (1.94 g, 10 mmol), benzaldehyde dimethyl acetal (0.30 mL, 20 mmol, 2 eq.) and *p*-TsOH·H_2O (475 mg, 2,5 mmol, 0.25 eq.) were dissolved in CH_3CN (50 mL) and DMF (15 mL) and the poorly soluble reaction mixture was stirred at 60°C, 350 mbar for 3 h. Et_3N (0.8 mL) was added and the reaction mixture was portioned between EtOAc and H_2O. The organic layer did not contain observable product, therefore the water layer was evaporated to give the crude product. Column chromatography (1:0 to 9/1 DCM/MeOH) gave the benzylidene protected galactoside as a waxy solid (1.73 g, 6.1 mmol, 61%). Spectroscopic data were in accord with those previously reported.[77,95,101] ^{1}H NMR ($CDCl_3$, 400 MHz): δ 7.55 – 7.46 (m, 2H), 7.40 – 7.34 (m, 3H), 5.55 (s, 1H), 4.36 (dd, 1H, *J* = 12.5, 1.5 Hz), 4.24 – 4.20 (m, 2H), 4.12 – 4.07 (m, 1H), 3.79 – 3.67 (m, 2H), 3.59 (d, 3H, *J* = 0.7 Hz), 3.49 (t, 1H, *J* = 1.6 Hz).The crude methyl 4,6-*O*-benzylidene-β-D-galactopyranoside was coevaporated with dry toluene twice before being dissolved in DMF (30 mL). Benzyl bromide (3.2 mL, 18.4 mmol, 3 eq.) and NaH (60% dispersion in mineral oil, 736 mg, 18.4 mmol, 3 eq.) were added and the reaction mixture was stirred overnight. H_2O was added and the mixture was extracted with EtOAc twice. The organic layer was washed with brine twice and dried ($MgSO_4$), filtered, and concentrated *in vacuo*. The crude product was purified by flash column chromatography (8/1 to 3/1 pentane/EtOAc) to afford the benzylated product (2.11 g, 4.56 mmol, 75%). R_f: 0.63 (3/2 pentane/EtOAc). Spectroscopic data were in accord with those previously reported.[77] ^{1}H NMR ($CDCl_3$, 400 MHz, HH-COSY, HSQC): δ 7.59 – 7.53 (m, 2H, CH_{arom}), 7.42 – 7.26 (m, 13H, CH_{arom}), 5.50 (s, 1H, C*H*Ph), 4.91 (d, 1H, *J* = 10.9 Hz, C*H*H Bn), 4.81 – 4.71 (m, 3H, CH*H* Bn, CH_2 Bn), 4.36 – 4.27 (m, 2H, H-1, H-6), 4.11 (dd, 1H, *J* = 3.7, 1.1 Hz, H-4), 4.02 (dd, 1H, *J* = 12.3, 1.8 Hz, H-6), 3.84 (dd, 1H, *J* = 9.7, 7.7 Hz, H-2), 3.60 – 3.53 (m, 4H, H-3, CH_3 OMe), 3.32 (d, 1H, *J* = 1.3 Hz, H-5); ^{13}C-APT NMR ($CDCl_3$, 101 MHz, HSQC): δ 139.0, 138.5, 137.9 (C_q), 129.1, 128.5, 128.4, 128.2, 128.2, 127.9, 127.8, 127.6, 126.7 (CH_{arom}), 104.8 (C-1), 101.5 (CHPh), 79.3 (C-3), 78.6 (C-2), 75.4 (CH_2 Bn), 74.1 (C-4), 72.1 (CH_2 Bn), 69.4 (C-6), 66.5 (C-5), 57.2 (OMe).



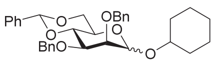
Methyl 2,3,6-tri-*O*-benzyl-β-D-galactopyranoside (13). To a solution of **S16** (2.10 g, 4.54 mmol) and $NaCNBH_3$ (1.7 g, 27.2 mmol, 6 eq.) in THF (60 mL), 4.0 M HCl in 1,4-dioxane (9 mL, 36 mmol, 7.9 eq.) was added. The reaction mixture was stirred for 1 h and then H_2O was added. The solution was extracted twice with DCM and the organic layer was washed with brine, dried with $MgSO_4$ en concentrated *in vacuo*. Flash column chromatography (9/1 to 1/1 pentane/EtOAc) provided the free alcohol as an oil (1.56 g, 3.36 mmol, 74%). R_f: 0.74 (3/2 pentane/EtOAc). Spectroscopic data were in accord with those previously reported.[77,102,103] ^{1}H NMR ($CDCl_3$, 400 MHz, HH-COSY, HSQC): δ 7.41 – 7.21 (m, 15H, CH_{arom}), 4.88 (d, 1H, *J* = 11.1 Hz, C*H*H Bn), 4.71 (d, 1H, *J* = 11.0 Hz, CH*H* Bn), 4.67 (s, 2H, CH_2 Bn), 4.56 (s, 2H, CH_2 Bn), 4.26 (d, 1H, *J* = 7.7 Hz, H-1), 3.98 (d, 1H, *J* = 3.4 Hz, H-4)), 3.79 (dd, 1H, *J* = 9.9, 5.9 Hz, H-6), 3.72 (dd, 1H, *J* = 9.9, 6.0 Hz, H-6), 3.64 (dd, 1H, *J* = 9.4, 7.7 Hz, H-2), 3.59 – 3.50 (m, 4H, H-5, CH3 OMe), 3.46 (dd, 1H, *J* = 9.4, 3.4 Hz, H-3), 2.70 (s, 1H, 4-OH); ^{13}C-APT NMR ($CDCl_3$, 101 MHz, HSQC): δ 138.6, 137.9, 137.8 (C_q), 128.4, 128.3, 128.0, 127.8, 127.8, 127.7, 127.7, 127.5 (CH_{arom}), 104.7 (C-1), 80.5 (C-3), 79.0 (C-2), 75.1, 73.6 (CH_2 Bn), 73.1 (C-5), 72.3 (CH_2 Bn), 69.2 (C-6), 66.8 (C-4), 56.9 (OMe); HRMS: $[M+Na]^+$ calcd for $C_{28}H_{33}O_6Na$ 487.20911, found 487.20848.



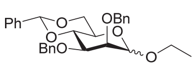
Methyl 2,3-*exo*;4,6-di-*O*-benzylidene-α-D-mannopyranoside (S15). To a solution of methyl α-D-mannoside (19.4 g, 100 mmol) in CH_3CN (120 mL) was added benzylidene dimethyl acetal (36 mL, 240 mmol, 2.4 eq.) and *p*-TsOH·H_2O (475 mg, 2.5 mmol, 0.025 eq.). The reaction mixture was stirred at 60°C and 500 mbar for 3 h and the volume was reduced by half. Sat. aq. $NaHCO_3$ was added to quench the reaction and the precipitate collected and washed with cold H_2O. The solids were recrystallized from EtOH/EtOAc to obtain two crops of white needles (total yield: 29.6 g, 80 mmol, 80% exo only). Spectroscopic data were in accord with those previously reported.[104] ^{1}H NMR ($CDCl_3$, 400 MHz, HH-COSY, HSQC): δ 7.55 – 7.51 (m, 2H, CH_{arom}), 7.48 – 7.44 (m, 2H, CH_{arom}), 7.41 – 7.34 (m, 6H, CH_{arom}), 6.30 (s, 1H, C*H*$Ph_{2,3\ exo}$), 5.64 (s, 1H, C*H*$Ph_{4,6}$), 5.02 (s, 1H, H-1), 4.63 (dd, 1H, *J* = 7.8, 5.4 Hz, H-3), 4.40 – 4.32 (m, 1H, H-6), 4.14 (d, 1H, *J* = 5.4 Hz, H-2), 3.93 – 3.88 (m, 1H, H-4), 3.88 – 3.81 (m, 2H, H-5, H-6), 3.41 (s, 3H, CH_3 OMe); ^{13}C-APT NMR ($CDCl_3$, 101 MHz, HSQC): δ 138.7, 137.3 (C_q), 129.3, 128.5, 128.4, 126.4, 126.2 (CH_{arom}), 103.1 ($CHPh_{2,3\ exo}$), 102.2 ($CHPh_{4,6}$), 99.0 (C-1), 77.6 (C-4), 75.7 (C-3), 75.4 (C-2), 69.1 (C-6), 60.5 (C-5), 55.4 (OMe).



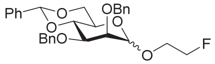
Methyl 3-*O*-benzyl-4,6-*O*-benzylidene-α-D-mannopyranoside (14). Compound **S15** (5.56 g, 15 mmol) was dissolved in 100 mL DCM and 150 mL Et_2O. A solution of $LiAlH_4$ (2.4 M in THF, 8 mL, 19.2 mmol, 1.3 eq.) was added to the reaction mixture at 0°C followed by addition of $AlCl_3$ (2.2 g, 16.4 mmol, 1.1 eq.). The reaction mixture was allowed to stir for 3 h at r.t. before being quenched by careful addition of EtOAc and H_2O. The mixture was extracted with EtOAc and the organic phase was washed with brine, dried $MgSO_4$ and concentrated under reduced pressure. Purification of the crude product by flash column chromatography (6/1 to 1/1 pentane/EtOAc) gave the title compound as a colorless oil (5.37 g, 14.4 mmol, 96%). R_f: 0.38 (2/1 pentane/EtOAc). Spectroscopic data were in accord with those previously reported.[32,79,104] ^{1}H NMR ($CDCl_3$, 400 MHz, HH-COSY, HSQC): δ 7.53 – 7.47 (m, 2H, CH_{arom}), 7.41 – 7.27 (m, 8H, CH_{arom}), 5.60 (s, 1H, C*H*Ph), 4.84 (d, 1H, *J* = 11.9 Hz, C*H*H Bn), 4.73 (d, 1H, *J* = 1.4 Hz, H-1), 4.69 (d, 1H, *J* = 11.9 Hz, CH*H* Bn), 4.27 (dd, 1H, *J* = 9.4, 4.0 Hz, H-6), 4.09 (t, 1H, *J* = 9.2 Hz, H-4), 4.01 (dt, 1H, *J* = 3.3, 1.6 Hz, H-2), 3.93 – 3.75 (m, 3H, H-3, H-5, H-5), 3.35 (s, 3H, CH_3 OMe), 2.82 (d, 1H, *J* = 1.7 Hz, 2-OH); ^{13}C-APT NMR ($CDCl_3$, 101 MHz, HSQC): δ 138.1, 137.7 (C_q), 129.0, 128.6, 128.3, 128.0, 127.9, 126.2 (CH_{arom}), 101.7 (CHPh), 101.2 (C-1), 78.9 (C-4), 75.7 (C-3), 73.1 (CH_2 Bn), 69.9 (C-2), 69.0 (C-6), 63.3 (C-5), 55.0 (OMe); HRMS: $[M+Na]^+$ calcd for C21H24O6Na 395.14651, found 395.14638.



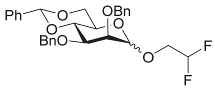
Cyclohexyl 2,3-di-*O*-benzyl-4,6-*O*-benzylidene-α/β-D-mannopyranoside (1A). Donor **1** and cyclohexanol were condensed using the general procedure for Tf_2O/Ph_2SO mediated and purified by flash column chromatography (1/0 to 9/1 pentane/EtOAc) to yield glycosylation product **1A** (50.9 mg, 51 µmol, 96%, α:β = 1:5). R_f: 0.43 (9/1 pentane/EtOAc). Spectroscopic data were in accord with those previously reported.[105,106] IR (neat): 694, 733, 964, 1026, 1047, 1084, 1361, 1452, 2857, 2857, 2930; Data for the β-anomer: ^{1}H NMR (400 MHz, $CDCl_3$, HH-COSY, HSQC): δ 7.55 – 7.23 (m, 15H, CH_{arom}), 5.61 (s, 1H, C*H*Ph), 5.02 (d, 1H, *J* = 12.5 Hz, C*H*H Bn), 4.91 (d, 1H, *J* = 12.5 Hz, CH*H* Bn), 4.67 (d, 1H, *J* = 12.5 Hz, C*H*H Bn), 4.58 (s, 1H, H-1), 4.58 (d, 1H, *J* = 12.5 Hz, CH*H* Bn), 4.30 (dd, 1H, *J* = 10.4, 4.9 Hz, H-6), 4.22 (t, 1H, *J* = 9.6 Hz, H-4), 3.94 (t, 1H, *J* = 10.3 Hz, H-6), 3.87 (d, 1H, *J* = 3.0 Hz, H-2), 3.70 (dt, 1H, *J* = 8.6, 4.7 Hz, CH Cy), 3.58 (dd, 1H, *J* = 9.9, 3.1 Hz, H-3), 3.31 (td, 1H, *J* = 9.9, 4.9 Hz, H-5), 2.06 – 0.99 (m, 10H, CH_2 Cy); ^{13}C-APT NMR (101 MHz, $CDCl_3$, HSQC): δ 138.68, 138.54, 137.79 (C_q), 129.05, 128.92, 128.85, 128.49, 128.40, 128.28, 128.22, 128.19, 127.84, 127.68, 127.62, 127.60, 127.58, 127.53, 126.18, 126.14, 125.21 (CH_{arom}), 101.48 (CHPh), 100.12 (C-1), 78.76 (C-4), 78.25 (C-3), 76.84 (CH Cy), 76.31 (C-2), 74.71 (CH_2 Bn), 72.39 (CH_2 Bn), 68.82 (C-6), 67.68 (C-5), 33.48, 31.57, 25.78, 23.87, 23.72 (CH_2 Cy); ^{13}C-GATED NMR (101 MHz, $CDCl_3$): 100.1 ($J_{C1,H1}$ = 154 Hz, C-1 β); Diagnostic peaks α-anomer: ^{1}H NMR (400 MHz, $CDCl_3$, HH-COSY, HSQC): δ 5.64 (s, 0.20H, C*H*Ph), 4.89 – 4.79 (m, 0.60H, C*H*H Bn, CH*H* Bn, C-1), 4.71 (d, 0.20H, *J* = 12.3 Hz, CH*H* Bn), 4.00 (dd, 0.20H, *J* = 10.0, 3.2 Hz, H-2), 3.78 (dd, 0.20H, *J* = 3.1, 1.6 Hz, H-3), 3.54 – 3.49 (m, 0.20H, CH Cy); ^{13}C-APT NMR (101 MHz, $CDCl_3$, HSQC): δ 97.41 (C-1), 64.36 (C-5), 33.38, 31.31, 25.69, 25.25, 24.11 (CH_2 Cy); HRMS: $[M+Na]^+$ calcd for $C_{33}H_{38}O_6Na$ 553.25606, found 553.25531.



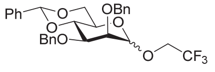
Ethyl 2,3-di-*O*-benzyl-4,6-*O*-benzylidene-α/β-D-mannopyranoside (1B). Donor **1** and ethanol were condensed using the general procedure for Tf_2O/Ph_2SO mediated glycosylations and purified by flash column chromatography (1/0 to 9/1 pentane/EtOAc) to yield glycosylation product **1B** (33.5 mg, 70 µmol, 70%, α:β = 1:5). R_f: 0.43 (9/1 pentane/EtOAc). IR (neat): 696, 734, 893, 912, 968, 1004, 1049, 1088, 1373, 1452, 2866, 2926; Data for the β-anomer: ^{1}H NMR (400 MHz, $CDCl_3$, HH-COSY, HSQC): δ 7.53 – 7.28 (m, 15H, CH_{arom}), 5.62 (s, 1H, C*H*Ph), 4.99 (d, 1H, *J* = 12.4 Hz, C*H*H Bn), 4.89 (d, 1H, *J* = 12.4 Hz, CH*H* Bn), 4.68 (d, 1H, *J* = 12.6 Hz, C*H*H Bn), 4.58 (d, 1H, *J* = 12.5 Hz, CH*H* Bn), 4.46 (s, 1H, H-1), 4.31 (dd, 1H, *J* = 10.4, 4.9 Hz, H-6), 4.21 (t, 1H, *J* = 9.6 Hz, H-4), 4.02 – 3.89 (m, 3H, C*H*HCH_3 Et, H-2, H-6), 3.58 (dd, 1H, *J* = 9.9, 3.1 Hz, H-3), 3.56 – 3.47 (m, 1H, CH*H*CH_3 Et), 3.36 – 3.28 (m, 1H, H-5), 1.27 (t, 3H, *J* = 7.0 Hz, CH_3 Et); ^{13}C-APT NMR (101 MHz, $CDCl_3$, HSQC): δ 138.6, 138.5, 137.8 (C_q), 123.0, 128.9, 128.4, 128.3, 128.2, 127.7, 127.7, 127.6, 126.2, (CH_{arom}) 102.2 (C-1), 101.5 (CHPh), 78.8 (C-4), 78.0 (C-3), 75.9 (C-2), 74.8 (CH_2 Bn), 72.5 (CH_2 Bn), 68.8 (C-6), 67.7 (C-5), 65.7 (CH_2 Et), 15.3 (CH_3 Et); ^{13}C-GATED NMR (101 MHz, $CDCl_3$): δ 102.2 ($J_{C1,H1}$ = 153 Hz, C-1 β); Diagnostic peaks α-anomer: ^{1}H NMR (400 MHz, $CDCl_3$): δ 5.65 (s, 0.20H), 4.86 – 4.81 (m, 0.40H, C*H*H Bn, CH*H* Bn), 4.80 (d, 0.20H, *J* = 1.5 Hz, H-1), 4.74 (d, 0.20H, *J* = 12.3 Hz, C*H*H Bn), 3.74 – 3.66 (m, 0.20H, CH*H*CH_3), 3.46 – 3.39 (m, 0.20H, CH*H*CH_3 Et); ^{13}C-APT NMR (101 MHz, $CDCl_3$, HSQC): δ 128.9, 128.5, 128.4, 128.3, 128.2, 127.9, 127.6, 126.2 (C_q), 101.6 (CHPh), 99.3 (C-1), 79.4 (C-3), 76.5 (C-4), 76.4 (C-2), 73.7 (CH_2 Bn), 73.3 (CH_2 Bn), 69.3 (C-6), 64.3 (C-5) 63.3 (CH_2 Et), 15.1 (CH_3 Et); HRMS: $[M+Na]^+$ calcd for $C_{29}H_{32}O_6Na$ 499.20911, found 499.20846.



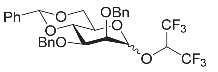
2-Fluoroethyl 2,3-di-*O*-benzyl-4,6-*O*-benzylidene-α/β-D-mannopyranoside (1C). Donor **1** and 2-fluoroethanol were condensed using the general procedure for Tf_2O/Ph_2SO mediated and purified by flash column chromatography (1/0 to 4/1 pentane/EtOAc) to yield glycosylation product **1C** (42.7 mg, 86 µmol, 86%, α:β = 1:5). R_f: 0.18 (9/1 pentane/EtOAc). IR (neat): 696, 738, 802, 887, 1025, 1043, 1066, 1086, 1261, 1371, 1454, 2870; Data for the β-anomer: ^{1}H NMR (400 MHz, $CDCl_3$, HH-COSY, HSQC): δ 7.66 – 7.32 (m, 15H, CH_{arom}), 5.62 (s, 1H, C*H*Ph), 4.99 (d, 1H, *J* = 12.3 Hz, C*H*H Bn), 4.89 (d, 1H, *J* = 12.3 Hz, CH*H* Bn), 4.70 – 4.51 (m, 5H, C*H*H Bn, CH*H* Bn, H-1, CH_2C*H*HF, CH_2CH*H*F), 4.30 (dd, 1H, *J* = 10.4, 4.8 Hz, H-6), 4.22 (t, 1H, *J* = 9.6 Hz, H-4), 4.08 (ddt, 1H, *J* = 35.7, 12.2, 3.0 Hz, C*H*HCH_2F), 3.98 (d, 1H, *J* = 2.9 Hz, H-2), 3.92 (t, 1H, *J* = 10.3 Hz, H-6), 3.80 (dtd, 1H, *J* = 22.6, 11.9, 7.8, 2.4 Hz, CH*H*CH_2F), 3.59 (dd, 1H, *J* = 9.9, 3.1 Hz, H-3), 3.33 (td, 1H, *J* = 9.7, 4.9 Hz, H-5); ^{13}C-APT NMR (101 MHz, $CDCl_3$, HSQC): δ 138.4, 138.4, 137.6 (C_q), 131.2, 129.4, 129.0, 128.8, 128.4, 128.3, 128.2, 127.7, 127.7, 126.2, 124.9 (CH_{arom}), 102.3 (C-1), 101.5 (CHPh), 82.8 (d, *J* = 169.74 Hz, CH_2F), 78.6 (C-4), 77.8 (C-3), 75.7 (C-2), 75.0 (CH_2 Bn), 72.5 (CH_2 Bn), 69.0 (d, *J* = 19.7 Hz, *CH_2*CH_2F), 67.7 (C-6). ^{13}C-GATED NMR (101 MHz, $CDCl_3$): δ 102.3 ($J_{C1,H1}$ = 156 Hz, C-1 β); Diagnostic peaks α-anomer: ^{1}H NMR (400 MHz, $CDCl_3$, HH-COSY, HSQC): δ 5.62 (s, 0.20H, C*H*Ph), 4.93 – 4.80 (m, 0.60H, C*H*H Bn, CH*H* Bn, H-1); ^{13}C-APT NMR (101 MHz, $CDCl_3$, HSQC): δ 99.7 (C-1), 82.5 (d, *J* = 170 Hz, CH_2F), 79.2 (C-4), 76.5 (C-3), 76.4 (C-2), 73.8 (CH_2 Bn), 73.3 (CH_2 Bn), 68.9 (C-6), 66.7 (d, *J* = 19.9 Hz, *CH_2*CH_2F), 64.4 (C-5); ^{13}C-GATED NMR (101 MHz, $CDCl_3$): δ 99.7 ($J_{C1,H1}$ = 170 Hz, C-1 α); HRMS: $[M+Na]^+$ calcd for $C_{29}H_{31}FO_6Na$ 517.19969, found 517.19888.



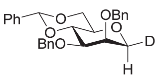
2,2-Difluoroethyl 2,3-di-*O*-benzyl-4,6-*O*-benzylidene-α/β-D-mannopyranoside (1D). Donor **1** and 2,2-difluoroethanol were condensed using the general procedure for Tf_2O/Ph_2SO mediated glycosylations and purified by flash column chromatography (1/0 to 4/1 pentane/EtOAc) to yield glycosylation product **1D** (46.1 mg, 90 µmol, 90%, α:β = 1:5). R_f: 0.50 (9/1 pentane/EtOAc). IR (neat): 694, 744, 795, 1026, 1094, 1261, 1369, 1454, 2868; Data for the β-anomer: ^{1}H NMR (400 MHz, $CDCl_3$, HH-COSY, HSQC): δ 7.68 – 7.27 (m, 15H, CH_{arom}), 5.90 (dddd, 1H, *J* = 54.8, 5.1, 2.8, 1.5 Hz, CHF_2) 5.62 (s, 1H, C*H*Ph), 4.94 (d, 1H, *J* = 12.2 Hz, C*H*H Bn), 4.86 (d, 1H, *J* = 12.2 Hz, CH*H* Bn), 4.70 (d, 1H, *J* = 12.5 Hz, C*H*H Bn), 4.60 (d, 1H, *J* = 12.4 Hz, CH*H* Bn), 4.51 (s, 1H. H-1), 4.31 (dd, 1H, *J* = 10.4, 4.9 Hz, H-6), 4.22 (t, 1H, *J* = 9.6 Hz, H-4), 4.05 (dtd, 1H, *J* = 20.7, 11.1, 2.9 Hz, C*H*HCHF_2), 3.98 – 3.88 (m, 2H, H-2, H-6), 3.82 – 3.65 (m, 1H, CH*H*CHF_2), 3.59 (dd, 1H, *J* = 9.9, 3.1 Hz, H-3), 3.33 (td, 1H, *J* = 9.7, 4.8 Hz, H-5); ^{13}C-APT NMR (101 MHz, $CDCl_3$, HSQC): δ 138.3, 138.2, 137.5 (C_q), 128.8, 128.5, 128.3, 127.7, 126.2 (C_{arom}), 115.4 (t, *J* = 241.9, CHF_2), 102.3 (C-1), 101.6 (CHPh), 78.6 (C-4), 77.8 (C-3), 75.5 (C-2), 75.1 (CH_2 Bn), 72.6 (CH_2 Bn), 68.5 (t, *J* = 33.0 Hz, *CH_2*CHF_2), 68.5 (C-6), 67.8 (C-5); ^{13}C-GATED NMR (101 MHz, $CDCl_3$): 102.3 ($J_{C1,H1}$ = 156 Hz, C-1 β); Diagnostic peaks α-anomer: ^{1}H NMR (400 MHz, $CDCl_3$, HH-COSY, HSQC): δ 5.98 (dt, 0.03 H, *J* = 5.7, 4.1 Hz, CHF_2), 5.84 (dt, 0.10H, *J* = 5.9, 4.1 Hz, CHF_2), 5.70 (dt, 0.03H, *J* = 6.1, 4.1 Hz, CHF_2), 4.84 (m, 0.34H, C-1, C*H*H Bn), 4.72 (d, 0.17H, *J* = 12.1 Hz, CH*H* Bn), 4.66 (d, 0.17H, *J* = 12.2 Hz, C*H*H Bn); ^{13}C-APT NMR (101 MHz, $CDCl_3$, HSQC): δ 115.4 (t, *J* = 240.10, CHF_2), 101.6 (CHPh), 100.1 (C-1), 79.0 (C-4), 76.3 (C-3), 76.2 (C-2), 73.9 (CH_2 Bn), 73.4 (CH_2 Bn), 68.5 (C-6), 64.8 (C-5); HRMS: $[M+Na]^+$ calcd for $C_{29}H_{30}F_2O_6Na$ 535.19027, found 535.18950.



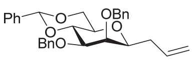
2,2,2-Trifluoroethyl 2,3-di-*O*-benzyl-4,6-*O*-benzylidene-α/β-D-mannopyranoside (1E). Donor **1** and 2,2,2-trifluoroethanol were condensed using the general procedure for Tf_2O/Ph_2SO mediated glycosylations and purified by flash column chromatography (1/0 to 9/1 pentane/EtOAc) to yield glycosylation product **1E** (41.7 mg, 79 µmol, 79%, α:β = 1:3.4). R_f: 0.60 (9/1 pentane/EtOAc). IR (neat): 696, 737, 1028, 1057, 1085, 1161, 1277, 1454, 2870; Data for the β-anomer: ^{1}H NMR (400 MHz, $CDCl_3$, HH-COSY, HSQC): δ 7.50 – 7.28 (m, 15H, CH_{arom}) 5.62 (s, 1H, C*H*Ph), 4.96 (d, 1H, *J* = 12.2 Hz, C*H*H Bn), 4.87 (d, 1H, *J* = 12.1 Hz, CH*H* Bn), 4.69 (d, 1H, *J* = 12.5 Hz, C*H*H Bn), 4.59 (d, 1H, *J* = 12.5 Hz, CH*H* Bn), 4.57 (s, 1H, H-1), 4.31 (dd, 1H, *J* = 10.4, 4.9 Hz, C-6), 4.28 – 4.17 (m, 2H, C-4, C*H*HCF_3), 4.01 – 3.86 (m, 3H, H-2, H-6, CH*H*CF_3), 3.59 (dd, 1H, *J* = 9.9, 3.1 Hz, H-3), 3.34 (td, 1H, *J* = 9.8, 4.9 Hz, H-5); ^{13}C-APT NMR (101 MHz, $CDCl_3$, HSQC): δ 138.2, 138.0, 137.5 (C_q), 129.1, 128.9, 128.5, 128.3, 127.9, 127.8, 127.7, 126.2 (C_{arom}), 123.7 (q, *J* = 277.6 Hz, CF_3) 101.9 (C-1), 101.6 (CHPh), 78.4 (C-4), 77.7 (C-3), 77.5 (C-2), 75.1 (CH_2 Bn), 75.0 (CH_2 Bn), 72.6 (C-6), 68.4 (C-5), 66.2 (q, *J* = 34.9 Hz, *CH_2*CF_3); ^{13}C-GATED NMR (101 MHz, $CDCl_3$): 101.9 ($J_{C1,H1}$ = 157 Hz, C-1 β); Diagnostic peaks α-anomer: ^{1}H NMR (400 MHz, $CDCl_3$, HH-COSY, HSQC): δ 5.64 (s, 0.29H, C*H*Ph), 4.88 – 4.82 (m, 0.87H, C*H*H Bn, CH*H* Bn, H-1), 4.73 – 4.64 (m, 0.58H, C*H*H Bn, CH*H* Bn); ^{13}C-APT NMR (101 MHz, $CDCl_3$, HSQC): δ 101.6 (CHPh), 100.1 (C-1), 78.9 (C-4), 76.2 (C-3), 76.0 (C-2), 74.1 (CH_2 Bn), 73.5 (CH_2 Bn), 68.7 (C-6), 65.0 (C-5); HRMS: $[M+Na]^+$ calcd for $C_{29}H_{29}F_3O_6Na$ 553.18084, found 553.18021.



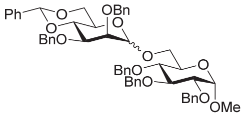
1,1,1,3,3,3-Hexafluoro-2-propyl 2,3-di-*O*-benzyl-4,6-*O*-benzylidene-α/β-D-mannopyranoside (1F). Donor **1** and 1,1,1,3,3,3-hexafluoro-2-propanol were condensed using the general procedure for Tf_2O/Ph_2SO mediated glycosylations (for an additional 120 hours at -40°C) and purified by flash column chromatography (1/0 to 9/1 pentane/EtOAc) to yield glycosylation product **1F** (33.6 mg, 34 µmol, 56%, α:β = 3.3:1). R*f*: 0.81 (8/2 pentane/EtOAc). IR (neat): 694, 898, 977, 1058, 1091, 1195, 1217, 1287, 136, 2924; Data for the α-anomer: ^{1}H NMR (400 MHz, $CDCl_3$, HH-COSY, HSQC): δ 7.54 – 7.27 (m, 15H, CH_{arom}), 5.64 (s, 1H, C*H*Ph), 4.95 (s, 1H, H-1), 4.86 (d, 1H, *J* = 5.5 Hz, C*H*H Bn), 4.82 (d, 1H, *J* = 8.9 Hz, CH*H* Bn), 4.69 (d, 1H, *J* = 2.8 Hz, C*H*H Bn), 4.65 (d, 1H, *J* = 7.7 Hz, CH*H* Bn), 4.38 – 4.19 (m, 3H, H-3, H-6, $CH(CF_3)_2$), 3.92 (d, 1H, *J* = 4.9 Hz, H-4), 3.89 – 3.83 (m, 2H, H-6, H-5); ^{13}C-APT NMR (101 MHz, $CDCl_3$, HSQC): δ 138.5, 137.5, 137.4 (C_q), 129.1, 128.7, 128.5, 128.4, 128.3, 127.8, 127.7, 126.1 (CH_{arom}), 121.6 (q, *J* = 282.7 Hz, CF_3), 101.8 (C-1), 101.6 (CHPh), 78.4 (C-3), 76.1 (C-4), 75.5 (C-2), 74.3 (CH_2 Bn), 73.8 (CH_2 Bn), 72.4 (hept, *J* = 32.7 Hz, *CH*$(CF_3)_2$), 72.1 (CH_2 Bn), 68.3 (C-6), 65.8 (C-5);^{13}C-GATED NMR (101 MHz, $CDCl_3$): δ 101.8 ($J_{C1,H1}$ = 175 Hz, C-1 α); Diagnostic peaks β-anomer: ^{1}H NMR (400 MHz, $CDCl_3$, HH-COSY, HSQC, HMBC): δ 5.61 (s, 0.30H, C*H*Ph), 4.82 (d, 0.60H, *J* = 11.9 Hz, C*H*H Bn), 4.79 (s, 0.30H, H-1,), 4.69 (d, 0.30H, *J* = 12.9 Hz, CH*H* Bn), 4.02 (d, 0.30H, *J* = 2.9 Hz, H-2), 3.61 (dd, 0.30H, *J* = 9.9, 3.1 Hz, H-3), 3.36 (td, 0.30H, *J* = 9.9, 4.9 Hz, H-5); ^{13}C-APT NMR (101 MHz, $CDCl_3$, HSQC, HMBC): δ 101.3 (C-1), 72.6 (C-6), 68.2 (C-5); ^{13}C HMBC-GATED NMR (101 MHz, $CDCl_3$): δ 101.3 ($J_{C1,H1}$ = 159 Hz, C-1 β); HRMS: $[M+Na]^+$ calcd for $C_{30}H_{28}F_6O_6Na$ 621.16823, found 621.16790.



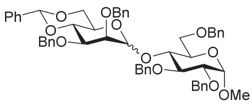
1-[^{2}H]-1,5-anhydro-2,3-di-*O*-benzyl-4,6-*O*-benzylidene-α-D-mannitol (1G). Donor **1** and triethylsilane-D were condensed using the general procedure for Tf_2O/Ph_2SO mediated glycosylations (for an additional 24 hours at -40°C) and purified by flash column chromatography (19/1 to 3/1 pentane/Et_2O) to yield glycosylation product **42** (25.8 mg, 60 µmol, 60%, α:β = <1:20). R*f*: 0.2 (4/1 pentane/Et_2O). Spectroscopic data of the non-dueterated mannitol were in accord with those previously reported.[107] $[\alpha]_D^{22}$ = -27.2° (*c* = 0.5, $CHCl_3$); IR (neat): 694, 733, 1092, 1119, 1452, 2349, 2866; Data for the β-anomer: ^{1}H NMR ($CDCl_3$, 400 MHz, HH-COSY, HSQC): δ 7.54 – 7.48 (m, 2H, CH_{arom}), 7.44 – 7.26 (m, 13H, CH_{arom}), 5.65 (s, 1H, C*H*Ph), 4.82 (d, 1H, *J* = 12.6 Hz, C*H*H Bn), 4.81 (d, 1H, *J* = 12.5 Hz, C*H*H Bn), 4.76 (d, 1H, *J* = 12.5 Hz, CH*H* Bn), 4.68 (d, 1H, *J* = 12.4 Hz, CH*H* Bn), 4.28 (dd, 1H, *J* = 11.2, 4.1 Hz, H-6), 4.25 (t, 1H, *J* = 10.1 Hz, H-4), 3.85 (t, 1H, *J* = 10.3 Hz, H-6), 3.79 (d, 1H, *J* = 3.3 Hz, H-2), 3.68 (dd, 1H, *J* = 9.8, 3.3 Hz, H-3), 3.42 (s, 1H, H-1), 3.34 (td, 1H, *J* = 9.7, 4.9 Hz, H-5); ^{13}C-APT NMR ($CDCl_3$, 101 MHz, HSQC): δ 138.6, 138.3, 137.8 (C_q), 128.9, 128.5, 128.4, 128.3, 128.2, 127.9, 127.7, 127.7, 126.1 (CH_{arom}), 101.5 (CHPh), 79.4 (C-4), 78.6 (C-3), 74.4 (C-2), 72.7 (CH_2 Bn), 72.5 (C-5), 72.4 (CH_2 Bn), 68.8 (t, *J* = 22 Hz, C-1), 68.7 (C-6); ^{2}H NMR ($CHCl_3$, 77 MHz): δ 4.08 (D-1); HRMS: $[M+H]^+$ calcd for $C_{27}H_{28}DO_5$ 434.20723, found 434.20691.



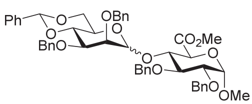
Allyl 2,3-di-*O*-benzyl-4,6-*O*-benzylidene-1-deoxy-β-D-mannopyranose (1H). Donor **1** and allyl trimethylsilane were condensed using the general procedure for Tf_2O/Ph_2SO mediated glycosylations (for an additional 96 hours at -40°C) and purified by flash column chromatography (1/0 to 9/1 pentane/EtOAc) to yield glycosylation product **1H** (20.7 mg, 44 µmol, 44%, α:β = <1:20). R*f*: 0.80 (9/1 pentane/EtOAc). Spectroscopic data were in accord with those previously reported.[72] $[\alpha]_D^{26}$ = -19.6° (*c* = 0.5, $CHCl_3$); IR (neat): 696, 1028, 1097, 1454, 2860, 2924; Data for the β-anomer: ^{1}H NMR (400 MHz, $CDCl_3$, HH-COSY, HSQC, NOESY): δ 7.52 – 7.26 (m, 15H, CH_{arom}), 5.76 – 5.59 (m, 1H, C*H*CH_2 allyl), 5.64 (s, 1H, C*H*Ph), 5.11 – 4.98 (m, 3H, C*H*H Bn, CH*CH_2* allyl), 4.92 (d, 1H, *J* = 12.3 Hz, C*H*H Bn), 4.76 (d, 1H, *J* = 12.3 Hz, CH*H* Bn), 4.69 (d, 1H, *J* = 11.4 Hz, CH*H* Bn), 4.35 – 4.16 (m, 2H, H-4, H-6), 3.84 (t, 1H, *J* = 10.3 Hz, H-6), 3.80 (d, 1H, *J* = 2.2 Hz, H-2), 3.73 (dd, 1H, *J* = 9.8, 2.9 Hz, H-3), 3.45 (t, 1H, *J* = 6.8 Hz, H-1), 3.38 (td, 1H, *J* = 9.8, 4.9 Hz, H-5), 2.46 (dt, 1H, *J* = 13.5, 6.7 Hz, C*H*HCH allylic), 2.25 (dt, 1H, *J* = 14.3, 7.2 Hz, CH*H*CH allylic); ^{13}C-APT NMR (101 MHz, $CDCl_3$, HSQC, HMBC): δ 138.8, 138.6, 137.9 (C_q), 134.4 (*CH*CH_2 allyl), 128.9, 128.6, 128.5, 128.4, 128.3, 127.8, 127.7, 127.7, 126.2 (CH_{arom}), 117.6 (CH*CH_2* allyl), 101.5 (CHPh), 80.9 (C-3), 79.8 (C-1), 79.7 (C-4), 76.6 (C-2), 75.1 (CH_2 Bn), 73.3 (CH_2 Bn), 72.1 (C-5), 68.8 (C-6), 35.6 (*CH_2*CH allylic); HRMS: $[M+H]^+$ calcd for $C_{30}H_{33}O_5$ 473.23225, found 473.23219.



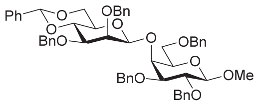
Methyl 6-*O*-(2,3-di-*O*-benzyl-4,6-*O*-benzylidene-α/β-D-mannopyranosyl)-2,3,4-tri-*O*-benzyl-α-D-glucopyranoside (20). Donor **1** and acceptor **10** were condensed using the general procedure for Tf_2O/Ph_2SO mediated glycosylations (for an additional 16 hours at -40°C) and purified by flash column chromatography (9/1 to 7/3 pentane/EtOAc) to yield glycosylation product **20** (86.6mg, 97 µmol, 97%, α:β = 1:10). R_f: 0.67 (7/3 pentane/EtOAc). Spectroscopic data were in accord with those previously reported.[105,108,109] $[\alpha]_D^{26}$ +5.2° (*c* = 1, $CHCl_3$, 546 nm), $[\alpha]_D^{26}$ 0.0° (*c* = 1, $CHCl_3$, 589 nm), (lit:[108] $[\alpha]_D^{20}$ = -1.7° (*c* = 1.8, $CHCl_3$), lit:[105] $[\alpha]_D^{27}$ = -5.8° (*c* = 0.94, $CHCl_3$)); IR (neat): 731, 1026, 1049, 1084, 1452, 2872; Data for the β-anomer: ^1H NMR (400 MHz, $CDCl_3$, HH-COSY, HSQC): δ 7.58 – 7.05 (m, 30H, CH_{arom}), 5.59 (s, 1H, C*H*Ph), 5.03 (d, 1H, *J* = 10.9 Hz, C*H*H Bn), 4.92 (d, 1H, *J* = 12.3 Hz, C*H*H Bn), 4.86 – 4.76 (m, 4H, C*H*H Bn, C*H*H Bn, CH*H* Bn, CH*H* Bn), 4.72 (d, 1H, *J* = 12.5 Hz, C*H*H Bn), 4.67 (d, 1H, *J* = 12.2 Hz, CH*H* Bn), 4.61 (d, 1H, *J* = 12.6 Hz, CH*H* Bn), 4.58 (d, 1H, *J* = 3.5 Hz, H-1), 4.50 (d, 1H, *J* = 11.6 Hz, CH*H* Bn), 4.25 (dd, 1H, *J* = 10.4, 4.8 Hz, H-6'), 4.18 (t, 1H, *J* = 9.6 Hz, H-4'), 4.08 (m, 2H, H-1', H-6), 4.02 (t, 1H, *J* = 9.3 Hz, H-4), 3.91 (t, 1H, *J* = 10.3 Hz, H-6'), 3.80 – 3.72 (m, 1H, H-2), 3.69 (d, 1H, *J* = 2.9 Hz, H-2'), 3.47 (m, 4H, H-3, H-3', H-5, H-6), 3.33 (s, 3H, CH_3 OMe), 3.22 (td, 1H, *J* = 9.8, 4.8 Hz, H-5'); ^{13}C-APT NMR (101 MHz, $CDCl_3$): δ 138.9, 138.5, 138.5, 138.5, 138.1, 137.7 (C_q), 129.0, 128.7, 128.6, 128.5, 128.5, 128.5, 128.3, 128.3, 128.2, 128.1, 128.1, 127.8, 127.8, 127.7, 126.1 (CH_{arom}), 102.1 (H-1'), 101.5 (CHPh), 97.9 (C-1), 82.3 (C-4), 79.9 (C-3), 78.8 (C-4), 77.9 (C-3'), 76.8 (C-5), 75.8 (CH_2 Bn), 75.7 (C-2'), 74.8 (CH_2 Bn), 74.6 (CH_2 Bn), 73.5 (CH_2 Bn), 72.6 (CH_2 Bn), 69.7 (C-2), 68.7 (C-6'), 68.3 (C-6), 67.7 (C-5'), 55.2 (CH_3 OMe); HRMS: $[M+Na]^+$ calcd for $C_{55}H_{58}O_{11}Na$ 917.38713, found 917.38729.



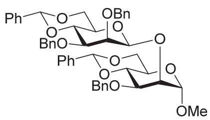
Methyl 4-*O*-(2,3-di-*O*-benzyl-4,6-*O*-benzylidene-α/β-D-mannopyranosyl)-2,3,6-tri-*O*-benzyl-α-D-glucopyranoside (21). Donor **1** and acceptor **11** were condensed using the general procedure for Tf_2O/Ph_2SO mediated glycosylations (for an additional 16 hours at -40°C) and purified by flash column chromatography (9/1 to 7/3 pentane/EtOAc) to yield glycosylation product **21** (67.4 mg, 75 µmol, 75%, α:β = 1:9). R_f: 0.67 (7/3 pentane/EtOAc). Spectroscopic data were in accord with those previously reported.[105,108–110] $[\alpha]_D^{26}$ –15.8° (*c* = 1, $CHCl_3$), (lit:[110] $[\alpha]_D^{25}$ = –15.5° (*c* = 0.8, $CHCl_3$)); IR (neat): 735, 1028, 1083, 1452, 2862; Data for the β-anomer: ^1H NMR (400 MHz, $CDCl_3$, HH-COSY, HSQC): δ 7.46 – 7.21 (m, 25H, CH_{arom}), 5.51 (s, 1H, C*H*Ph), 5.05 (d, 1H, *J* = 10.6 Hz, C*H*H Bn), 4.84 – 4.70 (m, 5H, CH*H* Bn, C*H*H Bn, CH*H* Bn, C*H*H Bn, C*H*H Bn), 4.70 – 4.52 (m, 4H, CH*H* Bn, CH*H* Bn, C*H*H Bn, H-1), 4.36 (s, 1H, H-1'), 4.28 (d, 1H, *J* = 12.1 Hz, CH*H* Bn), 4.12 – 4.01 (m, 2H, H-4', H-6), 3.94 – 3.81 (m, 2H, H-3, H-4), 3.63 (d, 1H, *J* = 2.9 Hz, H-2'), 3.62 – 3.47 (m, 4H, H-5, H-2, H-6, H-6', H-6'), 3.47, 3.40 (s, 3H, CH_3 OMe), 3.32 (dd, 1H, *J* = 9.8, 3.0 Hz, H-3'), 3.05 (td, 1H, *J* = 9.7, 4.8 Hz, H-5'); ^{13}C-APT NMR (101 MHz, $CDCl_3$, HSQC): δ 139.5, 138.8, 138.7, 138.4, 137.8, 137.6 (C_q), 128.9, 128.7, 128.6, 128.5, 128.5, 128.4, 128.3, 128.2, 128.1, 127.9, 127.8, 127.6, 127.6, 127.4, 127.3, 126.2 (CH_{arom}), 101.7 (C-1'), 101.4 (CHPh), 98.5 (C-1), 80.4 (C-4), 79.1 (C-2), 78.8 (C-4'), 78.4 (C-3'), 77.8 (C-3), 77.1 (C-2), 75.4 (CH_2 Bn), 75.1 (CH_2 Bn), 73.8 (CH_2 Bn), 73.7 (CH_2 Bn), 72.6 (CH_2 Bn), 69.7 (C-5), 68.7 (C-6), 68.4 (C-6'), 67.4 (C-5), 55.5 (CH_3 OMe); ^{13}C-GATED NMR (101 MHz, $CDCl_3$): 101.7 ($J_{C1,H1}$ = 156 Hz, C-1 β); Diagnostic peaks α-anomer: ^1H NMR (400 MHz, $CDCl_3$, HH-COSY, HSQC): δ 5.60 (s, 0.11H, C*H*Ph), 5.30 (d, 0.11H, *J* = 1.3 Hz, C-1'); ^{13}C-APT NMR (101 MHz, $CDCl_3$, HSQC): δ 101.5 (C-1'), 101.4 (CHPh); HRMS: $[M+Na]^+$ calcd for $C_{55}H_{58}O_{11}Na$ 917.38713, found 917.38706.



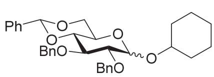
Methyl (methyl [4-*O*-(2,3-di-*O*-benzyl-4,6-*O*-benzylidene-α/β-D-mannopyranosyl]-2,3-di-*O*-benzyl-α-D-glucopyranosyl uronate) (22). Donor **1** and acceptor **12** were condensed using the general procedure for Tf_2O/Ph_2SO mediated glycosylations (for an additional 48 hours at -40°C) and purified by flash column chromatography (9/1 to 7/3 pentane/EtOAc) to yield glycosylation product **22** (72.8 mg, 87 µmol, 87%, α:β = 1:10). R_f: 0.65 (7/3 pentane/EtOAc); $[\alpha]_D^{26}$ = -19.2° (*c* = 1, $CHCl_3$); IR (neat): 735, 1045, 1084, 1454, 1748, 2866; Data for the β-anomer: ^1H NMR (400 MHz, $CDCl_3$, HH-COSY, HSQC): δ 7.55 – 7.24 (m, 25H, CH_{arom}), 5.54 (s, 1H, C*H*Ph), 5.06 (d, 1H, *J* = 10.6 Hz, C*H*H Bn), 4.88 – 4.71 (m, 5H, CH*H* Bn, C*H*H Bn, CH*H* Bn, C*H*HBn, C*H*H Bn), 4.67 – 4.53 (m, 4H, CH*H* Bn, CH*H* Bn, H-1), 4.45 (s, 1H, H-1), 4.17 – 4.01 (m, 3H, H-4, H-4', H-6'), 3.95 – 3.85 (m, 2H, H-3, H-5), 3.82 – 3.75 (m, 1H, H-2'), 3.65 – 3.55 (m, 4H, H-6', CH_3 CO_2Me), 3.55 – 3.47 (m, 2H, H-2, H-3'), 3.44 (s, 3H, CH_3 OMe), 3.19 (td, 1H, *J* = 9.6, 4.8 Hz, H-5'); ^{13}C-APT NMR (101 MHz, $CDCl_3$, HSQC): δ 170.2 (C=O CO_2Me), 139.2, 138.7, 138.5, 138.1, 137.7 (C_q), 128.6, 128.5, 128.4, 128.3, 128.2, 128.2, 128.1, 127.7, 127.7, 127.6, 127.4, 126.2 (CH_{arom}), 102.5 (H-1'), 101.5 (CHPh), 98.9 (C-1), 80.2 (C-3/C-5), 79.8 (C-3/C-5), 78.7 (C-4'), 78.5 (H-2, H-3'), 77.9 (C-2'), 77.2 (CH_2 Bn), 75.6 (CH_2 Bn), 75.2 (CH_2 Bn), 74.0 (CH_2 Bn), 72.7 (CH_2 Bn), 69.7 (C-6), 68.6 (C-6'), 67.7 (C-5'), 56.0 (CH_3 CO_2Me) , 52.5 (CH_3 OMe); ^{13}C-GATED NMR (101 MHz, $CDCl_3$): δ 102.5 ($J_{C1,H1}$ = 157 Hz, C-1 β); Diagnostic peaks α-anomer: ^1H NMR (400 MHz, $CDCl_3$, HH-COSY, HSQC): δ 5.58 (s, 0.10H, C*H*Ph), 5.27 (s, 0.10H, H-1'), 4.98 (d, 0.10H, *J* = 11.4 Hz, C*H*H Bn), 4.31 (d, 0.10H, *J* = 11.9 Hz, CH*H* Bn); ^{13}C-APT NMR (101 MHz, $CDCl_3$): δ 101.54 (CHPh), 100.45 (C-1'), 98.63 (C-1); HRMS: $[M+Na]^+$ calcd for $C_{49}H_{52}O_{12}Na$ 855.33510, found 855.33507.



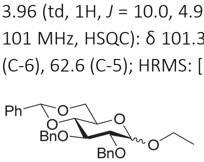
Methyl 4-*O*-(2,3-di-*O*-benzyl-4,6-*O*-benzylidene-β-D-mannopyranosyl)-2,3,6-tri-*O*-benzyl-β-D-galactopyranoside (23). Donor **1** and acceptor **13** were condensed using the general procedure for Tf_2O/Ph_2SO mediated glycosylations (for an additional 16 hours at -40°C) and purified by flash column chromatography (9/1 to 7/3 pentane/EtOAc) to yield glycosylation product **23** (62.7 mg, 70 µmol, 70%, α:β = <1:20). R_f: 0.80 (7/3 pentane/EtOAc); $[\alpha]_D^{26}$ = -26.8° (*c* = 1, $CHCl_3$); IR (neat): 737, 1072, 1454, 2866; Data for the β-anomer: ^{1}H NMR (400 MHz, $CDCl_3$, HH-COSY, HSQC): δ 7.46 – 7.14 (m, 30H, CH_{arom}), 5.59 (s, 1H, C*H*Ph), 4.96 (d, 1H, *J* = 12.4 Hz, C*H*H Bn), 4.91 (d, 1H, *J* = 11.0 Hz, C*H*H Bn), 4.86 (d, 1H, *J* = 12.4 Hz, CH*H* Bn), 4.79 (s, 1H, H-1'), 4.78 (d, 1H, *J* = 11.6 Hz, C*H*H Bn), 4.68 (d, 1H, *J* = 11.0 Hz, CH*H* Bn), 4.62 – 4.47 (m, 5H, CH*H* Bn, C*H*H Bn, CH*H* Bn, C*H*H Bn, CH*H* Bn), 4.31 (d, 1H, *J* = 7.7 Hz, H-1), 4.21 – 4.09 (m, 3H, H-4', H-6'), 4.01 (d, 1H, *J* = 3.0 Hz, H-2'), 3.90 – 3.81 (m, 2H, H-6, H-6'), 3.72 (dd, 1H, *J* = 9.8, 5.7 Hz, H-6), 3.67 (dd, 1H, *J* = 9.6, 7.7 Hz, H-2), 3.63 – 3.55 (m, 4H, H-5, CH_3 OMe), 3.52 (dd, 1H, *J* = 9.6, 3.0 Hz, H-3), 3.40 (dd, 1H, *J* = 9.9, 3.1 Hz, H-3'), 3.18 (td, 1H, *J* = 9.8, 4.9 Hz, H-5); ^{13}C-APT NMR (101 MHz, $CDCl_3$, HSQC): δ 138.9, 138.8, 138.5, 138.4, 138.2, 137.6 (C_q), 129.0, 128.7, 128.7, 128.5, 128.4, 128.4, 128.3, 128.3, 128.2, 128.0, 127.8, 127.7, 127.6, 127.6, 127.5, 126.1 (CH_{arom}), 105.1 (C-1), 102.6 (C-1'), 101.4 (CHPh), 81.8 (H-3), 79.5 (H-2), 78.5 (C-3'), 78.5 (C-4'), 75.4 (C-2'), 75.1 (CH_2 Bn), 74.7 (CH_2 Bn), 73.7 (CH_2 Bn), 73.6 (H-5), 73.6 (CH_2 Bn), 73.3 (C-4), 72.2(CH_2 Bn), 69.5 (C-6), 68.7 (C-6'), 67.8 (C-5), 57.2 (CH_3 OMe); ^{13}C-GATED NMR (101 MHz, $CDCl_3$): δ 102.6 ($J_{C1,H1}$ = 159 Hz, C-1 β); HRMS: $[M+Na]^+$ calcd for $C_{55}H_{58}O_{11}Na$ 917.38713, found 917.38696.



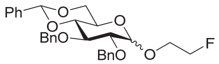
Methyl 2-*O*-(2,3-di-*O*-benzyl-4,6-*O*-benzylidene-β-D-mannopyranosyl)-3-*O*-benzyl-4,6-*O*-benzylidene-α-D-mannopyranoside (24). Donor **1** and acceptor **14** were condensed using the general procedure for Tf_2O/Ph_2SO mediated glycosylations (for an additional 16 hours at -40°C) and purified by flash column chromatography (9/1 to 7/3 pentane/EtOAc) to yield glycosylation product **24** (70.2 mg, 87 µmol, 87%, α:β = <1:20). R_f: 0.68 (7/3 pentane/EtOAc). Spectroscopic data were in accord with those previously reported.[108–111] $[\alpha]_D^{26}$ –44.4° (*c* = 1, $CHCl_3$); (lit:[110] $[\alpha]_D^{25}$ = –44.2° (*c* = 4.2, $CHCl_3$), lit:[111] $[\alpha]_D^{20}$ = –44.8° (*c* = 3.9, $CHCl_3$)); IR (neat): 733, 1002, 1028, 1055, 1083, 1452, 2862; Data for the β-anomer: ^{1}H NMR (400 MHz, $CDCl_3$, HH-COSY, HSQC): δ 7.53 – 7.16 (m, 25H, CH_{arom}), 5.60 (s, 1H, C*H*Ph), 5.51 (s, 1H, C*H*Ph), 5.06 (d, 1H, *J* = 12.3 Hz, C*H*H Bn), 4.97 (d, 1H, *J* = 12.3 Hz, CH*H* Bn), 4.81 – 4.56 (m, 6H, C*H*H Bn, CH*H* Bn, C*H*H Bn, CH*H* Bn, H-1, H-1'), 4.30 – 4.18 (m, 4H, H-2, H-4´, H-6, H-6'), 4.10 (t, 1H, *J* = 9.2 Hz, H-4), 3.98 (d, 1H, *J* = 2.8 Hz, H-2'), 3.94 (dd, 1H, *J* = 10.0, 3.2 Hz, H-3) 3.88 (t, 1H, *J* = 10.3 Hz, H-6'), 3.78 (m, 2H, H-5, H-6), 3.59 (dd, 1H, *J* = 9.9, 3.0 Hz, H-3'), 3.46 – 3.21 (m, 4H, H-5', CH_3 OMe); ^{13}C-APT NMR (101 MHz, $CDCl_3$, HSQC): δ δ 139.0, 138.7, 138.5, 137.7, 137.7 (C_q), 129.0, 128.7, 128.4, 128.3, 128.3, 128.2, 127.7, 127.6, 127.6, 127.4, 126.2, 126.2 (CH_{arom}), 101.7 (CHPh), 101.5 (CHPh), 101.0 (C-1'), 99.6 (C-1), 78.8 (C-4), 78.6 (H-4'), 77.8 (C-3'), 76.1 (C-2'), 75.3 (H-2), 74.7 (H-3), 74.2 (CH_2 Bn), 72.4 (CH_2 Bn), 71.5 (CH_2 Bn), 69.1 (C-6), 68.7 (C-6'), 67.9 (C-5'), 64.2 (C-5), 55.1 (CH_3 OMe); ^{13}C-GATED NMR (101 MHz, $CDCl_3$): δ 101.0 ($J_{C1,H1}$ = 154 Hz, C-1' β); HRMS: $[M+Na]^+$ calcd for $C_{48}H_{50}O_{11}Na$ 825.32453, found 825.32425.



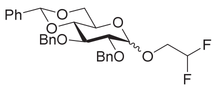
Cyclohexyl 2,3-di-*O*-benzyl-4,6-*O*-benzylidene- α/β-D-glucopyranoside (2A). Donor **2** and cyclohexanol were condensed using the general procedure for Tf_2O/Ph_2SO mediated glycosylations and purified by flash column chromatography (1/0 to 0/1 pentane/toluene to 6% EtOAc in toluene) to yield glycosylation product **2A** (37.8 mg, 71 µmol, 71%, α:β = 1:5). R_f: 0.22 (toluene). Spectroscopic data were in accord with those previously reported.[65] IR (neat): 696, 735, 746, 997, 1028, 1049, 1072, 1366, 1452, 1497, 2857, 2930; Data for the β-anomer:^{1}H NMR ($CDCl_3$, 400 MHz, HH-COSY, HSQC): δ 7.51 – 7.46 (m, 2H, CH_{arom}), 7.41 – 7.24 (m, 13H, CH_{arom}), 5.56 (s, 1H, C*H*Ph), 4.94 (d, 1H, *J* = 10.8 Hz, C*H*H Bn), 4.90 (d, 1H, *J* = 11.1 Hz, C*H*H Bn), 4.79 (d, 1H, *J* = 11.5 Hz, CH*H* Bn), 4.76 (d, 1H, *J* = 10.9 Hz, CH*H* Bn), 4.62 (d, 1H, *J* = 7.7 Hz, H-1), 4.33 (dd, 1H, *J* = 10.5, 5.0 Hz, H-6), 3.79 (t, 1H, *J* = 10.3 Hz, H-6), 3.76 – 3.65 (m, 3H, C*H* Cy, H-3, H-4), 3.46 (t, 1H, *J* = 8.1 Hz, H-2), 3.39 (td, 1H, *J* = 9.5, 5.0 Hz, H-5), 2.00 – 1.91 (m, 2H, CH_2 Cy), 1.82 – 1.72 (m, 2H, CH_2 Cy), 1.59 – 1.18 (m, 6H, CH_2 Cy); ^{13}C-APT NMR ($CDCl_3$, 101 MHz, HSQC): δ 138.7, 138.6, 137.5 (C_q), 129.0, 128.4, 128.4, 128.3, 128.3, 128.1, 127.8, 127.7, 126.1 (CH_{arom}), 102.5 (C-1), 101.2 (CHPh), 82.3 (C-2), 81.6, 81.2 (C-3, C-4), 78.3 (CH Cy), 75.5, 75.2 (CH_2 Bn), 69.0 (C-6), 66.1 (C-5), 33.9, 32.1, 25.7, 24.2, 24.1 (CH_2 Cy); Diagnostic peaks α-anomer: ^{1}H NMR ($CDCl_3$, 400 MHz, HH-COSY, HSQC): δ 4.69 (d, 1H, *J* = 12.1 Hz, CH*H* Bn), 4.26 (dd, 1H, *J* = 10.2, 4.9 Hz, H-6), 4.07 (t, 1H, *J* = 9.3 Hz, H-3), 3.96 (td, 1H, *J* = 10.0, 4.9 Hz, H-5), 3.61 (t, 1H, *J* = 9.4 Hz, H-4), 3.58 – 3.50 (m, 2H, CH Cy, H-2); ^{13}C-APT NMR ($CDCl_3$, 101 MHz, HSQC): δ 101.3 (CHPh), 96.1 (C-1), 82.5 (C-4), 79.5 (C-2) 78.8 (C-3), 76.1 (CH Cy), 75.4, 73.4 (CH_2 Bn), 69.2 (C-6), 62.6 (C-5); HRMS: $[M+H]^+$ calcd for $C_{33}H_{39}O_6$ 531.27412, found 531.27400.



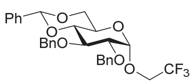
Ethyl 2,3-di-*O*-benzyl-4,6-*O*-benzylidene-α/β-D-glucopyranoside (2B). Donor **2** and ethanol were condensed using the general procedure for Tf_2O/Ph_2SO mediated glycosylations and purified by flash column chromatography (1/1 to 0/1 pentane/toluene to 6% EtOAc in toluene) to yield glycosylation product **2B** (32.2 mg, 68 µmol, 68%, α:β = 1:10). R_f: 0.43 (6% EtOAc in toluene). IR (neat): 692, 743, 1006, 1028, 1183, 1364, 1453, 2872; Data for the β-anomer: ^{1}H NMR ($CDCl_3$, 400 MHz, HH-COSY, HSQC): δ 7.52 – 7.46 (m, 2H, CH_{arom}), 7.41 – 7.24 (m, 13H, CH_{arom}), 5.56 (s, 1H, C*H*Ph), 4.93 – 4.88 (m, 2H, 2xC*H*H Bn), 4.83 – 4.74 (m, 2H, 2xCH*H* Bn), 4.51 (d, 1H, *J* = 7.7 Hz, H-1), 4.34 (dd, 1H, *J* = 10.5, 5.0 Hz, H-6), 3.97 (dq, 1H, *J* = 9.6, 7.1 Hz, C*H*H Et), 3.79 (t, 1H, *J* = 9.5 Hz, H-6), 3.76 – 3.63 (m, 3H, H-3, H-4, CH*H* Et), 3.46 (t, 1H, *J* = 8.1 Hz, H-2), 3.40 (ddd, 1H, *J* = 10.0, 9.0, 5.0 Hz, H-5), 1.29 (t, 3H, *J* = 7.0 Hz, CH_3 Et); ^{13}C-APT NMR ($CDCl_3$, 101 MHz, HSQC): δ 138.7, 138.6, 137.5 (C_q), 129.0, 128.5, 128.4, 128.4, 128.2, 128.1, 127.8, 127.7, 126.1 (CH_{arom}), 104.1 (C-1), 101.3 (CHPh), 82.3 (C-2), 81.7 (C-4), 81.0 (C-3), 75.5, 75.2 (CH_2 Bn), 69.0 (C-6), 66.2 (CH_2 Et), 66.2 (C-5), 15.5 (CH_3 Et); Diagnostic peaks α-anomer: ^{1}H NMR ($CDCl_3$, 400 MHz, HH-COSY, HSQC): δ 5.55 (s, 1H, C*H*Ph), 4.92 (d, 1H, *J* = 11.2 Hz, C*H*H Bn), 4.86 – 4.83 (m, 2H, C*H*H Bn, CH*H* Bn), 4.73 (d, 1H, *J* = 3.8 Hz, H-1), 4.68 (d, 1H, *J* = 12.2 Hz, CH*H* Bn), 4.25 (dd, 1H, *J* = 10.2, 4.8 Hz, H-6), 4.06 (t, 1H, *J* = 9.3 Hz, H-3), 3.88 (td, 1H, *J* = 10.0, 4.8 Hz, H-5), 3.63 – 3.60 (m, 1H, H-4), 3.59 – 3.52 (m, 2H, H-2, CH*H* Et); ^{13}C-APT NMR ($CDCl_3$, 101 MHz, HSQC): δ 101.3 (CHPh), 97.9 (C-1), 82.4 (C-4), 79.5 (C-2), 78.8 (C-3), 73.7 (CH_2 Bn), 69.2 (C-6), 63.8 (CH_2 Et), 62.5 (C-5); HRMS: $[M+H]^+$ calcd for $C_{29}H_{33}O_6$ 477.22717, found 477.22699.



2-Fluoroethyl 2,3-di-*O*-benzyl-4,6-*O*-benzylidene-α/β-D-glucopyranoside (2C). Donor **2** and 2-fluoroethanol were condensed using the general procedure for Tf_2O/Ph_2SO mediated glycosylations and purified by flash column chromatography (1/1 to 0/1 pentane/toluene to 6% EtOAc in toluene) to yield glycosylation product **2C** (34.7 mg, 70 µmol, 70%, α:β = 1:3). R_f: 0.30 and 0.34 (4% EtOAc in toluene). IR (neat): 695, 744, 1000, 1028, 1072, 1085, 1177, 1452, 2868. Reported as a 0.33 : 1.00 mixture of anomers: ^{1}H NMR ($CDCl_3$, 400 MHz, HH-COSY, HSQC): δ 7.52 – 7.44 (m, 2.66H, CH_{arom}), 7.42 – 7.24 (m, 17.29H, CH_{arom}), 5.56 (s, 1H, C*H*Ph_β), 5.55 (s, 0.33H, C*H*Ph_α), 4.92 (dd, 2.33H, *J* = 11.1, 3.4 Hz, 2xC*H*H Bn_β, C*H*H Bn_α), 4.87 – 4.73 (m, 2.99H, 2xCH*H* Bn_β, CH*H* Bn_α, C*H*H Bn_α, H-1_α), 4.72 – 4.60 (m, 1.66H, CH*H* Bn_α, C*H*H-CH_2F_α, C*H*H-CH_2F_β), 4.59 – 4.49 (m, 2.33H, CH*H*-CH_2F_α, CH*H*-CH_2F_β, H-1_β), 4.34 (dd, 1H, *J* = 10.5, 5.0 Hz, H-6_β), 4.26 (dd, 0.33H, *J* = 10.2, 4.9 Hz, H-6_α), 4.13 (ddd, 0.50H, *J* = 12.1, 4.7, 2.6 Hz, C*H*HF_β), 4.10 – 4.02 (m, 0.83H, C*H*HF_β, H-3_α), 3.94 – 3.66 (m, 5.32H, CH*H*F_β, C*H$_2$*F_α, H-3_β, H-4_β, H-5_α, H-6_α, H-6_β), 3.61 (t, 0.33H, *J* = 9.4 Hz, H-4_α), 3.58 (dd, 0.33H, *J* = 9.3, 3.8 Hz, H-2_α), 3.50 (t, 1H, *J* = 8.1 Hz, H-2_β), 3.41 (ddd, 1H, *J* = 10.0, 9.0, 5.0 Hz, H-5_β); ^{13}C-APT NMR ($CDCl_3$, 101 MHz, HSQC): δ 138.9, 138.6, 138.4, 138.3, 137.5, 137.4 (C_q), 129.1, 129.0, 128.6, 128.5, 128.4, 128.4, 128.3, 128.2, 128.1, 128.1, 128.0, 127.7, 126.1 (CH_{arom}), 104.4 (C-1_β, 101.4 ($CHPh_\alpha$), 101.3 ($CHPh_\beta$), 98.4 (C-1_α), 82.7 (d, *J* = 170.2 Hz, CH_2F_α), 82.6 (d, *J* = 170.2 Hz, CH_2F_β), 82.2 (C-4_α), 82.1 (C-2_β), 81.5 (C-4_β), 80.9 (C-3_β), 79.4 (C-2_α), 78.6 (C-3_α), 75.5 (CH_2 $Bn_{\alpha,\beta}$), 75.2 (CH_2 Bn_β), 73.7 (CH_2 Bn_α), 69.4 (d, *J* = 20.0 Hz, *CH_2*-CH_2F_β), 69.1 (C-6_α), 68.8 (C-6), 67.3 (d, *J* = 20.2 Hz, *CH_2*-CH_2F_α), 66.2 (C-5_β), 62.6 (C-5_α); HRMS: $[M+H]^+$ calcd for $C_{29}H_{32}FO_6$ 495.21774, found 495.21745.

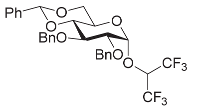


2,2-Difluoroethyl 2,3-di-*O*-benzyl-4,6-*O*-benzylidene-α/β-D-glucopyranoside (2D). Donor **2** and 2,2-difluoroethanol were condensed using the general procedure for Tf_2O/Ph_2SO mediated glycosylations and purified by flash column chromatography (1/1 to 0/1 pentane/toluene to 6% EtOAc in toluene) to yield glycosylation product **2D** (36 mg, 70 µmol, 70%, α:β = 5:1). R_f: 0.32 and 0.36 (4% EtOAc in toluene). IR (neat): 696, 747, 996, 1028, 1071, 1086, 1369, 1453, 2865. Data for the α-anomer: ^{1}H NMR ($CDCl_3$, 400 MHz, HH-COSY, HSQC): δ 7.48 (m, 2H, CH_{arom}), 7.41 – 7.26 (m, 13H, CH_{arom}), 5.95 (tt, 1H, *J* = 55.4, 4.2 Hz, C*H*F_2), 5.55 (s, 1H, C*H*Ph), 4.92 (d, 1H, *J* = 11.3 Hz, C*H*H Bn), 4.84 (d, 1H, *J* = 12.0 Hz, C*H*H Bn), 4.83 (d, 1H, *J* = 11.4 Hz, CH*H* Bn), 4.75 (d, 1H, *J* = 3.9 Hz, H-1), 4.66 (d, 1H, *J* = 12.0 Hz, CH*H* Bn), 4.25 (dd, 1H, *J* = 10.2, 4.8 Hz, H-6), 4.03 (t, 1H, *J* = 9.3 Hz, H-3), 3.90 – 3.65 (m, 4H, C*H$_2$*-CHF_2, H-5, H-6), 3.62 (t, 1H, *J* = 9.4 Hz, H-4), 3.58 (dd, 1H, *J* = 9.3, 3.8 Hz, H-2); ^{13}C-APT NMR ($CDCl_3$, 101 MHz, HSQC): δ 138.8, 138.2, 137.4 (C_q), 129.1, 128.6, 128.4, 128.4, 128.2, 128.1, 128.1, 127.7, 126.1 (CH_{arom}), 114.2 (t, *J* = 241.5 Hz, CHF_2), 101.4 (CHPh), 98.9 (C-1), 82.0 (C-4), 79.3 (C-2), 78.4 (C-3), 75.5, 74.0 (CH_2 Bn), 69.0 (C-6), 67.4 (t, *J* = 28.8 Hz, *CH_2*-CHF_2), 63.0 (C-5); Diagnostic peaks β-anomer: ^{1}H NMR ($CDCl_3$, 400 MHz, HH-COSY, HSQC): δ 5.90 (tdd, 1H, *J* = 55.4, 5.0, 3.4 Hz, C*H*F_2), 5.56 (s, 1H, C*H*Ph), 4.54 (d, 1H, *J* = 7.6 Hz, H-1), 4.34 (dd, 1H, *J* = 10.5, 5.0 Hz, H-6), 3.48 (t, 1H, *J* = 8.1 Hz, H-2), 3.41 (td, 1H, *J* = 9.6, 5.0 Hz, H-5); ^{13}C-APT NMR ($CDCl_3$, 101 MHz, HSQC): δ 104.5 (C-1), 101.3 (CHPh), 81.9 (c-2), 81.4, 80.8 (C-3, C-4), 75.6, 75.3 (CH_2 Bn), 68.7 (C-6), 66.3 (C-5); HRMS: $[M+H]^+$ calcd for $C_{29}H_{31}F_2O_6$ 513.20832, found 513.20808.

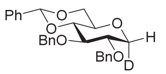


2,2,2-Trifluoroethyl 2,3-di-*O*-benzyl-4,6-*O*-benzylidene-α-D-glucopyranoside (2E). Donor **2** and 2,2,2-trifluoroethanol were condensed using the general procedure for Tf_2O/Ph_2SO mediated glycosylations and purified by flash column chromatography (1/1 to 0/1 pentane/toluene to 6% EtOAc in toluene) to yield glycosylation product **2E** (33.7 mg, 64 µmol, 64%, α:β = >20:1). R_f: 0.45 (4% EtOAc in toluene). $[\alpha]_D^{23}$ = +7.0° (*c* = 0.67, DCM); IR (neat): 697, 747, 1001, 1029, 1077, 1161, 1279, 1373, 1454, 2864; Data for the α-anomer: ^{1}H NMR ($CDCl_3$, 400 MHz, HH-COSY, HSQC): δ 7.51 – 7.46 (m, 2H, CH_{arom}), 7.41 –

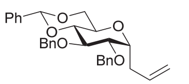
7.26 (m, 13H, CH_{arom}), 5.55 (s, 1H, C*H*Ph), 4.92 (d, 1H, *J* = 11.2 Hz, C*H*H Bn), 4.84 (d, 1H, *J* = 12.0 Hz, C*H*H Bn), 4.83 (d, 1H, *J* = 11.3 Hz, CH*H* Bn), 4.80 (d, 1H, *J* = 3.9 Hz, H-1), 4.67 (d, 1H, *J* = 12.0 Hz, CH*H* Bn), 4.25 (dd, 1H, *J* = 10.2, 4.8 Hz, H-6), 4.05 (t, 1H, *J* = 9.3 Hz, H-3), 3.92 (q, 2H, *J* = 8.7 Hz, CH_2-CF_3), 3.85 (td, 1H, *J* = 9.9, 4.8 Hz, H-5), 3.70 (t, 1H, *J* = 10.3 Hz, H-6), 3.63 (t, 1H, *J* = 9.4 Hz, H-4), 3.59 (dd, 1H, *J* = 9.3, 3.8 Hz, H-2); ^{13}C-APT NMR ($CDCl_3$, 101 MHz, HSQC): δ 138.8, 138.2, 137.4 (C_q), 129.1, 128.6, 128.4, 128.4, 128.2, 128.1, 128.1, 127.8, 126.2 (CH_{arom}), 123.8 (q, *J* = 278.6 Hz, CF_3), 101.4 (CHPh), 99.0 (C-1), 81.9 (C-4), 79.2 (C-2), 78.3 (C-3), 75.5, 73.9 (CH_2 Bn), 68.9 (C-6), 65.2 (q, *J* = 35.0 Hz, CH_2-CF_3), 63.3 (C-5); Diagnostic peaks β-anomer: ^{1}H NMR ($CDCl_3$, 400 MHz, HH-COSY, HSQC): δ 5.56 (s, 1H, C*H*Ph), 4.73 (d, 1H, *J* = 10.7 Hz, CH*H* Bn), 4.60 (d, 1H, *J* = 7.7 Hz, H-1), 4.34 (dd, 1H, *J* = 10.5, 5.0 Hz, H-6), 3.51 (t, 1H, *J* = 8.0 Hz), 3.41 (td, 1H, *J* = 9.6, 5.2 Hz, H-5); HRMS: $[M+H]^+$ calcd for $C_{29}H_{30}F_3O_6$ 531.19890, found 531.19857.



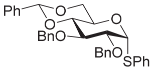
1,1,1,3,3,3-Hexafluoro-2-propyl 2,3-di-*O*-benzyl-4,6-*O*-benzylidene-α-D-glucopyranoside (2F). Donor **2** and 1,1,1,3,3,3-hexafluoroisopropanol were condensed using the general procedure for Tf_2O/Ph_2SO mediated glycosylations (for an additional 144 hours at -40°C) and purified by flash column chromatography (1/1 to 0/1 pentane/toluene to 10% EtOAc in toluene) to yield glycosylation product **2F** (39 mg, 65 µmol, 65%, α:β = >20:1). R_f: 0.31 (4/1 pentane/Et_2O). $[\alpha]_D^{25}$ = -40.9° (*c* = 0.68, $CHCl_3$); IR (neat): 689, 746, 997, 1086, 1196, 1219, 1368, 1454, 2868; ^{1}H NMR ($CDCl_3$, 400 MHz, HH-COSY, HSQC): δ 7.51 – 7.47 (m, 2H, CH_{arom}), 7.40 – 7.27 (m, 13H, CH_{arom}), 5.55 (s, 1H, C*H*Ph), 5.07 (d, 1H, *J* = 4.0 Hz, H-1), 4.93 (d, 1H, *J* = 11.1 Hz, C*H*H Bn), 4.83 (d, 1H, *J* = 11.1 Hz, CH*H* Bn), 4.79 (d, 1H, *J* = 11.7 Hz, C*H*H Bn), 4.73 (d, 1H, *J* = 11.7 Hz, CH*H* Bn), 4.41 (hept, 1H, *J* = 5.9 Hz, CH HFIP), 4.24 (dd, 1H, *J* = 10.2, 5.0 Hz, H-6), 4.06 (t, 1H, *J* = 9.4 Hz, H-3), 3.94 (td, 1H, *J* = 10.0, 4.9 Hz, H-5), 3.70 (t, 1H, *J* = 10.2 Hz, H-6), 3.75 – 3.60 (m, 2H, H-2, H-4); ^{13}C-APT NMR ($CDCl_3$, 101 MHz, HSQC): δ 138.6, 137.7, 137.2 (C_q), 129.2, 128.6, 128.5, 128.4, 128.2, 128.1, 127.8, 126.1 (CH_{arom}), 121.7 (q, *J* = 285 Hz, CF_3), 121.2 (q, *J* = 285 Hz, CF_3), 101.4 (CHPh), 100.4 (C-1), 81.5 (C-4), 78.3, 78.3 (C-2, C-3), 75.6, 74.1 (CH_2 Bn), 73.4 (hept, *J* = 32.9 Hz, CH HFIP), 68.5 (C-6), 64.0 (C-5); ^{13}C-HMBC NMR ($CDCl_3$, 101 MHz): $^3J(H_{HFIP}$-C1) observed; HRMS: $[2M-2(CF_3)_2CHO+H_2O+NH_4]^+$ calcd for $(C_{27}H_{27}O_5)_2O$ 896.40044, found 896.40115; LC-MS: Rt = 10.09, no conclusive mass. TLC-MS: $[M+Na]^+$ calcd for $C_{30}H_{28}F_6O_6Na$ 621.17 found 621.2, and $[M+H_2O$-benzaldehyde$+Na]^+$ calcd for $C_{23}H_{24}F_6O_6Na$ 533.14 found 533.0.



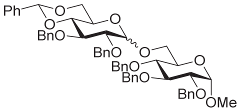
1-[^{2}H]-1,5-anhydro-2,3-di-*O*-benzyl-4,6-*O*-benzylidene-α-D-glucitol (2G). Donor **2** and triethylsilane-D were condensed using the general procedure for Tf_2O/Ph_2SO mediated glycosylations (for an additional 144 hours at -40°C) and purified by flash column chromatography (19/1 to 4/1 Et_2O/pentane) to yield glycosylation product **2G** (34 mg, 79 µmol, 79%, α:β = >20:1). R_f: 0.38 (4/1 pentane/Et_2O). Spectroscopic data of the non-dueterated glucitol were in accord with those previously reported.[112] $[\alpha]_D^{23}$ = +5.4° (*c* = 0.78, $CHCl_3$); IR (neat): 696, 748, 1009, 1028, 1088, 1368, 1454, 2868; ^{1}H NMR ($CDCl_3$, 400 MHz, HH-COSY, HSQC): δ 7.51 – 7.48 (m, 2H, CH_{arom}), 7.41 – 7.34 (m, 5H, CH_{arom}), 7.34 – 7.26 (m, 7H, CH_{arom}), 5.55 (s, 1H, C*H*Ph), 4.96 (d, 1H, *J* = 11.4 Hz, C*H*H Bn), 4.83 (d, 1H, *J* = 11.6 Hz, CH*H* Bn), 4.80 (d, 1H, *J* = 11.7 Hz, C*H*H Bn), 4.66 (d, 1H, *J* = 11.6 Hz, CH*H* Bn), 4.31 (dd, 1H, *J* = 10.4, 5.0 Hz, H-6), 3.98 (d, 1H, *J* = 5.6 Hz, H-1), 3.75 (t, 1H, *J* = 8.8 Hz, H-3), 3.70 – 3.63 (m, 2H, H-2, H-6), 3.61 (t, 1H, *J* = 9.2 Hz, H-4), 3.36 (ddd, 1H, *J* = 10.1, 9.2, 5.0 Hz, H-5); ^{13}C-APT NMR ($CDCl_3$, 101 MHz, HSQC): δ 138.8, 138.3, 137.5 (C_q), 129.0, 128.6, 128.4, 128.4, 128.1, 128.0, 128.0, 127.7, 126.1 (CH_{arom}), 101.3 (CHPh), 82.5 (C-3), 82.2 (C-4), 77.7 (C-2, 75.1, 74.0 (CH_2 Bn), 71.4 (C-5), 69.0 (C-6), 68.7 (t, $J_{C1,D1}$ = 22.3 Hz); ^{2}H NMR ($CHCl_3$, 61 MHz): 3.34 (s, 1D, D-1); HRMS: $[M+H]^+$ calcd for $C_{27}H_{28}DO_5S$ 434.20723, found 434.20714.



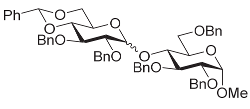
Allyl 2,3-di-*O*-benzyl-1-deoxy-4,6-*O*-benzylidene-α-D-glucopyranoside (2H). Donor **2** and allyl trimethylsilane were condensed using the general procedure for Tf_2O/Ph_2SO mediated glycosylations (for an additional 16 hours at -40°C) and purified by flash column chromatography (19/1 to 9/1 pentane/EtOAc) to yield glycosylation product **2H** (20 mg, 42 µmol, 42%, α:β = >1:20). Contaminated with a 1-OTMS glycoside by-product. α-Thio glycoside **2α** was formed as a by-product. R_f: 0.60 (9/1 pentane/EtOAc). Spectroscopic data were in accord with those previously reported.[40,72] ^{1}H NMR ($CDCl_3$, 400 MHz, HH-COSY, HH-NOESY, HSQC): δ 7.53 – 7.47 (m, 2H, CH_{arom}), 7.42 – 7.27 (m, 13H, CH_{arom}), 5.77 (ddt, 1H, *J* = 17.1, 10.2, 6.9 Hz, C*H* allyl), 5.57 (s, 1H, C*H*Ph), 5.18 – 5.05 (m, 2H, CH_2 allyl), 4.93 (d, 1H, *J* = 11.4 Hz, C*H*H Bn), 4.81 (d, 1H, *J* = 11.4 Hz, CH*H* Bn), 4.78 (d, 1H, *J* = 11.7 Hz, C*H*H Bn), 4.64 (d, 1H, *J* = 11.7 Hz, CH*H* Bn), 4.27 – 4.21 (m, 1H, H-6), 4.08 (td, 1H, *J* = 7.7, 5.7 Hz, H-1), 3.92 – 3.85 (m, 1H, H-3), 3.76 (dd, 1H, *J* = 8.6, 5.7 Hz, H-2), 3.69 – 3.63 (m, 3H, H-4, H-5, H-6), 2.57 – 2.51 (m, 2H, CH_2 allylic); ^{13}C-APT NMR ($CDCl_3$, 101 MHz, HSQC, HMBC): δ 138.7, 138.3, 137.5 ($C_{q\text{-}arom}$), 134.4 (CH allyl), 129.0, 128.6, 128.5, 128.4, 128.1, 128.0, 127.9, 127.8, 126.1 (CH_{arom}), 117.4 (CH_2 allyl), 101.3 (CHPh), 82.9 (C-4), 79.5 (C-2), 78.9 (C-3), 75.0 (C-1), 75.0, 73.7 (CH_2 Bn), 69.6 (C-6), 63.5 (C-5), 30.8 (CH_2 allylic); HRMS: $[M+H]^+$ calcd for $C_{30}H_{33}O_5$ 473.23225, found 473.23228.



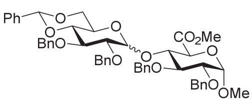
Phenyl 2,3-di-*O*-benzyl-4,6-*O*-benzylidene-1-thio-α-D-glucopyranoside (2α). R*f*: 0.38 (4/1 pentane/Et_2O). Spectroscopic data were in accord with those previously reported.[21] ^{1}H NMR ($CDCl_3$, 400 MHz, HH-COSY, HSQC): δ 7.53 – 7.44 (m, 4H, CH_{arom}), 7.43 – 7.36 (m, 7H, CH_{arom}), 7.36 – 7.27 (m, 9H, CH_{arom}), 5.59 (d, 1H, *J* = 5.5 Hz, H-1), 5.57 (s, 1H, C*H*Ph), 4.92 (d, 1H, *J* = 11.3 Hz, CH*H* Bn), 4.86 (d, 1H, *J* = 11.3 Hz, CH*H* Bn), 4.81 (d, 1H, *J* = 11.8 Hz, C*H*H Bn), 4.76 (d, 1H, *J* = 11.8 Hz, CH*H* Bn), 4.39 (td, 1H, *J* = 9.9, 4.9 Hz, H-5), 4.19 (dd, 1H, *J* = 10.3, 5.0 Hz, H-6), 3.98 (t, 1H, *J* = 9.2 Hz, H-3), 3.90 (dd, 1H, *J* = 9.3, 5.5 Hz, H-2), 3.71 (t, *J* = 10.3 Hz, H-6), 3.66 (t, *J* = 9.3 Hz, H-4); HRMS: $[M+NH_4]^+$ calcd for $C_{33}H_{36}NO_5$ 558.23087, found 558.23075.



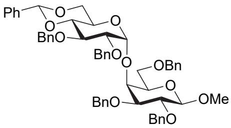
Methyl 6-*O*-(2,3-di-*O*-benzyl-4,6-*O*-benzylidene-α/β-D-glucopyranosyl)-2,3,4-tri-*O*-benzyl-α-D-glucopyranoside (25). Donor **2** and acceptor **10** were condensed using the general procedure for Tf_2O/Ph_2SO mediated glycosylations (for an additional 16 hours at -40°C) and purified by flash column chromatography (9/1 to 3/1 pentane/EtOAc) to yield glycosylation product **25** (72.1 mg, 81 µmol, 81%, α:β = 1:2.7). R*f*: 0.83 (6/4 pentane/EtOAc). Spectroscopic data were in accord with those previously reported.[108] ^{1}H NMR ($CDCl_3$, 400 MHz, HH-COSY, HSQC, HMBC): δ 7.51 – 7.44 (m, 2H, CH_{arom}), 7.41 – 7.12 (m, 28H, CH_{arom}), 5.54 (s, 1H, C*H*Ph), 4.97 (d, 1H, *J* = 10.8 Hz, C*H*H Bn), 4.93 – 4.88 (m, 2H, 2xC*H*H Bn), 4.84 – 4.76 (m, 4H, 3xCH*H* Bn, C*H*H Bn), 4.73 – 4.63 (m, 2H, C*H*H Bn, CH*H* Bn), 4.61 (d, 1H, *J* = 3.6 Hz, H-1), 4.49 (d, 1H, *J* = 11.2 Hz, CH*H* Bn), 4.44 (d, 1H, *J* = 7.7 Hz, H-1’), 4.31 (dd, 1H, *J* = 10.5, 5.0 Hz, H-6’), 4.11 (dd, 1H, *J* = 10.7, 2.0 Hz, H-6), 3.99 (t, *J* = 9.3 Hz, 1H, H-3), 3.82 – 3.65 (m, 5H, H-3’, H-4’, H-5, H-6, H-6’), 3.56 – 3.48 (m, 3H, H-2, H-2’, H-4), 3.40 – 3.34 (m, 1H, H-5’), 3.33 (s, 3H, CH_3 OMe); ^{13}C-APT NMR ($CDCl_3$, 101 MHz, HSQC, HMBC): δ 138.9, 138.5, 138.4, 138.3, 138.2, 137.4 (C_q), 128.6, 128.5, 128.5, 128.4, 128.4, 128.4, 128.4, 128.3, 128.3, 128.3, 128.2, 128.1, 128.1, 128.1, 128.1, 128.0, 128.0, 128.0, 127.7, 127.7, 127.7, 127.7, 126.1 (CH_{arom}), 104.2 (C-1’), 101.2 (CHPh), 98.2 (C-1), 82.1 (C-3), 81.9 (C-2’), 81.5, 81.2 (C-3’, C-4’), 79.8 (C-2), 77.9 (C-4), 75.8, 75.5, 75.2, 75.0, 73.5 (CH_2 Bn), 69.8 (C-5), 68.8 (C-6, C-6’), 66.2 (C-5’), 55.3 (OMe); Diagnostic peaks α-anomer: ^{1}H NMR ($CDCl_3$, 400 MHz): δ 5.53 (s, 0.33H), 4.57 (d, 0.33H, *J* = 3.6 Hz), 4.20 (dd, 0.33H, *J* = 10.1, 4.8 Hz), 3.89 (td, 0.33H, *J* = 10.0, 4.8 Hz), 3.43 (dd, 0.33H, *J* = 9.6, 3.6 Hz), 3.34 (s, 1H); ^{13}C-APT NMR ($CDCl_3$, 101 MHz): δ 138.9, 138.8, 138.5, 138.3, 137.6, 129.0-126.2, 101.4, 98.3, 98.1, 82.3, 82.2, 80.2, 79.4, 78.0, 77.8, 75.8, 75.1, 75.1, 73.5, 73.0, 70.5, 69.2, 66.4, 62.6, 55.3; HRMS: $[M+Na]^+$ calcd for $C_{55}H_{58}O_{11}Na$ 917.38713, found 917.38678.



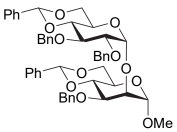
Methyl 4-*O*-(2,3-di-*O*-benzyl-4,6-*O*-benzylidene-α/β-D-glucopyranosyl)-2,3,6-tri-*O*-benzyl-α-D-glucopyranoside (26). Donor **2** and acceptor **11** were condensed using the general procedure for Tf_2O/Ph_2SO mediated glycosylations (for an additional 16 hours at -40°C) and purified by flash column chromatography (19/1 to 4/1 pentane/EtOAc) to yield glycosylation product **26** (71 mg, 79 µmol, 79%, α:β = 1:1). R*f*: 0.54 (4/1 pentane/EtOAc). Spectroscopic data were in accord with those previously reported for the α-anomer.[108] ^{1}H NMR ($CDCl_3$, 400 MHz, HH-COSY, HSQC, HMBC): δ 7.52 – 7.45 (m, 4H, CH_{arom}), 7.44 – 7.18 (m, 56H, CH_{arom}), 5.75 (d, 1H, *J* = 3.8 Hz, H-1’$_{\alpha}$), 5.52 (s, 1H, C*H*Ph$_{\alpha}$), 5.49 (s, 1H, C*H*Ph$_{\beta}$), 5.04 (d, 1H, *J* = 11.7 Hz, C*H*H Bn$_{\alpha}$), 4.95 – 4.87 (m, 3H, 3xC*H*H Bn), 4.84 – 4.51 (m, 17H, 6xC*H*H Bn, 9xCH*H* Bn, H-1, H-1$_{\beta}$), 4.36 (d, 1H, *J* = 7.8 Hz, H-1’$_{\beta}$), 4.30 (d, 1H, *J* = 12.0 Hz, CH*H* Bn$_{\beta}$), 4.19 (dd, 1H, *J* = 10.5, 5.0 Hz, H-6’$_{\beta}$), 4.15 – 4.09 (m, 3H, H-3$_{\alpha}$, H-4$_{\alpha}$, H-6’$_{\alpha}$), 3.99 (t, 1H, *J* = 9.3 Hz, H-3’$_{\alpha}$), 3.94 (t, 1H, *J* = 9.4 Hz, H-4$_{\beta}$), 3.90 – 3.78 (m, 5H, H-2$_{\beta}$, H-5$_{\alpha}$, H-5$_{\alpha}$’, H-6$_{\alpha}$, H-6$_{\beta}$), 3.69 – 3.41 (m, 11H, H-2$_{\alpha}$, H-2’$_{\alpha}$, H-3$_{\beta}$, H-3’$_{\beta}$, H-4’$_{\alpha}$, H-4’$_{\beta}$, H-5$_{\beta}$, H-6$_{\alpha}$, H-6$_{\beta}$, H-6’$_{\alpha}$, H-6’$_{\beta}$), 3.40 – 3.31 (m, 7H, CH_3 OMe, CH_3 OMe$_{\beta}$, H-2’$_{\beta}$), 3.10 (td, 1H, *J* = 9.5, 4.9 Hz, H-5’$_{\beta}$); ^{13}C-APT NMR ($CDCl_3$, 101 MHz, HSQC, HMBC): δ 139.4, 139.0, 138.7, 138.6, 138.5, 138.4, 138.2, 138.0, 137.9, 137.9, 137.6, 137.5 (C_q), 129.0, 128.9, 128.6, 128.5, 128.5, 128.4, 128.3, 128.3, 128.3, 128.2, 128.2, 128.2, 128.1, 128.1, 128.0, 128.0, 127.9, 127.8, 127.7, 127.7, 127.5, 127.5, 127.4, 127.3, 126.8, 126.1, 126.1 (CH_{arom}), 102.9 (C-1’$_{\beta}$), 101.2 (CHPh), 98.5, 97.8 (C-1$_{\alpha}$, C-1$_{\beta}$), 97.2 (C-1’$_{\alpha}$), 82.7 (C-2’$_{\beta}$), 82.4 (C-4’$_{\alpha}$), 82.2 (C-3$_{\alpha}$), 81.8 (C-4’$_{\beta}$), 81.0 (C-3’$_{\beta}$), 80.3 (C-2$_{\beta}$), 80.3, 78.9 (C-2$_{\alpha}$, C-3’$_{\alpha}$), 78.8 (C-2’$_{\alpha}$, C-3$_{\beta}$), 76.9 (C-4$_{\beta}$), 75.6, 75.5, 75.4, 75.0, 74.4, 73.9, 73.7, 73.4, 73.4 (CH_2 Bn), 71.6 (C-4$_{\alpha}$), 70.0 (C-5$_{\beta}$), 69.4 (C-5$_{\alpha}$), 69.0, 68.9, 68.8 (C-6$_{\alpha}$, C-6’$_{\alpha}$, C-6’$_{\beta}$), 67.7 (C-6$_{\beta}$), 65.8 (C-5’$_{\beta}$), 63.4 (C-5’$_{\alpha}$), 55.5 (OMe$_{\beta}$), 55.3 (OMe$_{\alpha}$); HRMS: $[M+NH_4]^+$ calcd for $C_{55}H_{62}O_{11}N$ 912.43174, found 912.43282.



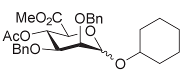
Methyl (methyl 4-*O*-[2,3-di-*O*-benzyl-4,6-*O*-benzylidene-α/β-D-glucopyranosyl]-2,3,6-tri-*O*-benzyl-α-D-glucopyranosyl uronate) (27). Donor **2** and acceptor **12** were condensed using the general procedure for Tf_2O/Ph_2SO mediated glycosylations (for an additional 24 hours at -40°C) and purified by flash column chromatography (19/1 to 4/1 pentane/EtOAc) to yield glycosylation product **27** (75.2 mg, 90 µmol, 90%, α:β = 5:1). R*f*: 0.77 (7/3 pentane/EtOAc). IR (neat): 694, 732, 912, 988, 1026, 1043, 1074, 1086, 1358, 1454, 1749, 28866, 2932; Data for the α-anomer: ^{1}H NMR ($CDCl_3$, 400 MHz, HH-COSY, HSQC, HMBC): δ 7.48 – 7.43 (m, 2H, CH_{arom}), 7.40 – 7.16 (m, 23H, CH_{arom}), 5.51 (s, 1H, C*H*Ph), 5.44 (d, 1H, *J* = 3.8 Hz, H-1’), 4.95 – 4.86 (m, 3H, CH_2 Bn, C*H*H Bn), 4.78 (d, 1H, *J* = 11.2 Hz, CH*H* Bn), 4.71 (d, 1H, *J* = 12.1 Hz, C*H*H Bn), 4.67 (d, 1H, *J* = 12.0 Hz, C*H*H Bn), 4.59 – 4.53 (m, 3H, 2xCH*H* Bn, H-1), 4.28 (dd, 1H, *J* = 6.5, 3.8 Hz, H-6'), 4.25 (d, 1H, *J* = 9.5 Hz, H-5), 4.11 (t, 1H, *J* = 9.1 Hz, H-4), 4.05 (t, 1H, *J* = 8.9 Hz, H-3), 3.98 (t, 1H, *J* = 9.1 Hz, H-3'), 3.76 (s, 3H, CH_3 CO_2Me), 3.64 (t, 1H, *J* = 10.0 Hz, H-6'), 3.61 – 3.54 (m, 3H, H-2, H-4', H-5'), 3.48 (dd, 1H, *J* = 5.6, 3.9 Hz, H-2'), 3.40 (s, 3H, CH_3 OMe); ^{13}C-APT NMR ($CDCl_3$, 101 MHz, HSQC, HMBC): δ 170.1 (C=O CO_2Me), 139.0, 138.6, 138.0, 137.8, 137.6 (C_q), 129.0, 128.6, 128.4, 128.4, 128.3, 128.3, 128.3, 128.2, 128.1, 128.1, 127.8, 127.7, 127.7, 127.3, 127.0, 126.1 (CH_{arom}), 101.3 (CHPh), 98.6 (C-1), 98.4 (C-1'), 82.0 (C-4'), 80.8 (C-3), 79.2 (C-2), 78.7 (C-2'), 78.4 (C-3'), 76.1 (C-4), 75.3, 75.0, 73.7, 73.7 (CH_2 Bn), 70.3 (C-5), 68.6 (C-6'), 63.1 (C-5'), 55.8 (CH_3 OMe), 52.9 (CH_3 CO_2Me); ^{13}C-HMBC NMR ($CDCl_3$, 101 MHz): δ 98.4 ($J_{C1',H1'}$ = 174 Hz, C-1' α); Diagnostic peaks β-anomer: ^{1}H NMR ($CDCl_3$, 400 MHz): δ 5.47 (s, 0.18H, CHPh), 4.62 (d, 0.18H, *J* = 12.1 Hz), 3.87 (dd, 0.18H, *J* = 9.6, 8.4 Hz), 3.50 (s, 0.54H, CH_3 CO_2Me), 3.44 (s, 0.54H, CH_3 OMe), 3.38 – 3.28 (m, 0.36H, H-2', H-5'); ^{13}C-APT NMR ($CDCl_3$, 101 MHz): δ 170.1, 139.2, 138.6, 138.2, 137.4, 129.0, 128.5, 128.3, 128.1, 127.7, 127.5, 126.1, 102.9 (C-1'), 101.2 (CHPh), 99.0 (C-1), 82.3, 81.8, 81.3, 79.6, 78.5, 78.2, 75.6, 75.5, 75.2, 73.9, 70.0, 68.8, 65.9, 55.9, 52.7; ^{13}C-HMBC NMR ($CDCl_3$, 101 MHz): δ 102.9 ($J_{C1',H1'}$ = 164 Hz, C-1' β); HRMS: $[M+Na]^+$ calcd for $C_{49}H_{52}O_{12}Na$ 855.33510, found 855.33496.



Methyl 4-*O*-(2,3-di-*O*-benzyl-4,6-*O*-benzylidene-α-D-glucopyranosyl)-2,3,6-tri-*O*-benzyl-β-D-galactopyranoside (28). Donor **2** and acceptor **13** were condensed using the general procedure for Tf_2O/Ph_2SO mediated glycosylations (for an additional 16 hours at -40°C) and purified by flash column chromatography (19/1 to 4/1 pentane/EtOAc) to yield glycosylation product **28** (74 mg, 83 µmol, 83%, α:β = >20:1). R_f: 0.50 (4/1 pentane/EtOAc). $[\alpha]_D^{23}$ = +38.4° (*c* = 1.0, $CHCl_3$); IR (neat): 696, 735, 997, 1028, 1072, 1366, 1452, 1497, 2859, 2922; ^{1}H NMR ($CDCl_3$, 400 MHz, HH-COSY, HSQC, HMBC): δ 7.49 (dd, 2H, *J* = 7.9, 1.8 Hz, CH_{arom}), 7.42 – 7.16 (m, 28H, CH_{arom}), 5.50 (s, 1H, C*H*Ph), 4.98 (d, *J* = 3.7 Hz, H-1'), 4.97 (d, *J* = 11.0 Hz, C*H*H Bn), 4.93 – 4.87 (m, 2H, 2xC*H*H Bn), 4.85 – 4.74 (m, 3H, 2xCH*H* Bn, C*H*H Bn), 4.72 – 4.63 (m, 2H, 2xCH*H* Bn), 4.31 – 4.22 (m, 4H, CH_2 Bn, H-1, H-5'), 4.18 (t, 1H, *J* = 9.4 Hz, H-3'), 4.06 – 3.97 (m, 2H, H-4, H-6), 3.84 (dd, 1H, *J* = 10.1, 4.9 Hz, H-6'), 3.72 (dd, 1H, *J* = 10.0, 7.6 Hz, H-2), 3.63 – 3.45 (m, 8H, CH_3 OMe, H-2', H-4', H-5, H-6, H-6'), 3.42 (dd, 1H, *J* = 10.0, 2.9 Hz, H-3); ^{13}C-APT NMR ($CDCl_3$, 101 MHz, HSQC, HMBC): δ 138.9, 138.7, 138.6, 138.4, 138.2, 137.8 (C_q), 128.9, 128.5, 128.4, 128.4, 128.3, 128.3, 128.1, 128.0, 127.8, 127.7, 127.6, 126.2 (CH_{arom}), 105.1 (C-1), 101.2 (CHPh), 100.7 (C-1'), 83.0 (C-4'), 80.6 (C-3), 79.7 (C-2'), 78.9 (C-2, C-3'), 75.9 (C-4), 75.3, 75.2, 74.0 (CH_2 Bn), 73.5 (C-5), 73.2, 72.8 (CH_2 Bn), 69.1 (C-6'), 68.0 (C-6), 63.0 (C-5'), 57.2 (OMe); ^{13}C-HMBC NMR ($CDCl_3$, 101 MHz): δ 105.1 ($J_{C1',H1'}$ = 159 Hz, C-1 β), 100.7 ($J_{C1',H1'}$ = 170 Hz, C-1' α); HRMS: $[M+NH_4]^+$ calcd for $C_{55}H_{62}O_{11}N$ 912.43174, found 912.43266.

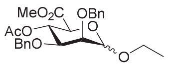


Methyl 2-*O*-(2,3-di-*O*-benzyl-4,6-*O*-benzylidene-α/β-D-glucopyranosyl)-3-*O*-benzyl-4,6-*O*-benzylidene-α-D-mannopyranoside (29). Donor **2** and acceptor **14** were condensed using the general procedure for Tf_2O/Ph_2SO mediated glycosylations (for an additional 16 hours at -40°C) and purified by flash column chromatography (19/1 to 4/1 pentane/EtOAc) to yield glycosylation product **29** (64.3 mg, 80 µmol, 80%, α:β = >20:1). R_f: 0.27 (8/1 pentane/EtOAc). Spectroscopic data were in accord with those previously reported.[108] IR (neat): 696, 748, 999, 1028, 1074, 1088, 1369, 1454, 1498, 2864, 2911; ^{1}H NMR ($CDCl_3$, 400 MHz, HH-COSY, HSQC, HMBC): δ 7.49 (ddd, 4H, *J* = 8.9, 5.8, 1.9 Hz, CH_{arom}), 7.44 – 7.35 (m, 8H, CH_{arom}), 7.35 – 7.24 (m, 10H, CH_{arom}), 7.17 (dp, 3H, *J* = 4.4, 1.6 Hz, CH_{arom}), 5.60 (d, 1H, *J* = 3.9 Hz, H-1'), 5.57 (s, 1H, CHPh'), 5.43 (s, 1H, CHPh), 4.95 – 4.85 (m, 3H, C*H*H Bn, CH_2 Bn), 4.78 (d, 1H, *J* = 11.2 Hz, C*H*H Bn), 4.72 (d, 1H, *J* = 11.7 Hz, CH*H* Bn), 4.71 (d, 1H, *J* = 1.7 Hz, H-1), 4.47 (d, 1H, *J* = 11.1 Hz, CH*H* Bn), 4.33 – 4.26 (m, 2H, H-4, H-6'), 4.24 – 4.18 (m, 2H, H-2, H-6), 4.08 (t, 1H, *J* = 9.3 Hz, H-3'), 4.02 (dd, 1H, *J* = 9.9, 2.9 Hz, H-3), 3.93 – 3.70 (m, 4H, H-5, H-5', H-6, H-6'), 3.63 (t, 1H, *J* = 9.4 Hz, H-4'), 3.56 (dd, 1H, *J* = 9.3, 3.9 Hz, H-2'), 3.36 (s, 3H, CH_3 OMe); ^{13}C-APT NMR ($CDCl_3$, 101 MHz, HSQC, HMBC): δ 139.1, 138.6, 138.5, 137.9, 137.5 (C_q), 129.1, 129.0, 128.5, 128.4, 128.3, 128.3, 128.3, 128.0, 127.9, 127.9, 127.8, 127.6, 127.6, 126.1, 126.1 (CH_{arom}), 101.3, 101.3, 101.2 (CHPh, C-1'), 98.0 (C-1), 82.1 (C-4'), 79.4 (C-2'), 79.3 (C-4), 77.9 (C-3'), 76.9 (C-3), 75.3 (CH_2 Bn), 74.4 (C-2), 74.0, 71.9 (CH_2 Bn), 69.1 (C-6'), 68.8 (C-6), 64.4 (C-5), 63.0 (C-5'), 54.9 (OMe); ^{13}C-HMBC NMR ($CDCl_3$, 101 MHz): δ 101.3 ($J_{C1',H1'}$ = 168 Hz, C-1' α), 98.0 ($J_{C1',H1'}$ = 170 Hz, C-1' α); HRMS: $[M+NH_4]^+$ calcd for $C_{48}H_{54}NO_{11}$ 820.36914, found 820.36958.

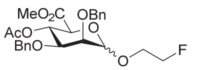


Methyl (cyclohexyl 4-*O*-acetyl-2,3-di-*O*-benzyl-α/β-D-mannopyranosyl uronate) (3A). Donor **3** and cyclohexanol were condensed using the general procedure for Tf_2O/Ph_2SO mediated glycosylations (for an additional 16 hours at -40°C) and purified by flash column chromatography (9/1 to 4/1 pentane/EtOAc) to yield glycosylation product **3A** (42.5 mg, 83 µmol, 83%, α:β = 1:8.3). R_f: 0.46 (7/3 pentane/EtOAc). IR (neat): 1026, 1047, 1105, 1238, 1368, 1452, 1740, 1751, 2855, 2930; Data for the β-anomer: ^{1}H NMR (400 MHz, $CDCl_3$, HH-COSY, HSQC): δ 7.48 – 7.18 (m, 10H, CH_{arom}), 5.50 (t, 1H, *J* = 9.7 Hz, H-4), 5.00 (d, 1H, *J* = 12.8 Hz, C*H*H Bn), 4.88 (d, 1H, *J* = 12.8 Hz, CH*H* Bn), 4.54 (s, 1H, H-1), 4.46 (d, 1H, *J* = 12.4 Hz, C*H*H Bn), 4.31

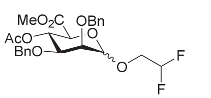
(d, 1H, *J* = 12.4 Hz, CH*H* Bn), 3.84 (d, 1H, *J* = 2.8 Hz, H-2), 3.82 (d, 1H, *J* = 9.7 Hz, H-5), 3.73 (s, 3H, CH_3 CO_2Me), 3.73 – 3.65 (m, 1H, CH Cy), 3.46 (dd, 1H, *J* = 9.8, 2.9 Hz, H-2), 2.02 (s, 3H, CH_3 OAc), 1.99 – 1.21 (m, 15H, CH_2 Cy); ^{13}C-APT NMR (101 MHz, $CDCl_3$, HSQC): δ 169.7, 168.3 (C=O CO_2Me, Ac), 138.6, 138.0 (C_q), 128.7, 128.5, 128.2, 127.8, 127.5, 127.5 (CH_{arom}), 99.5 (C-1), 78.7 (C-3), 77.0 (CH Cy), 74.0 (C-5), 73.9 (CH_2 Bn), 73.4 (C-2), 71.4 (CH_2 Bn), 69.1 (C-4), 52.7 (CH_3 CO_2Me), 33.4, 31.4, 25.8, 23.9 (CH_2 Cy), 21.0 (CH_3 Ac); Diagnostic peaks α-anomer: ^{1}H NMR (400 MHz, $CDCl_3$, HH-COSY, HSQC): δ 5.50 (t, 0.12H, *J* = 9.7 Hz, H-4), 5.24 (d, 0.12H, *J* = 3.3 Hz, H-1), 4.78 (d, 0.12H, *J* = 12.0 Hz, C*H*H Bn), 4.68 (d, 0.12H, *J* = 12.4 Hz, CH*H* Bn); ^{13}C-APT NMR (101 MHz, $CDCl_3$, HSQC): δ 69.7 (C-1); HRMS: $[M+NH_4]^+$ calcd for $C_{29}H_{40}NO_8$ 530.27484, found 530.27495.



Methyl (ethyl 4-*O*-acetyl-2,3-di-*O*-benzyl-α/β-D-mannopyranosyl uronate) (3B). Donor **3** and ethanol were condensed using the general procedure for Tf_2O/Ph_2SO mediated glycosylations (for an additional 16 hours at -40°C) and purified by flash column chromatography (9/1 to 4/1 pentane/EtOAc) to yield glycosylation product **3B** (43.4 mg, 95 µmol, 95%, α:β = 1:8.3). R_f: 0.36 (7/3 pentane/EtOAc). IR (neat): 735, 1026, 1047, 1103, 1229, 1369, 1454, 1744, 2924; Data for the β-anomer: ^{1}H NMR (400 MHz, $CDCl_3$, HH-COSY, HSQC): δ 7.68 – 7.15 (m, 10H, CH_{arom}), 5.51 (t, 1H, *J* = 9.5 Hz, H-4), 4.96 (d, 1H, *J* = 12.6 Hz, C*H*HBn), 4.84 (d, 1H, *J* = 12.6 Hz, CH*H* Bn), 4.48 (d, 1H, *J* = 12.4 Hz, C*H*H Bn), 4.43 (s, 1H, H-1), 4.33 (d, 1H, *J* = 12.4 Hz, CH*H* Bn), 4.02 (dq, 1H, *J* = 9.2, 7.1 Hz, C*H*HCH_3 Et), 3.88 (d, 1H, *J* = 2.8 Hz, H-2), 3.84 (d, 1H, *J* = 9.5 Hz, H-5), 3.73 (s, 3H, CH_3 CO_2Me), 3.54 – 3.44 (m, 2H, H-3, CH*H*CH_3 Et, H-3), 2.02 (s, 3H, CH_3 OAc), 1.27 (t, 3H, *J* = 7.0 Hz, CH_3 Et); ^{13}C-APT NMR (101 MHz, $CDCl_3$, HSQC): δ 169.7, 168.2 (C=O CO_2Me, Ac), 138.5, 137.9 (C_q), 129.4, 128.6, 1285, 128.2, 124.9 (CH_{arom}), 101.5 (C-1), 78.2 (C-3), 73.9 (CH_2 Bn), 73.9 (C-5), 73.1 (C-2), 71.4 (CH_2 Bn), 69.1 (C-4), 65.9 (CH_2 Et), 52.7 (CH_3 CO_2Me), 21.0 (CH_3 Ac), 15.2 (CH_3 Et); ^{13}C-GATED NMR (101 MHz, $CDCl_3$): δ 101.5 ($J_{C1,H1}$ = 160 Hz, C-1 β); Diagnostic peaks α-anomer: ^{1}H NMR (400 MHz, $CDCl_3$, HH-COSY, HSQC): δ 5.51 (t, 0.12H, H-4), 5.13 (d, 0.12H, *J* = 4.3 Hz, H-1), 4.78 (d, 0.12H, *J* = 12.4 Hz, C*H*H Bn), 4.68 (d, 0.12H, *J* = 12.3 Hz, CH*H* Bn), 3.67 (s, 0.36H, CH_3 CO_2Me). ^{13}C-APT NMR (101 MHz, $CDCl_3$) δ 98.4 (C-1), 77.4 (C-3), 74.6 (C-5), 73.2 (CH_2 Bn), 72.5 (CH_2 Bn), 69.5 (CH_2 Et), 52.6 (CH_3 CO_2Me); HRMS: $[M+Na]^+$ calcd for $C_{25}H_{30}O_8Na$ 481.18329, found 481.18250.

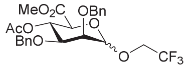


Methyl (2-fluoroethyl 4-*O*-acetyl-2,3-di-*O*-benzyl-α/β-D-mannopyranosyl uronate) (3C). Donor **3** and 2-fluoroethanol were condensed using the general procedure for Tf_2O/Ph_2SO mediated glycosylations (for an additional 16 hours at -40°C) and purified by flash column chromatography (9/1 to 7/3 pentane/EtOAc) to yield glycosylation product **3C** (33.2 mg, 70 µmol, 70%, α:β = 1:5). R_f: 0.18 (7/3 pentane/EtOAc). IR (neat): 1045, 1103, 1231, 1369, 1454, 1746, 2895, 2924; Data for the β-anomer: ^{1}H NMR (400 MHz, $CDCl_3$, HH-COSY, HSQC): δ 7.69 – 7.18 (m, 10H, CH_{arom}), 5.52 (t, 1H, *J* = 9.3 Hz, H-4), 4.95 (d, 1H, *J* = 12.5 Hz, C*H*H Bn), 4.83 (d, 1H, *J* = 12.5 Hz, CH*H* Bn), 4.76 – 4.94 (m, 2H, CH_2F), 4.54 (s, 1H, H-1), 4.49 (d, 1H, *J* = 12.4 Hz, C*H*H Bn), 4.34 (d, 1H, *J* = 12.4 Hz, CH*H* Bn) 4.13 (dddd, 1H, *J* = 37.0, 12.2, 3.3, 2.2 Hz, C*H*HCH_2F), 3.95 (d, 1H, *J* = 2.6 Hz, H-2), 3.86 (d, 1H, *J* = 9.2 Hz, H-5), 3.84 – 3.74 (m, 1H, CH*H*CH_2F), 3.72 (s, 3H, CH_3 CO_2Me), 3.49 (dd, 1H, *J* = 9.4, 2.9 Hz, H-3), 2.10 – 1.94 (s, 3H, CH_3 OAc); ^{13}C-APT NMR (101 MHz, $CDCl_3$, HSQC): δ 169.7, 168.1 (C=O CO_2Me, Ac), 138.3, 137.81 (C_q), 131.2, 129.46, 128.6, 128.5, 128.4, 128.3, 128.0, 127.9, 127.7, 127.7, 127.6, 124.9 (CH_{arom}), 101.6 (C-1), 82.96 (d, *J* = 169.5 Hz, CH_2F), 77.9 (C-3), 74.5 (CH_2 Bn), 74.1 (C-5), 73.8 (C-2), 72.9 (CH_2 Bn), 69.01 (d, *J* = 19.5 Hz, *CH_2*CH_2F), 68.9 (C-4), 52.8 (CH_3 CO_2Me), 21.0 (CH_3 Ac). ^{13}C-GATED NMR (101 MHz, $CDCl_3$) δ 101.6 ($J_{C1,H1}$ = 156 Hz, C-1); Diagnostic peaks α-anomer: ^{1}H NMR (400 MHz, $CDCl_3$, HH-COSY, HSQC): δ 5.52 (t, 0.20H, *J* = 9.3 Hz, H-4), 5.19 (d, 0.20H, *J* = 4.7 Hz, H-1), 3.66 (s, 0.60H, CH_3 CO_2Me), 2.04 (s, 0.6H, CH_3 OAc); ^{13}C-APT NMR (101 MHz, $CDCl_3$): δ 98.9 (C-1); HRMS: $[M+Na]^+$ calcd for $C_{25}H_{29}FO_8Na$ 499.17387, found 499.17297.

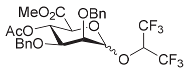


Methyl (2,2-difluoroethyl 4-*O*-acetyl-2,3-di-*O*-benzyl-α/β-D-mannopyranosyl uronate) (3D). Donor **3** and 2,2-difluoroethanol were condensed using the general procedure for Tf_2O/Ph_2SO mediated glycosylations (for an additional 16 hours at -40°C) and purified by flash column chromatography (9/1 to 7/3 pentane/EtOAc) to yield glycosylation product **3D** (43.1 mg, 87 µmol, 87%, α:β = 1:4.2). R_f: 0.51 (7/3 pentane/EtOAc). IR (neat): 737, 1026, 1051, 1078, 1232, 1439, 1454, 1741, 2870, 2924; Data for the β-anomer: ^{1}H NMR (400 MHz, $CDCl_3$, HH-COSY, HSQC): δ 7.57 – 7.12 (m, 10H, CH_{arom}), 5.94 (dddd, 1H, *J* = 56.7, 54.4, 5.7, 2.5 Hz, CH_2C*H*F_2), 5.54 (t, 1H, *J* = 8.9 Hz, H-4), 4.89 (d, 1H, *J* = 12.4 Hz, C*H*H Bn), 4.78 (d, 1H, *J* = 12.4 Hz, C*H*H Bn), 4.56 (s, 1H, H-1), 4.53 (d, 1H, *J* = 12.3 Hz, C*H*H Bn), 4.38 (d, 1H, *J* = 12.4 Hz, C*H*H Bn), 4.19 – 4.04 (m, 1H, C*H*HCHF_2), 3.92 (d, 1H, *J* = 2.1 Hz, H-2), 3.89 (d, 1H, *J* = 8.7 Hz, H-5), 3.80 – 3.67 (m, 1H, C*H*HCHF_2), 3.70 (s, 3H, CH_3 CO_2Me), 3.52 (dd, 1H, *J* = 9.0, 2.9 Hz, H-3), 2.03 (s, 3H, CH_3 OAc); ^{13}C-APT NMR (101 MHz, $CDCl_3$, HSQC):δ 169.7, 167.9 (C=O CO_2Me, Ac), 138.1, 137.8 (C_q), 131.2, 129.5, 128.5, 128.3, 127.9, 127.8, 127.6, 124.9 (CH_{arom}), 114.3 (dd, *J* = 242.2, 239.7 Hz, CHF_2), 101.3 (C-1), 77.4 (C-3), 74.0 (CH_2 Bn), 73.6 (C-5), 72.8 (C-2), 71.7 (CH_2 Bn), 69.0 (C-4) 68.5 (dd, *J* = 31.2, 25.6 Hz, *CH_2*CHF_2), 52.8 (CH_3 CO_2Me), 21.0 (CH_3 Ac); ^{13}C-GATED NMR (101 MHz, $CDCl_3$): δ 101.3

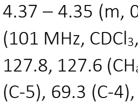
($J_{C1,H1}$ = 160 Hz, C-1 β); Diagnostic peaks α-anomer: ^{1}H NMR (400 MHz, $CDCl_3$, HH-COSY, HSQC): δ 5.52 (t, 0.24H, *J* = 11.2 Hz, H-4), 5.23 (d, 0.24H, *J* = 5.6 Hz, H-1), 3.64 (s, 0.72H, CH_3 CO_2Me); ^{13}C-APT NMR (101 MHz, $CDCl_3$, HSQC):δ 99.31 (C-1), 75.45 (C-3), 74.47 (C-2), 73.41 (CH_2 Bn), 69.46 (C-4), 52.61 (CH_3 CO_2Me); HRMS: $[M+NH_4]^+$ calcd for $C_{25}H_{32}F_2NO_8$ 512.20905, found 512.20889.



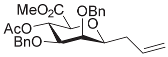
Methyl (2,2,2-trifluoroethyl 4-*O*-acetyl-2,3-di-*O*-benzyl-α/β-D-mannopyranosyl uronate) (3E). Donor **3** and 2,2,2-trifluoroethanol were condensed using the general procedure for Tf_2O/Ph_2SO mediated glycosylations (for an additional 24 hours at -40°C) and purified by flash column chromatography (9/1 to 7/3 pentane/EtOAc) to yield glycosylation product **3E** (43.7 mg, 85 µmol, 85%, α:β = 1:2.6). R*f*: 0.60 (9/1 pentane/EtOAc). IR (neat): 741, 1058, 1161, 1234, 1280, 1371, 1443, 1748, 2854, 2924; Data for the β-anomer: ^{1}H NMR (400 MHz, $CDCl_3$, HH-COSY, HSQC): δ 7.83 – 6.86 (m, 10H, CH_{arom}), 5.55 (t, 1H, *J* = 8.6 Hz, H-4), 4.90 (d, 1H, *J* = 12.3 Hz, C*H*H Bn), 4.78 (d, 1H, *J* = 12.4 Hz, CH*H* Bn), 4.65 (s, 1H, H-1), 4.54 (d, 1H, *J* = 12.3 Hz, C*H*H Bn), 4.37 (d, 1H, *J* = 12.3 Hz, CH*H* Bn), 4.35 – 4.23 (m, 1H, C*H*HCF_3), 3.98 – 3.94 (m, 2H, CH*H*CF_3, H-2), 3.92 (d, 1H, *J* = 8.3 Hz, H-5), 3.69 (s, 3H, CH_3 CO_2Me), 3.54 (dd, 1H, *J* = 8.8, 2.8 Hz, H-3), 2.03 (s, 3H, CH_3 OAc); ^{13}C-APT NMR (101 MHz, $CDCl_3$, HSQC): δ 169.7, 167.8 (C=O CO_2Me, Ac), 137.9, 137.8 (C_q), 131.2, 129.5, 129.5, 128.5, 128.5, 128.3, 128.0, 127.9, 127.8, 127.5 (CH_{arom}), 123.8 (q, *J* = 278.7 Hz, CF_3), 100.8 (C-1), 77.1 (C-3), 73.8 (CH_2 Bn), 73.6 (C-5), 72.4 (C-2), 71.7 (CH_2 Bn), 69.0 (C-4), 66.1 (q, *J* = 34.8 Hz, *CH_2*CF_3), 52.8 (CH_3 CO_2Me), 21.0 (CH_3 Ac); ^{13}C-GATED NMR (101 MHz, $CDCl_3$): δ 100.8 ($J_{C1,H1}$ = 160 Hz, C-1 β); Diagnostic peaks α-anomer: ^{1}H NMR (400 MHz, $CDCl_3$, HH-COSY, HSQC): δ 5.51 (t, 0.38H, *J* = 5.5 Hz, H-4), 5.27 (d, 0.38H, *J* = 5.6 Hz, H-1), 4.23 – 4.12 (m, 0.38H, C*H*HCHF_2), 3.86 (dd, 0.38H, *J* = 6.2, 3.0 Hz, H-3); ^{13}C-APT NMR (101 MHz, $CDCl_3$, HSQC): δ 99.1 (C-1), 75.4 (C-3), 74.3 (C-2), 73.5 (CH_2 Bn), 72.9 (CH_2 Bn), 69.4 (C-4), 52.6 (CH_3 CO_2Me), 21.0 (CH_3 Ac); ^{13}C-GATED NMR (101 MHz, $CDCl_3$) δ 99.1 ($J_{C1,H1}$ = 172 Hz, C-1 α); HRMS: $[M+Na]^+$ calcd for $C_{25}H_{27}F_3O_8Na$ 535.15502, found 535.15415.



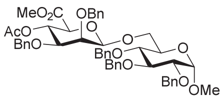
Methyl (1,1,1,3,3,3-hexafluoro-2-propyl 4-*O*-acetyl-2,3-di-*O*-benzyl-α/β-D-mannopyranosyl uronate) (3F). Donor **3** and 1,1,1,3,3,3-hexafluoro-2-propanol were condensed using the general procedure for Tf_2O/Ph_2SO mediated glycosylations (for an additional 240 hours at -40°C) and purified by flash column chromatography (9/1 to 4/1 pentane/EtOAc) to yield glycosylation product **3F** (30.1 mg, 52 µmol, 52%, α:β = 1:1). R*f*: 0.85 (α), 0.75 (β) (7/3 pentane/EtOAc). IR (neat): 1105, 1371, 1454, 1751, 2872, 2924; Data for the β-anomer: ^{1}H NMR (400 MHz, $CDCl_3$, HH-COSY, HSQC): δ 7.72 – 7.13 (m, 10H, CH_{arom}), 5.55 (t, 1H, *J* = 9.5 Hz, H-4), 4.92 (d, 1H, *J* = 12.3 Hz, C*H*H Bn), 4.78 (d, 1H, *J* = 12.1 Hz, CH*H* Bn), 4.74 (s, 1H, H-1), 4.51 (d, 1H, *J* = 12.3 Hz, C*H*H Bn), 4.72 – 4.56 (m, 1H, $CH(CF_3)_2$) 4.36 (d, 1H, *J* = 12.7 Hz, CH*H* Bn), 3.99 (d, 1H, *J* = 2.5 Hz, H-2), 3.87 (d, 1H, *J* = 9.4 Hz, H-5), 3.73 (s, 3H, CH_3 CO_2Me), 3.50 (dd, 1H, *J* = 9.6, 2.8 Hz, H-3), 2.02 (s, 3H, CH_3 OAc); ^{13}C-APT NMR (101 MHz, $CDCl_3$, HSQC): δ 169.6, 167.3 (C=O CO_2Me, Ac), 137.8, 137.5 (C_q), 128.6, 128.5, 128.4, 128.0, 128.0, 127.8, 127.6, (CH_{arom}), 120.8 (q, *J* = 281.0 Hz, CF_3), 100.3 (C-1), 78.0 (C-3), 74.3 (CH_2 Bn), 73.9 (C-5), 72.8 (C-2), 72.4 (CH_2 Bn), 71.8 (hept, *J* = 33.0 Hz, *CH*$(CF_3)_2$), 68.5 (C-4), 53.0 (CH_3 CO_2Me), 20.9 (CH_3 Ac); ^{13}C-GATED NMR (101 MHz, $CDCl_3$): δ 100.3 ($J_{C1,H1}$ = 165 Hz, C-1 β); Diagnostic peaks α-anomer: ^{1}H NMR (400 MHz, $CDCl_3$, HH-COSY, HSQC): δ 5.49 (t, 0.90H, *J* = 5.6 Hz, H-4), 5.39 (d, 0.90H, *J* = 5.5 Hz, H-1), 4.72 – 4.56 (m, 4.5H, C*H*H Bn, CH*H* Bn, C*H*H Bn, CH*H* Bn, $CH(CF_3)_2$), 4.37 – 4.35 (m, 0.90H, H-5), 3.84 (dd, 0.90H, *J* = 6.0, 2.9 Hz, H-3), 3.68 (dd, 0.90H, *J* = 5.5, 2.8 Hz, H-2). ^{13}C-APT NMR (101 MHz, $CDCl_3$, HSQC):δ 169.9, 168.3 (C=O CO_2Me, Ac), 137.8, 137.65 (C_q), 128.6, 128.5, 128.4, 128.0, 128.0, 127.9, 127.8, 127.6 (CH_{arom}), 100.0 (C-1), 75.4 (C-3), 74.3 (CH_2 Bn), 74.3 (C-2), 73.7 (C-2), 73.17 (d, *J* = 32.8 Hz, *CH*$(CF_3)_2$), 72.7 (C-5), 69.3 (C-4), 52.7 (CH_3 CO_2Me), 21.0 (CH_3 Ac); ^{13}C-GATED NMR (101 MHz, $CDCl_3$): δ 100.0 ($J_{C1,H1}$ = 175 Hz, C-1 α); HRMS: $[M+NH_4]^+$ calcd for $C_{26}H_{30}F_6NO_8$ 598.18707, found 598.18711.



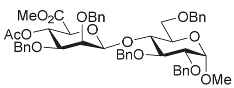
Methyl (4-*O*-acetyl-2,3-di-*O*-benzyl-1-deoxy-β-deuterio-D-mannopyranosyl uronate) (3G). Donor **3** and triethylsilane-D were condensed using the general procedure for Tf_2O/Ph_2SO mediated glycosylations (for an additional 240 hours at -40°C) and purified by flash column chromatography (9/1 to 7/3 pentane/EtOAc) to yield glycosylation product **3G** (39.6 mg, 95 µmol, 95%, α:β = <1:20). R*f*: 0.45 (7/3 pentane/EtOAc). $[\alpha]_D^{26}$ = -34.4° (*c* = 0.5, $CHCl_3$); IR (neat): 698, 736, 1051, 1136, 1228, 1371, 1454, 1745, 2872, 2924; Data for the β-anomer: ^{1}H NMR (400 MHz, $CDCl_3$, HH-COSY, HSQC, NOESY) δ 7.39 – 7.17 (m, 10H, CH_{arom}), 5.60 (dd, 1H, *J* = 4.9, 3.5 Hz, H-4), 4.63 (s, 2H, CH_2 Bn), 4.53 (s, 2H, CH_2 Bn), 4.19 (d, 1H, *J* = 3.2 Hz, H-5), 3.81 (m, 2H, H-2, H-3), 3.68 (d, 1H, *J* = 3.9 Hz, H-1), 3.61 (s, 3H, CH_3 CO_2Me), 2.06 (s, 3H, CH_3 OAc); ^{2}H NMR (61 MHz, $CHCl_3$) δ 4.73 (D-1); ^{13}C-APT NMR (101 MHz, $CDCl_3$, HSQC, HMBC): δ 169.9, 168.9 (C=O CO_2Me, Ac), 138.1, 137.8 (C_q), 131.2, 129.4, 128.6, 128.5, 128.4, 127.9, 127.8, 127.8, 127.8, 124.9 (CH_{arom}), 73.8 (C-5), 73.4 (C-3), 72.3 (CH_2 Bn), 71.4 (C-2), 71.3 (CH_2 Bn), 70.0 (C-4), 62.4 (C-1), 52.4 (CH_3 CO_2Me), 21.1 (CH_3 Ac). HRMS: $[M+Na]^+$ calcd for $C_{23}H_{25}DO_7Na$ 438.16335, found 438.16264.



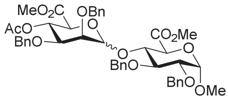
Methyl (allyl 4-*O*-acetyl-2,3-di-*O*-benzyl-1-deoxy-β-D-mannopyranosyl uronate) (3H). Donor **3** and allyl trimethylsilane were condensed using the general procedure for Tf_2O/Ph_2SO mediated glycosylations (for an additional 96 hours at -40°C) and purified by flash column chromatography (9/1 to 7/3 pentane/EtOAc) to yield glycosylation product **3H** (18.3 mg, 40 µmol, 40%, α:β = <1:20). R_f: 0.25 (8/2 pentane/EtOAc). $[\alpha]_D^{20}$ = -38.8° (*c* = 1, $CHCl_3$); IR (neat): 696, 735, 1026, 1055, 1114, 1228, 1368, 1746, 2855, 2924; Data for the β-anomer: ^1H NMR (400 MHz, $CDCl_3$, HH-COSY, HSQC, NOESY): δ 7.36 – 7.20 (m, 10H, CH_{arom}), 5.71 – 5.58 (m, 1H, C*H*CH_2 allyl), 5.53 (t, 1H, *J* = 9.8 Hz, H-4), 5.07 – 4.95 (m, 1H, CHC*H₂* allyl), 5.01 (d, 1H, *J* = 11.5 Hz, C*H*H Bn), 4.72 (d, 1H, *J* = 12.2 Hz, C*H*H Bn), 4.66 (d, 1H, *J* = 11.6 Hz, CH*H* Bn), 4.61 (d, 1H, *J* = 12.2 Hz, CH*H* Bn), 3.83 (d, 1H, *J* = 9.9 Hz, H-5), 3.79 (d, 1H, *J* = 2.3 Hz, H-2), 3.71 (s, 3H, CH_3 CO_2Me), 3.60 (dd, 1H, *J* = 9.9, 2.7 Hz, H-3), 3.36 (t, 1H, *J* = 7.1 Hz, H-1), 2.56 – 2.48 (m, 1H, C*H*HCH allylic), 2.40 – 2.26 (m, 1H, CH*H*CH), 2.01 (s, 3H, CH_3 OAc); ^{13}C-APT NMR (101 MHz, $CDCl_3$, HSQC, HMBC): δ 169.9, 168.5 (C=O CO_2Me, Ac), 138.3, 138.0 (C_q), 134.0 (*CH*CH_2 allyl), 131.3, 131.2, 129.4, 129.1, 128.6, 128.6, 128.6, 128.5, 128.4, 128.3, 128.1, 128.1, 128.0, 127.9, 127.8, 127.7, 127.6, 127.6, 124.9 (CH_{arom}), 117.9 (CH*CH₂* allyl), 88.6 (H-3), 79.1 (H-1), 77.6 (C-5), 74.5 (CH_2 Bn), 73.7 (C-2), 72.6 (CH_2 Bn), 69.5 (C-4), 52.7 (CH_3 CO_2Me), 35.4 (*CH₂*CH allyl), 21.0 (CH_3 Ac); HRMS: $[M+NH_4]^+$ calcd for $C_{26}H_{34}NO_7$ 472.23298, found 472.23294.



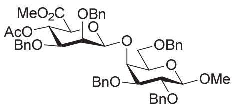
Methyl 6-*O*-(methyl [4-*O*-acetyl-2,3-di-*O*-benzyl-β-D-mannopyranosyl uronate])-2,3,4-tri-*O*-benzyl-α-D-glucopyranoside (30). Donor **3** and acceptor **10** were condensed using the general procedure for Tf_2O/Ph_2SO mediated glycosylations (for an additional 16 hours at -40°C) and purified by flash column chromatography (9/1 to 7/3 pentane/EtOAc) to yield glycosylation product **30** (57.5 mg, 66 µmol, 66%, α:β = <1:20). R_f: 0.54 (7/3 pentane/EtOAc). Spectroscopic data were in accord with those previously reported.[113] $[\alpha]_D^{26}$ = -11,6° (*c* = 1, $CHCl_3$), (lit:[113] $[\alpha]_D^{22}$ = -11.0° (*c* = 0.6, $CHCl_3$)). IR (neat): 733, 906, 1028, 1055, 1101, 1242, 1361, 1452, 1748, 2908; Data for the β-anomer: ^1H NMR (400 MHz, $CDCl_3$, HH-COSY, HSQC, HMBC): δ 7.40 – 7.19 (m, 25H, CH_{arom}), 5.48 (t, 1H, *J* = 9.6 Hz, H-4'), 5.02 (d, 1H, *J* = 10.9 Hz, C*H*H Bn), 4.91 (d, 1H, *J* = 12.6 Hz, C*H*H Bn), 4.83 (d, 1H, *J* = 10.9 Hz, CH*H* Bn), 4.82 (d, 1H, *J* = 11.7 Hz, C*H*H Bn), 4.80 – 4.71 (m, 3H, CH*H* Bn, CH*H* Bn, C*H*H Bn), 4.67 (d, 1H, *J* = 12.2 Hz, CH*H* Bn), 4.57 (d, 1H, *J* = 3.5 Hz, H-1), 4.50 (d, 1H, *J* = 4.4 Hz, CH*H* Bn), 4.47 (d, 1H, *J* = 5.3 Hz, C*H*H Bn), 4.36 (d, 1H, *J* = 12.4 Hz, CH*H* Bn), 4.16 – 4.09 (m, 2H, H-6, H-1'), 4.01 (t, 1H, *J* = 9.2 Hz, H-3), 3.79 (dq, 1H, *J* = 7.3, 2.8, 1.7 Hz, H-5), 3.74 (d, 1H, *J* = 9.5 Hz, H-5'), 3.72 – 3.66 (m, 4H, CH_3 CO_2Me, H-2'), 3.50 (dd, 1H, *J* = 9.7, 3.5 Hz, H-2), 3.45 – 3.34 (m, 3H, H-4, H-6, H-3'), 3.31 (s, 3H, CH_3 OMe), 2.02 (s, 3H, CH_3 OAc); ^{13}C-APT NMR (101 MHz, $CDCl_3$, HSQC, HMBC): δ 169.7, 168.1 (C=O CO_2Me, Ac), 138.9, 138.4, 138.1, 137.8 (C_q), 128.6, 128.5, 128.5, 128.5, 128.3, 128.3, 128.2, 128.1, 128.1, 127.9, 127.8, 127.8, 127.6, 127.6 (CH_{arom}), 101.7 (C-1'), 97.9 (C-1), 82.2 (H-3), 79.9 (H-2), 78.3 (H-3'), 77.7 (H-4), 75.9 (CH_2 Bn), 74.9 (CH_2 Bn), 73.8 (C-5'), 73.7 (CH_2 Bn), 73.5 (CH_2 Bn), 72.9 (C-2'), 71.6 (CH_2 Bn), 69.8 (C-5), 69.0 (C-4'), 68.8 (C-6), 55.2 (CH_3 OMe), 52.7 (CH_3 CO_2Me), 21.0 (CH_3 Ac); ^{13}C-GATED NMR (101 MHz, $CDCl_3$) δ 101.7 ($J_{C1,H1}$ = 155 Hz, C-1' β); HRMS: $[M+Na]^+$ calcd for $C_{51}H_{56}O_{13}Na$ 899.36131, found 899.36111.



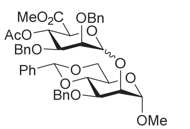
Methyl 4-*O*-(methyl [4-*O*-acetyl-2,3-di-*O*-benzyl-β-D-mannopyranosyl uronate])-2,3,6-tri-*O*-benzyl-α-D-glucopyranoside (31). Donor **3** and acceptor **11** were condensed using the general procedure for Tf_2O/Ph_2SO mediated glycosylations (for an additional 16 hours at -40°C) and purified by flash column chromatography (9/1 to 7/3 pentane/EtOAc) to yield glycosylation product **31** (53.1 mg, 61 µmol, 61%, α:β = <1:20). R_f: 0.65 (7/3 pentane/EtOAc); $[\alpha]_D^{26}$ = -30.2° (*c* = 1, $CHCl_3$). IR (neat): 733, 1026, 1096, 1366, 1454, 1746, 2920; Data for the β-anomer: ^1H NMR (400 MHz, $CDCl_3$, HH-COSY, HSQC, HMBC): δ 7.39 – 7.19 (m, 25H, CH_{arom}), 5.41 (t, 1H, *J* = 9.7 Hz, H-4'), 5.17 (d, 1H, *J* = 11.3 Hz, C*H*H Bn), 4.78 – 4.72 (m, 4H, CH*H* Bn, C*H*H Bn, CH*H* Bn, C*H*H Bn), 4.64 – 4.56 (m, 3H, CH*H* Bn, C*H*H Bn, H-1), 4.44 (d, 1H, *J* = 12.3 Hz, CH*H* Bn), 4.40 (s, 1H, H-1'), 4.36 (d, 1H, *J* = 12.3 Hz, C*H*H Bn), 4.28 (d, 1H, *J* = 12.1 Hz, CH*H* Bn), 3.89 (m, 2H, H-3, H-5), 3.68 – 3.63 (m, 1H,), 3.62 (d, 1H, *J* = 2.7 Hz, H-2'), 3.57 (d, 1H, *J* = 9.7 Hz, H-5'), 3.55 – 3.45 (m, 5H, H-2, CH_3 CO_2Me, C-6), 3.38 (s, 3H, CH_3 OMe), 3.18 (dd, 1H, *J* = 9.7, 2.8 Hz, H-3'), 2.01 (s, 3H, CH_3 OAc); ^{13}C-APT NMR (101 MHz, $CDCl_3$, HSQC, HMBC): δ 169.7, 167.9 (C=O CO_2Me, Ac), 139.6, 138.5, 138.3, 138.1, 137.9 (C_q), 128.7, 128.5, 128.5, 128.2, 128.2, 128.2, 128.2, 128.1, 128.0, 127.9, 127.9, 127.8, 127.5, 127.4, 127.1 (CH_{arom}), 101.1 (C-1'), 98.4 (C-1), 80.4 (C-3), 79.3 (H-2), 78.8 (C-3'), 78.2 (C-5), 75.4 (CH_2 Bn), 74.6 (C-2'), 74.2 (C-5'), 73.7 (CH_2 Bn), 73.7 (CH_2 Bn), 73.6 (CH_2 Bn), 71.8 (CH_2 Bn), 69.5 (H-4), 69.0 (C-4'), 68.7 (C-6), 55.4 (CH_3 OMe), 52.5 (CH_3 CO_2Me), 20.9 (CH_3 Ac); ^{13}C-GATED NMR (101 MHz, $CDCl_3$): δ 101.1 ($J_{C1,H1}$ = 158 Hz, C-1' β); HRMS: $[M+Na]^+$ calcd for $C_{51}H_{56}O_{13}Na$ 899.36131, found 899.36094.



Methyl (methyl 4-*O*-[methyl (4-*O*-acetyl-2,3-di-*O*-benzyl-α/β-D-mannopyranosyl uronate)]-2,3-di-*O*-benzyl-α-D-glucopyranosyl uronate) (32). Donor **3** and acceptor **12** were condensed using the general procedure for Tf_2O/Ph_2SO mediated glycosylations (for an additional 48 hours at -40°C) and purified by flash column chromatography (9/1 to 7/3 pentane/EtOAc) to yield glycosylation product **32** (58.0 mg, 71 μmol, 71%, α:β = 1:10). R*f*: 0.38 (7/3 pentane/EtOAc); $[\alpha]_D^{26}$ = -31.2° (*c* = 1, $CHCl_3$). IR (neat): 733, 1026, 1043, 1229, 1454, 1744, 2855, 2926; Data for the β-anomer: ^{1}H NMR (400 MHz, $CDCl_3$, HH-COSY, HSQC, HMBC): δ 7.42 – 7.23 (m, 20H, CH_{arom}), 5.44 (t, 1H, *J* = 9.8 Hz, H-4'), 5.19 (d, 1H, *J* = 11.3 Hz, C*H*H Bn), 4.88 – 4.69 (m, 4H, C*H*H Bn, CH*H* Bn, C*H*H Bn, CH*H* Bn), 4.62 – 4.38 (m, 5H, CH*H* Bn, C*H*H Bn, C*H*H Bn, H-1', H-1), 4.08 (d, 1H, *J* = 9.3 Hz, H-5), 3.96 – 3.85 (m, 2H, H-3, H-4), 3.76 (d, 1H, *J* = 2.7 Hz, H-2'), 3.70 (d, 1H, *J* = 9.7 Hz, H-5'), 3.59 (s, 3H, CH_3 CO_2Me), 3.53 – 3.46 (m, 4H, CH_3 CO_2Me, H-2), 3.46 – 3.37 (m, 4H, CH_3 OMe, H-3'), 2.00 (s, 3H, CH_3 OAc); ^{13}C-APT NMR (101 MHz, $CDCl_3$, HSQC, HMBC): δ 170.2, 169.8, 167.8 (C=O CO_2Me, Ac), 139.4, 138.6, 138.1, 137.9 (C_q), 128.6, 128.5, 128.5, 128.5, 128.4, 128.3, 128.3, 128.2, 128.2, 128.1, 127.9, 127.8, 127.7, 127.6, 127.5, 127.2 (CH_{arom}), 102.3 (C-1'), 98.9 (C-1), 80.7 (C-4), 80.0 (C-3), 78.6 (C-2), 78.4 (C-3'), 75.7 (CH_2 Bn), 74.7 (C-2'), 74.5 (CH_2 Bn), 73.9 (CH_2 Bn, C-5'), 71.8 (CH_2 Bn), 69.6 (C-5), 69.0 (C-4'), 56.0 (CH_3 OMe), 52.6 (CH_3 CO_2Me), 52.5 (CH_3 CO_2Me), 20.9 (CH_3 Ac); ^{13}C-GATED NMR (101 MHz, $CDCl_3$): δ 102.3 ($J_{C1,H1}$ = 154 Hz, C-1' β); Diagnostic peaks α-anomer: ^{1}H NMR (400 MHz, $CDCl_3$, HH-COSY, HSQC): 5.44 (m, 0.20H, H-1', H-4'), 2.00 (s, 0.30H, CH_3 OAc); HRMS: $[M+Na]^+$ calcd for $C_{45}H_{50}O_{14}Na$ 837.30928, found 837.30903.



Methyl 4-*O*-(methyl [4-*O*-acetyl-2,3-di-*O*-benzyl-β-D-mannopyranosyl uronate])-2,3,6-tri-*O*-benzyl-β-D-galactopyranoside (33). Donor **3** and acceptor **13** were condensed using the general procedure for Tf_2O/Ph_2SO mediated glycosylations (for an additional 16 hours at -40°C) and purified by flash column chromatography (9/1 to 7/3 pentane/EtOAc) to yield glycosylation product **33** (66.8 mg, 76 μmol, 76%, α:β = <1:20). R*f*: 0.39 (7/3 pentane/EtOAc); $[\alpha]_D^{26}$ = -31.6° (*c* = 1, $CHCl_3$). IR (neat): 735, 1026, 1051 1231, 1748, 2870; Data for the β-anomer: ^{1}H NMR (400 MHz, $CDCl_3$, HH-COSY, HSQC, HMBC): δ 7.35 – 7.22 (m, 25H, CH_{arom}), 5.45 (t, 1H, *J* = 9.8 Hz, H-4'), 4.95 (d, 1H, *J* = 12.7 Hz, C*H*H Bn), , 4.93 (d, 1H, *J* = 10.9 Hz, CH*H* Bn), 4.85 (d, 1H, *J* = 12.7 Hz, CH*H* Bn), 4.78 (d, 1H, *J* = 11.7 Hz, C*H*H Bn), 4.75 (s, 1H, H-1'), 4.67 (d, 1H, *J* = 11.0 Hz, CH*H* Bn), 4.60 (d, 1H, *J* = 11.7 Hz, C*H*H Bn), 4.58 (d, 1H, *J* = 11.7 Hz, CH*H* Bn), 4.51 (d, 1H, *J* = 11.7 Hz, CH*H* Bn), 4.43 (d, 1H, *J* = 12.3 Hz, C*H*H Bn), 4.30 (d, 1H, *J* = 7.6 Hz, H-1), 4.22 (d, 1H, *J* = 12.3 Hz, CH*H* Bn), 4.15 (d, 1H, *J* = 2.5 Hz, H-2), 3.95 (d, 1H, *J* = 2.8 Hz, H-2'), 3.90 (dd, 1H, *J* = 9.7, 6.3 Hz, H-6), 3.74 (dd, 1H, *J* = 9.6, 5.7 Hz, H-6), 3.70 – 3.63 (m, 2H, H-5, H-5'), 3.63 – 3.56 (m, 7H, H-4, CH_3 OMe, CH_3 CO_2Me), 3.56 – 3.50 (m, 1H, H-3), 3.24 (dd, 1H, *J* = 9.8, 2.9 Hz, H-3'), 1.99 (s, 3H, CH_3 OAc); ^{13}C-APT NMR (101 MHz, $CDCl_3$, HSQC, HMBC): δ 169.8, 168.1 (C=O CO_2Me, Ac), 138.8, 138.7, 138.3, 138.0 (C_q), 128.7, 128.6, 128.5, 128.3, 128.2, 128.0, 127.9, 127.8, 127.8, 127.7, 127.5, 127.5 (CH_{arom}), 105.1 (C-1), 101.9 (C-1'), 81.8 (C-3), 79.6 (C-5), 79.0 (C-3'), 75.1 (CH_2 Bn), 73.9 (C-5), 73.8 (CH_2 Bn), 73.6 (CH_2 Bn), 73.6 (C-4), 73.2 (C-2), 72.5 (C-2'), 71.3 (CH_2 Bn), 69.4 (C-6), 68.9 (C-4'),57.2 (CH_3 CO_2Me), 52.6 (CH_3 OMe), 20.9 (CH_3 Ac); HRMS: $[M+Na]^+$ calcd for $C_{51}H_{56}O_{13}Na$ 899.36131, found 899.36109.



Methyl 2-*O*-(methyl [4-*O*-acetyl-2,3-di-*O*-benzyl-α/β-D-mannopyranosyl uronate])-3-*O*-benzyl-4,6-bezylidene-α-D-mannopyranoside (34). Donor **3** and acceptor **14** were condensed using the general procedure for Tf_2O/Ph_2SO mediated glycosylations (for an additional 16 hours at -40°C) and purified by flash column chromatography (9/1 to 7/3 pentane/EtOAc) to yield glycosylation product **34** (60.4 mg, 77 μmol, 77%, α:β = 1:7.1). R*f*: .34 (7/3 pentane/EtOAc); $[\alpha]_D^{26}$ = -48.6° (*c* = 1, $CHCl_3$). IR (neat): 735, 1026, 1053, 1230, 1369, 1454, 1748, 2868, 2924; Data for the β-anomer: ^{1}H NMR (400 MHz, $CDCl_3$, HH-COSY, HSQC, HMBC): δ 7.51 – 7.22 (m, 15H, CH_{arom}), 5.60 – 5.53 (m, 2H, H-4', C*H*Ph), 5.02 (d, 1H, *J* = 12.5 Hz, C*H*H Bn), 4.93 (d, 1H, *J* = 12.5 Hz, CH*H* Bn), 4.83 (d, 1H, *J* = 12.1 Hz, C*H*H Bn), 4.72 (d, 1H, *J* = 1.1 Hz, H-1), 4.64 (d, 1H, *J* = 12.1 Hz, CH*H* Bn), 4.62 (s, 1H, H-1'), 4.50 (d, 1H, *J* = 12.4 Hz, C*H*H Bn), 4.36 – 4.31 (m, 2H, CH*H* Bn, H-2), 4.29 – 4.24 (m, 1H, H-6), 4.15 – 4.07 (m, 1H, H-4), 4.01 – 3.91 (m, 2H, H-2', H-3), 3.85 (d, 1H, *J* = 9.7 Hz, H-5'), 3.82 – 3.75 (m, 2H, H-5, H-6), 3.63 (s, 3H, CH_3 CO_2Me), 3.48 (dd, 1H, *J* = 9.7, 2.9 Hz, H-3'), 3.35 (s, 3H, CH_3 OMe), 2.03 (s, 3H, CH_3 OAc); ^{13}C-APT NMR (101 MHz, $CDCl_3$, HSQC, HMBC): δ 169.7, 167.9 (C=O CO_2Me, Ac), 138.8, 138.5, 137.8, 137.7 (C_q), 129.0, 128.7, 128.5, 128.4, 128.4, 128.4, 128.3, 128.3, 127.9, 127.9, 127.8, 127.8, 127.7, 127.6, 127.5, 127.4, 126.3, 126.2 (C_{arom}), 101.8 (CHPh), 99.8 (C-1'), 99.2 (C-1), 78.5 (C-4), 78.2 (C-3), 74.0 (C-5'), 73.9 (H-2), 73.9 (H-3), 73.9 (CH_2 Bn), 73.0 (H-2'), 71.3 (CH_2 Bn), 71.0 (CH_2 Bn), 69.0 (C-6), 68.8 (C-4'), 64.1 (H-5), 55.1 (CH_3 OMe), 52.7 (CH_3 CO_2Me), 21.0 (CH_3 Ac); ^{13}C-GATED NMR (101 MHz, $CDCl_3$): δ 99.8 ($J_{C1,H1}$ = 154 Hz, C-1' β); Diagnostic peaks α-anomer: ^{1}H NMR (400 MHz, $CDCl_3$, HH-COSY, HSQC, HMBC): 5.59 (s, 0.14H, C*H*Ph), 5.50 (t, 0.14H, *J* = 7.5 Hz, H-4'), 5.45 (d, 0.14H, *J* = 4.0 Hz, H-1'), 3.66 (s, 0.42H, CH_3 CO_2Me), 3.35 (s, 0.42H, CH_3 OMe), 2.03 (s, 0.42H, CH_3 OAc); ^{13}C-APT NMR (101 MHz, $CDCl_3$, HSQC, HMBC): δ 100.3 (C-1'), 69.5 (C-4'); HRMS: $[M+NH_4]^+$ calcd for $C_{44}H_{52}NO_{13}$ 802.34332, found 802.34387.

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