Structure-reactivity relationships in glycosylation chemistry

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Structure-reactivity relationships in glycosylation chemistry

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Contents

Abbreviations

A.	Acinetobacter
Ac	acetyl
ACN	acetonitrile
AIBN	2,2’-azobis(2-methylpropionitrile)
APT	attached proton test
aq.	aqueous
Arom	aromatic
B	boat
B3LYP	Becke, 3-parameter, Lee-Yang-Parr
BAIB	(diacetoxyiodo)benzene
Bn	benzyl
bs	broad singlet
Bu	butyl
Bz	benzoyl
C	chair
cal	calorie
calcd	calculated
cat.	Catalytic
CCSDT	coupled cluster single-double-triple
CEL	conformational energy landscape
CIP	contact ion pair
COSY	correlation spectroscopy
C_q	quaternary carbon atom
CSA	camphor-10-sulfonic acid
δ	chemical shift
d	doublet
DBTO	dibutyltin oxide
DCE	1,2-dichloroethane
DCM	dichloromethane
dd	double doublet
ddd	doublet of double doublets
dddd	double doublet of double doublets
DDQ	2,3-Dichloro-5,6-dicyano-1,4-benzoquinone
ddt	doublet of double triplets
DFE	difluoroethanol
DFT	density function theory
DIAD	diisopropyl azocarboxylate
DIPEA	diisopropylethylamine
DLNPO	domain-based local pair natural orbital
DMAP	4-dimethylaminopyridine
DMBA	1,3-Dimethylbarbituric acid
DMF	*N,N*-dimethylformamide
DMP	Dess-Martin periodinane
DMSO	dimethylsulfoxide
dq	double quartet
dt	double triplet
dtd	doublet of triple doublets
DTBS	di-tert-butylsilylidene
E	energy
E	envelope
EDC(I)	1-Ethyl-3-(3-dimethylaminopropyl) carbodiimide
eq.	molar equivalent
Et	ethyl
E-X	electrophilic activator system
gg	gauche-gauche
gt	gauche-trans
GATED	proton decoupling applied only during relaxation
GlcNAc3NAcA	2,3-di-*N*-acetyl-D-glucuronic acid
h	hour(s)
H	half-chair
HFIP	hexafluoro-iso-propanol
HMBC	heteronuclear multiple-bond correlation spectroscopy
HMDS	hexamethyldisilazane
HRMS	high-resolution mass spectroscopy

HSQC	heteronuclear single quantum coherence
IR	infrared
IRIS	infrared ion spectroscopy
J	coupling constant
LAH	lithium aluminium hydride
Lev	Levulinoyl
LG	leaving group
M	molar
m	multiplet
m.s.	molecular sieves
m/z	mass over charge ratio
min	minute(s)
Me	methyl
MFE	monofluoroethanol
M.S.	molecular sieves
Ms	methanesulfonyl
Nap	2-methylnaphthyl
NIS	N-iodosuccinimide
NMR	nuclear magnetic resonance
NOESY	nuclear Overhauser effect spectroscopy
Nu	nucleophile
p	para
PG	protection group
PCM	polarizable continuum model
Ph	phenyl
PMB	4-methoxybenzyl
ppm	parts per million
PTFAI	2,2,2-Trifluoro-*N*-phenylacetimidoyl
PTSA	para-toluenesulfonic acid
q	quartet
qd	quartet of doublets
QuiNAc4NAc	2,4-di-*N*-acetyl-D-quinovose
R^2 or r^2	coefficient of determination
Rf	retention factor
RRV	relative reactivity value
rt	room temperature
rxn	reaction
s	singlet
S	skew boat
sat.	saturated
S_N1	uni-molecular nucleophilic substitution
S_N2	bi-molecular nucleophilic substitution
SSIP	solvent-separated ion pair
SAR	structure-activity-relationships
t	triplet
t	*tert*
T	twist
tg	trans-gauge
TBA	tetrabutylammonium
TBS	*tert*-butyldimethylsilyl
TBDMS	*tert*-butyldimethylsilyl
TBDPS	tert-butyldiphenylsilyl
TCA	trichloroacetyl
TES	triethylsilyl
TEMPO	2,2,6,6-tetramethylpiperidine 1-oxyl
TFA	trifluoroacetic acid
TFAA	trifluoroacetic anhydride
TFE	trifluoroethanol
Tf	trifluoromethanesulfonyl
THF	tetrahydrofuran
TIPS	tri-isopropylsilyl
TLC	thin layer chromatography
TMS	trimethylsilyl
TOCSY	total correlation spectroscopy
Ts	4-methylbenzene-1-sulfonyl
TS	transition state
td	triple doublet
tt	triple triplet
TTBP	2,4,6-tri-tert-butylpyrimidine
UV	ultraviolet
VT	variable temperature

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Chapter 1: General introduction

Introduction

Carbohydrates are a class of biopolymers with large variety in terms of both structure and function in both prokaryotes and eukaryotes. The main difference that separates carbohydrates from the other biopolymers (nucleotides and proteins) is that when two carbohydrate building blocks are linked together, a new stereocenter is introduced. The stereocenter is important for the properties of the carbohydrate, for example starch is a polymer of α 1→4 linked glucose and cellulose is a polymer of β 1→4 linked glucose (***Figure 1***).

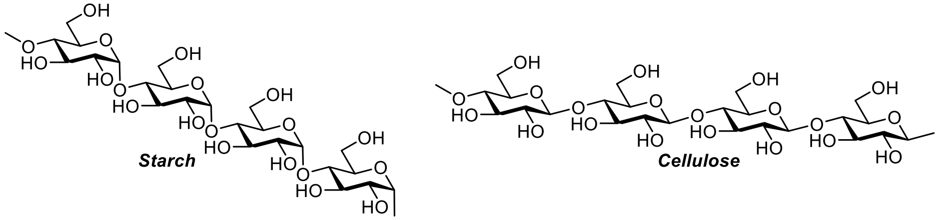
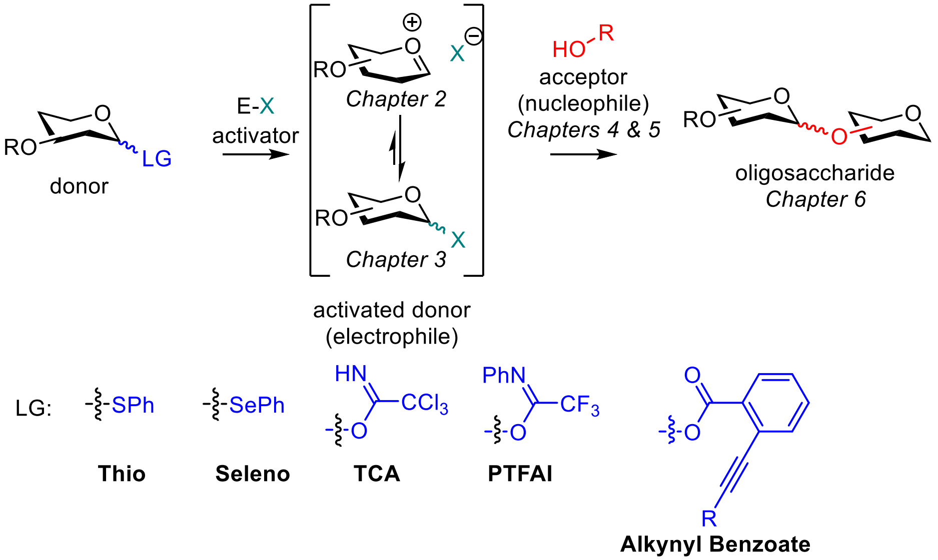


Figure 1: *Structure differences between starch and cellulose*

There are many (bio)medical applications of carbohydrates.[1-3] However, carbohydrates can be difficult to isolate from biological sources in sufficient quantify and purity. Therefore, chemical synthesis is an attractive alternative, because it allows for full control over the structure of the obtained product regarding properties including substitution pattern and chain length. The two main challenges in synthetic carbohydrate chemistry are regio- and/or chemoselective protection of hydroxyl- and other functional groups[4-7] and the stereoselective formation of a glycosidic bond.[8-12] This thesis will focus mainly on the latter.

Carbohydrate synthesis

A typical synthesis of a glycosidic bond is depicted in ***Scheme 1***. There are many variations in glycosylation protocols, but the vast majority of them follows this same scheme, where a donor with a latent leaving group reacts with an electrophilic activator. Examples of leaving groups include thio- or selenophenol, which are activated by a stoichiometric amount of an electrophilic promotor such as NIS/TMSOTf or a sulfoxonium ion, generated from, for example, Ph_2SO/Tf_2O[13-16]. A different class of leaving groups are the glycosyl imidates (most importantly the trichloroacetimidate (TCA) or *N*-phenyl trifluoroacetimidate (PTFAI) donors), which are activated by a catalytic amount of Lewis- or Brønsted acid such as $BF_3.OEt_2$, TMSOTf or TfOH.[17, 18] Another type of donor, introduced by Yu and coworkers, are the alkynyl benzoates, which can react under mild conditions catalysed by Au(I).[19] Upon activation of the donor, a mixture of electrophilic species is generated, varying from oxocarbenium ions, which react via a S_N1 like mechanism, to covalent species which react via a S_N2 mechanism with a nucleophile (acceptor). These are attacked by the incoming nucleophile leading to either the α-product, the β-product or a mixture of the two.[18]



Scheme 1: *General overview of a glycosylation reaction and the contents of this thesis*

Stereoselective glycosylation methods

Many methods have been developed for the stereoselective formation of a glycosidic bond (***Figure 2***). 1,2-Trans glycosidic bonds are usually relatively easy to construct using neighbouring group participation (***Figure 2A***), where an acyl type protecting group, usually an ester, amide or carbamate, is placed on O-2 or N-2. Upon activation of the donor, the carbonyl group reacts to form a dioxolenium ion, which reacts with an acceptor to form a 1,2-trans glycosidic bond.[20, 21] Participation of protecting groups on other positions has also been observed and used for the control of stereochemical outcome (*vide infra*). More recently, it has also been reported that alkoxymethyl protecting groups can provide 1,2-trans glycosidic bonds via a similar mechanism.[22]
For the formation of 1,2-cis glycosidic bond no such universally applicable technique exists, making the synthesis of these linkages more challenging.[11, 23] Nevertheless, multiple methods for the construction of these glycosidic bonds have been developed and this chapter will discuss a few examples.

Historically, the β-mannosidic bond was one of the most difficult ones to synthesize.[24] One method to synthesize this kind of glycosidic bond was developed by the laboratory of Crich, in which a benzylidene is used as a protecting group for the C-4-OH and C-6-OH (***Figure 2B***).[25, 26] Evidence based on variable temperature NMR,[27-29] and a combination of kinetic isotope effect[30] and cation clock experiments[31] show that the β-mannosidic bond is formed through a S_N2 reaction with the α-triflate, which is formed when the donor is activated with a triflate based promotor.[32] However, there is also evidence that the stereoselectivity can be explained via an S_N1 reaction via an oxocarbenium ion adopting a $B_{2,5}$-conformation.[33]

Another method for generating a 1,2-cis glycosidic bond based on the use of a cyclic protecting group on the C-4-OH and C-6-OH, is the use of a di-tert-butylsilylene (DTBS) group on galactose and galactosamine (***Figure 2C***). Introduced by Kiso and coworkers in 2003, glycosylation with this type of donor stereoselectively yields the α-galactoside, even when a participating group is present on C-2.[34] In the mechanism that explains this selectivity, an oxocarbenium ion is generated where the bulky DTBS group shields the top-side from attack by a nucleophile, so that only an attack from the bottom of the oxocarbenium ion is possible, which yields the α-product.[35]

Participation of the protecting group on C-2 has also been used to introduce a 1,2-cis glycosidic bond via a chiral auxiliary (***Figure 2D***). In this system, a nucleophilic group (for example CO_2Et[36] or SPh[37]) on the protecting group on C-2 reacts with the oxocarbenium ion upon activation of the donor. The *S*-configuration of the protecting group is necessary for the stabilisation of the *trans*-decalin species to form the desired α-product. When the corresponding *R*-configured protecting group was used, the *cis*-decalin intermediate was generated, delivering the β-product.[36, 37] Of note, the use of a non-chiral, nucleophilic protecting group on C-2 for the formation of α-glucosidic bonds was also described.[38-40]

The final two methods discussed in this chapter rely on “directing” the acceptor in the right direction, either through hydrogen bond formation (hydrogen bond mediated aglycon delivery, ***Figure 2E***) or by covalently attaching the acceptor to a protecting group on C-2 (intramolecular aglycon delivery, ***Figure 2F***). In hydrogen bond mediated aglycon delivery, a protecting group (in this case a picoloyl) with a hydrogen accepting functional group forms a hydrogen bond with the nucleophilic alcohol, which is then positioned on the “right” side of the reactive species to ensure a stereoselective glycosylation. This method has delivered β-mannosides using a C-3-picolyl ester[41], α-glucosides and α-xylosides using a C-4-picolyl ester[42,43], and β-glycosides and β-fructosides using a C-6-picolyl ester[44,45]. With intramolecular aglycon delivery, the protecting group on C-2 first forms a covalent bond with the acceptor. In the next step, an activator is added, and the 1,2-cis-glycosidic bond is formed. In the depicted example, the PMB protecting group is first oxidised to form an acetal with the acceptor, which in the next step forms the desired β-mannosidic bond. Other acetals, as well as silyl based protecting groups have also been described.[46, 47]

The reason that stereoselective glycosylation remains challenging is two-fold. For one part, solutions are usually target-oriented and the other reason is that there are multiple different mechanistic pathways that can lead to two different products and that the mechanistic pathways are influenced by external factors such as solvent, temperature and concentration, as well as properties inherent to the donor and the acceptor.[48] A better understanding of the mechanistic pathways and the factors that influence these makes it easier to rationalize and eventually predict the outcome of glycosylation reaction and as such will streamline the total synthesis of biologically relevant carbohydrates.

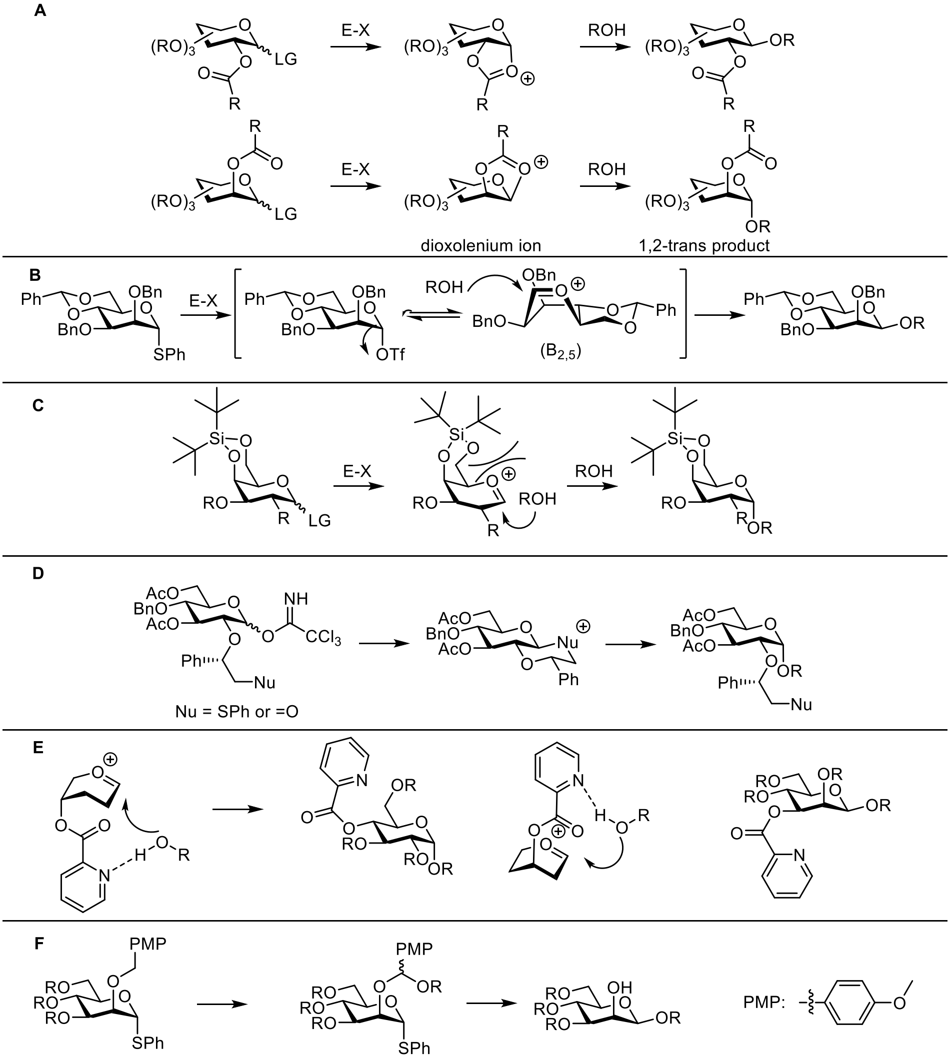


Figure 2: *Representative examples of methods for the stereoselective formation of glycosidic bonds. A: 1,2-Trans selective glycosylation through neighbouring group participation via a dioxolenium ion; B: β-Selective mannosylation via a conformationally restricted donor; C: α-Selective galactosylation using the bulky di-tert-butylsilylene (DTBS) group; D: α-Selective glucosylation using a chiral auxilary; E: 1,2-Cis selective glycosylation via hydrogen bond mediated aglycon delivery using the picoloyl (pico) protecting group; F) 1,2-Cis selective glycosylation via a covalent intermediate, using intramolecular aglycon delivery using the 4-methoxybenzyl (PMB) group as an example.*

Oxocarbenium ions in glycosylation reactions

In a S$_N$1 type glycosylation reaction, the acceptor reacts with an oxocarbenium ion to form a glycosidic bond. The stereochemical outcome of these reactions is determined by the conformation and reactivity of the corresponding oxocarbenium ion. Oxocarbenium ions typically take up either a $^3H_4$- or $^4H_3$-like conformation (***Figure 3***) and the relative stability of the two conformers depends on the substituents on the ring.[49] The two different conformations can give rise to opposite stereochemical outcomes of the glycosylation reactions. For a $^4H_3$ oxocarbenium ion, a top-faced attack will result in an unfavourable twist-boat like transition state, while a bottom-face attack proceeds through a favourable chair-like transition state, causing the $^4H_3$ oxocarbenium ions to be bottom-face selective. For the same reasons, $^3H_4$ oxocarbenium ions are top face selective (see ***Figure 3***).[50, 51] Consequently, this means that for D-configured hexoses, the $^4H_3$-configured oxocarbenium ion yields the α-product and the $^3H_4$-configured oxocarbenium ion yields the β-product. For L-configured hexoses the opposite is true.[52]

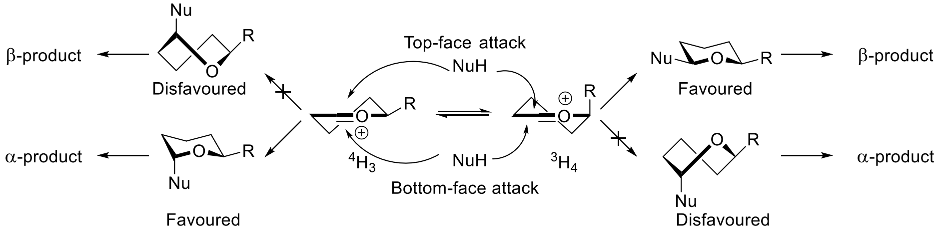


Figure 3: *Equilibrium between $^3H_4$ and $^4H_3$ oxocarbenium ions and mechanistic explanation why $^3H_4$-like oxocarbenium ions are Top-face selective and why $^4H_3$-like oxocarbenium are bottom face selective. Prediction for the formation of an α- or β-product from a conformation is based on D-configured carbohydrates, for L-configured carbohydrates, the opposite product is formed.*

The effects of single substituents on the $^4H_3$/$^3H_4$ equilibrium of oxocarbenium ions, and by extension the outcome of S$_N$1 reactions were first experimentally investigated by Woerpel and coworkers, who found that *O*-alkyl substituents on C-3 and C-4 prefer a pseudo-axial orientation in the oxocarbenium ion half chairs, due to electrostatic stabilisation of the positive charge, while alkyl substituents on the same positions prefer a pseudo-equatorial orientation because of steric reasons.[51, 53-55]

A more quantitative investigation of the reactivity of oxocarbenium ions was recently reported by Hansen *et al.*[56] A combination of computational chemistry, superacid NMR[57] and model glycosylations with deuterium nucleophiles was used to show that a S$_N$1 type glycosylation reactions with fully functionalised glycosyl donors are typically highly 1,2-cis selective.

Another technique used to characterise glycosyl cations is infrared ion spectroscopy (IRIS).[58, 59] In this technique, glycosyl cations are generated in the gas phase, for example by ion collision. The cations are then measured using IR spectroscopy. This technique has been used to study the formation of oxocarbenium and dioxolenium ions, formed by attack of the carbonyl group of one of the protecting groups (as is well described for neighbouring group participation from C-2, *vide supra*). The structures of dioxolenium ions were characterised using IRIS by Pagel and coworkers (***Figure 4A***), showing that the glucosyl 1,2-dioxolenium ion takes up a $^3S_1$ conformation, the mannosyl dioxolenium ion a $B_{O,3}$ conformation, and the galactose dioxolenium ion forms a mixture of ^4E and $^1S_3$ conformers.[21]

Acyl protecting group participation from other positions than C-2, has been less well understood than neighboring group participation by C-2-acyl groups. IRIS has been used to better understand remote participation of acyl groups on other positions than C-2.[58, 59] Rijs, Boltje and coworkers used a combination of NMR and IRIS to investigate the mechanisms behind the stereoselectivity of 3,6-uronic acid lactone donors. The high β-selectivity of the mannuronic acid 3,6-lactone donor was explained by participation from the acetyl group on C-4 via a dioxolenium ion with a $B_{1,4}$ conformation (***Figure 4B***).[60] To prove that the increased α-selectivity of 4-O-acetyl galactosyl donors (compared to per-benzyl donors) is due to remote participation, Marianski, Pagel and coworkers used IR spectroscopy to characterise a $^1S_5$ configured dioxolenium ion that is formed when a 4-O-acetyl galactosyl donor is activated (***Figure 4C***).[61]

Boltje, Codée and coworkers studied the stabilisation of uronic acid glycosyl cations through participation from a C-4 acetyl protecting group or participation from the ester on C-5 using IRIS. It was concluded that stabilisation happens mainly through participation of the C-5 carboxyl, when C-2 and C-5 are *cis*, as is the case with mannuronic and taluronic acid. When C-2 and C-5 are *trans*, as is the case for glucuronic and galacturonic acid, stabilisation mainly happens trough participation from the acetyl group on C-4. (***Figure 4D***) [62]

Finally, through a combination of experimental glycosylations, DFT-calculations and IR-spectroscopy, it was found that remote participation is particularly strong from the C-3 position of mannose, making glycosylations with these donors highly α-selective. The order of remote participation was found to be as follows (strongest to weakest) 3-Ac-Man » 4-Ac-Gal > 3-Ac-Glu ≈ 3-Ac-Gal > 4-Ac-Glu > 4-Ac-Man ≈ 6-Ac-Glc/Gal/Man.[63]

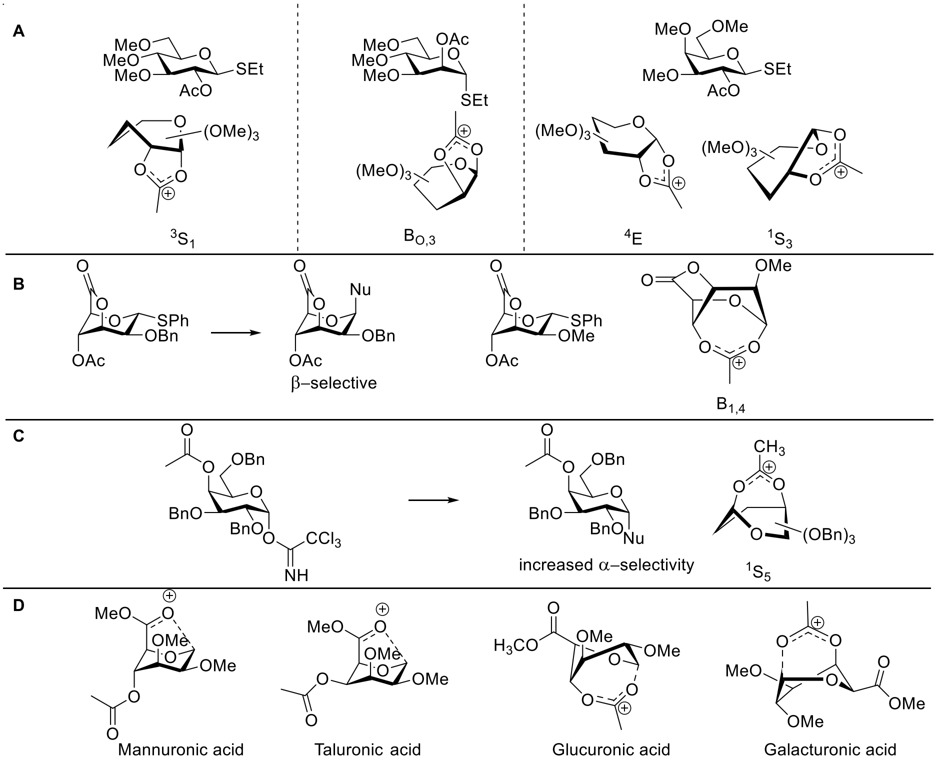


Figure 4: *Selected IRIS experiments. A: structures of glucose, mannose and galactose dioxolenium ions with neighbouring group participation.*[21] *B: the 3,6-mannuronic acid lactone donor is β-selective by participation of the acetyl group on C-4.*[60] *C: remote participation of the C-4-O-acetyl group on a galactose donor via a $^1S_5$ dioxolenium ion.*[62] *D: the structure of the dioxolenium ion of 4-O-acyl glucuronic acid donors is mainly determined by the stereochemistry of C-2. Mannuronic acid and taluronic acid show participation via C-5, while glucuronic acid and galacturonic acid show participation via C-4-O-acetyl.*[62]

Covalent species in glycosylation reactions

On the other side of the mechanistic spectrum of glycosylation reactions, are S_N2-like reactions, in which covalent reactive intermediates play a decisive role. Through *in-situ* anomerisation, first described by Lemieux and coworkers, a relatively stable and unreactive α-species is in equilibrium with a more reactive and less stable β-species. The equilibrium leans towards the side of the α-species, but the more reactive β-species can selectively react with an acceptor in an S_N2 reaction to form an α-glycosidic bond (***Figure 5A***).[64] Examples using this phenomenon have been described for bromides[65] and iodides[66-69] using a source of X^- ions, for example TBABr or TBAI.

Based on this mechanism, the use of nucleophilic additives to modulate the stereochemical outcome of the glycosylation reaction has been explored (***Figure 5B***). West and Schuerch used dimethylsulfide, triethylamine and triphenylphosphine for the modulation of methanolysis of glucosyl bromides. They proposed that through the formation of a β-adduct with the additive, the α-product is formed through an S_N2 mechanism. Dimethylsulfide gave a 6:1 α:β ratio, where triethylamine and triphenylphosphine gave full α-selectivity.[70] Amides are also used as glycosylation modulator. Koto and coworkers introduced *N,N*-dimethylacetamide (DMA) as an additive for the stereoselective synthesis of α-glucosides.[71-73] More recently *N,N*-dimethylformamide (DMF) was introduced as a glycosylation modulator by Mong and coworkers for the synthesis of α-glucosides[74] and α-2-deoxy or 2,6-deoxy sugars.[75] DMF was, however, less successful in the modulation of less reactive 2-azido-glycosyl donors. Therefore, *N*-formylmorpholine (NFM) was introduced to overcome the low reactivity issues. With NFM α-2-azido-glucosides and α-2-azido-galactosides could be synthesised with good yield and selectivity.[76] Of note, the amide additives work well for stereoselectivity modulation with secondary alcohols, but not that well with more reactive primary alcohols.

Based on their success with sulfur containing chiral auxiliaries (see above) Boons and coworkers investigated phenyl ethyl sulfide (PhSEt) and thiophene as additive for 1,2-cis glycosylation of α-2-azido-glucoside donors. With a disarmed donor, these additives gave good yield and selectivity. With an armed donor, significantly less selectivity was obtained.[77] Diphenyl sulfoxide was first introduced for dehydrative glycosylations by Gin and coworkers,[13] but is was also used as an additive for the glycosylation with sialic acid donors by Crich and Li (see also chapter 7), where it was shown that the sulfoxonium adduct plays an important role in ensuring a productive outcome of the glycosylation reaction.[78] Bennett and coworkers used 2,3-bis(2,3,4-trimethoxyphenyl)-cyclopropene-1-thione for stereoselective glycosylation 2,6-dideoxy sugars with a quaternary carbon on C-3 in the total synthesis of the antibiotic saccharomicin B.[79]

Like West and Schuerch, Ye and coworkers investigated phosphines for the synthesis of α-glucosides and galactosides. In a system based on urea catalysed glycosylation of chloride donors, they found tri-(2,4,6-trimethoxyphenyl)-phosphine to be the most effective.[80] The use of phosphine oxides was first described by Bogusiak and Szeja, who used HMPA as an additive for the stereoselective synthesis of α-xylofuranoses.[81] Later, Mukaiyama and coworkers further investigated the effect of different phosphine oxides with glycosyl bromides, iodides and acetates for the synthesis of α-glucosides. The inherent instability of glucosyl iodides was overcome by using TMSI and phosphine oxide on glucosyl acetates to generate the glucosyl iodide *in situ*.[82-84] Phosphine oxides were also used in the synthesis of α-ribofuranosides,[85] α-2-deoxyglycosides[86] and β-3-amino-2,3,6-trideoxy sugars.[87] A representative example which shows the synthetic utility of glycosylation modulated by nucleophilic additives was published by Wang *et* *al.* (***Figure 5C***). For secondary alcohols, DMF was used as an additive, while TMSI/$Ph_3P=O$ was used in glycosylations with primary alcohols in the stereoselective synthesis of the α-glucosidic bonds using an *in-situ* anomerisation mechanism.[88-90] In a similar way, methyl(phenyl)formamide was used for glucosazide donors.[76, 91]

The extent to which in-situ anomerisation plays a role in pre-activation based glycosylations which generate triflates as reactive species remains somewhat controversial, but recently, sophisticated NMR studies have also shown that in situ anomerisation can also play a role in glycosylations which have triflates as reactive intermediates (see below)

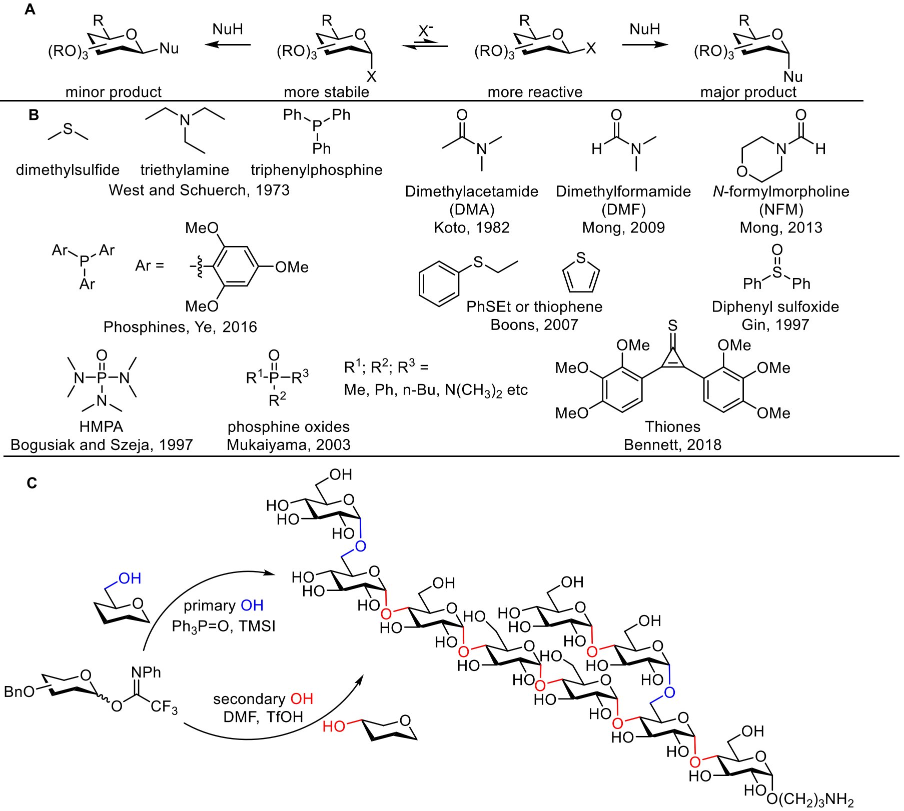


Figure 5: *A: explanation of in-situ anomerisation. B: Structures of additives used for the modulation of stereoselectivity in glycosylation reactions. C: representative synthesis of an oligosaccharide using additives by Wang et al.*[88]

Variable temperature NMR (VT –NMR) is a versatile technique to investigate the covalent reactive intermediates in glycosylation reactions. In this method, a donor and an activator are reacted in an NMR tube to enable the recording of NMR spectra of the reaction mixture at low temperature to characterise the reactive species that are formed. Many reactive intermediates, mostly triflates, have been characterised using this method. Frihed, Bols and Pedersen have provided an extensive review on glycosyl triflates[92] and a few representative examples will be highlighted here.

When trichloroacetimidates (TCA) are used as donor, the reactive intermediates that are formed are determined by the nature of the activator (***Figure 6A***). By using a combination of 1-H NMR, 19-F NMR and DOSY NMR, Qiao *et al.* showed that when triflate based activators are used, α-triflates can be formed, which eventually decompose to provide a mixture of α- and β-trichloroacetamides. With BF_3-Et_2O, the β-fluorides were formed, which isomerise to the α-anomer at higher temperature. When bistriflimide activators are used, the silylated donor was found to be formed as a reactive intermediate, which decomposes by an intramolecular Friedel-Crafts type reaction of the C-2-benzyl group.[93]

During the synthesis of mannuronic acid and 2- and 2,3-deoxy amino mannuronic acid containing bacterial oligosaccharides, Walvoort *et al.* characterised the triflates that are formed when the thio donors are activated with the Ph_2SO/Tf_2O reagent combination (***Figure 6B***). The α-triflate was formed exclusively in all cases, but two species were observed by VT-NMR, because the triflates were present as a conformational mixture of $^4C_1$ and $^1C_4$ conformers.[94-96]

During the total synthesis of a complex oligosaccharide from *Mycobacterium marinum* by Hansen *et al*, VT-NMR was used in the optimisation of glycosylations with rare caryophyllose donors (***Figure 6C***). When the alcohols on the side-chain on C-4 were protected with benzyl groups, the glycosylation reactions were unsuccessful due to the rapid formation of a bicyclic side product. When the benzyl groups were replaced by carbonate protecting groups, the caryophyllose β-oxosulfonium triflate was found as the main reactive intermediate, which successfully react to form the glycosylation products.[97]

Santana *et al.* have used VT-NMR to show that β-triflates play a role in glycosylation reactions of benzylidene protected glucosyl, mannosyl and allosyl donors, (***Figure 6D***). Normally, β-triflates are not visible in VT-NMR experiments due to their low concentration, but though a series of sophisticated 1D and 2D experiments it was possible to confirm their presence.[98]

The aforementioned formation of dioxolenium ions that occurs when there is a participating protecting group on C-2 can also be observed using VT-NMR (***Figure 6E***). When a peracetylthio glucosyl donor was activated with AgOTf/p-TolSCl in $CDCl_3$ at -60 °C, a 1:1 mixture of anomeric triflates and dioxolenium ions was obtained. Upon warming to -20 °C, the dioxolenium ion was converted into the α-triflate. When the mixture was recooled to -60 °C, the mixture of triflates and dioxolenium ions was formed again.[99]

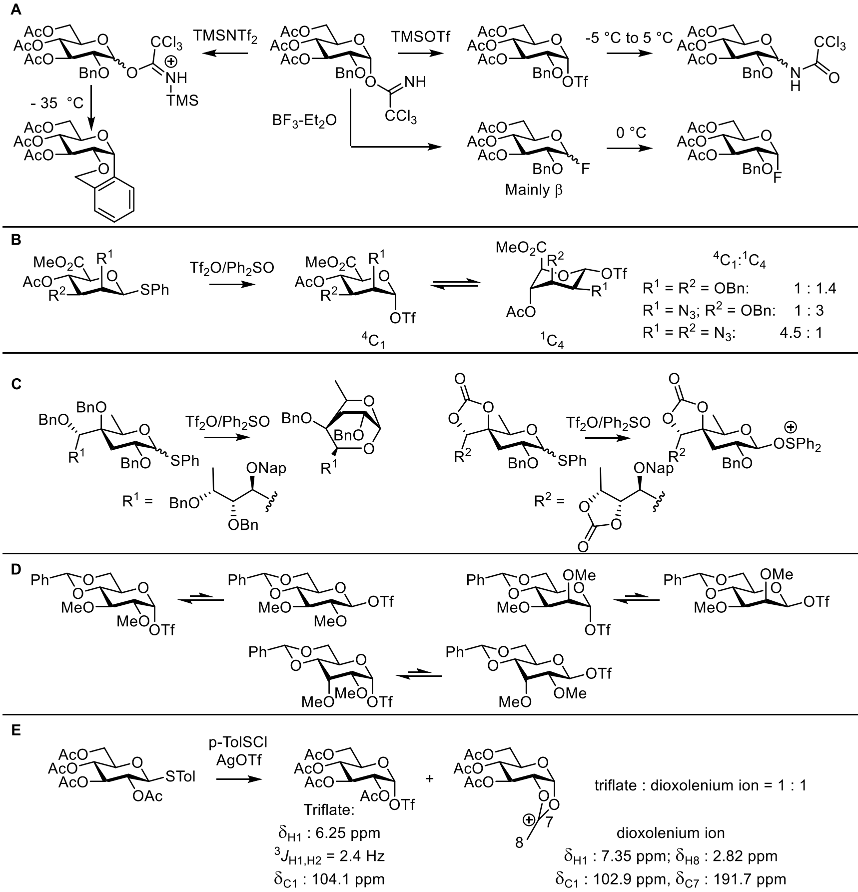


Figure 6: *Examples of VT-NMR used to investigate reactive intermediates formed in glycosylation reactions. A: Reactive species and decomposition products from a trichloroacetimidate donor with different activators.*[93] *B: Conformational equilibrium of triflates that form upon activation of the mannuronic acid donors.*[95] *C: Donor optimisation in the total synthesis of a Mycobacterium marinum Lipooligosaccharide.*[97] *D: In-situ anomerisation studied with VT-NMR.*[98] *E: The equilibrium between dioxolenium ions and anomeric triflates, observed by VT-NMR.*[99]

Acceptor reactivity

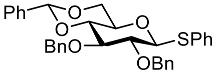
Influence of acceptor reactivity on the glycosylation reaction

The reactivity of the acceptor plays a crucial role in the outcome of a glycosylation reaction. The extent to which the reactivity of the acceptor affects the outcome depends heavily on other factors such as the reaction conditions and the donor. To understand the influence of acceptor reactivity on the outcome of glycosylation reactions, a series of model acceptors with varying nucleophilicity was introduced, with ethanol (EtOH) being the most nucleophilic and 1,1,1,3,3,3-hexafluoro-2-propanol (HFIP) the least.[100] The acceptors in this set are not chiral, so that any difference in stereochemical outcome is due to differences in nucleophilicity and not due to diastereomeric effects.[101] ***Table 1*** shows a few key results in recent studies.

Glucose, mannose and mannuronic acid donors (Donors **1**, **2** and **4**) were used by van der Vorm *et al.* to investigate the influence of acceptor nucleophilicity on the reaction mechanism of glycosylation reactions. This set of ethanol acceptors together with some carbohydrate acceptors show that more nucleophilic acceptors react via a S_N2 type mechanism, while less nucleophilic acceptors react via a mechanism with more S_N1 character.[102] In another study, it was shown that the stereoselectivity of conformationally restricted glucosazide donors **3** strongly depends on the nucleophilicity of the acceptor. This donor is more β-selective than its glucose counterpart, because the electron withdrawing azide on C-2 stabilises the α-triflate more, making a S_N2-type glycosylation more favourable.[103]

Hagen *et al.* have used the set of model acceptors to map the relation between acceptor nucleophilicity and stereoselectivity for 2-azidofucosyl donors (*e.g.* using donor **5**).[104] The set of fluorinated acceptors was also used by Hansen *et al.* to generate more insight into the reactivity of rare building blocks used in the synthesis of a complex oligosaccharide from *Mycobacterium marinum* (donors **6** and **7**).[97] Finally, this set of nucleophiles was also used in the aforementioned study on remote participation.[63]

Table 1: *Model glycosylations by van der Vorm et al. (**1-4**)[102, 103], Hagen et al. (**5**)[104] and Hansen et al. (**6** and **7**)[97] n.d. = not determined*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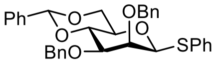
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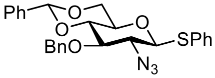
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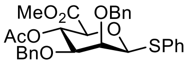
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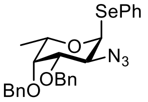
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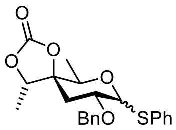
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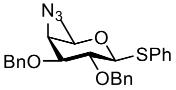
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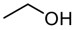
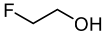
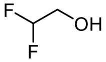

EtOH


MFE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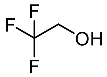
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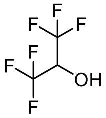
HFIP

Donor	**Acceptor (product, α:β,** yield)				
	EtOH	MFE	DFE	TFE	HFIP
1	**1A** **1:10** (83%)	**1B** **1:2.8** (70%)	**1C** **5:1** (90%)	**1D** **>20:1** (80%)	**1E** **>20:1** (65%)
2	**2A** **1:5** (70%)	**2B** **1:5** (86%)	**2C** **1:5** (90%)	**2D** **1:4** (78%)	**2E** **3:1** (56%)
3	**3A** **<1:20** (83%)	**3B** **1:6.7** (90%)	**3C** **2.9:1** (64%)	**3D** **>20:1** (94%)	**3E** **>20:1** (53%)
4	**4A** **1:8** (95%)	**4B** **1:6** (70%)	**4C** **1:5** (87%)	**4D** **1:2.5** (85%)	**4E** **1:1** (52%)
5	**5A** **1:1** (88%)	**5B** **1:1** (72%)	**5C** **2:1** (81%)	**5D** **19:1** (80%)	**n.d.**
6	**6A** **1:1** (60%)	**6B** **2:1** (76%)	**6C** **4:1** (100%)	**6D** **>20:1** (77%)	**6E** **>20:1** (28%)
7	**7A** **1.8:1** (87%)	**7B** **1:1.1** (100%)	**7C** **3.3:1** (91%)	**7D** **>20:1** (70%)	**7E** **>20:1** (69%)

Reactivity of carbohydrate acceptors

The glycosylations with fluorinated model acceptors highlight the importance of acceptor reactivity on the outcome of glycosylation reactions. But in contrast to glycosyl donors, where the structure-reactivity relations are relatively well described thank to spectroscopic and computational studies (see above) as well as measurement of relative reactivity values of thioglycosides,[105-107] factors influencing the reactivity of glycosyl acceptors are less well studied.[108] As described above, the stereochemical outcome of benzylidene glucose and glucosamine donors **1** and **3** highly depends on the nucleophilicity of the acceptor. This property was used to "measure" the reactivity of a large set of acceptors, all with systematic variations in stereochemistry and protecting group patterns. Screening of systematically varied sets of acceptors using this system shows how seemingly small changes on in the protecting group pattern of the acceptor can drastically change the reactivity of an acceptor. For example, when the C-3 protecting group of a C-4-OH glucose acceptor was changed from a benzyl to a sterically similar benzoyl group (effectively substituting a CH_2 group for a C=O group) the outcome of the glycosylation reaction changed from being unselective to fully α-selective and from β-selective to α-selective (***Figure*** *7*).[109]

A more systematic understanding of which factors influence the reactivity of the acceptor could also help developing a quantitative measurement system for the reactivity of acceptor reactivity, as proposed by Wong, Wang and coworkers.[110] This can in turn be used to measure the influence of acceptor reactivity on the outcome of glycosylation reactions.

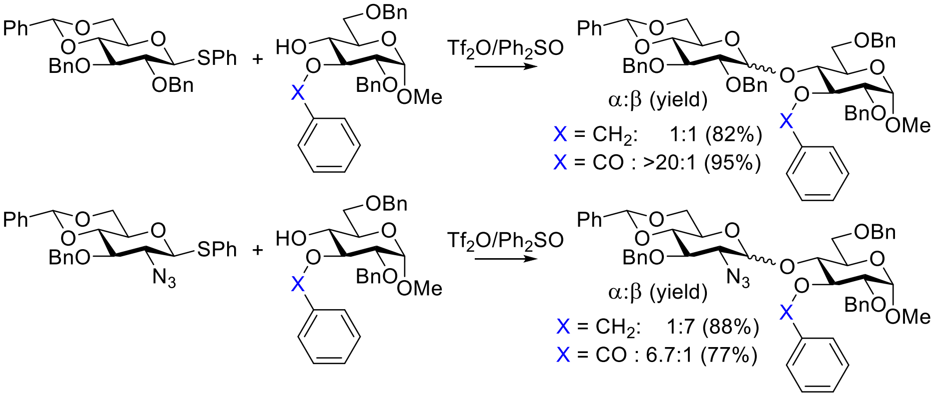

Figure 7: *Seemingly small differences in the glycosyl acceptors have a detrimental outcome on the glycosylation reaction in terms of stereoselectivity. Changing a* CH_2 *group into a C=O group on an acceptor reverses the stereoselectivity of the glycosylation reaction.*[109]

Contents

The aim of this thesis is to increase the understanding of several aspects of the glycosylation reaction and the influence of these on the (stereochemical) outcome, and as such make rational design of a synthesis route towards a target oligosaccharide possible.

Chapter 2 describes the synthesis of glycosyl donors of all the eight diastereomers of phenyl 2,3,4,6-tetra-*O*-benzyl-1-thio-β-pyranosyl donors, as well as their 6-deoxy analogues and studies the behaviour in S_N1-like reactions via computational and experimental chemistry.

Chapter 3 deals with the characterisation of reactive covalent species in S_N2 like reactions with VT-NMR and the investigation of the influence of nucleophilicity of oxygen nucleophiles on the mechanism of the glycosylation reaction.

Chapter 4 reports the structure-reactivity relationships of ether and ester protected carbohydrate acceptors using the stereoselectivity of two conformational restricted donors.

Chapter 5 builds on chapter 4 and outlines the influence of azides, trifluoro- and trichloroacetamides on the reactivity of different glycosyl acceptors.

Chapter 6 presents an application of the research as described in chapter 2-5 for the synthesis of an oligosaccharide with an unusual structure found in *Acinetobacter Baumannii*, an antibiotic resistant pathogen, through the mapping of the reactivity and selectivity of 2,3-di-*N*-acetlyglucuronic acid and bacillosamine donors and acceptors using VT-NMR and model glycosylations.

Chapter 7 provides a brief summary and gives some suggestions for further research.

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2

Chapter 2: Stereoselectivity of S_N1-like reactions of all eight diastereoisomeric pyranosyl and 6-deoxy pyranosyl donors with D- or C-nucleophiles

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Introduction

Despite significant progress over the last decades, the construction of a glycosidic bond in a stereoselective and high yielding way remains a challenging, time consuming and resource intensive operation for which no universal guidelines exist.[1-3] The outcome of a glycosylation reaction is dependent on properties inherent to the used building blocks, as well as on environmental factors, including but not limited to solvent, temperature and concentration.[4] The reason that the outcome of a reaction between a donor and an acceptor remains hard to predict, is the continuum of reaction mechanisms that can be followed to lead to two products (***Figure 1***). When a glycosyl donor (**I**) is activated by a promotor (E-X) a variety of reactive species can form (**II-VIII**), including α- or β-covalent species (**VIII** and **II** respectively) which react predominantly via a S_N2 mechanism and oxocarbenium ion like species (**III-VII**) which react in a S_N1-type fashion. Which pathways are followed depends on the reactivity of the donor and the incoming nucleophile (NuH) and the S_N2- and S_N1-type pathways can yield the α-product (**IX**), the β-product (**X**) or a mixture of the two.[5-8] In order to better understand, and eventually predict the outcome of a glycosylation reaction, it is essential to know which products can be formed by following the different mechanistic pathways. The covalent species involved in the S_N2 reactions can be studied by spectroscopic techniques and over the years multiple covalent species, such as triflates and oxosulfonium triflates, have been observed by the use of variable temperature NMR (VT-NMR).[9-16] On the other hand, oxocarbenium ions are more difficult to study due to their high reactivity and short lifetime, and currently no spectroscopic method exists to observe, let alone characterise oxocarbenium ions of relevant donors, in reaction-like media.

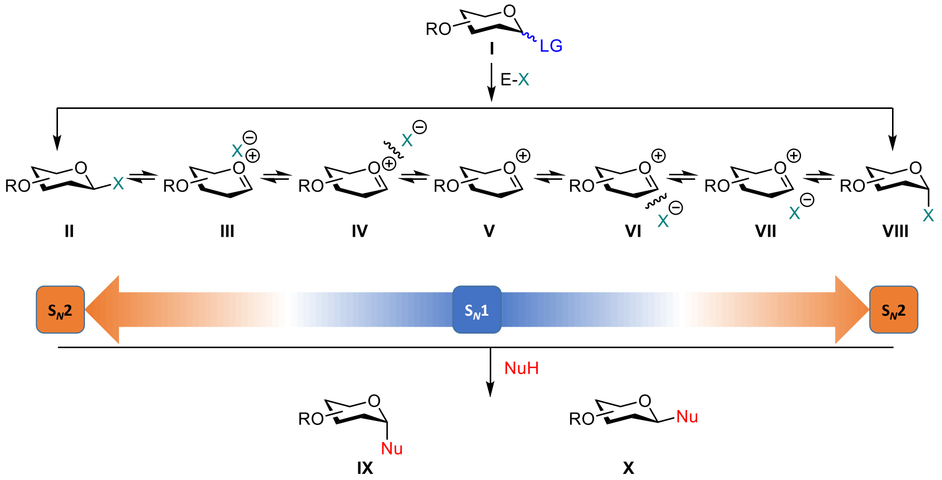
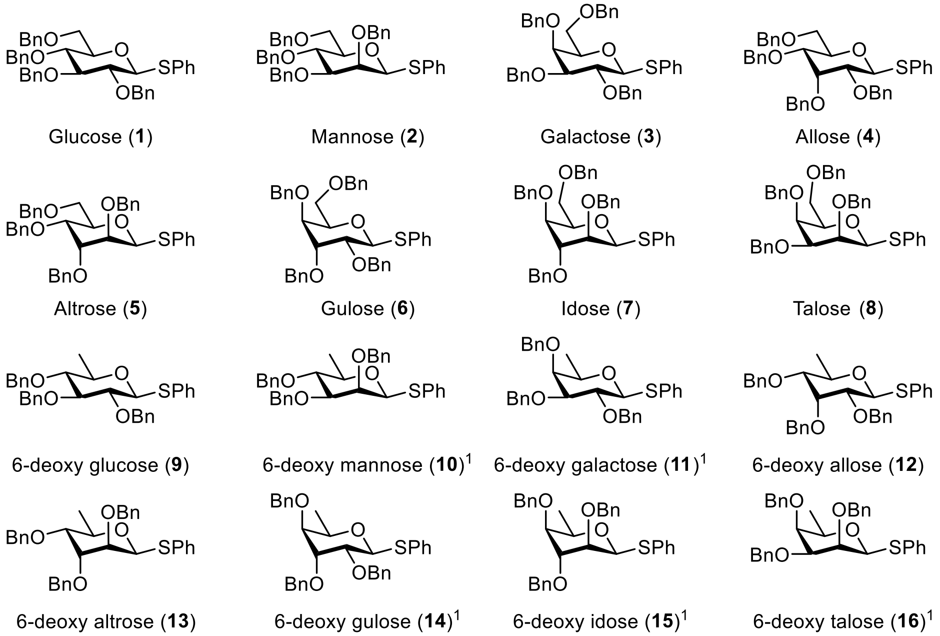


***Figure 1**: Mechanistic continuum of a glycosylation reaction, **II**, **VIII:** covalent species; **III**, **VII:** contact ion pair; **IV**, **VI:** solvent separated ion pair; **V:** oxocarbenium ion. this work investigates **V**. **LG:** leaving group, **E-X:** activator, **NuH**: nucleophile*

Over the last years, tremendous progress has been made in the understanding of glycosyl cations and their reactivity thanks to a combination of mechanistic experiments, NMR experiments in superacid media, IR spectroscopy, computational chemistry, or a combination thereof.[17-31] Understanding, and predicting the (stereochemical) outcome of S_N1 like glycosylation reactions remains challenging nonetheless. While it has long been clear that the conformational behaviour of oxocarbenium ions –and by extension the stereochemical outcome of S_N1 like reactions- is heavily dependent on the substitution pattern on the carbohydrate ring,[19, 31, 32] there is a need for more quantitative data on how the effects of the functional groups on C-2, C-3, C-4 and C-6 together impact the ions. In order to systematically investigate the combined effect of the ring substituents on fully decorated glycosyl oxocarbenium ions, here all 8 possible diastereoisomeric β-thiophenol 2,3,4,6-tetra-*O*-benzyl pyranosyl donors, as well their 6-deoxy counterparts (***Figure 2***) are probed in reactions that typically follow an S_N1-like pathway. To this end, the addition reactions of two nucleophiles, TES-D and allyl-TMS were studied. To investigate the conformational preferences of the involved oxocarbenium ions, conformational energy landscape (CEL) maps were generated using density functional theory (DFT) according to the recently published method by Hansen *et al.*[26] It has previously been reported that the outcome of addition reactions of TES-D to (partially stripped) glycosyl oxocarbenium ions can be rationalized using the most relevant conformers of the glycosyl oxocarbenium ions.[26] For some fully decorated glycosyl cations, however, the addition reactions of allyl-TMS proceeded with different selectivity that what would be expected based on the conformational preference of the intermediate glycosyl cations.

For example, the mannosyl donor **2** reacts with TES-D to selectively gives the β-product, which can be accounted for by the diastereoselective attack of the nucleophile on the β-face of the ${}^{3}H_{4}$-half chair oxocarbenium ion,[26] but the reaction with allyl-TMS under the same conditions gives a 66:34 α:β mixture. The systematic investigation of all possible diastereoisomeric pyranosyl oxocarbenium ions reported here reveals that the addition of TES-D to the oxocarbenium ions, in most cases, proceeds in a stereoselective fashion to provide the products derived from the most favourable oxocarbenium ions. However, when significant steric interactions develop between the incoming nucleophile and the ions and between substituents on the pyranosyl ring, additions to higher energy ions can become more favorable. The complete set of all eight possible pyranosyl diastereoisomers and the use of the two different nucleophiles has allowed to define these Curtin-Hammett kinetic scenarios, which all together provide a detailed picture of the interplay between oxocarbenium ion stability/reactivity, steric interactions in the developing transition states and nucleophile reactivity. These will be instrumental in the understanding and optimisation of the stereochemical outcome of glycosylation reactions.



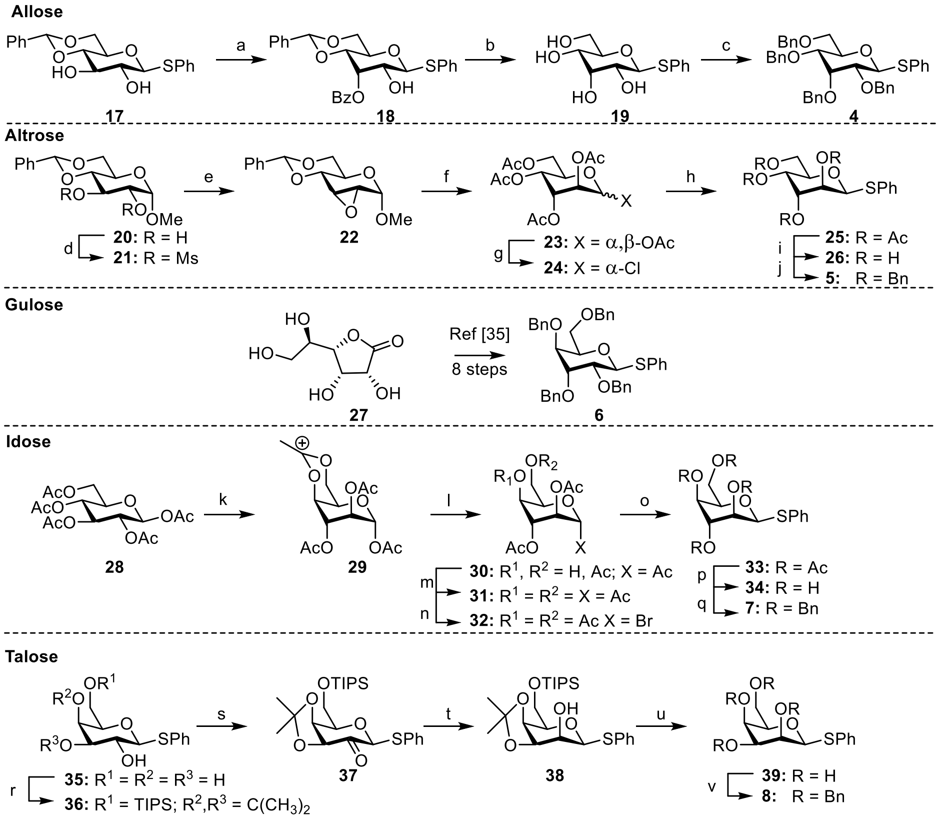
Glucose (**1**)
Mannose (**2**)
Galactose (**3**)
Allose (**4**)
Altrose (**5**)
Gulose (**6**)
Idose (**7**)
Talose (**8**)
6-deoxy glucose (**9**)
6-deoxy mannose (**10**)[1]
6-deoxy galactose (**11**)[1]
6-deoxy allose (**12**)
6-deoxy altrose (**13**)
6-deoxy gulose (**14**)[1]
6-deoxy idose (**15**)[1]
6-deoxy talose (**16**)[1]

***Figure 2**: structures of the donors (**1-16**) used in this study. [1]: The D-isomer is shown for ease of comparison, but the L-isomer is used in the experiments.*

Results and discussion:

Donor synthesis

The glycosyl donors, derived from monosaccharides that are commercially readily available (*i.e.* glucose, mannose, galactose, rhamnose and fucose), was achieved using the following (well-established) reaction sequence: acetylation, installation of the anomeric thiophenol group, deacetylation and benzylation.[26] The synthesis of the other diastereomers is depicted in ***Scheme 1*** (the 6-*O*-benzyl donors) and ***Scheme 2*** (the 6-deoxy sugars). Allose donor **4** was synthesized by the regioselective inversion of the C-3-OH of benzylidene protected glucose **17** via a Mitsunobu reaction with benzoic acid, followed by global deprotection and benzylation. Altrose **5** was synthesised by formation of 2,3-anhydro allose **22** from methyl 4,6-*O*-benzylidene-α-D-glucopyranose (**20**),[12] followed by sulfuric acid catalysed acetolysis.[33] The β-thiophenol moiety was installed by converting the anomeric acetyl group to a chloride using $SOCl_2/SnCl_4$,[34] followed by treatment with NaH/PhSH in DMF. Finally, the acetyl esters were replaced by benzyl ethers under standard conditions. D-Gulose donor **6** was prepared as previously described for the L-isomer,[35] using D-gulonic acid 1,4-lactone (**27**) as starting material. Idose donor **7** was synthesised by antimony(V) chloride mediated inversion of the C-1, C-2, C-3 and C-4 stereocenters of peracetylated glucose (**28**).[36] The β-thiophenol moiety was installed by converting the anomeric acetyl group to the anomeric α-bromide with HBr in acetic acid, followed by treatment with NaH/PhSH in DMF. Next the acetyl groups were replaced by benzyl groups. Finally, talose donor **8** was synthesised from partially protected galactose building block **36** by inversion of C-2 via an oxidation and reduction sequence, followed by acid catalysed deprotection of the TIPS-ether and isopropylidene groups and benzylation. The 6-deoxy glucose, allose and altrose donors were synthesised by deoxygenation of the C-6-*O*-tosyl precursors with lithium aluminium hydride, as shown in ***Scheme 2***. The 6-deoxy gulose donor **14** was synthesised from fucose building block **49**, which was transformed into 6-deoxygulose **50** in 5 steps according to literature procedure,[37] followed by deprotection and benzylation. Both the 6-deoxy idose and 6-deoxy talose donors were synthesised from 3,4-isopropylidene protected fucose building block **52**. The C-2-OH was inverted by oxidation with Dess-Martin periodinane followed by reduction with $NaBH_4$ to give talose configured building block **54**. The idose donor was obtained by removal of the isopropylidene, followed by regioselective benzoylation of the resulting diol, yielding compound **56**. Inversion of the free C-3-OH was then achieved by triflation followed by substitution with $TBANO_2$[38]. Unfortunately, the substitution reaction was accompanied by the formation of elimination products leading to a low yield of compound **58.**[*] Sufficient material could be generated nonetheless for the upcoming glycosylation studies. Debenzoylation followed by benzylation yielded donor **15**. Acidic deprotection followed by benzylation of compound **54** yielded talose donor **16**.



***Scheme 1**: synthesis of per-benzylated Allose (**4**), altrose (**5**), gulose (**6**), idose (**7**) and talose (**8**) β-thiophenol donors. Reagents and conditions: a) BzOH, Ph_3P, DIAD, THF, 70 °C, 52%; b) i: pTsOH, MeOH, 50 °C, ii: NaOMe, MeOH, 81%; c) NaH, BnBr, DMF, 83 %; d) MsCl, pyridine; e) KOH, THF/MeOH 3:2, reflux, 43% over 2 steps; f) Ac_2O, H_2SO_4, 70%; g) $SOCl_2$, $SnCl_4$, DCM; h) NaH, PhSH, DMF, 49% over 2 steps; i) NaOMe, MeOH; j) BnBr, NaH, DMF, 84% over 2 steps; k) $SbCl_5$, DCM; l) NaOAc, H_2O; m) Ac_2O, pyridine, 38% over 3 steps; n) HBr/HOAc, DCM; o) NaH, PhSH, DMF, 56% over 2 steps; p) NaOMe, MeOH, q) BnBr, NaH, DMF, 73% r) i: TIPS-Cl, imidazole, DMF, ii: 2,2,-dimetoxypropane, pTsOH, 57% over 2 steps; s) Dess-Martin, DCM, 94%; t) $NaBH_4$, MeOH, 0 °C, 67%; u) pTsOH, MeOH, 50 °C; v) BnBr, NaH, DMF, 64% over 2 steps*

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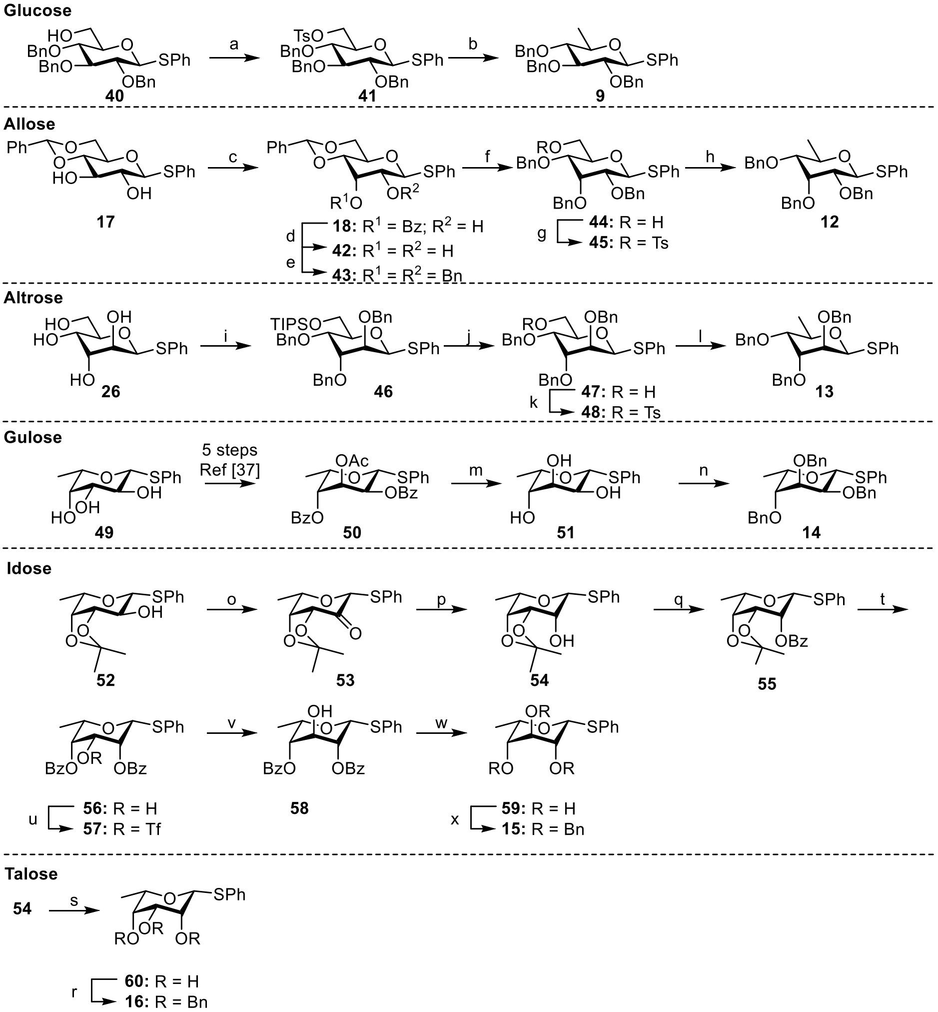
[*] Sanapala and Kulkarni have reported that inversion of the C-3-OH, of a very similar building block carrying a C-4-O-2,2,2-trichloroethoxycarbonyl (Troc) group, under the same conditions proceeds in 54% yield, see ref 38.



***Scheme 2**: synthesis of 6-deoxy donors **9, 12, 13, 14, 15** and **16**. Reagents and conditions: a) pyridine, pTsCl; b) $LiAlH_4$, THF reflux, 47% over 2 steps; c) Ph_3P, BzOH, DIAD, THF reflux; d) NaOMe, MeOH; e) BnBr, NaH, DMF, 32% over 3 steps; f) BH_3-THF, $CoCl_2$, THF; g) pTsCl, pyridine; h) $LiAlH_4$, THF reflux, 48% over 3 steps; i) i: TIPS-Cl, imidazole, DMF, ii: BnBr, NaH, DMF, 85% over 2 steps; j) TFA, THF/H_2O 4:1, 84%; k) pTsCl, pyridine; l) $LiAlH_4$, THF reflux, 64% over 2 steps; m) NaOMe, MeOH; n) BnBr, NaH, DMF, 65% over 2 steps; o) Dess-Martin periodinane, DCM; p) $NaBH_4$, MeOH, -10 °C, 33% over 2 steps; r) BzCl, pyridine, DCM, 79%; r) i: MeOH, amberlite, reflux, ii: $PhC(OMe)_3$, CSA, DCM, iii: H_2O, 54% over 3 steps; s) Tf_2O, pyridine, DCM, -10 °C; t) $TBANO_2$, ACN, 80 °C; u) NaOMe, MeOH; v) BnBr, NaH, DMF, 9% over 4 steps; w) i: PTSA, MeOH, 50 °C; x) BnBr, NaH, DMF, 75% over 2 steps*

CEL maps and stereoselectivity of glycosylations with TES-D and Allyl-TMS

The generation of the oxocarbenium ion CEL maps and the prediction of the stereochemical outcome of S_N1 reactions to these was done as previously described by Hansen *et al.*[26] In order to reduce the required calculation time, the benzyl (OBn) protecting groups were changed for smaller, electronically similar methyl (OMe) groups. The workflow is depicted in ***Figure 3***. The starting conformation for the CEL map was determined by first generating a conformational library using the *'conformation distribution search'* included in spartan '14[39] using the B3LYP as hybrid functional in the gas phase with 6-31G(d) as the basis set. Next, the found structures were re-optimised using Gaussian 09[40] using DFT/B3LYP/6-311G(d,p), including an optimisation with a polarisable continuum solvent model (PCM) to account for the solvation in dichloromethane. The structure with the lowest energy was used as starting point for the CEL map generation. In order to make sure that the entire conformational space was scanned, three dihedral angles, C1-C2-C3-C4 (D1), C3-C4-C5-O (D3) and C5-O-C1-C2 (D5) were changed from -60° to 60° in steps of 15°, giving a total of 729 structures. For donors **1-8**, three different O5-C5-C6-O6 rotamers (the *gg*, *gt* and *tg* structures) were taken into account, as it has been shown that the stability and reactivity of the ions is significantly impacted by the orientation of the C-6-group.[41] The three CEL maps were generated separately and subsequently the maps were merged using the structures that were lowest in energy.

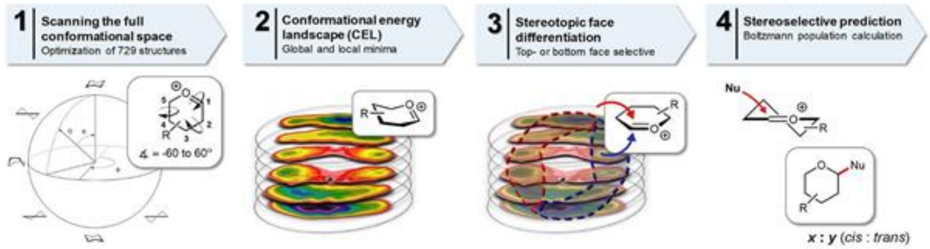


Figure 3: *Overview of the workflow to map the conformational and stereoselective preference of pyranosyl oxocarbenium ions. (1) The complete conformational space of a six-membered ring was scanned by computing 729 prefixed structures. A few canonical conformations (chair, half-chair, envelope, and boat) are depicted. (2) The associated energies were graphed on slices dividing the Cremer–Pople sphere. (3) Top- and bottom-face selective conformers lie in separate areas of the sphere. The family of the top face-selective (*^{3}E*,* $^{3}H_{4}$*,* E_{4}*, and* $B_{2,5}$*)-like structures is found in the area contoured with the red-dashed line, while the bottom face-selective family of (*^{4}E*,* $^{4}H_{3}$*,* E_{3}*, and* $^{2,5}B$*)-like conformers is found on the opposite side of the sphere, grouped within the blue-dashed line. (4) On the basis of the Boltzmann distribution of the top- and bottom-face selective structures, the stereochemical outcome of nucleophilic addition reactions to pyranosyl oxocarbenium ions can be computed.*** *The picture and description are reprinted from ACS Central Science by T. Hansen et al.*[26]

In order to visualise the energy levels of the conformations on the Cremer-Pople sphere,[42] the sphere was dissected in slices that combine closely associated conformers. The OriginPro software[43] was employed to produce the energy heat maps, contoured at 0.5 kcal/mol. The CEL maps revealed that the ^3E, $^3H_4$, E_4, and $B_{2,5}$ conformations together with the opposing ^4E, $^4H_3$, E_3, and $^{2,5}B$ conformations are generally energetially most favourable. To predict the stereoselectivity of the oxocarbenium ions the conformations were divided in top-face (the ^3E, $^3H_4$, E_4, and $B_{2,5}$-type conformations) and bottom-face (^4E, $^4H_3$, E_3, and $^{2,5}B$-type conformations) selective families, based on the most likely mode of attack by the nucleophile. The most favourable reaction path for the half chair-type structures leads to the products via a chair-like structure, while the most favourable approach of the boat-like ions is from the convex face of the structures. To calculate the theoretical α:β ratio based on a given CEL map, the Boltzmann distribution (eq. 1) was used to determine the relative population of the α- and β-selective conformations. Only the conformations with a relative energy lower than 5 kcal/mol were included in the calculations.

$$\frac{N_i}{N_{total}} = \frac{e^{-E_{rel}/RT}}{\sum_{k=1}^{N_{total}} e^{-E_k/RT}} \quad \textit{(eq. 1)}$$

The CEL maps for the 6-deoxy pyranosyl oxocarbenium ions and the C-6-OMe ions are depicted in ***Figure 4*** and ***Figure 5***, respectively. The collection of CEL maps clearly illustrates how changing the configuration of one, two or three stereocenters impacts the conformational preference of the ions. When comparing the structures of the 6-deoxy ions to their C-6-OMe counterparts is becomes apparent that similar families of favourable conformers are found for both pyranosyl classes but that there is a difference between the relative energy of the conformations. The stability of the conformations identified by the CEL maps may be rationalised by taking into account the individual 'preferences' of the susbtituents to best stabilise (or least destabilise) the ions, as experimentally determined by Woerpel and co-workers[19, 20, 31, 32] and computationally substantiated by Hansen *et al.*[26] Pyranosyl oxocarbenium ions placing alkoxy groups at the C-3 and C-4 positions in a *pseudo*-axial orientation are more stable than their *pseudo*-equatorial counterparts. For steric reasons, the C-5 group is placed preferentially in a pseudo-equatorial orientation, just like the C-2-alkoxy group. This orientation of the C-2-group also enables stabilisation of the oxocarbenium ion by hyperconjugative stabilization by the *pseudo*-axial C-2-H atom. When all these preferences can be achieved in concert, as is the case for the 6-deoxy gulosyl oxocarbenium ion, the ion shows a very strong preference for a single well-defined conformation, *i.e.* the $^4H_3$ half chair. The structures that are capable of placing three out of the four substituents in their favorable orientation (6-deoxy mannose/galactose/allose/idose) also show a relatively strong preference for the structure with the three substituents placed in a stereoelectronic favourable orientation. The structures where only two substituents can be placed in a favourable manner show the most 'filled' CEL maps with multiple structures being relatively close in energy.

The results of the glycosylations of the eight 6-deoxy pyranosyl and eight C-6-*O*-benzyl donors are summarized in ***Table 1***, and ***Table 2***, respectively, where they are also compared to the calculated α:β ratio based on the CEL maps of the oxocarbenium ions. It has previously been described for a large set of "stripped" pyranosyl oxocarbeniums, that the CEL maps could be used well to rationalise the stereoselectivity of reactions of these with TES-D. From the results in ***Table 1*** it becomes apparent that in the 6-deoxy series the theoretically predicted and experimentally observed selectivities for the addition of TES-D to the mannose-, galactose-, allose-, altrose-, gulose- and talose-configured ions match well. Discrepancies are found for the 6-deoxy glucose and 6-deoxy idose ions. While the 6-deoxy glucose CEL-map predicts an unselective addition reaction, the experiment delivers the α-product with excellent stereoselectivity. Based on the ground-state energy of the different conformers of the 6-deoxy idose ion an α-selective addition could be expected, where a β-selective addition is experimentally observed. The deviation in the selectivity predicted based on the ground-state energy of the ions and the experimentally determined stereoselectivity may be rationalded by steric interactions that develop in the transition states leading to the products, between the oxocarbenium ion and the incoming nucleophile and the interactions of the axial susbtituents of the ions/products. For the 6-deoxy glucose ion, the E_4 conformer is relatively close in energy to the $^4H_3$ half chair ion (ΔG = 0.5 kcalmol^{-1}) but attack on the top face of the E_4 conformer will lead to significant steric interactions with the *pseudo*-axial C-3 and C-5 substituents. In addition, transformation from the envelope structure to a $^4C_1$ chair will increase the 1,3-diaxial interactions between the groups at C-2 and C-4. For the addition of TES-D to the 6-deoxy idose ion a similar analysis can be made. Even though there is a significant difference in stability between the $^3H_4$ half chair and the ^4E envelope (ΔG = 3.4 kcalmol^{-1}), attack at the latter conformer is hindered by the axial C-3-group and, in line with the analysis above, the ^4E to $^1C_4$ transformation will lead to the development of significant 1,3-diaxial interactions of the C-2 and C-4 groups.

The developing steric interactions are even more important in the additions of allyl-TMS to the oxocarbenium ions. Allyl-TMS is a weaker nucleophile than TES-D and therefore the transition state of the reactions of this nucleophile (Mayr nucleophilicity parameter 1.96 (TES-D) *vs* 3.58 (allyl-TMS)) are expected to be later on the reaction coordinate. Thus, for the 6-deoxy mannose case this leads to erosion of β-selectivity, as attack on the β-face of the ^3E envelope generates 1,3-diaxial interactions with the substituents at the C-3 and C-5 position and a gauche interaction with the C-2-substituent. Even though the ground state energy difference between the ^3E envelope and the $^4H_3$ half chair ions is significant ($\Delta G = 3.1$ kcalmol^{-1}), the developing steric interactions counterbalance this energy gap. For 6-deoxy altrose the ground state energy difference between the two half chairs on either side of the CEL is relatively small. With the reactive and small nucleophile TES-D the intrinsic difference between the $^3H_4$ and $^4H_3$ half chair ions ($\Delta G = 0.4$ kcalmol^{-1}) is mirrored in the stereoselectivity of the addition reaction (α:β = 12:88), while the less reactive allyl-TMS provides an α-selective reaction (α:β = 89:11). The developing 1,3-diaxial interaction between the nucleophile and the C-5 methyl group and gauche interaction with the C-2-substituent raise the transition state energy for the addition on the β-face of the $^3H_4$ half chair ion such that addition to the α-face of the opposite half chair becomes more favorable. For 6-deoxy idose, these steric interactions also make addition to the less stable ^4E oxocarbenium ion less favorable than top-face addition to the $^4H_3$ half chair. As the addition of allyl-TMS to this ion proceeds with lower β-selectivity than the addition of the smaller and more reactive TES-D it appears that the steric interactions of the incoming allyl-TMS with the substituent at C-2 and C-5 make the transition state for the allyl-TMS addition on the top face more unfavorable leading to the formation of relatively more of the α-product. For 6-deoxy talose a complete shift in stereoselectivity is observed when comparing the TES-D and allyl-TMS additions, again indicating important steric gauche and di-axial interactions in top-face attack of the most stable $^3H_4$ half chair ion. As the difference in ground state energy between the 6-deoxy talose $^3H_4$ and $^4H_3$ half chair ions ($\Delta G = 1.2$ kcalmol^{-1}) is smaller than that of the 6-deoxy mannose ions ($\Delta G = 3.1$ kcalmol^{-1}) and therefore the change in stereoselectivity observed for addition to the 6-deoxy talose ion is more significant (<2:98 to >98:2 *vs* <2:98 to 77:23).

Table 1: *predicted and experimental stereoselectivities of all 8 6-deoxy pyranosyl donors*

Donor	Calculated α:β selectivity	TES-D		Allyl-TMS	
		Product (Yield)	α:β	Product (Yield)	α:β
9 (6-deoxy glucose)	**55:45**	**9A** (59%)	**>98:2**	**9B** (64%)	**>98:2**
10 (6-deoxy mannose)	**<2:98**	**10A** (79%)	**<2:98**	**10B** (83%)	**77:23**
11 (6-deoxy galactose)	**>98:2**	**11A** (74%)	**>98:2**	**11B** (76%)	**>98:2**
12 (6-deoxy allose)	**>98:2**	**12A** (57%)	**>98:2**	**12B** (57%)	**>98:2**
13 (6-deoxy altrose)	**23:77**	**13A** (85%)	**12:88**[a]	**13B** (67%)	**89:11**
14 (6-deoxy gulose)	**>98:2**	**14A** (86%)	**>98:2**	**14B** (75%)	**>98:2**
15 (6-deoxy idose)	**>98:2**	**15A** (50%)	**<2:98**	**15B** (48%)	**21:79**
16 (6-deoxy talose)	**12:88**	**16A** (68%)	**<2:98**[a]	**16B** (55%)	**>98:2**

a: determined after debenzylation followed by benzoylation. Calculated α:β ratios are based on methylated oxocarbenium ions, experimental α:β values are based on benzylated donors. The CEL maps and TES-D results of donors ***10*** *and* ***11*** *were previously reported.*[26]

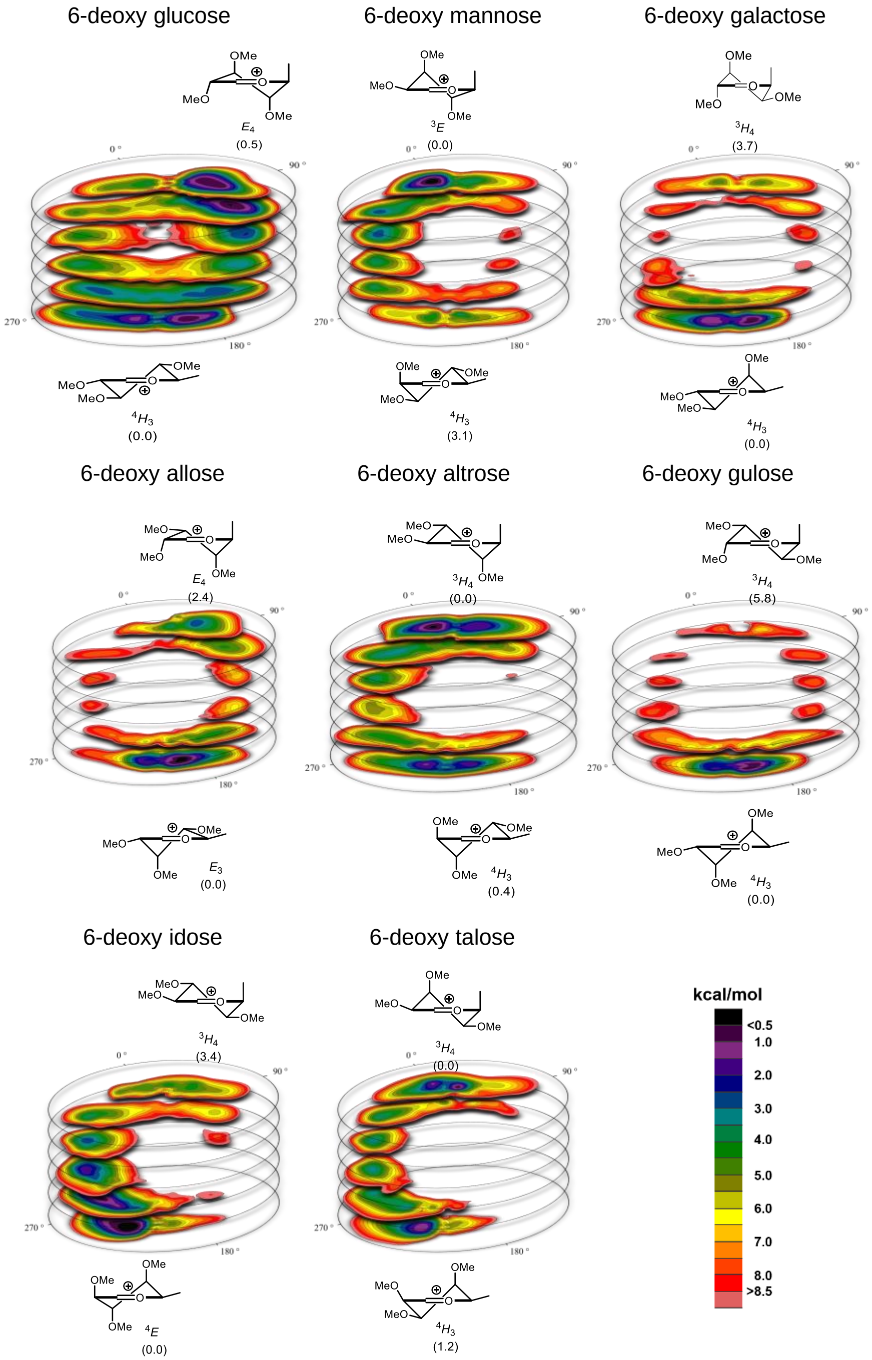


***Figure 4:** CEL maps of all 6-deoxy pyranosyl oxocarbenium ions*

Table 2 summarises the results for the reactions of the C-6-OMe/OBn pyranosyl donors. When these results are compared to the experimental results of the 6-deoxy series it becomes apparent that these are very similar and thus that in most cases the C-6-substituent has relatively little influence on the stereoselectivity of the reactions. As mentioned above, the CEL maps of the C-6-OMe and 6-deoxy pyranosyl oxocarbenium ions reveal similar conformations to be relevant and this translates into comparable stereoselectivities in the addition reactions. A notable difference can be observed for the glucopyranosyl ion, where there is a significantly larger difference in stability between the $^4H_3$ half chair ion and the $E_4/^2S_O$ (ΔG = 2.3 kcalmol^{-1}) than found for the 6-deoxyglucosyl ions (ΔG = 0.5 kcalmol^{-1}). This however does not lead to a different stereochemical outcome of the addition reactions, as the sterically least hindered mode of attack can now take place on the most stable oxocarbenium ion conformer. For the talose ion a significant difference is observed as well, with the $^3H_4$ and $^4H_3$ half chair ions being of comparable stability, which translates to a theoretical 1:1 α:β-ratio. The TES-D addition however provides solely the β-product. This would indicate that the 1,3-diaxial interactions between the C-2 and C-4 groups, that develop in the transition state of the reaction of TES-D on the bottom face of the ^{4}E envelope, are prohibitively large to favour attack of the nucleophile on the top face of the $^3H_4$ half chair ion. When allyl-TMS is used as a nucleophile the steric interactions of the nucleophile with the electrophile will become more important (*i.e.* the 1,3-diaxial type interaction with the groups at C-3 and C-5 as well as the gauche interaction with the group at C-2) making the top face attack less favourable and thus leading to the formation of an α/β-mixture.

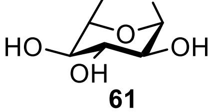
In all, the above-described analyses show that, in line with the study of Hansen *et al.*, the conformational preference of a pyranosyl oxocarbenium ion translates well into the selectivity observed in the addition of TES-D to these ions. TES-D experiences relatively little steric interactions with the substituents on the ring during the addition reaction. If, however, 1,3-diaxial interactions develop between the substituents on the ring in the transition state of the addition reaction (as in the β-face attack on the 6-deoxy glucose ^{4}E-ion, the α-face attack on the 6-deoxy idose ^{4}E-ion and the α-face attack on the 6-deoxy talose $^4H_3$-ion), these can significantly increase the hight of the transition states. Allyl-TMS, a larger and less reactive nucleophile, in contrast can experiences significant 1,3-diaxial type interactions with axial substitutions at the C-3 and C-5 position of the pyranosyl ion as well as gauche interactions with the group at C-2. These interactions can induce a Curtin-Hammett kinetic scenario, in which the higher energy oxocarbenium ion conformer becomes the most relevant product forming intermediate.

Table 2: *predicted and experimental stereoselectivities of all 8 pyranosyl donors*

Donor	Calculated α:β selectivity	TES-D		Allyl-TMS	
		Product (Yield)	α:β	Product (Yield)	α:β
1 (Glucose)	**>98:2**	**1A** (70%)	**>98:2**	**1B** (71%)	**>98:2**
2 (Mannose)	**3:97**	**2A** (93%)	**3:97**	**2B** (80%)	**66:34**
3 (Galactose)	**>98:2**	**3A** (86%)	**>98:2**	**3B** (80%)	**>98:2**
4 (Allose)	**>98:2**	**4A** (74%)	**>98:2**	**4B** (46%)	**>98:2**
5 (Altrose)	**4:96**	**5A** (55%)	**20:80**	**5B** (68%)	**89:11**
6 (Gulose)	**>98:2**	**6A** (83%)	**>98:2**	**6B** (71%)	**>98:2**
7 (Idose)	**90:10**	**7A** (74%)	**<2:98**[a]	**7B** (n.d.)[b]	**13:87**
8 (Talose)	**52:48**	**8A** (51%)	**<2:98**[a]	**8B** (67%)	**57:43**

[a] determined after debenzylation followed by benzoylation. [b] an accurate determination of the yield is not possible due to poor separation from a side product.[†] *Calculated α:β ratios are based on methylated oxocarbenium ions, experimental α:β values are based on benzylated donors. The CEL maps and TES-D results of donors **1-3** were previously reported.*[26]

[†]



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*The side product is the 1,6-anhydro product from donor **7**, compound **61.** This product forms in 81% yield when donor **7** is activated, but no nucleophile is added.*

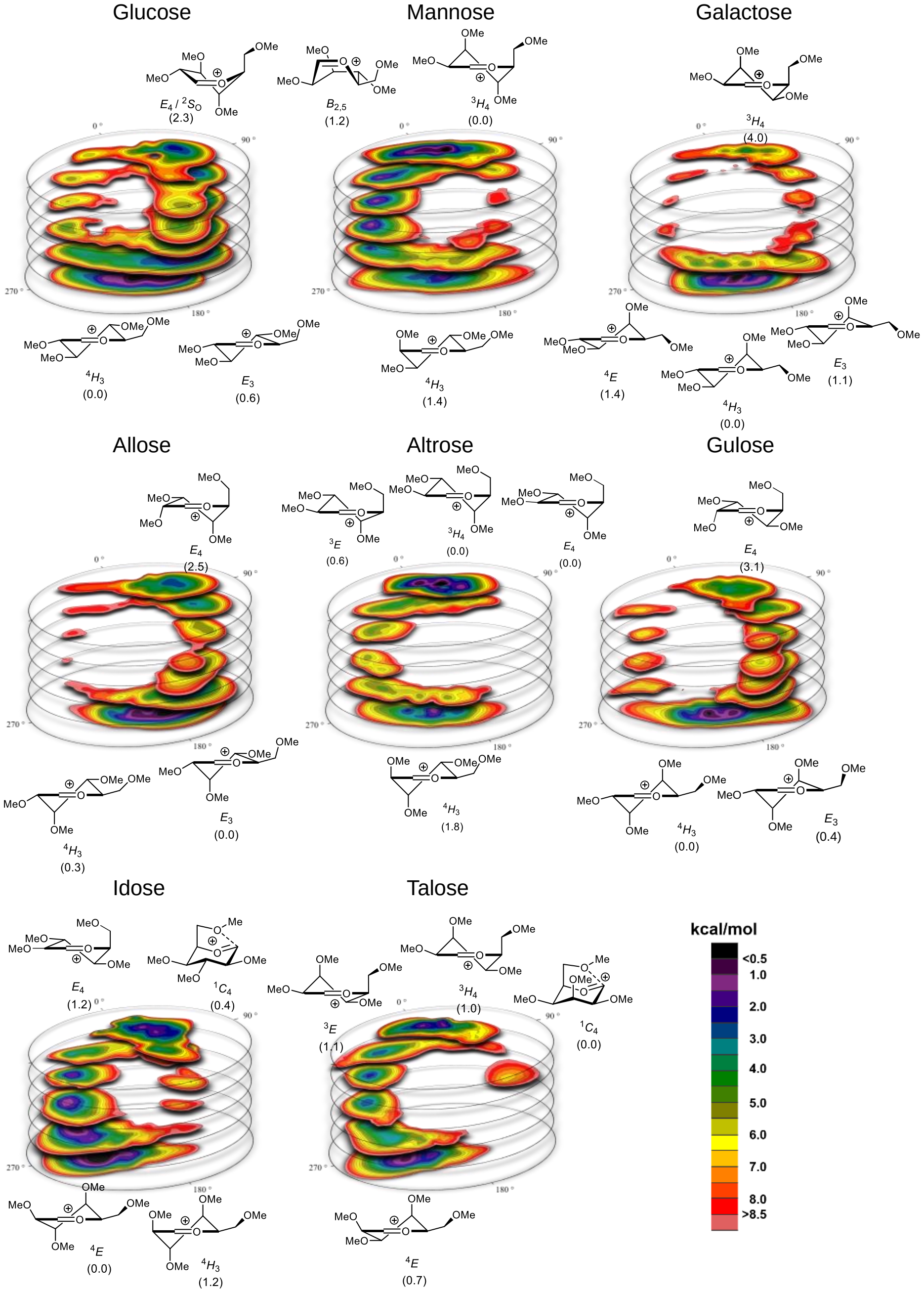


Figure 5: *CEL maps of all pyranosyl oxocarbenium ions*

Conclusion

In conclusion, this chapter has investigated S_N1-like glycosylation reaction mechanisms and the influence of the substitution pattern of the glycosyl donor on the conformational preference of the involved oxocarbenium ions. To fuel these studies, synthetic routes towards all 8 possible diastereoisomeric β-thiophenol 2,3,4,6-tetra-*O*-benzyl pyranosyl donors, and their 6-deoxy-counterparts were developed. Next, the conformational preference of the oxocarbenium ions was mapped by the generation of CEL maps and the donors were reacted with both TES-D and allyl-TMS in order to trap the oxocarbenium ions. These results show that the stereochemical outcome of C-6-deoxy and C-6-OBn donors to be very similar. Even for idose and talose, where the $^1C_4$ conformation of the C-6-OBn oxocarbenium ions was found to be found relatively favorable, the C-6-substituents does not significantly contribute to the stereochemical outcome. Another observation is that the stereochemistry of C-2 is a very important factor for the stereochemical outcome of the reactions with TES-D, since all TES-D reactions were highly *1,2-cis* selective, even when the CEL maps predict a mixture or *1,2-trans* selectivity. This *1,2-cis* selectivity is correctly predicted in 12 out of 16 cases by the CEL maps. A striking difference in the stereoselectivity of the reactions with TES-D and allyl-TMS were observed for the pyranosides having an axial C-2-OBn. Where the TES-D reactions are all highly β-selective, the allyl-TMS reactions are either α-selective or proceed with relatively poor β-selectivity. For the reactions in which the ground state energy of the oxocarbenium ions proved to be a poor predictor of the stereoselectivity of the glycosylation reactions, Curtin Hammett kinetic scenarios were invoked to rationalize the outcome of the reactions. When developing steric interactions between the incoming nucleophile and the electrophile, as well as interactions developing between the substituents on the pyranosyl ring become prohibitively large, reactions on less favorable oxocarbenium ions can become attractive. To better understand the steric and electronic factors at play during the transition state of the reactions, future research will have to focus on computationally studying the transition state of these reactions, in which the donor oxocarbenium ions are systematically varied and paired with *C*-nucleophiles, of gradually changing nucleophilicity.

Experimental

Generation of CEL-maps and calculation of the expected stereochemistry based on the CEL-maps

The generation of CEL-maps and the calculation of the expected stereoselectivity of the oxocarbenium ions based on the CEL-maps was performed as previously described by T. Hansen *et al.*[26]

General experimental procedures

General experimental procedures: All chemicals were of commercial grade and used as received unless stated otherwise. Dichloromethane (DCM) was stored over activated 4 Å molecular sieves for at least 24 h before use. Trifluoromethanesulfonic anhydride (Tf_2O) was distilled over P_2O_5 and stored at -20°C under a nitrogen atmosphere. Overnight temperature control was achieved by a FT902 Immersion Cooler (Julabo). Flash column chromatography was performed on silica gel 60 Å (0.04 – 0.063 mm, Screening Devices B.V.). Thin-layer chromatography (TLC) analysis was conducted on TLC silica gel 60 plates (Kieselgel 60 F254, Merck) with UV detection by (254 nm) and by spraying with 20% sulfuric acid in ethanol or by spraying with a solution of $(NH_4)_6Mo_7O_{24}\cdot H_2O$ (25 g/L) and $(NH_4)_4Ce(SO4)_4\cdot 2H_2O$ (10 g/L) in 10% aq. sulfuric acid followed by charring at ±250 °C. High-resolution mass spectrometry (HRMS) was performed on a Thermo Finnigan LTQ Orbitrap mass spectrometer equipped with an electrospray ion source in positive-ion mode (source voltage 3.5 kV, sheath gas flow 10, capillary temperature 275 °C) with resolution R = 60.000 at m/z 400 (mass range of 150-4000) and dioctylphtalate (m/z=391.28428) as lock mass, or on a Waters Synapt G2-Si (TOF) equipped with an electrospray ion source in positive mode (source voltage 3.5 kV) and LeuEnk (m/z = 556.2771). as internal lock mass. 1H and 13C NMR spectra were recorded on Bruker AV-400, Bruker DMX-400, and Bruker AV-500 NMR instruments. Chemical shifts (δ) are given in parts per million (ppm) relative to tetramethylsilane as an internal standard or the residual signal of the deuterated solvent. Coupling constants (J) are given in Hertz (Hz). All presented 13C-APT spectra are proton-decoupled. NMR peak assignments were made using COSY and HSQC. When necessary, additional NOESY, HMBC and HMBC-GATED experiments were used to further elucidate the structure. The anomeric product ratios were based on careful analysis of the crude reaction mixture and the purified reaction product by integration of representative 1H NMR signals. IR spectra were recorded on a Shimadzu FTIR-8300 IR spectrometer and are reported in cm-1. Specific rotations were measured on a Propol automatic polarimeter or an Anton-Paar MCP-100 modular circular polarimeter at 589 nm unless otherwise stated.

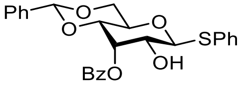
General procedure for Ph_2SO/Tf_2O meditated glycosylations

Donor (0.1 mmol, 1 eq), Ph_2SO (0.13 mmol, 1.3 eq) and TTBP (0.25 mmol, 2.5 eq) were coevaporated twice with toluene, dissolved in 2 mL DCM and stirred for 30 min at RT with 3Å molecular sieves. The solution was cooled to -80 ^{0}C and Tf_2O (22 µL, 0.13 mmol, 2 eq) was added. The reaction mixture was allowed to warm to −60 ^{0}C and then recooled to −78 ^{0}C, after which the acceptor (2-6 eq) was added. The reaction mixture was allowed to warm to −60 ^{0}C for and stirred between 1-24 hr at that temperature. The reaction was quenched with 2 mL sat aq $NaHCO_3$ or 0.2 mL 1M Et_3N in DCM, and the mixture was diluted with DCM. The solution was transferred to a separatory funnel, water was added, the layers were separated, and the water phase was extracted once more with DCM. The combined organic layers were dried over MgSO4, filtered, and concentrated in vacuo. Purification by silica gel flash column chromatography yielded the glycosylation product as a mixture of anomers.

General procedure for debenzylation followed by benzoylation

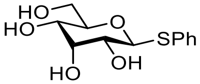
Benzylated product was dissolved in EtOH (0.05 M) with an equal weight of 5% Pd/C. the reaction mixture was flushed with N_2 (2x) and H_2 (2x) and kept under H_2 atmosphere overnight, after which it was flushed twice with N_2, filtered over a plug of celite and concentrated under reduced pressure. The crude tri- or tetra-ol was coevaporated 3x with toluene and dissolved in pyridine (1 mL) and treated with BzCl (2 eq per OH). After 24 hr, the reaction mixture was diluted with EA and washed with 1M HCl and bicarb. The organic phase was dried with $MgSO_4$ and concentrated. Silica chromatography yields the benzoylated product.

Phenyl 3-*O*-benzoyl-4,6-*O*-benzylidene-1-thio-β-D-allopyranose (18)



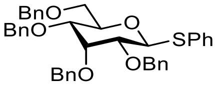
Phenyl 4,6-*O*-benzylidene-1-thio-β-D-glucopyranose[44] (**17**, 7.21 g, 20 mmol), benzoic acid (3.66 g, 30 mmol, 1.5 eq) and triphenylphosphine (7.87 g, 30 mmol,1.5 eq) were dissolved in THF and heated to a gentle reflux. DIAD (5.91 mL, 30 mmol,1.5 eq) was added dropwise over 5 min, after which TLC showed full conversion of the starting material. The reaction mixture was cooled to RT and concentrated under reduced pressure. The residue was dissolved in EtOAc and washed with sat. aq. $NaHCO_3$. The organic phase was dried with $MgSO_4$ and concentrated under reduced pressure. Purification over silica (10%→25% acetone in pentane) yields the title compound as off-white foam. Yield: 4.87 g, 10.5 mmol, 52%. ^1H NMR (400 MHz, $CDCl_3$) δ 8.09 – 8.02 (m, 2H, CH_{arom}), 7.70 – 7.63 (m, 2H, CH_{arom}), 7.60 – 7.51 (m, 4H, CH_{arom}), 7.49 – 7.41 (m, 4H, CH_{arom}), 7.39 – 7.34 (m, 5H, CH_{arom}), 7.28 (dd, *J* = 5.1, 1.9 Hz, 3H, CH_{arom}), 6.01 (t, *J* = 2.8 Hz, 1H, H-3), 5.55 (s, 1H, C*H*Ph), 5.00 (d, *J* = 9.8 Hz, 1H, H-1), 4.46 (dd, *J* = 10.6, 5.0 Hz, 1H, H-6), 4.15 (td, *J* = 9.9, 5.1 Hz, 1H, H-5), 3.80 (t, *J* = 10.4 Hz, 1H, H-6), 3.75 (dd, *J* = 9.5, 2.6 Hz, 2H, H-2, H-4), 2.75 (s, 1H, OH); ^{13}C NMR (101 MHz, $CDCl_3$) δ 166.5 (C=O), 136.9 (C_q), 133.6, 133.5, 132.3, 132.2 (CH_{arom}), 132.1, 132.1 (C_q), 131.1, 130.0, 129.2, 128.7, 128.7, 128.6, 128.6, 128.4, 126.2 (CH_{arom}), 101.8 (CHPh), 86.5 (C-1), 77.0 (C-4), 70.4 (C-3), 69.2 (C-6), 69.0 (C-5), 67.8 (C-2);); HRMS: $[M+NH_4]^+$ calcd for $C_{26}H_{24}O_6SNH_4$ 482.16318, found 487.16258

Phenyl 1-thio-β-D-allopyranose (19)



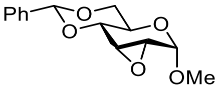
Compound **18** (3.17 g, 6.82 mmol) and pTsOH hydrate (130 mg, 0.68 mmol, 0.1 eq) were dissolved in methanol and heated to 50 °C. After TLC shows full removal of the benzylidene, the reaction mixture was cooled to RT and NaOMe (184 mg, 3.41 mmol, 0.5 eq) was added. After full deprotection, the solution was neutralised with Amberlite IR-120(H), filtered over celite and concentrated. The residue was purified over silica (50% acetone in DCM), to yield the title compound as colourless oil. Yield: 1.51 g, 5.55 mmol, 81%. ^{1}H NMR (400 MHz, Acetone) δ 7.55 – 7.49 (m, 2H, CH$_{arom}$), 7.33 – 7.27 (m, 2H, CH$_{arom}$), 7.27 – 7.21 (m, 1H, CH$_{arom}$), 4.94 (d, *J* = 9.8 Hz, 1H, H-1), 4.14 (t, *J* = 3.0 Hz, 1H, H-3), 3.88 – 3.79 (m, 1H, H-6), 3.70 – 3.60 (m, 2H, H-5, H-6), 3.53 (dd, *J* = 9.7, 3.0 Hz, 1H, H-4), 3.41 (d, *J* = 10.1 Hz, 1H, H-2); ^{13}C NMR (101 MHz, Acetone) δ 135.7 (C$_q$), 131.7, 129.6, 127.5 (CH$_{arom}$), 85.6 (C-1), 77.8 (C-5), 72.4 (C-3), 70.7 (C-2), 68.6 (C-4), 63.1 (C-6); HRMS: [M+Na]$^+$ calcd for $C_{12}H_{16}O_5S$ 295.06107, found 295.06054

Phenyl 2,3,4,6-tetra-*O*-benzyl-1-thio-β-D-allopyranose (4)



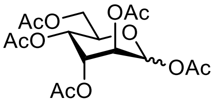
Compound **19** (1.63 g, 6 mmol, 1 eq) was dissolved in 50 mL DMF and cooled to 0^{o}C, after which sodium hydride (60% dispersion in mineral oil, 1.44 g, 36 mmol, 6 eq.) was added portionwise. After stirring for an additional 30 minutes, benzyl bromide (4.28 mL, 36 mmol, 6 eq) was added and the mixture was allowed to warm to RT. Upon completion of the reaction, excess sodium hydride was destroyed carefully with water. The aqueous phase was extracted with diethyl ether, the organic phase washed with distilled water and brine, dried with Na_2SO_4 and concentrated under reduced pressure. The residue was purifed over silica (5% EtOAc in pentane) to give the title compound as a colourless oil that solidifies over time. Yield: 2.80 g, 4.42 mmol, 74%.$[\alpha]_D^{25}$ = -0.6° (c = 0.85, $CHCl_3$); IR (thin film): 697, 737, 1050, 1089; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.64 – 7.49 (m, 2H, H-Ar), 7.40 – 7.14 (m, 23H, CH$_{arom}$), 5.24 (d, *J* = 9.7 Hz, 1H, H-1), 4.83 (d, *J* = 11.9 Hz, 1H, C*H*H Bn), 4.77 (d, *J* = 11.9 Hz, 1H, CH*H* Bn), 4.62 – 4.57 (m, 2H, 2x C*H*H Bn), 4.55 – 4.51 (m, 2H, 2x CH*H* Bn), 4.49 (d, *J* = 7.9 Hz, 1H, C*H*H Bn), 4.41 (d, *J* = 11.6 Hz, 1H, CH*H* Bn), 4.13 (t, *J* = 2.5 Hz, 1H, H-3), 4.09 (ddd, *J* = 9.8, 4.5, 1.9 Hz, 1H, H-5), 3.80 (dd, *J* = 10.9, 1.9 Hz, 1H, H-6), 3.71 (dd, *J* = 10.9, 4.5 Hz, 1H, H-6), 3.49 (dd, *J* = 9.8, 2.4 Hz, 1H, H-4), 3.31 (dd, *J* = 9.8, 2.4 Hz, 1H, H-2); ^{13}C NMR (101 MHz, $CDCl_3$) δ 139.0, 138.6, 138.0, 137.9, 134.1 (C$_q$), 131.9, 128.8, 128.6, 128.5, 128.5, 128.5, 128.4, 128.3, 128.3, 128.1, 128.1, 128.0, 128.0, 127.9, 127.9, 127.7, 127.5, 127.5, 127.2 (C-Ar), 83.9 (C-1), 78.0 (C-2), 75.6 (C-4), 75.2 (C-5), 74.4 (CH$_2$ Bn), 73.7 (C-3), 73.5 (CH$_2$ Bn), 72.5 (CH$_2$ Bn), 71.7 (CH$_2$ Bn), 69.4 (C-6); HRMS: [M+NH$_4$]$^+$ calcd for $C_{40}H_{40}O_5SNH_4$ 650.29347, found 650.29182

Methyl 2,3-anhydro-4,6-*O*-benzylidene-α-D-allopyranoside (22)



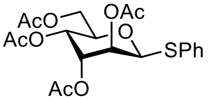
Compound **20**[44] (25.7 g, 91.2 mmol) was dissolved in pyridine (150 mL) and cooled to 0°C. methane sulfonyl chloride (21,2 mL, 273 mmol, 3 eq.) was added dropwise. The mixture was diluted with EA and washed with water and twice with brine. The organic layer was dried with $MgSO_4$ and concentrated in vacuo to obtain the crude dimesylate **21** which was used without further purification. Crude compound **21** (≤91.2 mmol) was dissolved in THF/MeOH (750 mL, 2:3, v:v). KOH (15.3 g, 273 mmol, 3 eq.) was added. The reaction mixture was refluxed overnight at 70°C. The mixture was concentrated to about 20% of the volume. Water was added, and the compound was extracted with EA. The organic fraction was washed with water 3 times. The organic layer was dried with $MgSO_4$ and concentrated in vacuo. The crude product was concentrated in vacuo. The residue was purified by multiple crystallizations in an EA/pentane mixture and yielded the title compound as a fluffy off-white solid. Yield: 10.5 g, 39.8 mmol, 43% over 2 steps. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.55 – 7.45 (m, 2H, CH_{arom}), 7.43 – 7.31 (m, 3H, CH_{arom}), 5.57 (s, 1H, C*H*Ph), 4.89 (d, *J* = 2.70 Hz, 1H, H-1), 4.24 (dd, *J* = 10.3, 5.0, 1H, H-6), 4.09 (ddd, *J* = 10.3, 9.1, 5.0 Hz, 1H, H-5), 3.96 (dd, *J* = 9.1, 1.2 Hz, 1H, H-4), 3.69 (t, *J* = 10.3 Hz, 1H, H-6), 3.53 (dt, *J* = 4.2, 1.1 Hz, 1H, H-3), 3.49 (dd, *J* = 4.3, 2.8 Hz, 1H, H-2), 3.47 (s, 3H, CH_3 OMe), ^{13}C NMR (101 MHz, $CDCl_3$) δ 137.2 (C_q), 129.4, 128.5, 126.4 (CH_{arom}), 102.9 (CHPh), 95.4 (C-1), 78.0 (C-4), 69.0 (C-6), 60.1 (C-5), 56.0 (OMe), 53.3 (C-2), 50.9 (C-3). Spectra in agreement with literature.[12]

1,2,3,4,6-penta-*O*-acetyl-α,β-D-altropyranoside (23)



Compound **22** (5.29 g, 20 mmol) was suspended in 30 mL Ac_2O and cooled to 0 °C. After dropwise addition of 0.6 mL H_2SO_4 in 30 mL Ac_2O, the reaction mixture was allowed to warm to RT and stirred overnight. The reaction mixture was poured in ice water and extracted twice with diethyl ether. Combined organic phases were washed with sat. aq. $NaHCO_3$, dried with $MgSO_4$ and concentrated. Purification with silica chromatography (15→25% acetone in pentane) yields the title compound as yellow oil which solidifies over time. Yield: 5.83 g, 14.9 mmol, 75%, major anomer (1): minor anomer (2) = 1 : 0.6, with traces of furanosides. ^{1}H NMR (400 MHz, $CDCl_3$) δ 6.16 (d, *J* = 2.0 Hz, 0.6H, H-1_2), 6.01 (t, *J* = 1.2 Hz, 1H, H-1_1), 5.44 (dd, *J* = 5.6, 3.3 Hz, 0.6H), 5.32 (td, *J* = 3.6, 1.0 Hz, 1H), 5.24 – 5.21 (m, 1H), 5.19 (dd, *J* = 5.7, 2.4 Hz, 1H), 4.99 (dd, *J* = 3.7, 1.5 Hz, 1H), 4.39 (td, *J* = 4.6, 2.0 Hz, 0.6H), 4.37 – 4.27 (m, 2H), 4.23 (t, *J* = 3.1 Hz, 0.6H), 4.20 (t, *J* = 2.8 Hz, 0.3H), 4.16 (dd, *J* = 12.1, 2.1 Hz, 1H), 2.21 – 2.00 (m, 24H, CH_3 Ac), ^{13}C NMR (101 MHz, $CDCl_3$) δ 170.8, 170.7, 169.6, 169.6, 169.5, 169.5, 169.3, 169.1, 168.8, 168.4 (C=O), 90.5 (C-1_1), 90.1 (C-1_2), 72.2, 68.4, 67.4, 66.7, 66.6, 66.6, 65.5, 64.6, 62.8 (C-6_2), 62.4 (C-6_1), 21.0, 20.9, 20.9, 20.8, 20.8, 20.7 (CH_3 Ac). Spectra in agreement with literature.[33]

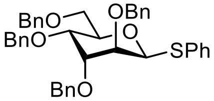
Phenyl 2,3,4,6-tetra-*O*-acetyl-1-thio-β-D-altropyranoside (25)



Compound **23** (5.80 g, 14.9 mmol) was dissolved in DCM and cooled to 0 °C. $SOCl_2$ (2.10 mL, 29.7 mmol, 2 eq) was added, followed by $SnCl_4$ (1M in DCM, 14.9 mL, 14.9 mmol, 1 eq). After TLC shows full conversion, the reaction mixture was quenched with ice water and extracted twice with DCM. Combined organic phases were washed with sat. aq. $NaHCO_3$, dried with $MgSO_4$ and concentrated, yielding chloride **24**, which was immediately dissolved in DMF. The solution was cooled to 0 °C, and thiophenol (2.12 mL, 20.8 mmol, 1.4 eq) and sodium hydride (60% dispersion in mineral oil, 713 mg, 17.8 mmol, 1.2 eq) were added. After full conversion, the reaction mixture was diluted with water and extracted twice with diethyl ether. The organic phases were dried with $MgSO_4$ and concentrated, yielding crude **25** as an α,β-mixture from which the desired β-anomer was isolated as white solid by silica chromatography (10→20% acetone in pentane), followed by recrystallization from the same solvents. Yield: 3.78 g, 8.58 mmol, 58%. ^{1}H

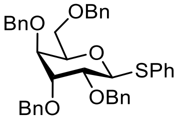
NMR (400 MHz, CDCl$_3$) δ 7.58 – 7.53 (m, 2H, CH$_{\text{arom}}$), 7.36 – 7.30 (m, 3H, CH$_{\text{arom}}$), 5.41 (t, *J* = 3.4 Hz, 1H, H-3), 5.22 (dd, *J* = 3.7, 1.5 Hz, 1H, H-2), 5.19 (d, *J* = 1.5 Hz, 1H, H-1), 5.12 (dd, *J* = 10.4, 3.2 Hz, 1H, H-4), 4.28 – 4.20 (m, 2H, 2x H-6), 4.09 (ddd, *J* = 10.4, 5.5, 3.5 Hz, 1H, H-5), 2.22 (s, 3H, CH$_3$ Ac), 2.12 (s, 3H, CH$_3$ Ac), 2.11 (s, 3H, CH$_3$ Ac), 1.99 (s, 3H, CH$_3$ Ac); ^{13}C NMR (101 MHz, CDCl$_3$) δ 170.8, 169.6, 169.6, 169.0 (C=O), 133.9 (C$_q$), 131.7, 129.1, 128.0 (CH$_{\text{arom}}$), 83.9 (C-1), 72.8 (C-5), 71.2 (C-2), 67.2 (C-3), 65.5 (C-4), 63.3 (C-6), 20.9, 20.9, 20.8, 20.7 (CH$_3$ Ac); ^{13}C-HMBC-GATED NMR (101 MHz, CDCl$_3$): δ 83.9 ($J_{\text{H1-C1}}$ = 157 Hz, β); HRMS: [M+NH$_4$]$^+$ calcd for C$_{20}$H$_{24}$O$_9$SNH$_4$ 458.14793, found 458.14698

Phenyl 2,3,4,6-tetra-*O*-benzyl-1-thio-β-D-altropyranoside (5)



Compound **25** (1.50 g, 3.41 mmol) was dissolved in methanol with NaOMe (46 mg, 0.85 mmol, 0.25 eq). After TLC shows full deacetylation, the reaction mixture was neutralised with amberlite IR-120(H), filtered and concentrated under reduced pressure to yield crude tetra-ol **26**, which was used without further purification. Compound **26** was dissolved in DMF, and NaH (60% dispersion in mineral oil, 0.681 g, 17.03 mmol, 5 eq) and benzyl bromide (2.02 mL, 17.03 mmol, 5 eq) were added. After completion, the reaction was quenched with water and extracted with diethyl ether. The organic phase was dried with Na$_2$SO$_4$ and concentrated under reduced pressure. The residue was purified over silica (5% EtOAc in pentane), obtaing the title compound as colourless oil. Yield: 1.82 g, 2.88 mmol, 84% over 2 steps. $[\alpha]_D^{25}$ = -12.2° (c = 0.88, CHCl$_3$); IR (thin film): 698, 750, 1027, 1070, 1454; ^{1}H NMR (400 MHz, CDCl$_3$) δ 7.55 – 7.50 (m, 2H, CH$_{\text{arom}}$), 7.36 – 7.25 (m, 16H, CH$_{\text{arom}}$), 7.24 – 7.16 (m, 7H, CH$_{\text{arom}}$), 5.23 (d, *J* = 1.4 Hz, 1H, H-1), 4.65 – 4.59 (m, 2H, 2x C*H*H Bn), 4.56 (d, *J* = 11.6 Hz, 2H, C*H*H Bn ,CH*H* Bn), 4.47 – 4.41 (m, 2H, 2x CH*H* Bn), 4.34 (s, 2H, CH$_2$ Bn), 4.12 (ddd, *J* = 10.1, 6.6, 1.9 Hz, 1H, H-5), 3.87 (dd, *J* = 11.0, 1.9 Hz, 1H, H-6), 3.79 (dd, *J* = 10.1, 2.7 Hz, 1H, H-4), 3.73 (dd, *J* = 3.7, 1.4 Hz, 1H, H-2), 3.72 – 3.67 (m, 2H, H-3, H-6); ^{13}C NMR (101 MHz, CDCl$_3$) δ 138.8, 138.2, 138.0, 137.9, 136.0 (C$_q$), 130.5, 128.9, 128.6, 128.5, 128.5, 128.5, 128.3, 128.3, 128.2, 128.0, 128.0, 127.9, 127.9, 127.5, 126.8 (CH$_{\text{arom}}$), 85.0 (C-1), 78.8 (C-2), 75.8 (C-5), 73.7, 73.6 (CH$_2$ Bn), 73.1 (C-4), 73.1 (CH$_2$ Bn), 72.6 (C-3), 71.8 (CH$_2$ Bn), 70.3 (C-6); HRMS: [M+NH$_4$]$^+$ calcd for C$_{40}$H$_{40}$O$_5$SNH$_4$ 650.29347, found 650.29153

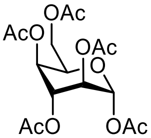
Phenyl-2,3,4,6-tetra-O-benzyl-1-thio-β-D-gulopyranoside (6)



The title compound was synthesised in 8 steps as previously described for the L-isomer from L-gulonolactone,[35] but with D-gulonolactone **27** as starting material. $[\alpha]_D^{25}$ = -9.2° (c = 0.20, CHCl$_3$); IR (thin film): 741, 1001, 1028, 1076, 1101, 1207, 1360, 1439, 1454, 1497; ^{1}H NMR (400 MHz, CDCl$_3$) δ 7.67 – 7.60 (m, 2H, CH$_{\text{arom}}$), 7.41 – 7.25 (m, 21H, CH$_{\text{arom}}$), 7.18 – 7.12 (m, 2H, CH$_{\text{arom}}$), 5.30 (d, *J* = 9.9 Hz, 1H, H-1), 4.72 (d, *J* = 12.1 Hz, 1H, C*H*H Bn), 4.65 (d, *J* = 11.7 Hz, 1H, C*H*H Bn), 4.58 – 4.52 (m, 2H, C*H*H Bn, CH*H* Bn), 4.49 (d, *J* = 11.9 Hz, 1H, CH*H* Bn), 4.45 (d, *J* =

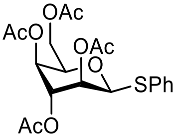
11.8 Hz, 1H, CH*H* Bn), 4.37 (d, *J* = 12.0 Hz, 1H, C*H*H Bn), 4.32 (d, *J* = 12.0 Hz, 1H, CH*H* Bn), 4.20 (td, *J* = 6.4, 1.5 Hz, 1H, H-5), 3.82 (dd, *J* = 9.9, 2.9 Hz, 1H, H-2), 3.77 (t, *J* = 3.4 Hz, 1H, H-3), 3.72 (dd, *J* = 9.8, 6.3 Hz, 1H, H-6), 3.66 (dd, *J* = 9.8, 6.5 Hz, 1H, H-6), 3.57 (dd, *J* = 3.8, 1.4 Hz, 1H, H-4); ^{13}C NMR (101 MHz, $CDCl_3$) δ 138.3, 138.3, 138.0, 138.0, 134.5 (C_q), 131.5, 128.7, 128.4, 128.4, 128.4, 128.0, 127.9, 127.9, 127.9, 127.8, 127.8, 127.6, 126.9 (CH_{arom}), 84.4 (C-1), 74.9, 74.8 (C-2, C-4), 74.5 (C-5), 73.4, 73.3 (CH_2 Bn), 73.1 (C-3), 72.8, 72.5 (CH_2 Bn), 69.0 (C-6); HRMS: calcd for $C_{40}H_{40}O_5SNH_4$ 650.29347, found 650.29166

1,2,3,4,6-Penta-*O*-acetyl-α-D-idopyranoside (31)



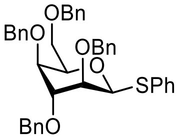
1,2,3,4,6-Penta-*O*-acetyl-β-D-glucopyranoside (**28**, 39.0 g, 100 mmol) was dissolved in 200 mL DCM and cooled to 0 °C after which $SbCl_5$ (15.4 mL, 120 mmol, 1.2 eq) was added. When dioxolenium ion **29** precipitated, the reaction mixture was warmed to RT and stirred for a further 15 minutes. The solids were filtered off, washed 3x with diethyl ether and suspended in 500 mL water with NaOAc (98 g, 1.2 mol, 12 eq). After 1 hr, the reaction mixture was extracted 3x with DCM. Combined organic phases were washed twice with sat. aq. $NaHCO_3$ and once with brine. After drying with $MgSO_4$ and concentration under reduced pressure, a mixture of tetra-acetates **30a** and **30b** was obtained. The residue was dissolved in 60 mL pyridine and 20 mL Ac_2O and stirred overnight. The reaction mixture was diluted with DCM and washed with 1M HCl and sat. aq. $NaHCO_3$. Drying and concentration of the organic phase yields the pure title compound as yellowish oil. Yield: 13 g, 33 mmol, 33%. ^{1}H NMR (400 MHz, $CDCl_3$) δ 6.05 (d, *J* = 1.6 Hz, 1H, H-1), 5.06 (td, *J* = 3.8, 1.1 Hz, 1H, H-3), 4.93 (dd, *J* = 3.8, 2.4 Hz, 1H, H-4), 4.87 (ddd, *J* = 3.9, 2.2, 0.8 Hz, 1H, H-2), 4.47 (td, *J* = 6.3, 2.3 Hz, 1H, H-5), 4.25 – 4.13 (m, 2H, H-6), 2.13 – 2.11 (m, 9H, 3x CH_3 Ac), 2.11 (s, 3H, CH_3 Ac), 2.07 (s, 3H, CH_3 Ac); ^{13}C NMR (101 MHz, $CDCl_3$) δ 170.5, 169.7, 169.1, 168.8, 168.5 (C=O), 90.6 (C-1), 66.6 (C-3), 66.3, 66.1, 66.1 (C-2, C-4, C-5), 61.8 (C-6), 20.8, 20.7, 20.7, 20.6 (CH_3 Ac). Spectra in agreement with literature.[36]

Phenyl 2,3,4,6-tetra-*O*-acetyl-1-thio-β-D-idopyranoside (33)



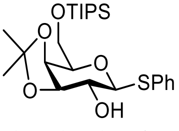
Compound **31** (13 g, 33.3 mmol) was dissolved in 100 mL DCM, after which HBr (33% in AcOH, 29 mL, 167 mmol, 5 eq) was added. After full conversion, as indicated by TLC, the reaction mixture was diluted with DCM and washed twice with cold water. The organic phase was dried with $MgSO_4$ and concentrated under reduced pressure. The residue was coevaporated twice with toluene to yield crude bromide **32**, which was immediately dissolved in DMF. The solution was cooled to 0 °C and PhSH (5.10 mL, 50 mmol, 1.5 eq) and NaH (60% dispersion in mineral oil, 1.87g, 46.6 mmol, 1.4 eq) were added. The reaction mixture was allowed to warm to RT and stirred for a further 2 hr, after which the reaction was quenched with water and extracted with diethyl ether. The organic phase was dried with $MgSO_4$ and concentrated under reduced pressure and the residue purified over silica (10%→20% acetone) to obtain the title compound as yellow oil. Yield: 8.16 g, 18.5 mmol, 56%. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.61 – 7.54 (m, 2H, CH_{arom}), 7.38 – 7.29 (m, 3H, CH_{arom}), 5.14 (d, *J* = 1.7 Hz, 1H, H-1), 5.12 (t, *J* = 2.7 Hz, 1H, H-3) 5.08 (ddd, *J* = 2.6, 1.7, 1.0 Hz, 1H, H-2), 4.86 (ddd, *J* = 2.8, 1.6, 1.0 Hz, 1H, H-4), 4.31 – 4.21 (m, 2H, H-6), 4.18 (ddd, *J* = 7.9, 4.8, 1.6 Hz, 1H, H-5), 2.20 (s, 3H, CH_3 Ac), 2.16 (s, 3H, CH_3 Ac), 2.14 (s, 3H, CH_3 Ac), 2.09 (s, 3H, CH_3 Ac); ^{13}C NMR (101 MHz, $CDCl_3$) δ 170.5, 169.6, 169.4, 168.0 (C=O), 134.0 (C_q), 131.7, 131.5, 129.0, 127.9 (CH_{arom}), 84.4 (C-1), 73.5 (C-5), 68.2 (C-4), 66.7 (C-3), 64.8 (C-2), 62.6 (C-6), 20.8, 20.7, 20.7, 20.6 (CH_3 Ac); ^{13}C-HMBC-GATED NMR (101 MHz, $CDCl_3$): δ 84.4 (J_{H1-C1} = 157 Hz, β); HRMS: $[M+NH_4]^+$ calcd for $C_{20}H_{24}O_9SNH_4$ 458.14793, found 458.14678

Phenyl 2,3,4,6-tetra-*O*-benzyl-1-thio-β-D-idopyranoside (7)



Compound **33** was deactylated and benzylated as described for compound **5,** yielding the title compound as colourless oil. Yield: 3.40 g, 5.37 mmol, 73%; $[\alpha]_D^{25}$ = -42.7° (c = 0.54, $CHCl_3$); IR (thin film): 698, 753, 1027, 1049 ; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.60 – 7.55 (m, 2H, CH_{arom}), 7.45 – 7.32 (m, 16H, CH_{arom}), 7.30 – 7.21 (m, 5H, CH_{arom}), 7.20 – 7.16 (m, 2H, CH_{arom}), 5.19 (d, *J* = 1.7 Hz, 1H, H-1), 4.68 (s, 2H, CH_2 Bn), 4.62 – 4.56 (m, 2H, 2x C*H*H Bn), 4.52 (d, *J* = 11.6 Hz, 1H, CH*H* Bn), 4.41 (d, *J* = 12.2 Hz, 1H, CH*H* Bn), 4.32 (d, *J* = 2.4 Hz, 2H, CH_2 Bn), 4.10 (ddd, *J* = 6.9, 5.3, 1.8 Hz, 1H, H-5), 3.89 (dd, *J* = 10.1, 6.8 Hz, 1H, H-6), 3.73 (dd, *J* = 10.2, 5.3 Hz, 1H, H-6), 3.71 – 3.67 (m, 2H, H-2, H-3), 3.40 (dt, *J* = 2.9, 1.4 Hz, 1H, H-4); ^{13}C NMR (101 MHz, $CDCl_3$) δ 138.5 138.0, 137.8, 137.5, 136.5 (C_q), 130.3, 128.8, 128.7, 128.5, 128.5, 128.4, 128.4, 128.1, 128.0, 127.9, 127.9, 127.8, 127.6, 126.6 (CH_{arom}), 86.5 (C-1), 76.4 (C-5), 75.8 (C-2/C-3), 73.6, 73.4, 72.2, 72.1 (CH_2 Bn), 71.7 (C-4), 71.1 (C-2/C-3), 70.1 (C-6); HRMS: calcd for $C_{40}H_{40}O_5SNH_4$ 650.29347, found 650.29149

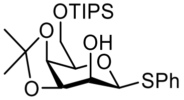
Phenyl 3,4-*O*-isopropylidene-6-*O*-triisopropylsilyl-1-thio-β-D-galactopyranoside (36)



Phenyl 1-thio-β-D-galactopyranoside (**35**, 8.17 g, 30 mmol) was dissolved in DMF with imidazole (5.11 g, 75 mmol, 2.5 eq) and TIPS-Cl (8.35 mL, 39 mmol, 1.3 eq). After 3 hr, the reaction mixture was quenched with 10 mL methanol and concentrated under reduced pressure. The residue was dissolved in DCM and washed with 1M HCl and with sat. aq. $NaHCO_3$. The organic phase was dried with $MgSO_4$ and concentrated under reduced pressure. The residue was dissolved in 150 mL 2,2-dimethoxypropane with PTSA-H_2O (0.57 g, 3 mmol, 0.1 eq). After full conversion, triethylamine (0.82 mL, 6 mmol, 0.2 eq) was added and solvent removed *in vacuo*. Silica chromatography (15% EtOAc in pentane) yield the title compound as colourless oil. Yield: 8.00 g, 17.0 mmol, 57% over 2 steps. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.57 – 7.53 (m, 2H, CH_{arom}), 7.30 (dd, *J* = 5.1, 2.0 Hz, 3H, CH_{arom}), 4.46 (d, *J* = 10.3 Hz, 1H, H-1), 4.28 (dd, *J* = 5.4, 2.0 Hz, 1H, H-4), 4.08 (dd, *J* = 6.9, 5.3 Hz, 1H, H-3), 4.00 – 3.95 (m, 2H, 2x H-6), 3.85 (ddd, *J* = 6.9, 5.9, 2.1

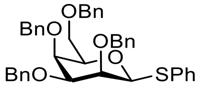
Hz, 1H, H-5), 3.57 (ddd, *J* = 10.3, 6.9, 1.8 Hz, 1H, H-2), 2.50 (d, *J* = 2.0 Hz, 1H, OH), 1.43 (s, 3H, CH_3 isopropylidene), 1.33 (s, 3H, CH_3 isopropylidene), 1.17 – 1.03 (m, 21H, 6x CH_3 TIPS, 3x CH TIPS); ^{13}C NMR (101 MHz, $CDCl_3$) δ 132.6 (C_q), 132.4, 129.1, 129.1, 128.1 (CH_{arom}), 110.2 (C_q isopropylidene), 88.5 (C-1), 79.0 (C-3), 77.6 (C-5), 73.3 (C-4), 71.8 (C-2), 62.6 (C-6), 28.3, 26.4 (CH_3 isopropylidene), 18.1, 18.1, 12.0 (CH_3 TIPS, CH TIPS); HRMS: $[M+NH_4]^+$ calcd for $C_{24}H_{40}O_5SSiNH_4$ 486.27040, found 486.26949

Phenyl 3,4-*O*-isopropylidene-6-*O*-triisopropylsilyl-1-thio-β-D-talopyranoside (38)



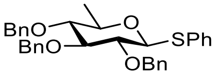
Compound **36** (8.00 g, 17.0 mmol) was dissolved in DCM and Dess-Martin periodiane (10.9g, 25.6 mmol, 1.5 eq) was added. After full conversion, the reaction mixture was diluted with DCM and washed with sat. aq. $Na_2S_2O_3$. The organic phase was dried with $MgSO_4$ and concentrated to obain crude ketone **37** (94% yield) which was used without further purification. The ketone was dissolved in 1:1 THF/MeOH and cooled to 0 °C, after which $NaBH_4$ (1.21 g, 31.9 mmol, 2 eq) was added. After full conversion, the reaction mixture was concentrated. The residue was dissolved in ethyl acetate and washed with water. The organic phase was dried with $MgSO_4$ and concentrated under reduced pressure. Silica chromatography (10% EtOAc in pentane) yields the title compound as colourless oil that solidifies upon standing. Yield: 5.02g, 10.7 mmol, 67% based on ketone **37**. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.54 – 7.46 (m, 2H, CH_{arom}), 7.34 – 7.17 (m, 3H, CH_{arom}), 4.77 (d, *J* = 1.4 Hz, 1H, H-1), 4.30 – 4.18 (m, 2H, H-3, H-4), 4.05 – 3.96 (m, 3H, H-2, 2x H-6), 3.89 – 3.82 (m, 1H, H-5), 2.57 (d, *J* = 9.0 Hz, 1H, OH), 1.62 (s, 3H, CH_3 isopropylidene), 1.38 (s, 3H, CH_3 isopropylidene), 1.16 – 0.98 (m, 21H, 6x CH_3 TIPS, 3x CH TIPS); ^{13}C NMR (101 MHz, $CDCl_3$) δ 135.8 (C_q), 130.8, 129.0, 127.2 (CH_{arom}), 110.1(C_q isopropylidene), 88.0 (C-1), 77.3 (C-5), 74.0 (C-3), 71.0 (C-4), 68.1 (C-2), 62.7 (C-6), 25.9, 25.5(CH_3 isopropylidene), 18.1, 18.1, 12.0 (CH_3 TIPS, CH TIPS); HRMS: $[M+NH_4]^+$ calcd for $C_{24}H_{40}O_5SSiNH_4$ 486.27040, found 486.26972

Phenyl 2,3,4,6-tetra-*O*-benzyl-1-thio-β-D-talopyranoside (8)



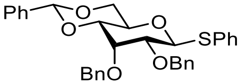
Compound **38** (4.90 g, 10.5 mmol) and PTSA-H_2O (0.40 g, 2.10 mmol, 0.2 eq) were dissolved in methanol and heated to a reflux. After TLC shows full deprotection, triethylamine (0.43 mL, 3.14 mmol, 0.3 eq) was added and the reaction mixture was concentrated under reduced pressure, yielding crude tetra-ol **39**, which was coevaporated twice with toluene, dissolved in DMF and treated with benzyl bromide (6.8 mL, 57.5 mmol, 5.5 eq) and sodium hydride (60% dispersion in mineral oil, 2.30 g, 57.5 mmol, 5.5 eq). After full conversion, the reaction mixture was quenched with water and extracted with diethyl ether. The organic phase was dried with $MgSO_4$ and concentrated. Recrystallization from EtOAc/pentane yields the title compound as white powder. Yield: 4.20 g, 6.64 mmol, 64% over 2 steps. $[\alpha]_D^{25}$ = -38.7° (c = 0.30, $CHCl_3$); IR (thin film): 695, 737, 1027, 1069, 1362, 1454; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.49 (ddt, *J* = 11.0, 7.7, 1.6 Hz, 4H, CH_{arom}), 7.38 – 7.16 (m, 21H, CH_{arom}), 5.06 (d, *J* = 11.7 Hz, 1H, C*H*H Bn), 5.01 – 4.91 (m, 2H, C*H*H Bn, CH*H* Bn), 4.80 – 4.71 (m, 2H, H-1, CH*H* Bn), 4.59 (d, *J* = 1.5 Hz, 2H, CH_2 Bn), 4.51 (d, *J* = 11.5 Hz, 1H, C*H*H Bn), 4.44 (d, *J* = 11.5 Hz, 1H, CH*H* Bn), 4.12 (dt, *J* = 2.9, 1.3 Hz, 1H, H-2), 3.91 (dt, *J* = 3.0, 1.4 Hz, 1H, H-4), 3.84 (dd, *J* = 9.8, 6.2 Hz, 1H, H-6), 3.76 (dd, *J* = 9.8, 5.8 Hz, 1H, H-6), 3.60 (td, *J* = 6.1, 1.5 Hz, 1H, H-5), 3.50 (t, *J* = 3.0 Hz, 1H, H-3); ^{13}C NMR (101 MHz, $CDCl_3$) δ 139.0, 138.7, 138.2, 137.8, 136.3 (C_q), 130.7, 128.8, 128.6, 128.4, 128.4, 128.3, 128.1, 128.0, 127.9, 127.8, 127.7, 127.4, 127.3, 127.3, 126.9 (CH_{arom}), 89.0 (C-1), 81.0 (C-3), 79.1 (C-5), 76.3 (C-2), 74.8, 74.0, 73.7 (CH_2 Bn), 72.1 (C-4), 71.0 (CH_2 Bn), 69.9 (C-6); HRMS: calcd for $C_{40}H_{40}O_5SNH_4$ 650.29347, found 650.29169

Phenyl 6-deoxy-2,3,4-tri-*O*-benzyl-1-thio-β-D-glucopyranoside (9)



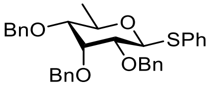
Phenyl 2,3,4-tri-*O*-benzyl-1-thio-β-D-glucopyranoside[45] (**40,** 0.95 g, 1.75 mmol) was dissolved in 5 mL pyridine with p-TsCl (0.50 g, 2.63 mmol, 1.5 eq). After full conversion, the reaction mixture was diluted with EtOAc and washed with 1M HCl and sat. aq. $NaHCO_3$. The organic phase was dried with $MgSO_4$ and concentrated under reduced pressure, yielding the crude tosylate **41**, which was dissolved in THF with $LiAlH_4$ (1M sln in THF, 7 mL, 7 mmol, 4 eq) and heated to 70 °C. After full conversion, the reaction mixture was cooled to 0 °C and carefully quenched with 1M HCl, after which the reaction mixture was extracted with EtOAc. The organic phase was washed with sat. aq. $NaHCO_3$, dried with $MgSO_4$ and concentrated under reduced pressure. Silica chromatography (10% Et_2O in pentane) yields the title compound as white solid. Yield: 0.43 g, 0.82 mmol, 47% over 2 steps. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.56 – 7.52 (m, 2H, CH_{arom}), 7.39 (dd, *J* = 8.0, 1.5 Hz, 2H, CH_{arom}), 7.36 – 7.25 (m, 16H, CH_{arom}), 4.93 – 4.82 (m, 4H, 3x C*H*H Bn, CH*H* Bn), 4.75 (d, *J* = 10.2 Hz, 1H, CH*H* Bn), 4.68 – 4.63 (m, 2H, H-1, CH*H* Bn), 3.67 (t, *J* = 8.9 Hz, 1H, H-3), 3.49 (dd, *J* = 9.7, 9.0 Hz, 1H, H-2), 3.42 (dq, *J* = 9.5, 6.1 Hz, 1H, H-5), 3.23 (t, *J* = 9.2 Hz, 1H, H-4), 1.35 (d, *J* = 6.1 Hz, 3H, H-6); ^{13}C NMR (101 MHz, $CDCl_3$) δ 138.5, 138.2, 134.0 (C_q), 132.0, 129.0, 128.6, 128.5, 128.3, 128.1, 128.0, 128.0, 128.0, 127.9, 127.6 (CH_{arom}), 87.6 (C-1), 86.7 (C-3), 83.4 (C-4), 81.4 (C-2), 75.9 (CH_2 Bn), 75.7 (C-5), 75.6, 75.5 (CH_2 Bn), 18.3 (C-6). Spectra in agreement with literature.[46]

Phenyl 2,3-di-*O*-benzyl-4,6-*O*-benzylidene-1-thio-β-D-allopyranose (43)



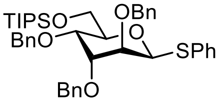
Phenyl 4,6-*O*-benzylidene-1-thio-β-D-glucopyranose (**17**, 2.74 g, 7.60 mmol), benzoic acid (1.39 g, 11.4 mmol, 1.5 eq) and triphenylphosphine (2.99 g, 11.4 mmol,1.5 eq) were dissolved in THF and heated to a gentle reflux. DIAD (2.25 mL, 11.4 mmol,1.5 eq) was added dropwise over 5 min, after which TLC showed full conversion of the starting material. The reaction mixture was cooled to RT and concentrated under reduced pressure. The residue was filtered over a short plug of silica (25% EA) to remove triphenylphosphine oxide, yielding impure product **18**. This was then dissolved in methanol and treated with NaOMe (0.5g). After debenzoylation, the reaction mixture was neutralised with acetic acid and concentrated under reduced pressure. The residue was dissolved in DMF and NaH (60% dispersion in mineral oil, 1.21 g, 30.1 mmol, 4 eq) and benzyl bromide (3.58 mL, 30.1 mmol 4 eq) were added. After 4 hr, the reaction was quenched with water and extracted with diethyl ether. The organic phase was dried with $MgSO_4$ and concentrated. The residue was purified over silica (100% toluene) to give the title compound as colourless oil. Yield: 1.30 g, 2.40 mmol, 32% over 3 steps. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.55 – 7.25 (m, 20H, CH_{arom}), 5.47 (s, 1C*H*Ph), 5.25 (d, *J* = 9.8 Hz, 1H, H-1), 4.89 (d, *J* = 12.0 Hz, 1H, C*H*H Bn), 4.78 (d, *J* = 12.0 Hz, 1H, CH*H* Bn), 4.54 (d, *J* = 2.5 Hz, 2H, C*H*$_2$ Bn), 4.38 (dd, *J* = 10.4, 5.2 Hz, 1H, H-6), 4.21 – 4.12 (m, 2H, H-3, H-5), 3.72 (t, *J* = 10.4 Hz, 1H, H-6), 3.52 (dd, *J* = 9.5, 2.1 Hz, 1H, H-4), 3.38 (dd, *J* = 9.8, 2.7 Hz, 1H, H-2); ^{13}C NMR (101 MHz, $CDCl_3$) δ 138.7, 137.6, 137.5 (C_q), 133.3, 132.2, 129.3, 128.9, 128.6, 128.5, 128.3, 128.2, 128.2, 128.0, 127.6, 127.6, 126.3 (CH_{arom}), 102.1 (CHPh), 84.7 (C-1), 79.9 (C-4), 77.1 (C-2), 74.1 (CH_2 Bn), 73.8 (C-3), 72.1 (CH_2 Bn), 69.4 (C-6), 66.4 (C-5); HRMS: $[M+NH_4]^+$ calcd for $C_{33}H_{32}O_5SNH_4$ 558.23087, found 558.22995

Phenyl 6-deoxy-2,3,4-tri-*O*-benzyl-1-thio-β-D-allopyranose (12)



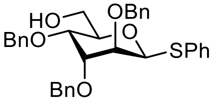
Phenyl 2,3-di-*O*-benzyl-4,6-*O*-benzylidene-1-thio-β-D-allopyranose (**43**, 1.25 g, 2.31 mmol) was dissolved in 7 mL of a 1M BH_3-THF solution in THF (7 mL, 6.94 mmol, 3 eq) and $CoCl_2$ (900 mg, 6.94 mmol, 3 eq) was added. After TLC shows full conversion of the stm, the reaction was diluted with ethyl acetate and filtered over celite. Water was added, and under vigorous stirring, excess $CoCl_2$ was reduced with $NaBH_4$. Solids were filtered off and the phases were separated. The organic phase was dried with $MgSO_4$ and concentrated, yielding crude Phenyl 2,3,4-tri-*O*-benzyl-1-thio-β-D-allopyranose (**44**) which was used without further purification. This compound was dissolved in DCM with DMAP (1.13 g, 9.25 mmol, 4 eq) and p-TsCl (881 mg, 4.62 mmol, 2 eq). After full conversion, the reaction mixture was diluted with EtOAc and washed with 1M HCl and sat. aq. $NaHCO_3$. The organic phase was dried with $MgSO_4$ and concentrated under reduced pressure, yielding the crude tosylate, which was dissolved in THF with $LiAlH_4$ (1M sln in THF, 9.3 mL, 9.3 mmol, 4 eq) and heated to 70 °C. After full conversion, the reaction mixture was cooled to 0 °C and carefully quenched with 1M HCl, after which the reaction mixture was extracted with EtOAc. The organic phase was washed with sat. aq. $NaHCO_3$, dried with $MgSO_4$ and concentrated under reduced pressure. Silica chromatography (10% Et_2O in pentane) yields the title compound as colourless oil. Yield: 588 mg, 1.12 mmol, 48% over 3 steps. $[\alpha]_D^{25}$ = 21.2° (c = 1.44, $CHCl_3$); IR (thin film): 697, 750, 1049, 1089, 1454 ; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.55 – 7.50 (m, 2H, CH_{arom}), 7.39 – 7.21 (m, 18H, CH_{arom}), 5.24 (d, *J* = 9.8 Hz, 1H, H-1), 4.84 (d, *J* = 11.9 Hz, 1H, C*H*H Bn), 4.77 (d, *J* = 11.9 Hz, 1H, CH*H* Bn), 4.63 (d, *J* = 11.6 Hz, 1H, C*H*H Bn), 4.56 (d, *J* = 11.6 Hz, 1H, CH*H* Bn), 4.52 (d, *J* = 11.7 Hz, 1H, C*H*H Bn), 4.39 (d, *J* = 11.7 Hz, 1H, CH*H* Bn), 4.13 (t, *J* = 2.4 Hz, 1H, H-3), 4.01 (dq, *J* = 9.5, 6.2 Hz, 1H, H-5), 3.30 (dd, *J* = 9.8, 2.5 Hz, 1H, H-2), 3.02 (dd, *J* = 9.5, 2.3 Hz, 1H, H-4), 1.28 (d, *J* = 6.2 Hz, 3H, H-6); ^{13}C NMR (101 MHz, $CDCl_3$) δ 139.0, 137.9, 134.2 (C_q), 131.6, 128.8, 128.5, 128.3, 128.1, 128.0, 128.0, 127.9, 127.5, 127.2 (CH_{arom}), 83.8 (C-1), 80.9 (C-4), 78.5 (C-2), 74.4 (CH_2 Bn), 73.2 (C-3), 72.6 (CH_2 Bn), 71.6 (C-5), 71.6 (CH_2 Bn), 18.3 (C-6); HRMS: $[M+NH_4]^+$ calcd for $C_{33}H_{34}O_4SNH_4$ 544.25161, found 544.25045

Phenyl 2,3,4-tri-*O*-benzyl-6-*O*-triisopropylsilyl-1-thio-β-D-altropyranoside (46)



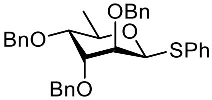
Compound **26** (1.47 g, 5.39 mmol) was dissolved in dry DMF (15 mL). Imidazole (917 mg, 13.5 mmol, 2.5 eq.) and then TIPS-Cl (1.49 mL, 7.01 mmol, 1.3 eq.) where added to the mixture. The reaction was stirred until TLC showed full conversion. The mixture was then quenched with methanol (743 µL, 18.4 mmol, 10 eq.) and diluted in water. The aqueous layer was then 3 times extracted with DCM. The combined organic layers where then washed with 0.1 M aq. HCl and sat. aq. bicarb. The organic layer was diluted dried with MgSO4 and concentrated in vacuo. This yielded a crude TIPS compound which was not characterized and immediately used in the next reaction. The TIPS compound was dissolved in dry DMF (20 mL) and cooled to 0^{o}C. NaH (60% dispersion in mineral oil, 1.08 g, 26.6 mmol, 5 eq.) was added in portions. The mixture was stirred for 30 minutes. Benzyl Bromide (3.20 mL, 26.6 mmol, 5 eq.) was added. The mixture was stirred for 30 minutes before being allowed to warm to room temperature. The reaction was stirred until TLC showed full conversion. The mixture was slowly quenched with water and extracted with a diethyl ether/pentane (1:1) mixture. The organic layer was washed with water and brine. After which it was dried using MgSO4 and concentrated in vacuo. The residue was purified over silica (1% EA in pentane) to yield the title compound as a colourless oil. Yield: 3.13 g, 4.57 mmol, 85%. ^{1}H NMR (400 MHz, CDCl$_3$) δ 7.55 – 7.49 (m, 2H,CH$_{\text{arom}}$), 7.39 – 7.14 (m, 18H, CH$_{\text{arom}}$), 5.22 (d, *J* = 1.4 Hz, 1H, H-1), 4.64 (d, *J* = 12.2 Hz, 1H, C*H*H Bn), 4.58 (d, *J* = 12.2 Hz, 1H, C*H*H Bn), 4.56 (s, 2H, CH*2* Bn), 4.46 (d, *J* = 12.3 Hz, 1H, CH*H* Bn), 4.43 (d, *J* = 12.2 Hz, 1H, CH*H* Bn), 4.36 (d, *J* = 1.6 Hz, 2H, CH$_2$ Bn), 4.03 (dd, *J* = 10.7, 1.8 Hz, 1H, H-6), 3.96 (ddd, *J* = 9.8, 6.1, 1.8 Hz, 1H, H-5), 3.83 (dd, *J* = 10.8, 6.1 Hz, 1H, H-6), 3.77 – 3.69 (m, 3H, H-2, H-3, H-4), 1.15 – 1.01 (m, 21H, CH$_3$ TIPS, CH TIPS); ^{13}C NMR (101 MHz, CDCl$_3$) δ 138.3, 138.2, 138.1, 136.6 (C$_q$), 130.2, 128.8, 128.5, 128.2, 128.2, 128.1, 128.0, 127.9, 126.6 (CH$_{\text{arom}}$), 85.1 (C-1), 79.3 (C-2), 77.2 (C-5), 73.7, 73.1 (CH$_2$ Bn), 73.0, 72.8 (C-3, C-4), 71.8 (CH$_2$ Bn), 63.8 (C-6), 18.2, 18.2 (CH$_3$ TIPS), 12.1 (CH TIPS).

Phenyl 2,3,4-tri-*O*-benzyl-1-thio-β-D-altropyranoside (47)



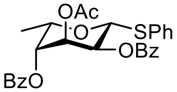
Compound **46** (3.13 g, 4.57 mmol) was dissolved in THF (30 mL). A mixture of TFA/H$_2$O (1:1, 20 mL) was then added. The reaction was allowed to stir until the TLC showed full conversion. It was quenched with bicarb, extracted with EA and washed with brine. The organic layer was dried using MgSO$_4$ and concentrated in vacuo. The residue was purified over silica (20% EA in pentane) to yield the title compound as a colourless oil. Yield: 1.66 g, 3.05 mmol, 84%. ^{1}H NMR (400 MHz, CDCl$_3$) δ 7.45 (dd, *J* = 7.2, 1.8 Hz, 2H, CH$_{\text{arom}}$), 7.38 – 7.19 (m, 18H, CH$_{\text{arom}}$), 5.25 (d, *J* = 1.3 Hz, 1H, H-1), 4.58 (dd, *J* = 12.1, 4.2 Hz, 2H, CH$_2$ Bn), 4.45 (t, *J* = 11.7 Hz, 2H, CH$_2$ Bn), 4.39 (s, 2H, CH$_2$ Bn), 3.95 (ddd, *J* = 9.8, 5.4, 3.1 Hz, 1H, H-3), 3.89 (ddd, *J* = 11.8, 6.3, 3.1 Hz, 1H, H-6), 3.81 (dd, *J* = 9.8, 2.5 Hz, 1H, H-4), 3.78 – 3.68 (m, 3H, H-2, H-5, H-6), 2.16 (t, *J* = 6.7 Hz, 1H, OH); ^{13}C NMR (101 MHz, CDCl$_3$) δ 138.1, 137.8, 137.6, 135.3 (C$_q$), 130.5, 129.1, 128.6, 128.6, 128.5, 128.5, 128.3, 128.3, 128.1, 128.1, 128.0, 127.1 (CH$_{\text{arom}}$), 84.9 (C-1), 78.7 (C-5), 75.5 (C-3), 73.7, 73.2 (CH_2 Bn), 73.0 (C-4), 72.5 (C-2), 71.8 (CH_2 Bn), 63.0 (C-6); HRMS: $[M+NH_4]^+$ calcd for $C_{33}H_{34}O_5SNH_4$ 560.24652, found 560.24545

Phenyl 6-deoxy-2,3,4-tri-*O*-benzyl-1-thio-β-D-altropyranoside (13)



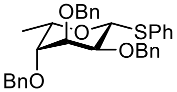
Compound **47** (1.66 g, 3.05 mmol) was dissolved in pyridine (5 mL) and cooled to 0°C. Tosylchloride (871 mg, 4.57 mmol, 1.5 eq.) was added after which the mixture was allowed to warm to room temperature. The reaction was stirred till the TLC showed full conversion. The reaction was quenched with 0.1 M aq. HCl and extracted with diethyl ether. The organic layer was then washed with bicarb and brine. The organic layer was then dried using $MgSO_4$ and concentrated in vacuo. This yielded a crude tosylate **48** which was immediately used in the next reaction. The tosylate was dissolved in THF (30 mL) and $LiAlH_4$ (2.3 M in 2-methylhydrofuran, 5.30 mL, 12.2 mmol, 4 eq.) was added. The mixture was heated to reflux temperature and stirred till TLC showed full conversion. After which the mixture was cooled to 0°C and quenched with 1 M aq. HCl. The aqueous phase was then extracted twice with EA. The combined organic layers where then washed with bicarb and brine. The organic phase was then dried using $MgSO_4$ and concentrated in vacuo. The residue was purified over silica (5% EA in pentane) to yield the title compound as a colourless oil. Yield: 1.03 g, 1.94mmol, 64%. $[\alpha]_D^{25}$ = 14.1° (c = 0.35, $CHCl_3$); IR (thin film): 697, 748, 1027, 1088, 1454; ^1H NMR (400 MHz, $CDCl_3$) δ 7.51 – 7.45 (m, 2H, CH_{arom}), 7.38 – 7.19 (m, 18H, CH_{arom}), 5.19 (d, *J* = 1.5 Hz, 1H, H-1), 4.63 (d, *J* = 12.1 Hz, 1H, C*H*H Bn), 4.55 (d, *J* = 12.2 Hz, 1H, C*H*H Bn), 4.51 – 4.40 (m, 2H, CH*H* Bn, CH*H* Bn), 4.37 (s, 2H, CH_2 Bn), 3.95 (dq, *J* = 9.7, 6.2 Hz, 1H, H-5), 3.73 (dd, *J* = 3.7, 1.5 Hz, 1H, H-2), 3.68 (t, *J* = 3.2 Hz, 1H, H-3), 3.51 (dd, *J* = 9.6, 2.7 Hz, 1H, H-4), 1.33 (d, *J* = 6.2 Hz, 3H, H-6), ^{13}C NMR (101 MHz, $CDCl_3$) δ 130.6, 128.9, 128.6, 128.6, 128.5, 128.3, 128.2, 128.1, 128.0, 128.0, 127.0 (CH_{arom}), 84.9 (C-1), 78.9 (C-2), 77.8 (C-4), 73.8, 73.1 (CH_2 Bn), 72.5 (C-3), 72.0 (CH_2 Bn), 71.8 (C-5), 18.4 (C-6); HRMS: $[M+NH_4]^+$ calcd for $C_{33}H_{34}O_4SNH_4$ 544.25161, found 544.25007

Phenyl 6-deoxy-3-*O*-acetyl-2,4-di-*O*-benzoyl-1-thio-β-L-gulopyranoside(50)



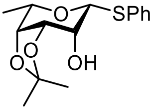
The title compound was synthesises in 5 steps from fucose building block **49** according to literature procedure.[37] ^1H NMR (400 MHz, $CDCl_3$) δ 8.01 – 7.93 (m, 4H, CH_{arom}), 7.65 – 7.53 (m, 4H, CH_{arom}), 7.50 – 7.42 (m, 4H, CH_{arom}), 7.41 – 7.30 (m, 3H, CH_{arom}), 5.60 (dd, *J* = 2.5, 1.4 Hz, 1H, H-3), 5.28 – 5.23 (m, 2H, H-1, H-2), 5.18 (dd, *J* = 3.8, 1.3 Hz, 1H, H-4), 4.33 (qd, *J* = 6.3, 1.2 Hz, 1H, H-5), 2.13 (s, 3H, CH_3 Ac), 1.30 (d, *J* = 6.5 Hz, 3H, H-6); ^{13}C NMR (101 MHz, $CDCl_3$) δ 169.0, 165.3, 164.9 (C=O), 134.0, 133.7, 133.4 (CH_{arom}), 131.3 (C_q), 130.1, 129.8 (CH_{arom}), 129.6, 129.1 (C_q), 128.9, 128.7, 128.6, 128.4 (CH_{arom}), 82.3 (C-1), 71.7 (C-5), 70.9 (C-4), 68.1 (C-3), 67.0 (C-2), 20.9 (CH_3 Ac), 16.5 (C-6).

Phenyl 6-deoxy-2,3,4-tri-*O*-benzyl-1-thio-β-L-gulopyranoside(14)



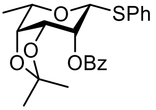
Compound **50** (1.60 g, 3.16 mmol) was dissolved in methanol with NaOMe (171 mg, 3.16 mmol, 1 eq) and stirred until TLC shows full deprotection. The reaction mixture was neutralised with amberlite, filtered and concentrated. The crude triol (**51**) was coevaporated twice with toluene and dissolved in DMF, after which NaH (60% dispersion in mineral oil, 505 mg, 12.6 mmol, 4 eq) and benzyl bromide (1.50 mL, 12.6 mmol, 4 eq) were added. After full conversion, the reaction was quenched with water and extracted with diethyl ether. The organic phase was dried with $MgSO_4$ and concentrated. Silica chromatography (5% to 10% diethyl ether in pentane) yields the title compound as colourless oil. Yield: 1.08 g, 2.05 mmol, 65%. $[\alpha]_D^{25}$ = -0.4° (c = 0.48, $CHCl_3$); IR (thin film): 698, 753, 1042, 1454; ^1H NMR (400 MHz, $CDCl_3$) δ 7.62 – 7.55 (m, 2H, CH_{arom}), 7.36 – 7.21 (m, 16H, CH_{arom}), 7.14 (dd, *J* = 7.0, 2.6 Hz, 2H, CH_{arom}), 5.19 (d, *J* = 9.6 Hz, 1H, H-1), 4.70 (d, *J* = 12.1 Hz, 1H, C*H*H Bn), 4.60 (d, *J* = 11.7 Hz, 1H, C*H*H Bn), 4.48 (d, *J* = 12.2 Hz, 1H, CH*H* Bn), 4.39 (d, *J* = 11.7 Hz, 1H, CH*H* Bn), 4.33 (s, 2H, CH_2 Bn), 4.03 (qd, *J* = 6.5, 1.2 Hz, 1H, H-5), 3.78 – 3.68 (m, 2H, H-2, H-3), 3.20 (dd, *J* = 3.4, 1.4 Hz, 1H, H-4), 1.20 (d, *J* = 6.6 Hz, 3H, H-6); ^{13}C NMR (101 MHz, $CDCl_3$) δ 138.5, 138.2, 138.2, 134.8 (C_q), 131.6, 128.7, 128.5, 128.5, 128.4, 128.0, 127.9, 127.9, 127.9, 126.9 (CH_{arom}), 84.4 (C-1), 77.7 (C-4), 74.8 (C-2), 73.6 (C-3), 73.5, 73.0, 72.7 (CH_2 Bn), 71.5 (C-5), 16.5 (C-6); HRMS: $[M+NH_4]^+$ calcd for $C_{33}H_{34}O_4SNH_4$ 544.25161, found 544.25079

Phenyl 6-deoxy-3,4-*O*-isopropylidene-1-thio-β-L-talopyranoside(54)



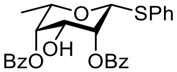
Known fucose intermediate **52**[47] (5.93 g, 20 mmol) was dissolved in DCM with Dess-Martin periodinane (12.7 g, 30 mmol, 1.5 eq) and $NaHCO_3$ (8.40 g, 100 mmol, 5 eq) were dissolved in dichloromethane. After TLC shows full conversion, the reaction mixture was washed with sat. aq. $Na_2S_2O_3$, dried with $MgSO_4$ and concentrated, yielding the crude ketone (**53**) which was used without further purification. The ketone was dissolved in 1:1 MeOH/THF and cooled to -10 °C, after which $NaBH_4$ (2.27 g, 60 mmol, 3 eq) was added in portions. After full conversion, the reaction mixture was concentrated, dissolved in ethyl acetate and washed with water. The organic phase was dried with $MgSO_4$ and concentrated. The residue was purified with silica chromatography, yielding the title compound as colourless oil. Yield: 1.97 g, 6.65 mmol, 33%. ^1H NMR (400 MHz, $CDCl_3$) δ 7.54 – 7.47 (m, 2H, CH_{arom}), 7.34 – 7.22 (m, 3H, CH_{arom}), 4.73 (d, *J* = 1.4 Hz, 1H, H-1), 4.20 (dd, *J* = 5.8, 5.0 Hz, 1H, H-3), 4.02 (dd, *J* = 5.8, 2.6 Hz, 1H, H-4), 3.96 (ddd, *J* = 9.1, 4.7, 1.2 Hz, 1H, H-2), 3.86 (qd, *J* = 6.6, 2.7 Hz, 1H, H-5), 2.57 (d, *J* = 9.1 Hz, 1H, OH), 1.63 (s, 3H, CH_3 isopropylidene), 1.45 (d, *J* = 6.6 Hz, 3H, H-6), 1.40 (s, 3H, CH_3 isopropylidene); ^{13}C NMR (101 MHz, $CDCl_3$) δ 135.5 (C_q), 131.2, 129.1, 127.4 (CH_{arom}), 109.8 (C_q isopropylidene), 87.6 (C-1), 74.2 (C-3), 73.9 (C-4), 72.5 (C-5), 67.8 (C-2), 25.9, 25.6 (CH_3 isopropylidene), 17.0 (C-6);); HRMS: $[M+NH_4]^+$ calcd for $C_{15}H_{20}O_4SNH_4$ 314.14206, found 314.14148.

Phenyl 6-deoxy-2-*O*-benzoyl-3,4-*O*-isopropylidene-1-thio-β-L-talopyranoside(55)



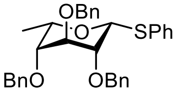
Product **54** (1.95 g, 6.58 mmol) was dissolved in 20 mL 1:1 DCM/pyridine and BzCl (1.15 mL, 9.87 mmol, 1.5 eq) was added. After TLC shows full conversion, the reaction mixture was diluted with DCM and washed twice with a 1 M $CuSO_4$ sln. The organic phase was dried with $MgSO_4$ and concentrated. Silica chromatography (10 to 15% acetone in pentane) yields the title compound as white solid. Yield: 2.08 g, 5.19 mmol, 79%. ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.27 – 8.19 (m, 2H, CH_{arom}), 7.65 – 7.56 (m, 1H, CH_{arom}), 7.49 (ddd, *J* = 8.0, 5.4, 1.5 Hz, 4H, CH_{arom}), 7.36 – 7.22 (m, 3H, CH_{arom}), 5.60 (dd, *J* = 5.7, 1.9 Hz, 1H, H-2), 4.94 (d, *J* = 1.9 Hz, 1H, H-1), 4.49 (t, *J* = 5.9 Hz, 1H, H-3), 4.10 (dd, *J* = 6.1, 2.7 Hz, 1H, H-4), 3.98 (qd, *J* = 6.5, 2.7 Hz, 1H, H-5), 1.57 (d, *J* = 6.6 Hz, 3H, H-6), 1.34 (s, 3H, CH_3 isopropylidene), 1.27 (s, 3H, CH_3 isopropylidene); ^{13}C NMR (101 MHz, $CDCl_3$) δ 166.1 (C=O), 135.2, 133.3 (C_q), 131.0, 130.4, 129.9, 129.1, 128.5, 127.5 (CH_{arom}), 110.2 (C_q isopropylidene), 85.8 (C-1), 73.2 (C-4), 72.9 (C-5), 72.5 (C-3), 68.2 (C-2), 26.0, 25.5 (CH_3 isopropylidene), 17.2 (C-6); HRMS: $[M+Na]^+$ calcd for $C_{22}H_{24}O_5SNa$ 423.12367, found 423.12293.

Phenyl 6-deoxy-2,4-di-*O*-benzoyl -1-thio-β-L-talopyranoside(56)



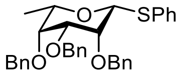
Product **55** (2.00 g, 4.99 mmol) was dissolved in methanol with 400 mg amberlite and heated to a gentle reflux. After isopropylidene removal, the reaction mixture was cooled to RT and filtered over celite. The filtrate was concentrated, coevaporated twice with toluene and dissolved in DCM. CSA (116 mg, 0.50 mmol, 0.1 eq) and trimethylorthobenzoate (1.29 mL, 7.49 mmol, 1.5 eq) were added and the reaction mixture was stirred for 24 hr, after which 10 mL of water was added. After vigorously stirring for another 24 hr, the reaction mixture was washed with sat. aq. $NaHCO_3$. The organic phase was dried with $MgSO_4$ and concentrated. Silica chromatography (25% EtOAc in pentane) yields the title compound as white solid. Yield: 1.24 g, 2.67 mmol 54%. ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.21 – 8.16 (m, 2H, CH_{arom}), 8.05 – 8.00 (m, 2H, CH_{arom}), 7.61 – 7.56 (m, 1H, CH_{arom}), 7.55 – 7.50 (m, 2H, CH_{arom}), 7.45 (tt, *J* = 7.7, 1.3 Hz, 1H, CH_{arom}), 7.41 – 7.35 (m, 2H, CH_{arom}), 7.34 – 7.26 (m, 3H, CH_{arom}), 7.19 – 7.12 (m, 2H, CH_{arom}), 5.73 (ddd, *J* = 3.8, 1.3, 0.8 Hz, 1H, H-2), 5.41 (dd, *J* = 2.8, 1.1 Hz, 1H, H-4), 5.04 (d, *J* = 1.5 Hz, 1H, H-1), 4.24 (q, *J* = 3.9 Hz, 1H, H-3), 3.92 (qd, *J* = 6.3, 1.2 Hz, 1H, H-5), 3.32 (d, *J* = 5.1 Hz, 1H, OH), 1.41 (d, *J* = 6.5 Hz, 3H, H-6); ^{13}C NMR (101 MHz, $CDCl_3$) δ 167.7, 167.2 (C=O), 134.4 (C_q), 133.6, 133.3, 131.2, 130.5, 130.2 (CH_{arom}), 129.4, 129.2 (C_q), 128.5, 128.2, 127.8 (CH_{arom}), 86.5 (C-1), 74.4 (C-5), 72.3 (C-2), 70.9 (C-3), 70.2 (C-2), 17.2 (C-6); HRMS: $[M+Na]^+$ calcd for $C_{26}H_{24}O_6SNa$ 487.11858, found 487.11790.

Phenyl 6-deoxy-2,3,4-tri-*O*-benzyl -1-thio-β-L-idopyranoside(15)



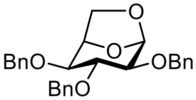
Compound **56** (1.20 g, 2.58 mmol) was dissolved in DCM and cooled to -10 °C, after which pyridine (0.63 mL, 7.75 mmol, 3 eq) and Tf_2O (0.65 mL, 3.87 mmol, 1.5 eq) were added. After full conversion, the reaction mixture was washed with 1M HCl and sat. aq. $NaHCO_3$, dried with $MgSO_4$ and concentrated at 25 °C. The triflate **57** was then dissolved in ACN and treated with $TBANO_2$ (1.49 g, 5.17 mmol, 2 eq) and heated to 80 °C. After 24 hr, the reaction mixture was cooled to RT and concentrated. Silica chromatography yields ca 0.4 g of very impure inverted product **58**. This was then treated with 50 mg NaOMe in MeOH. After debenzoylation, the reaction mixture was quenched with amberlite, filtered and concentrated under reduced pressure. The crude triol was coevaporated 3x with toluene and dissolved in DMF, after which BnBr and NaH, both 4 eq based on pure compound **58**, were added. After 4 hr, the reaction was quenched with water and extracted twice with Et_2O. Silica chromatography (5% Et_2O in pentane) yields the title compound as yellowish oil. Yield: 122 mg, 0.232 mmol, 9% over 4 steps. $[\alpha]_D^{25}$ = 20.8° (c = 0.07, $CHCl_3$); IR (thin film): 697, 1050, 1076, 1076, 1088, 1455; ^1H NMR (400 MHz, $CDCl_3$) δ 7.50 – 7.09 (m, 20H, CH_{arom}), 5.10 (d, *J* = 1.8 Hz, 1H, H-1), 4.64 (d, *J* = 1.8 Hz, 2H, CH_2 Bn), 4.58 (d, *J* = 12.4 Hz, 1H, C*H*H Bn), 4.38 (d, *J* = 12.4 Hz, 1H, CH*H* Bn), 4.31 (d, *J* = 12.1 Hz, 1H, C*H*H Bn), 4.23 (d, *J* = 12.1 Hz, 1H, CH*H* Bn), 3.88 (qd, *J* = 6.5, 1.7 Hz, 1H, H-5), 3.65 (t, *J* = 2.6 Hz, 1H, H-3), 3.61 (d, *J* = 2.7 Hz, 1H, H-2), 3.08 (s, 1H, H-4), 1.29 (d, *J* = 6.6 Hz, 3H, H-6); ^{13}C NMR (101 MHz, $CDCl_3$) δ 138.2, 138.0, 137.6, 136.8 (C_q), 130.4, 128.8, 128.7, 128.6, 128.6, 128.4, 128.4, 128.1, 128.0, 127.9, 127.9, 126.6 (CH_{arom}), 86.4 (C-1), 75.5 (C-2), 74.0 (C-4), 73.4 (CH_2 Bn), 72.8 (C-5), 72.4, 72.1 (CH_2 Bn), 71.6 (C-3), 17.0 (C-6); HRMS: $[M+NH_4]^+$ calcd for $C_{33}H_{34}O_4S$ 544.25161, found 544.25040.

Phenyl 6-deoxy-2,3,4-tri-*O*-benzyl-1-thio-β-L-talopyranoside(16)



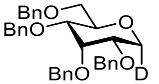
Compound **54** (0.60 g, 2.02 mmol) and PTSA-H_2O (0.04 g, 0.20 mmol, 0.1 eq) were dissolved in methanol and heated to 50 °c. After TLC shows full deprotection, the reaction mixture was concentrated under reduced pressure, yielding crude tri-ol **nr**, which was coevaporated twice with toluene, dissolved in DMF and treated with benzyl bromide (0.96 mL, 8.10 mmol, 4 eq) and sodium hydride (60% dispersion in mineral oil, 0.32 g, 8.10 mmol, 4 eq). After full conversion, the reaction mixture was quenched with water and extracted with diethyl ether. The organic phase was dried with $MgSO_4$ and concentrated under reduced pressure. Silica chromatography (5 to 10% acetone) yields the title compound as colourless oil. Yield: 800 mg, 1.52 mmol, 75%. $[\alpha]_D^{25}$ = 35.6° (c = 0.92, $CHCl_3$); IR (thin film): 695, 738, 1066, 1362, 1454; ^1H NMR (400 MHz, $CDCl_3$) δ 7.51 – 7.45 (m, 4H, CH_{arom}), 7.41 – 7.18 (m, 16H, CH_{arom}), 5.07 (d, *J* = 11.8 Hz, 1H, C*H*H Bn), 5.00 (d, *J* = 12.1 Hz, 1H, C*H*H Bn), 4.95 (d, *J* = 11.8 Hz, 1H, CH*H* Bn), 4.83 (d, *J* = 12.0 Hz, 1H, CH*H* Bn), 4.69 (d, *J* = 1.5 Hz, 1H, H-1), 4.59 (s, 2H, CH_2 Bn), 4.09 (dt, *J* = 2.8, 1.3 Hz, 1H, H-2), 3.64 – 3.60 (m, 1H, H-4), 3.52 – 3.44 (m, 2H, H-3, H-5), 1.34 (d, *J* = 6.4 Hz, 3H, H-6); ^{13}C NMR (101 MHz, $CDCl_3$) δ 139.2, 138.9, 138.0, 136.5 (C_q), 130.9, 128.8, 128.6, 128.5, 128.4, 128.1, 128.1, 127.9, 127.4, 127.4, 126.9 (CH_{arom}), 88.8 (C-1), 81.6 (C-3), 76.0 (C-5), 75.8 (C-2), 74.8 (CH_2 Bn), 74.6 (C-4), 74.3, 71.0 (CH_2 Bn), 17.6 (C-6); HRMS: $[M+NH_4]^+$ calcd for $C_{33}H_{34}O_4SNH_4$ 544.25161, found 544.25024.

1,6-anhydro-2,3,4-tri-*O*-benzyl-D-idopyranoside (61)



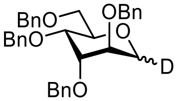
Title compound was formed as side product in reactions **7A** and **7B**. When the idose donor **7** was reacted according to the general procedure for Ph_2SO/Tf_2O mediated glycosylations, but no nucleophile was added, the product was formed in 81% yield after quenching after 24 hr. ^1H NMR (500 MHz, $CDCl_3$) δ 7.36 – 7.26 (m, 15H, CH_{arom}), 5.30 (d, *J* = 1.8 Hz, 1H, H-1), 4.84 (d, *J* = 2.2 Hz, 2H, CH_2 Bn), 4.73 – 4.70 (m, 2H, 2x C*H*H Bn), 4.68 (d, *J* = 11.9 Hz, 1H, CH*H* Bn), 4.62 (d, *J* = 11.8 Hz, 1H, CH*H* Bn), 4.39 (t, *J* = 4.6 Hz, 1H, H-5), 4.13 (dd, *J* = 7.7, 0.9 Hz, 1H, H-6), 3.78 (t, *J* = 8.1 Hz, 1H, H-3), 3.72 – 3.66 (m, 2H, H-4, H-6), 3.47 (dd, *J* = 7.9, 1.8 Hz, 1H, H-2); ^{13}C NMR (126 MHz, $CDCl_3$) δ 138.8, 138.2, 138.1 (C_q), 128.7, 128.6, 128.5, 128.5, 128.1, 128.1, 128.0, 128.0, 127.8, 127.8 (CH_{arom}), 99.8 (C-1), 82.6 (C-2), 82.0 (C-3), 79.5 (C-4), 75.6 (CH_2 Bn), 73.4 (C-5), 73.2, 73.2 (CH_2 Bn), 65.6 (C-6). Spectra in agreement with literature.[48]

1-deutero-1-deoxy-2,3,4,6-tetra-*O*-benzyl-α-D-allopyranoside (4A)



Title compound was prepared according to the general procedure for Ph_2SO/Tf_2O mediated glycosylations with donor **4** and TES-D, yielding compound **4A** (39 mg, 74 μmol, 74%, colourless oil, α:β >98:2) ^1H NMR (400 MHz, $CDCl_3$) δ 7.42 – 7.17 (m, 20H, CH_{arom}), 4.88 (d, *J* = 12.1 Hz, 1H, C*H*H Bn), 4.82 (d, *J* = 12.1 Hz, 1H, CH*H* Bn), 4.59 (d, *J* = 12.3 Hz, 1H, C*H*H Bn), 4.55 (d, *J* = 12.2 Hz, 1H, C*H*H Bn), 4.53 – 4.47 (m, 3H, CH*H* Bn, CH_2 Bn), 4.37 (d, *J* = 11.5 Hz, 1H, CH*H* Bn), 4.21 (t, *J* = 2.5 Hz, 1H, H-3), 3.89 (ddd, *J* = 9.8, 4.0, 2.1 Hz, 1H, H-5), 3.84 – 3.81 (m, 1H, H-1), 3.70 (dd, *J* = 10.5, 2.2 Hz, 1H, H-6), 3.65 (dd, *J* = 10.5, 4.1 Hz, 1H, H-6), 3.51 (dd, *J* = 5.1, 2.3 Hz, 1H, H-2), 3.46 (dd, *J* = 9.8, 2.4 Hz, 1H, H-4); ^{13}C NMR (101 MHz, $CDCl_3$) δ 139.3, 138.3, 138.2, 138.1 (C_q), 128.6, 128.5, 128.4, 128.3, 128.1, 127.9, 127.8, 127.8, 127.7, 127.5, 127.4 (CH_{arom}), 75.9, 75.8 (C-2, C-4), 74.0 (CH_2 Bn), 73.9 (C-5), 73.7 (CH_2 Bn), 73.1 (C-3), 71.4, 71.3 (CH_2 Bn), 69.4 (C-6), 64.0 (t, *J* = 22.0 Hz, C-1); HRMS: $[M+NH_4]^+$ calcd for $C_{34}H_{35}DO_5NH_4$ 543.29638, found 543.29537.

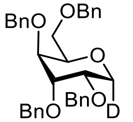
1-deutero-1-deoxy-2,3,4,6-tetra-*O*-benzyl-α,β-D-altropyranoside (5A)



Title compound was prepared according to the general procedure for Ph_2SO/Tf_2O mediated glycosylations with donor **5** and TES-D, yielding compound **5A** (29 mg, 55 μmol, 55%, colourless oil, α:β = 20:80) ^1H NMR (500 MHz, $CDCl_3$) δ 7.37 – 7.17 (m, 20H, CH_{arom}), 4.66 – 4.61 (m, 2H, 2x C*H*H Bn), 4.57 (d, *J* = 9.4 Hz, 1H, C*H*H Bn), 4.55 (d, *J* = 9.4 Hz, 1H, CH*H* Bn), 4.52 (d, *J* = 12.2 Hz, 1H, CH*H* Bn), 4.44 (d, *J* = 11.6 Hz, 1H, C*H*H Bn), 4.42 – 4.36 (m, 2H, 2x CH*H* Bn), 3.96 (ddd, *J* = 9.7, 5.7, 2.0 Hz, 1H, H-5), 3.88 (d, *J* = 1.5 Hz, 0.2H, H-1α), 3.86 – 3.81 (m, 1H, H-3), 3.80 (dd, *J* = 9.8, 2.9 Hz, 1H, H-4), 3.79 (d, *J* = 1.4 Hz, 0.8H, H-1β), 3.76 (dd, *J* = 10.6, 2.0 Hz, 1H, H-6), 3.66 (dd, *J* = 10.6, 5.7 Hz, 1H, H-6), 3.50 (dd, *J* = 3.8, 1.5 Hz, 1H, H-2); ^{13}C

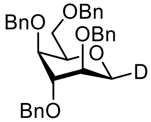
NMR (126 MHz, $CDCl_3$) δ 138.5, 138.5, 138.3, 138.3 (C_q), 128.5, 128.5, 128.4, 128.4, 128.1, 128.0, 127.9, 127.8, 127.8, 127.6 (CH_{arom}), 74.8 (C-2), 74.7 (C-5), 73.9 (C-4), 73.7, 72.9 (CH_2 Bn), 72.7 (C-3), 71.8, 71.0 (CH_2 Bn), 70.3 (C-6), 64.5 (t, *J* = 22.0 Hz, C-1); HRMS: $[M+NH_4]^+$ calcd for $C_{34}H_{35}DO_5NH_4$ 543.29638, found 543.29526.

1-deutero-1-deoxy-2,3,4,6-tetra-*O*-benzyl-α-D-gulopyranoside (6A)



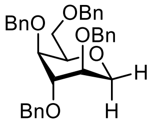
Title compound was prepared according to the general procedure for Ph_2SO/Tf_2O mediated glycosylations with donor **6** and TES-D, yielding compound **6A** (44 mg, 83 µmol, 83%, colourless oil, α:β >98:2); ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.35 – 7.25 (m, 18H, CH_{arom}), 7.15 – 7.11 (m, 2H, CH_{arom}), 4.70 (d, *J* = 12.2 Hz, 1H, C*H*H Bn), 4.56 – 4.50 (m, 3H, 2x C*H*H Bn, CH*H* Bn), 4.47 (d, *J* = 12.1 Hz, 1H, CH*H* Bn), 4.43 (d, *J* = 12.1 Hz, 1H, CH*H* Bn), 4.39 (d, *J* = 12.0 Hz, 1H, C*H*H Bn), 4.35 (d, *J* = 12.0 Hz, 1H, CH*H* Bn), 3.96 (ddd, *J* = 7.1, 5.8, 1.6 Hz, 1H, H-5), 3.86 (dd, *J* = 5.1, 2.7 Hz, 1H, H-2), 3.83 (dd, *J* = 5.1, 1.2 Hz, 1H, H-1), 3.80 (ddd, *J* = 4.0, 2.6, 1.3 Hz, 1H, H-3), 3.56 (dd, *J* = 9.7, 6.8 Hz, 1H, H-6), 3.50 (dd, *J* = 3.9, 1.6 Hz, 1H, H-4), 3.42 (dd, *J* = 9.8, 5.9 Hz, 1H); ^{13}C NMR (126 MHz, $CDCl_3$) δ 138.7, 138.5, 138.2, 138.0 (C_q), 128.6, 128.5, 128.5, 128.5, 128.3, 128.0, 128.0, 127.9, 127.8, 127.8, 127.7 (CH_{arom}), 75.3 (C-4), 73.6 (CH_2 Bn), 73.6 (C-5), 73.0 (CH_2 Bn), 73.0 (C-2), 72.9 (CH_2 Bn), 72.4 (C-3), 71.5 (CH_2 Bn), 69.5 (C-6), 64.1 (t, *J* = 22.0 Hz, C-1); HRMS: $[M+NH_4]^+$ calcd for $C_{34}H_{35}DO_5NH_4$ 543.29638, found 543.29537.

1-deutero-1-deoxy-2,3,4,6-tetra-*O*-benzyl-β-D-idopyranoside (7A)



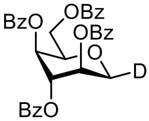
Title compound was prepared according to the general procedure for Ph_2SO/Tf_2O mediated glycosylations with donor **7** and TES-D, yielding compound **7A.** (39 mg, 74 µmol, 74%, colourless oil, α:β <2:98); ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.38 – 7.22 (m, 20H, CH_{arom}), 4.66 – 4.59 (m, 4H, 4x C*H*H Bn), 4.55 – 4.47 (m, 4H, CH*H* Bn), 4.01 (ddd, *J* = 7.6, 4.6, 3.1 Hz, 1H, H-5), 3.82 – 3.76 (m, 2H, H-1, H-6), 3.71 (t, *J* = 4.6 Hz, 1H, H-3), 3.62 (dd, *J* = 10.3, 4.6 Hz, 1H, H-6), 3.52 (dd, *J* = 4.8, 3.2 Hz, 1H, H-4), 3.42 (t, *J* = 3.9 Hz, 1H, H-2); ^{13}C NMR (126 MHz, $CDCl_3$) δ 138.4, 138.3, 138.3, 138.2 (C_q), 128.5, 128.5, 128.5, 128.4, 128.3, 128.0, 127.9, 127.9, 127.9, 127.8, 127.7 (CH_{arom}), 74.9 (C-4), 74.6 (C-5), 74.2 (C-2), 74.0 (C-3), 73.6, 73.1, 72.7, 71.9 (CH_2 Bn), 68.6 (C-6), 65.2 (t, *J* = 22.0 Hz, C-1); HRMS: $[M+NH_4]^+$ calcd for $C_{34}H_{35}DO_5NH_4$ 543.29638, found 543.29518. Comparison with **7A-H** confirms the formation of a single diastereomer, which is characterised as the β-anomer from the benzoylated derivative **7A-Bz**

1-deoxy-2,3,4,6-tetra-*O*-benzyl-D-idopyranoside (7A-H)



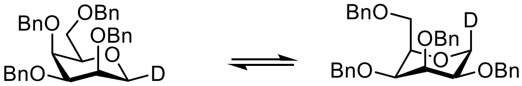
Title compound was prepared according to the general procedure for Ph_2SO/Tf_2O mediated glycosylations with donor **7** and TES-H, yielding compound **7A.** (45 mg, 86 μmol, 86%, colourless oil). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.41 – 7.24 (m, 20H, CH_{arom}), 4.67 – 4.61 (m, 4H, C*H*H Bn), 4.58 – 4.48 (m, 4H, CH*H* Bn), 4.04 (ddd, *J* = 7.6, 4.6, 3.1 Hz, 1H, H-5), 3.96 – 3.90 (m, 1H, H-1eq), 3.87 – 3.79 (m, 2H, H-1ax, H-6), 3.73 (t, *J* = 4.6 Hz, 1H, H-3), 3.64 (dd, *J* = 10.3, 4.6 Hz, 1H, H-6), 3.54 (ddd, *J* = 4.6, 3.2, 0.8 Hz, 1H, H-4), 3.45 (tdd, *J* = 4.2, 3.1, 0.8 Hz, 1H, H-2); ^{13}C NMR (101 MHz, $CDCl_3$) δ 138.4, 138.3, 138.2, 138.2 (C_q), 128.5, 128.5, 128.5, 128.4, 128.3, 128.0, 127.9, 127.9, 127.8, 127.8, 127.8, 127.7 (CH_{arom}, 74.9 (C-4), 74.6 (C-5), 74.2 (C-2), 73.9 (C-3), 73.6, 73.0, 72.7, 71.9 (CH_2 Bn), 68.6 (C-6), 65.5 (C-1); HRMS: $[M+NH_4]^+$ calcd for $C_{34}H_{36}O_5NH_4$ 542.29010, found 542.28852.

1-deutero-1-deoxy-2,3,4,6-tetra-*O*-benzoyl-β-D-idopyranoside (7A-Bz)



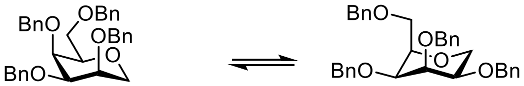
Title compound was prepared according to the general procedure for debenzylation and benzoylation of glycosylated products with **8A** in 60% yield. ^{1}H NMR (500 MHz, $CDCl_3$) δ 8.16 – 8.13 (m, 2H, CH_{arom}), 8.12 – 8.09 (m, 2H, CH_{arom}), 8.06 – 8.02 (m, 2H, CH_{arom}), 7.95 – 7.91 (m, 2H, CH_{arom}), 7.65 – 7.58 (m, 2H, CH_{arom}), 7.58 – 7.54 (m, 1H, CH_{arom}), 7.53 – 7.46 (m, 3H, CH_{arom}), 7.45 – 7.37 (m, 4H, CH_{arom}), 7.22 – 7.16 (m, 2H, CH_{arom}), 5.70 (t, *J* = 3.1 Hz, 1H, H-3), 5.40 (ddd, *J* = 3.2, 2.0, 1.0 Hz, 1H, H-4), 5.16 (ddd, *J* = 3.1, 2.1, 1.0 Hz, 1H, H-2), 4.70 (dd, *J* = 11.6, 7.5 Hz, 1H, H-6), 4.53 (dd, *J* = 11.6, 4.9 Hz, 1H, H-6), 4.46 (ddd, *J* = 7.2, 4.9, 2.0 Hz, 1H, H-5), 4.17 (d, *J* = 2.1 Hz, 1H, H-1); ^{13}C NMR (126 MHz, $CDCl_3$) δ 166.4, 165.7, 165.5, 164.3 (C=O), 133.9, 133.7, 133.4, 133.4, 130.3, 130.1, 129.9 (CH_{arom}), 129.7, 129.4, 129.3, 129.1 (C_q), 128.8, 128.7, 128.6, 128.4 (CH_{arom}), 73.1 (C-5), 67.3, 67.2 (C-2, C-4), 66.6 (C-3), 63.5 (C-6). C-1 is invisible in the 13C-spectrum, but shows a cross-peak at 66.1 in the HSQC spectrum; HRMS: $[M+Na]^+$ calcd for $C_{34}H_{27}DO_9Na$ 604.16883, found 604.16860.

1-deutero-1-deoxy-2,3,4,6-tetra-*O*-benzyl-β-D-talopyranoside (8A)



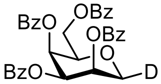
Title compound was prepared according to the general procedure for Ph_2SO/Tf_2O mediated glycosylations with donor **8** and TES-D, yielding compound **8A.** (27 mg, 51 μmol, 51%, colourless oil, α:β <2:98); ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.41 – 7.16 (m, 20H, CH_{arom}), 4.81 (d, *J* = 11.9 Hz, 1H, C*H*H Bn), 4.74 (d, *J* = 12.5 Hz, 1H, C*H*H Bn), 4.69 – 4.54 (m, 5H, 2x C*H*H Bn, 3x CH*H* Bn), 4.48 (d, *J* = 12.0 Hz, 1H, CH*H* Bn), 3.91 (dd, *J* = 10.4, 7.2 Hz, 1H, H-6), 3.75 (tdt, *J* = 8.9, 6.2, 3.1 Hz, 3H, H-3, H-4, H-5), 3.70 – 3.60 (m, 2H, H-2, H-6), 3.48 (d, *J* = 3.0 Hz, 1H, H-1); ^{13}C NMR (101 MHz, $CDCl_3$) δ 138.8, 138.7, 138.6, 138.4 (C_q), 128.5, 128.4, 128.4, 128.4, 128.3, 128.3, 128.1, 127.9, 127.7, 127.6, 127.6, 127.5 (CH_{arom}), 77.3, 74.6 (C-3, C-4, C-5), 73.6 (CH_2 Bn), 73.4 (C-2), 72.9, 72.0, 71.8 (CH_2 Bn), 68.4 (C-6); C-1 is invisible in the 13C-spectrum, but shows a cross-peak at 64.6 in the HSQC spectrum; HRMS: $[M+NH_4]^+$ calcd for $C_{34}H_{35}DO_5NH_4$ 543.29638, found 543.29541. Comparison with **8A-H** shows that one diastereomer is selectively formed, which is characterised as the β-anomer from the benzoylated derivative **8A-Bz**

1-deoxy-2,3,4,6-tetra-*O*-benzyl-β-D-talopyranoside (8A-H)



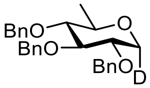
Title compound was prepared according to the general procedure for Ph$_2$SO/Tf$_2$O mediated glycosylations with donor **8** and TES-H, yielding compound **8A.** (28 mg, 53 µmol, 53%, colourless oil) ^{1}H NMR (500 MHz, CDCl$_3$) δ 7.52 – 6.88 (m, 20H, CH$_{\text{arom}}$), 4.81 (d, *J* = 11.9 Hz, 1H, C*H*H Bn), 4.74 (d, *J* = 12.4 Hz, 1H, C*H*H Bn), 4.68 – 4.54 (m, 5H, 2x C*H*H Bn, 3x CH*H* Bn), 4.48 (d, *J* = 12.0 Hz, 1H, CH*H* Bn), 4.04 (dd, *J* = 12.0, 5.4 Hz, 1H, H-1), 3.92 (dd, *J* = 10.6, 7.4 Hz, 1H, H-6), 3.83 – 3.72 (m, 3H, H-3, H-4, H-5), 3.69 – 3.60 (m, 2H, H-2, H-6), 3.50 (dd, *J* = 12.0, 3.1 Hz, 1H, H-1); ^{13}C NMR (126 MHz, CDCl$_3$) δ 138.8, 138.7, 138.6, 138.4 (C$_q$), 128.5, 128.4, 128.4, 128.4, 128.3, 128.3, 128.1, 127.9, 127.7, 127.6, 127.6, 127.5 (CH$_{\text{arom}}$), 77.3, 74.6 (C-3, C-4, C-5), 73.6 (CH$_2$ Bn), 73.4 (C-2), 72.9, 72.0, 71.8 (CH$_2$ Bn), 68.4 (C-6); C-1 is invisible in the 13C-spectrum, but shows a cross-peak at 64.6 in the HSQC spectrum; HRMS: [M+NH$_4$]$^+$ calcd for C$_{34}$H$_{36}$O$_5$NH$_4$ 542.29010, found 542.28886.

1-deutero-1-deoxy-2,3,4,6-tetra-*O*-benzoyl-β-D-talopyranoside (8A-Bz)



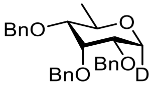
Title compound was prepared according to the general procedure for debenzylation and benzoylation of glycosylated products with **8A** in 36% yield. ^{1}H NMR (400 MHz, CDCl$_3$) δ 8.14 (ddd, *J* = 8.3, 6.6, 1.3 Hz, 4H, CH$_{\text{arom}}$), 8.07 – 8.04 (m, 2H, CH$_{\text{arom}}$), 8.03 – 7.99 (m, 2H, CH$_{\text{arom}}$), 7.85 – 7.80 (m, 2H, CH$_{\text{arom}}$), 7.68 – 7.55 (m, 4H, CH$_{\text{arom}}$), 7.54 – 7.44 (m, 6H, CH$_{\text{arom}}$), 7.42 – 7.37 (m, 2H, CH$_{\text{arom}}$), 7.33 – 7.22 (m, 6H, CH$_{\text{arom}}$), 5.96 (dt, *J* = 3.9, 1.2 Hz, 1H, H-4), 5.65 (t, *J* = 4.0 Hz, 1H, H-3), 5.62 (dt, *J* = 4.4, 1.2 Hz, 1H, H-2), 4.74 (dd, *J* = 11.5, 7.1 Hz, 1H, H-6), 4.49 (dd, *J* = 11.5, 5.8 Hz, 1H, H-6), 4.27 (ddd, *J* = 7.2, 5.8, 1.6 Hz, 1H, H-5), 4.02 (d, *J* = 1.6 Hz, 1H, H-1); ^{13}C NMR (101 MHz, CDCl$_3$) δ 166.3, 166.2, 166.0, 165.2 (C=O), 133.8, 133.3, 133.3, 133.1, 130.2, 130.1, 129.9, 129.8, 129.8 (CH$_{\text{arom}}$), 129.5, 129.3, 129.1, 128.5 (C$_q$), 128.5, 128.5, 128.3, 128.3 (CH$_{\text{arom}}$), 75.6 (C-5), 68.6 (C-1, C-3), 67.6 (C-2), 66.9 (C-4), 62.9 (C-6); HRMS: [M+NH$_4$]$^+$ calcd for C$_{34}$H$_{27}$DO$_9$NH$_4$ 599.21343, found 599.21225.

1-deutero-1,6-dideoxy-2,3,4-tri-*O*-benzyl-α-D-glucopyranoside (9A)



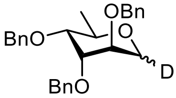
Title compound was prepared according to the general procedure for Ph$_2$SO/Tf$_2$O mediated glycosylations with donor **9** and TES-D, yielding compound **9A** (25 mg, 59 µmol, 59%, colourless oil, α:β >98:2); ^{1}H NMR (500 MHz, CDCl$_3$) δ 7.40 – 7.24 (m, 15H, CH$_{\text{arom}}$), 4.97 (d, *J* = 11.0 Hz, 1H, C*H*H Bn), 4.89 (d, *J* = 10.8 Hz, 1H, C*H*H Bn), 4.85 (d, *J* = 11.0 Hz, 1H, CH*H* Bn), 4.72 (d, *J* = 11.5 Hz, 1H, C*H*H Bn), 4.66 – 4.58 (m, 2H, 2x CH*H* Bn), 3.93 (d, *J* = 4.5 Hz, 1H, H-1), 3.64 – 3.55 (m, 2H, H-2, H-3), 3.31 (dq, *J* = 9.4, 6.1 Hz, 1H, H-5), 3.16 – 3.07 (m, 1H, H-4), 1.26 (d, *J* = 6.1 Hz, 3H, H-6); ^{13}C NMR (126 MHz, CDCl$_3$) δ 138.9, 138.4, 138.3 (C$_q$), 128.6, 128.6, 128.5, 128.1, 128.1, 128.0, 127.9, 127.8 (CH_{arom}), 86.3 (C-4), 83.8 (C-3), 79.0 (C-2), 76.2 (C-5), 75.7, 75.6, 73.4 (CH_2 Bn), 67.7 (t, *J* = 22.0 Hz, C-1) 18.4 (C-1); HRMS: $[M+NH_4]^+$ calcd for $C_{27}H_{29}DO_4NH_4$ 437.25451, found 437.25374.

1-deutero-1,6-dideoxy-2,3,4-tri-*O*-benzyl-α-D-allopyranoside (12A)



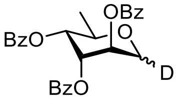
Title compound was prepared according to the general procedure for Ph_2SO/Tf_2O mediated glycosylations with donor **12A** and TES-D, yielding compound **12A** (24 mg, 57 µmol, 57%, colourless oil, α:β >98:2); ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.42 – 7.25 (m, 15H, CH_{arom}), 4.89 (d, *J* = 12.0 Hz, 1H, C*H*H Bn), 4.83 (d, *J* = 12.0 Hz, 1H, CH*H* Bn), 4.59 – 4.52 (m, 3H, 2x C*H*H Bn, CH*H* Bn), 4.40 (d, *J* = 11.7 Hz, 1H, CH*H* Bn), 4.21 (bs, 1H, H-3), 3.83 (dq, *J* = 9.4, 6.2 Hz, 1H, H-5), 3.74 (d, *J* = 4.8 Hz, 1H, H-1), 3.47 (dd, *J* = 4.9, 2.2 Hz, 1H, H-2), 2.97 (dd, *J* = 9.4, 2.4 Hz, 1H, H-4), 1.21 (d, *J* = 6.2 Hz, 3H, H-6); ^{13}C NMR (126 MHz, $CDCl_3$) δ 139.3, 138.4, 138.1 (C_q), 128.6, 128.5, 128.3, 128.1, 128.0, 127.9, 127.9, 127.9, 127.5, 127.4 (CH_{arom}), 81.3 (C-4), 76.4 (C-2), 74.0 (CH_2 Bn), 72.7 (C-3), 71.3 (2x CH_2 Bn), 70.7 (C-5), 63.82 (t, *J* = 22.0 Hz, C-1), 18.3 (C-6); HRMS: $[M+NH_4]^+$ calcd for $C_{27}H_{29}DO_4NH_4$ 437.25451, found 437.25365.

1-deutero-1,6-dideoxy-2,3,4-tri-*O*-benzyl-α,β-D-allopyranoside (13A)



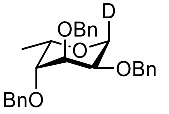
Title compound was prepared according to the general procedure for Ph_2SO/Tf_2O mediated glycosylations with donor **12A** and TES-D, yielding compound **12A** (36 mg, 85 µmol, 85%, colourless oil, α:β = 12:88) ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.59 – 6.76 (m, 15H, CH_{arom}), 4.67 (d, *J* = 12.2 Hz, 1H, C*H*H Bn), 4.58 (t, *J* = 12.8 Hz, 2H, C*H*H Bn, CH*H* Bn), 4.53 (d, *J* = 11.7 Hz, 1H, C*H*H Bn), 4.49 (d, *J* = 11.7 Hz, 1H, CH*H* Bn), 4.45 (d, *J* = 12.4 Hz, 1H, CH*H* Bn), 3.91 – 3.86 (m, 1H, H-5), 3.85 (t, *J* = 3.3 Hz, 1H, H-3), 3.82 – 3.79 (m, 1H, H-1αβ), 3.53 (dd, *J* = 3.8, 1.5 Hz, 1H, H-2), 3.49 (dd, *J* = 9.4, 2.8 Hz, 1H, H-4), 1.32 (d, *J* = 6.2 Hz, 3H, H-6); ^{13}C NMR (126 MHz, $CDCl_3$) δ 138.6, 138.4, 138.3 (C_q), 128.5, 128.5, 128.5, 128.1, 127.9, 127.9, 127.8, 127.8, 127.8 (CH_{arom}), 79.0 (C-4), 75.0 (C-2), 72.8 (CH_2 Bn), 72.4 (C-3), 71.9, 71.2 (CH_2 Bn), 71.2 (C-5), 64.6 (t, *J* = 22.0 Hz, C-1), 18.3 (C-6); HRMS: $[M+NH_4]^+$ calcd for $C_{27}H_{29}DO_4NH_4$ 437.25451, found 437.25365. Because of overlap of H-1α and H-1β, the ratio was determined from the benzoylated derivate **13A-Bz**

1-deutero-1,6-dideoxy-2,3,4-tri-*O*-benzoyl-α,β-D-allopyranoside (13A-Bz)



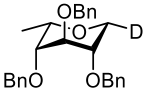
Title compound was prepared according to the general procedure for debenzylation and benzoylation of glycosylated products with **13A** in 80% yield. ^{1}H NMR (850 MHz, $CDCl_3$) δ 8.14 (dd, *J* = 8.3, 1.2 Hz, 2H, CH_{arom}), 8.06 (dd, *J* = 8.3, 1.2 Hz, 2H, CH_{arom}), 7.91 (dd, *J* = 8.4, 1.3 Hz, 2H, CH_{arom}), 7.64 – 7.59 (m, 2H, CH_{arom}), 7.52 (tt, *J* = 7.4, 1.3 Hz, 1H, CH_{arom}), 7.51 – 7.47 (m, 4H, CH$_{\text{arom}}$), 7.38 – 7.33 (m, 2H, CH$_{\text{arom}}$), 5.86 (t, *J* = 3.6 Hz, 1H, H-3), 5.42 (dd, *J* = 9.4, 3.2 Hz, 1H, H-4), 5.32 (dd, *J* = 4.1, 1.7 Hz, 1H, H-2), 4.18 (dq, *J* = 9.4, 6.3 Hz, 1H, H-5), 4.15 (s, 0.12Hα), 4.13 (d, *J* = 1.6 Hz, 0.88H, H-1β), 1.36 (d, *J* = 6.3 Hz, 3H, H-6); ^{13}C NMR (126 MHz, CDCl$_3$) δ 165.6, 165.5, 165.1 (C=O), 133.7, 133.6, 133.4, 130.1, 129.9, 129.8 (CH$_{\text{arom}}$), 129.6, 129.5 (C$_q$), 128.8, 128.7, 128.5 (CH$_{\text{arom}}$), 71.7 (C-4), 71.0 (C-3), 70.2 (C-2), 68.0 (C-3), 65.4 (t, *J* = 22.0 Hz, C-1), 18.0 (C-6); HRMS: [M+NH$_4$]$^+$ calcd for C$_{27}$H$_{23}$DO$_7$NH$_4$ 479.19231, found 479.19118.

1-deutero-1,6-dideoxy-2,3,4-tri-*O*-benzyl-α-L-gulopyranoside (14A)



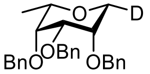
Title compound was prepared according to the general procedure for Ph$_2$SO/Tf$_2$O mediated glycosylations with donor **14A** and TES-D, yielding compound **14A** (36 mg, 86 μmol, 86%, colourless oil, α:β >98:2); ^{1}H NMR (400 MHz, CDCl$_3$) δ 7.37 – 7.26 (m, 13H, CH$_{\text{arom}}$), 7.22 – 7.18 (m, 2H, CH$_{\text{arom}}$), 4.74 (d, *J* = 12.2 Hz, 1H, C*H*H Bn), 4.56 – 4.52 (m, 2H, C*H*H Bn, CH*H* Bn), 4.49 (d, *J* = 10.3 Hz, 1H, CH*H* Bn), 4.46 (d, *J* = 10.3 Hz, 1H, C*H*H Bn), 4.41 (d, *J* = 12.1 Hz, 1H, CH*H* Bn), 3.89 – 3.83 (m, 2H, H-2, H-5), 3.82 (dd, *J* = 4.6, 2.0 Hz, 1H, H-2), 3.79 (d, *J* = 4.9 Hz, 1H, H-1), 3.25 (dd, *J* = 3.8, 1.4 Hz, 1H, H-4), 1.12 (d, *J* = 6.6 Hz, 3H, H-6); ^{13}C NMR (101 MHz, CDCl$_3$) δ 138.7, 138.5, 138.1 (C$_q$), 128.5, 128.5, 128.5, 128.3, 128.0, 127.9, 127.8, 127.8, 127.7 (CH$_{\text{arom}}$), 77.8 (C-4), 73.1 (2x CH$_2$ Bn), 73.0 (C-2), 72.7 (C-3), 71.5 (CH$_2$ Bn), 70.5 (C-5), 64.1 (t, *J* = 22.0 Hz, C-1) 16.4 (C-6); HRMS: [M+NH$_4$]$^+$ calcd for C$_{27}$H$_{29}$DO$_4$NH$_4$ 437.25451, found 437.25364.

1-deutero-1,6-dideoxy-2,3,4-tri-*O*-benzyl-β-L-idopyranoside (15A)



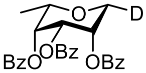
Title compound was prepared according to the general procedure for Ph$_2$SO/Tf$_2$O mediated glycosylations with donor **15** and TES-D on 50 μmol scale, yielding compound **15A**. (11 mg, 25 μmol, 50%, colourless oil, α:β <2:98); ^{1}H NMR (500 MHz, CDCl$_3$) δ 7.40 – 7.08 (m, 15H, CH$_{\text{arom}}$), 4.68 – 4.62 (m, 4H, 2x C*H*H Bn, CH$_2$ Bn), 4.60 (d, *J* = 12.1 Hz, 1H, CH*H* Bn), 4.55 (d, *J* = 11.9 Hz, 1H, CH*H* Bn), 3.96 (qd, *J* = 6.7, 3.9 Hz, 1H, H-5), 3.73 – 3.69 (m, 2H, H-1, H-3), 3.42 (dd, *J* = 5.7, 4.1 Hz, 1H, H-2), 3.39 (dd, *J* = 6.2, 3.9 Hz, 1H, H-4), 1.26 (d, *J* = 6.8 Hz, 3H, H-6); ^{13}C NMR (126 MHz, CDCl$_3$) δ 138.5, 138.5, 138.5 (C$_q$), 128.6, 128.5, 128.5, 128.2, 128.0, 128.0, 127.9, 127.8 (CH$_{\text{arom}}$), 77.8 (C-4), 76.4 (C-3), 75.5 (C-2), 73.9, 72.9, 72.5 (CH$_2$ Bn), 71.0 (C-5), 63.7 (t, *J* = 22.0 Hz, C-1), 14.4 (C-6); HRMS: [M+NH$_4$]$^+$ calcd for C$_{27}$H$_{29}$DO$_4$NH$_4$ 437.25451, found 437.25369

1-deutero-1,6-dideoxy-2,3,4-tri-*O*-benzyl-β-L-talopyranoside (16A)



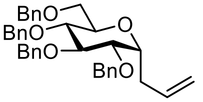
Title compound was prepared according to the general procedure for Ph$_2$SO/Tf$_2$O mediated glycosylations with donor **16** and TES-D, yielding compound **16A**. (29 mg, 68 μmol, 68%, colourless oil, α:β <2:98); ^{1}H NMR (500 MHz, CDCl$_3$) δ 7.60 – 6.99 (m, 15H, CH$_{\text{arom}}$), 4.90 (d, *J* = 12.0 Hz, 1H, C*H*H Bn), 4.80 (d, *J* = 12.6 Hz, 1H, C*H*H Bn), 4.75 (d, *J* = 12.0 Hz, 1H, CH*H* Bn), 4.68 – 4.63 (m, 2H, C*H*H Bn, CH*H* Bn), 4.59 (d, *J* = 12.1 Hz, 1H, CH*H* Bn), 3.70 (bs, 1H, H-4), 3.65 (t, *J* = 2.5 Hz, 1H, H-2), 3.63 – 3.55 (m, 2H, H-3, H-5), 3.41 (d, *J* = 2.4 Hz, 1H, H-1), 1.34 (d, *J* = 6.5 Hz, 3H, H-6); ^{13}C NMR (126 MHz, $CDCl_3$) δ 139.1, 138.9, 138.7 (C_q), 128.4, 128.3, 128.2, 128.2, 127.9, 127.6, 127.5, 127.5, 127.4 (CH_{arom}), 78.7 (C-4), 76.2 (C-3), 73.2 (CH_2 Bn), 72.9 (C-2), 71.8, 71.6 (CH_2 Bn), 16.4 (C-6), C-3 and C-1 are invisible in the 13C spectrum, but show cross-peaks at 74.1 and 65.4 respectively in the HSQC spectrum. HRMS: $[M+NH_4]^+$ calcd for $C_{27}H_{29}DO_4NH_4$ 437.25451, found 437.25372. The product is characterised as the β-anomer form **16A-Bz**

1-deutero-1,6-dideoxy-2,3,4-tri-*O*-benzoyl-β-L-talopyranoside (16A-Bz)



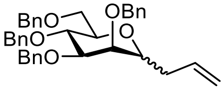
Title compound was prepared according to the general procedure for debenzylation and benzoylation of glycosylated products with **16A** in 91% yield. ^{1}H NMR (850 MHz, $CDCl_3$) δ 8.12 (dd, *J* = 8.4, 1.2 Hz, 2H, CH_{arom}), 8.01 – 7.97 (m, 2H, CH_{arom}), 7.81 – 7.75 (m, 2H, CH_{arom}), 7.58 (tt, *J* = 7.4, 1.3 Hz, 1H, CH_{arom}), 7.50 (tt, *J* = 7.5, 1.3 Hz, 1H, CH_{arom}), 7.46 (ddt, *J* = 8.7, 7.4, 1.5 Hz, 1H, CH_{arom}), 7.37 – 7.33 (m, 2H, CH_{arom}), 7.28 – 7.24 (m, 2H, CH_{arom}), 7.24 – 7.20 (m, 2H, CH_{arom}), 5.65 (dt, *J* = 3.9, 1.1 Hz, 2H, H-4), 5.57 (t, *J* = 4.1 Hz, 1H, H-3), 5.55 (dt, *J* = 4.1, 1.2 Hz, 2H, H-2), 3.95 (qd, *J* = 6.4, 1.3 Hz, 1H, H-5), 3.93 (d, *J* = 1.2 Hz, 1H, H-1), 1.37 (d, *J* = 6.5 Hz, 3H, H-6); ^{13}C NMR (126 MHz, $CDCl_3$) δ 166.6, 166.5, 165.5 (C=O), 133.8, 133.3, 133.3, 133.1, 130.3, 130.2, 130.1 (CH_{arom}), 130.1, 129.9 (C_q), 129.9 (CH_{arom}), 129.4 (C_q), 128.6 , 128.5, 128.4, 128.3 (CH_{arom}), 74.2 (C-5), 69.8 (C-4), 69.2 (C-3), 68.8 (t, *J* = 22.0 Hz, C-1), 67.5 (C-2), 17.1 (C-6); HRMS: $[M+NH_4]^+$ calcd for $C_{27}H_{23}DO_7NH_4$ 479.19231, found 479.19112.

1-allyl-1-deoxy-2,3,4,6-tetra-*O*-benzyl-α-D-glucopyranoside (1B)



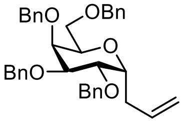
Title compound was prepared according to the general procedure for Ph_2SO/Tf_2O mediated glycosylations with donor **1** and Allyl-TMS, yielding compound **1B** (40 mg, 71 μmol, 71%, colourless oil, α:β >98:2); ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.38 – 7.13 (m, 20H, CH_{arom}), 5.81 (dddd, *J* = 16.6, 10.2, 7.4, 6.3 Hz, 1H, CH_2-C*H*=CH_2), 5.17 – 4.98 (m, 2H, CH_2-CH=C*H*$_2$), 4.93 (d, *J* = 11.0 Hz, 1H, C*H*H Bn), 4.84 – 4.76 (m, 2H, C*H*H Bn, CH*H* Bn), 4.69 (d, *J* = 11.6 Hz, 1H, C*H*H Bn), 4.67 – 4.58 (m, 2H, C*H*H Bn, CH*H* Bn), 4.50 – 4.44 (m, 2H, 2x CH*H* Bn), 4.13 (dt, *J* = 10.4, 5.0 Hz, 1H, H-1), 3.80 (dd, *J* = 9.4, 7.5 Hz, 1H, H-3), 3.76 (dd, *J* = 9.4, 5.5 Hz, 1H, H-2) 3.70 (dd, *J* = 10.6, 3.4 Hz, 1H, H-6), 3.67 – 3.59 (m, 3H, H-4, H-5, H-6), 2.56 – 2.44 (m, 2H, C*H*$_2$-CH=CH_2); ^{13}C NMR (126 MHz, $CDCl_3$) δ 138.9, 138.4, 138.3, 138.2 (C_q), 134.9 (CH_2-CH=CH_2), 128.6, 128.5, 128.5, 128.1, 128.1, 128.0, 128.0, 127.9, 127.9, 127.8, 127.8, 127.7 (CH_{arom}), 117.6(CH_2-CH=CH_2), 82.6 (C-2), 79.8 (C-3), 78.2 (C-4), 75.6, 75.2 (CH_2 Bn), 73.8 (C-1), 73.6, 73.2 (CH_2 Bn), 71.2 (C-5), 69.0 (C-6), 29.9 (*C*H$_2$-CH=CH_2); HRMS: $[M+Na]^+$ calcd for $C_{37}H_{40}NaO_5$ 587.2768, found 587.2770

1-allyl-1-deoxy-2,3,4,6-tetra-*O*-benzyl-α,β-D-mannopyranoside (2B)



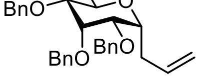
Title compound was prepared according to the general procedure for Ph_2SO/Tf_2O mediated glycosylations with donor **2** and Allyl-TMS, yielding compound **2B** (45 mg, 80 µmol, 80%, colourless oil, α:β >66:34); data of the α-anomer: ^1H NMR (500 MHz, $CDCl_3$): δ 7.41 – 7.23 (m, 20H, CH_{arom}), 5.81 – 5.69 (m, 1H, CH_2-C*H*=CH_2), 5.06 – 4.98 (m, 2H, CH_2-CH=C*H*$_2$), 4.74 – 4.65 (m, 2H, C*H*H Bn, CH*H* Bn), 4.61 – 4.48 (m, 6H, 3x C*H*H Bn, 3x CH*H*), 4.04 (ddd, J = 7.8, 6.1, 4.7 Hz, 1H, H-1), 3.88 – 3.81 (m, 2H, H-4, H-5), 3.80 – 3.74 (m, 2H, H-3, H-6), 3.71 (dd, J = 10.3, 3.5 Hz, 1H, H-6), 3.62 (dd, J = 4.9, 2.9 Hz, 1H, H-2), 2.39 – 2.27 (m, 2H, C*H*$_2$-CH=CH_2); 13C NMR (126 MHz, CDCl3, HSQC): δ 138.6, 138.4, 138.4, 138.3 (C_q), 134.0 (CH_2-*C*H-CH_2), 128.5, 128.4, 128.4, 128.4, 128.4, 128.3, 128.2, 128.2, 128.1, 128.1, 128.1, 128.0, 127.8, 127.7, 127.7, 127.6 (CH_{arom}), 117.3 (CH_2-CH=*C*H$_2$), 77.0 (C-3), 75.3 (C-2), 75.0, 74.0 (CH_2 Bn), 73.9 (C-5), 73.4 (CH_2 Bn), 72.5 (C-1), 72.2, 71.7 (CH_2 Bn), 69.3 (C-6), 33.9 (CH_2-CH=CH_2); diagnostic signals of the β-anomer: 1H NMR (500 MHz, $CDCl_3$): δ 4.87 (d, J = 10.8 Hz, 1H, C*H*H Bn), 4.78 (d, J = 11.7 Hz, 1H, C*H*H Bn), 3.46 (ddd, J = 9.7, 5.8, 1.8 Hz, 1H, H-5), 3.36 – 3.30 (m, 1H, H-1), 2.50 (dtt, J = 12.7, 6.4, 1.6 Hz, 1H, C*H*H-CH=CH_2); 13C NMR (126 MHz, CDCl3): δ 134.8 (CH_2-*C*H=CH_2), 117.4 (CH_2-CH=*C*H$_2$), 80.0 (C-5), 78.4 (C-1), 75.4, 74.5, 73.6, 72.6 (CH_2 Bn), 69.9 (C-6). HRMS: [M+Na]+ calcd for $C_{37}H_{40}NaO_5$ 587.2768, found 587.2781.

1-allyl-1-deoxy-2,3,4,6-tetra-*O*-benzyl-α-D-galactopyranoside (3B)



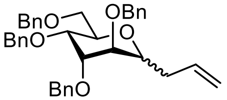
Title compound was prepared according to the general procedure for Ph_2SO/Tf_2O mediated glycosylations with donor **3** and Allyl-TMS, yielding compound **3B** (46 mg, 80 µmol, 80%, colourless oil, α:β >98:2); ^1H NMR (500 MHz, $CDCl_3$) δ 7.91 – 6.50 (m, 20H, CH_{arom}), 5.75 (ddt, *J* = 17.1, 10.2, 6.9 Hz, 1H, CH_2-C*H*=CH_2), 5.13 – 4.98 (m, 2H, CH_2-CH=C*H*$_2$), 4.80 – 4.63 (m, 2H, 2x C*H*H Bn), 4.65 – 4.39 (m, 6H, 2x C*H*H Bn, 4x CH*H* Bn), 4.05 (bs, 1H, H-5), 4.03 – 3.97 (m, 1H, H-3), 4.00 (dd, J = 4.0, 2.6 Hz, 1H, H-1), 3.88 – 3.81 (m, 1H, H-6), 3.75 (s, 1H, H-4), 3.72 (dd, *J* = 6.9, 2.8 Hz, 1H, H-2), 3.66 (dd, *J* = 10.6, 4.7 Hz, 1H, H-6), 2.47 – 2.38 (m, 1H, C*H*H-CH=CH_2), 2.38 – 2.29 (m, 1H, CH*H*-CH=CH_2); 13C NMR (126 MHz, CDCl3, HSQC): δ 138.8, 138.7, 138.7, 138.5 (C_q), 135.4 (CH_2-*C*H=CH_2), 128.6, 128.6, 128.6, 128.5, 128.2, 128.1, 128.0, 128.0, 127.8, 127.8, 127.7 (CH_{arom}), 117.0 (CH_2-CH=*C*H$_2$), 76.7 (C-2), 76.7 (C-4), 74.5 (C-3), 73.4, 73.3, 73.3, 73.2 (CH_2 Bn), 73.0 (C-5), 70.8 (C-1), 67.5 (C-6), 33.9 (*C*H$_2$-CH=CH_2); HRMS: $[M+Na]^+$ calcd for $C_{37}H_{40}NaO_5$ 587.2768, found 587.2776.

1-allyl-1-deoxy-2,3,4,6-tetra-*O*-benzyl-α-D-allopyranoside (4B)



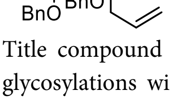
Title compound was prepared according to the general procedure for Ph_2SO/Tf_2O mediated glycosylations with donor **4** and Allyl-TMS, yielding compound **4B** (26 mg, 46 µmol, 46%, colourless oil, α:β >98:2); ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.38 – 7.18 (m, 20H, CH_{arom}), 5.93 – 5.81 (m, 1H, CH_2-C*H*-CH_2), 5.07 (dq, *J* = 17.2, 1.6 Hz, 1H, CH_2-CH=C*H*H), 5.02 (ddt, *J* = 10.2, 2.3, 1.1 Hz, 1H, CH_2-CH=CH*H*), 4.82 (d, *J* = 3.4 Hz, 2H, CH_2 Bn), 4.62 (d, *J* = 12.2 Hz, 1H, C*H*H Bn), 4.56 (s, 2H, CH_2 Bn), 4.50 (d, *J* = 6.9 Hz, 1H, C*H*H Bn), 4.47 (d, *J* = 8.3 Hz, 1H, CH*H* Bn), 4.38 (d, *J* = 11.4 Hz, 1H, CH*H* Bn), 4.21 (t, *J* = 2.8 Hz, 1H, H-3), 4.11 (ddd, *J* = 11.3, 6.1, 3.1 Hz, 1H, H-1), 4.00 (ddd, *J* = 9.7, 3.6, 2.1 Hz, 1H, H-5), 3.76 (dd, *J* = 10.4, 3.4 Hz, 1H, H-6), 3.67 (dd, *J* = 10.4, 2.1 Hz, 1H, H-6), 3.62 (dd, *J* = 6.0, 2.6 Hz, 1H, H-2), 3.56 (dd, *J* = 9.7, 2.8 Hz, 1H, H-4), 3.13 – 2.94 (m, 1H, C*H*H-CH=CH_2), 2.54 (dddt, *J* = 15.4, 6.2, 2.8, 1.4 Hz, 1H, CH*H*-CH=CH_2); ^{13}C NMR (101 MHz, $CDCl_3$) δ 139.3, 138.4, 138.2 (C_q), 136.8 (CH_2-*C*H=CH_2), 128.6, 128.4, 128.4, 128.4, 128.3, 128.0, 127.9, 127.9, 127.8, 127.8, 127.6, 127.5, 127.4 (CH_{arom}), 116.3 (CH_2-CH=*C*H_2), 77.2 (C-4), 75.1 (C-2), 74.5 (C-1), 74.2 (C-3), 74.1, 73.7, 71.4, 71.3 (CH_2 Bn), 69.4 (C-6), 67.2 (C-5), 31.5 (*C*H_2-CH=CH_2); HRMS: $[M+NH_4]^+$ calcd for $C_{37}H_{40}O_5NH_4$ 582.32140, found 582.32030.

1-allyl-1-deoxy-2,3,4,6-tetra-*O*-benzyl-α,β-D-altropyranoside (5B)



The title compound was prepared according to the general procedure for Ph_2SO/Tf_2O mediated glycosylations with donor **5** and Allyl-TMS, yielding compound **5B** (38 mg, 68 µmol, 68%, colourless oil, α:β = 89:11) Data for the α-anomer: ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.35 – 7.22 (m, 20H, CH_{arom}), 5.85 (ddt, *J* = 17.1, 10.2, 6.9 Hz, 1H, CH_2-C*H*=CH_2), 5.12 – 5.00 (m, 2H, CH_2-CH=C*H*$_2$), 4.68 (d, *J* = 11.3 Hz, 1H, C*H*H Bn), 4.59 – 4.53 (m, 3H, 3x C*H*H Bn), 4.53 – 4.47 (m, 4H, 4x CH*H* Bn), 4.17 (q, *J* = 5.2 Hz, 1H, H-5), 3.86 (dd, *J* = 5.3, 3.1 Hz, 1H, H-4), 3.77 – 3.71 (m, 2H, H-1, H-3), 3.66 – 3.61 (m, 2H, H-2, H-6), 3.57 (dd, *J* = 10.3, 4.8 Hz, 1H, H-6), 2.63 – 2.43 (m, 2H, C*H*$_2$-CH=CH_2); ^{13}C NMR (101 MHz, $CDCl_3$) δ 138.4, 138.4, 138.3 (C_q), 135.3 (CH_2=*C*H=CH_2), 128.5, 128.5, 128.4, 128.4, 128.3, 128.3, 128.2, 128.2, 128.1, 128.0, 128.0, 128.0, 127.9, 127.9, 127.8, 127.8, 127.7, 127.7 (CH_{arom}), 117.0 (CH_2-CH=*C*H_2), 77.3, 77.2 (C-2, C-3), 74.8 (C-1), 73.7, 73.4 (CH_2 Bn), 73.4 (C-4), 72.2, 71.7 (CH_2 Bn), 71.7 (C-5), 69.1 (C-6), 35.9 (*C*H_2-CH=CH_2); diagnostic peaks for the β-anomer: ^{1}H NMR (400 MHz, $CDCl_3$) δ 5.68 (dddd, *J* = 16.4, 10.1, 7.9, 6.1 Hz, 1H, CH_2-C*H*=CH_2), 4.02 – 3.94 (m, 2H), 3.32 (dd, *J* = 3.5, 1.5 Hz, 1H), 2.31 – 2.21 (m, 2H, C*H*$_2$-CH=CH_2); ^{13}C NMR (101 MHz, $CDCl_3$) δ 135.1 (CH_2-CH=CH_2), 75.9, 75.2, 74.3, 73.0, 72.7, 71.8, 70.2 (C-6), 35.2 (*C*H_2-CH=CH_2); HRMS: $[M+NH_4]^+$ calcd for $C_{37}H_{40}O_5NH_4$ 582.32140, found 582.31959.

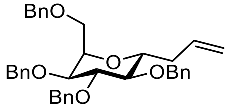
1-allyl-1-deoxy-2,3,4,6-tetra-*O*-benzyl-α-D-gulopyranoside (6B)



Title compound was prepared according to the general procedure for Ph_2SO/Tf_2O mediated glycosylations with donor **6** and Allyl-TMS, yielding compound **6B** (40 mg, 71 µmol, 71%, colourless oil, α:β >98:2); ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.36 – 7.19 (m, 20H, CH_{arom}), 5.78 (ddt, *J*

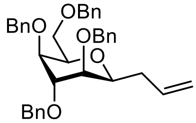
= 17.1, 10.2, 7.0 Hz, 1H, CH_2-C*H*=CH_2), 5.07 (dq, *J* = 17.2, 1.6 Hz, 1H, CH_2-CH=C*H*H), 5.01 (ddt, *J* = 10.2, 2.2, 1.2 Hz, 1H, CH_2-CH=CH*H*), 4.74 (d, *J* = 11.8 Hz, 1H, C*H*H Bn), 4.69 (d, *J* = 12.1 Hz, 1H, C*H*H Bn), 4.64 (d, *J* = 12.1 Hz, 1H, CH*H* Bn), 4.61 – 4.55 (m, 2H, 2x C*H*H Bn), 4.54 – 4.47 (m, 3H, 3x CH*H* Bn), 4.22 (dt, *J* = 6.6, 4.7 Hz, 1H, H-5), 3.94 – 3.87 (m, 2H, H-1, H-4), 3.85 (t, *J* = 3.4 Hz, 1H, H-3), 3.79 (dd, *J* = 6.8, 3.0 Hz, 1H, H-2), 3.69 (dd, *J* = 10.3, 6.6 Hz, 1H, H-6), 3.64 (dd, *J* = 10.3, 5.1 Hz, 1H, H-6), 2.73 (dt, *J* = 15.6, 8.0 Hz, 1H, C*H*H-CH=CH_2), 2.36 (dddt, *J* = 14.9, 7.4, 4.9, 1.3 Hz, 1H, CH*H*-CH=CH_2); ^{13}C NMR (101 MHz, $CDCl_3$) δ 138.8, 138.7, 138.5, 138.4 (C_q), 135.9 (CH_2=*C*H=CH_2), 128.5, 128.4, 128.4, 128.1, 128.0, 127.8, 127.8, 127.7, 127.7, 127.6, 127.6 (CH_{arom}), 116.7 (CH_2-CH=*C*H_2), 75.9 (C-4), 75.1 (C-3), 73.7 (C-1), 73.4, 73.3, 73.1, 73.1 (CH_2 Bn), 68.2 (C-6), 33.4 (*C*H_2-CH=CH_2); C-2 and C-5 are invisible in the 13C-spectrum, but show cross-peaks at 77.0 and 69.9 respectively in the HSQC spectrum; HRMS: $[M+NH_4]^+$ calcd for $C_{37}H_{40}O_5NH_4$ 582.32140, found 582.32010

1-allyl-1-deoxy-2,3,4,6-tetra-*O*-benzyl-α-D-idopyranoside (7B-α)



An analytical amount was isolated as the minor product from reaction between donor **7** and allyl-TMS according to the general procedure for Ph_2SO/Tf_2O mediated glycosylations. ^1H NMR (400 MHz, $CDCl_3$) δ 7.37 – 7.22 (m, 20H, CH_{arom}), 5.89 (dddd, *J* = 17.6, 10.3, 7.4, 6.1 Hz, 1H, CH_2-C*H*=CH_2), 5.16 – 5.02 (m, 2H, CH_2-CH=C*H_2*), 4.90 – 4.83 (m, 2H, 2x C*H*H Bn), 4.74 (d, *J* = 10.9 Hz, 1H, CH*H* Bn), 4.66 (d, *J* = 11.5 Hz, 1H, C*H*H Bn), 4.63 – 4.55 (m, 4H, 2x CH*H* Bn, CH_2 Bn), 4.24 (ddd, *J* = 8.5, 5.6, 3.3 Hz, 1H, H-5), 3.84 (dd, *J* = 11.0, 8.2 Hz, 1H, H-6), 3.80 – 3.69 (m, 4H, H-1, H-3, H-4, H-6), 3.27 (dd, *J* = 9.4, 7.8 Hz, 1H, H-2), 2.58 (dddt, *J* = 14.7, 6.3, 3.3, 1.5 Hz, 1H, C*H*H-CH=CH_2), 2.27 (dtt, *J* = 14.8, 7.4, 1.2 Hz, 1H, CH*H*-CH=CH_2); ^{13}C NMR (101 MHz, $CDCl_3$) δ 138.7, 138.4, 138.3, 138.2 (C_q), 134.8 (CH_2-*C*H=CH_2), 128.6, 128.5, 128.5, 128.0, 127.9, 127.9, 127.8, 127.7 (CH_{arom}), 117.2 (CH_2-CH=*C*H_2), 82.7 (C-3/C-4), 81.3 (C-2), 79.5 (C-3/C-4), 75.4, 75.0 (CH_2 Bn), 73.4 (C-5), 73.4, 73.3 (CH_2 Bn), 72.2 (C-1), 66.0 (CH_2 Bn), 36.3 (CH_2-CH=CH_2); HRMS: $[M+NH_4]^+$ calcd for $C_{37}H_{40}O_5NH_4$ 582.32140, found 582.31962.

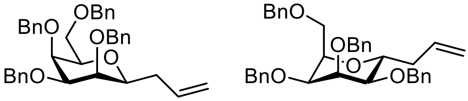
1-allyl-1-deoxy-2,3,4,6-tetra-*O*-benzyl-β-D-idopyranoside (7B-β)



An analytical amount was isolated as the major product from reaction between donor **7** and allyl-TMS according to the general procedure for Ph_2SO/Tf_2O mediated glycosylations. ^1H NMR (400 MHz, $CDCl_3$) δ 7.46 – 7.32 (m, 18H, CH_{arom}), 7.27 – 7.23 (m, 2H, CH_{arom}), 5.82 (dddd, *J* = 16.7, 10.2, 7.7, 6.3 Hz, 1H, CH_2-C*H*=CH_2), 5.13 (dq, *J* = 17.1, 1.6 Hz, 1H, CH_2-CH=C*H*H), 5.08 (ddt, *J* = 10.2, 2.2, 1.1 Hz, 1H, CH_2-CH=CH*H*), 4.69 – 4.64 (m, 2H, 2x C*H*H Bn), 4.62 (d, *J* = 12.3 Hz, 1H, C*H*H Bn), 4.57 (d, *J* = 12.0 Hz, 1H, CH*H* Bn), 4.52 – 4.46 (m, 2H, 2x CH*H* Bn), 4.43 (d, *J* = 12.3 Hz, 1H, C*H*H Bn), 4.36 (d, *J* = 12.3 Hz, 1H, CH*H* Bn), 4.04 (td, *J* = 6.2, 1.8 Hz, 1H, H-5), 3.84 – 3.77 (m, 2H, H-1, H-6), 3.75 – 3.70 (m, 2H, H-3, H-6), 3.49 (dt, *J* = 2.8, 1.4 Hz, 1H, H-4), 3.30 (dt, *J* = 2.9, 1.5 Hz, 1H, H-2), 2.68 (dddt, *J* = 14.0, 7.8, 6.3, 1.5 Hz, 1H, C*H*H-CH=CH_2), 2.36

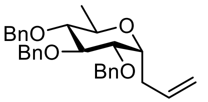
(dddt, *J* = 14.2, 7.6, 6.4, 1.2 Hz, 1H, CH*H*-CH=CH_2); ^{13}C NMR (101 MHz, $CDCl_3$) δ 138.5, 138.2, 138.1, 137.9 (C_q), 135.2 (CH_2-*C*H=CH_2), 128.7, 128.7, 128.5, 128.5, 128.4, 128.3, 128.3, 127.9, 127.8, 127.8, 127.7, 127.7, 127.5 (CH_{arom}), 116.7 (CH_2-CH=*C*H), 76.0 (C-1), 75.7 (C-5), 73.5 (CH_2 Bn), 73.4 (C-2), 72.4 (CH_2 Bn), 72.2 (C-4), 72.2 (CH_2 Bn, 71.8 (CH_2 Bn), 70.0 (C-3), 69.9 (C-6), 35.4 (*C*H_2-CH=CH_2); HRMS: $[M+NH_4]^+$ calcd for $C_{37}H_{40}O_5NH_4$ 582.32140, found 582.31991.

1-allyl-1-deoxy-2,3,4,6-tetra-*O*-benzyl-α,β-D-talopyranoside (8B)



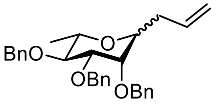
The title compound was prepared according to the general procedure for Ph_2SO/Tf_2O mediated glycosylations with donor **8** and Allyl-TMS, yielding compound **8B** (38 mg, 68 μmol, 68%, colourless oil, α:β = 57:43). Data reported for a 1:1 mixture: ^1H NMR (400 MHz, $CDCl_3$) δ 7.41 – 7.16 (m, 40H, CH_{arom}), 5.89 (dddd, *J* = 17.7, 10.2, 7.6, 6.2 Hz, 1H, CH_2-C*H*=CH_2), 5.71 (dddd, *J* = 16.7, 10.2, 7.7, 6.4 Hz, 1H, CH_2-C*H*=CH_2), 5.10 (dt, *J* = 17.2, 1.7 Hz, 1H, CH_2-CH=C*H*H), 5.07 – 4.96 (m, 4H, CH_2-CH=C*H*H, 2x CH_2-CH=CH*H*, C*H*H Bn), 4.94 (d, *J* = 12.0 Hz, 1H, C*H*H Bn), 4.85 – 4.77 (m, 2H, CH_2 Bn), 4.75 (d, *J* = 12.0 Hz, 1H, C*H*H Bn), 4.71 (d, *J* = 12.0 Hz, 1H, CH*H* Bn), 4.61 – 4.53 (m, 6H, 4x C*H*H Bn, 2x CH*H* Bn), 4.53 – 4.48 (m, 2H, 2x CH*H* Bn), 4.45 (d, *J* = 11.7 Hz, 1H, CH*H* Bn), 4.39 – 4.30 (m, 2H, H-5α, CH*H* Bn), 4.17 (dd, *J* = 11.9, 8.8 Hz, 1H, H-6α), 4.12 (t, *J* = 2.5 Hz, 1H, H-3α), 3.95 – 3.89 (m, 2H, H-1α, H-2β), 3.80 (dd, *J* = 12.0, 2.0 Hz, 1H, H-6α), 3.74 (dt, *J* = 2.9, 1.4 Hz, 1H, H-4β), 3.69 (dd, *J* = 6.1, 1.7 Hz, 2H, 2x H-6β), 3.59 (dd, *J* = 6.3, 2.3 Hz, 1H, H-4α), 3.52 (td, *J* = 6.2, 1.5 Hz, 1H, H-3β), 3.47 (t, *J* = 3.0 Hz, 1H, H-1β), 3.29 (ddd, *J* = 7.5, 6.4, 1.4 Hz, 1H, H-5β), 3.12 (dd, *J* = 9.4, 2.6 Hz, 1H, H-2α), 2.66 – 2.51 (m, 2H, 2x C*H*H-CH=CH_2), 2.36 – 2.27 (m, 1H, CH*H*-CH=CH_2), 2.27 – 2.18 (m, 1H, CH*H*-CH=CH_2); ^{13}C NMR (101 MHz, $CDCl_3$) δ 139.2, 138.9, 138.8, 138.3, 138.3, 138.1, 137.9 (C_q), 135.1, 135.0 (CH_2-*C*H=CH_2), 128.7, 128.6, 128.6, 128.6, 128.5, 128.5, 128.4, 128.4, 128.3, 128.2, 128.2, 128.2, 128.1, 128.0, 127.9, 127.9, 127.8, 127.8, 127.8, 127.7, 127.6, 127.5, 127.5, 127.5, 127.4, 127.3 (CH_{arom}), 117.1, 117.1 (CH_2-CH=*C*H_2), 82.3 (C-1β), 80.0 (C-5β), 79.0 (C-3β), 78.1 (C-2α), 76.8 (C-4α), 75.2 (C-5α), 74.3, 74.2, 74.0 (CH_2 Bn), 74.0 (C-4β), 73.7, 73.2 (CH_2 Bn), 73.1 (C-3α), 72.7 (C-2β), 71.4, 71.1, 71.0 (CH_2 Bn), 69.9 (C-6β), 67.4 (C-1α), 66.4 (C-6α), 35.9, 35.8 (*C*H_2-CH=CH_2); HRMS: $[M+NH_4]^+$ calcd for $C_{37}H_{40}O_5NH_4$ 582.32140, found 582.31986.

1-allyl-1,6-dideoxy-2,3,4-tri-*O*-benzyl-α-D-glucopyranoside (9B)



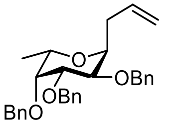
Title compound was prepared according to the general procedure for Ph_2SO/Tf_2O mediated glycosylations with donor **9** and Allyl-TMS, yielding compound **9B** (29 mg, 64 μmol, 64%, colourless oil, α:β >98:2); ^1H NMR (400 MHz, $CDCl_3$) δ 7.36 – 7.27 (m, 15H, CH_{arom}), 5.86 – 5.70 (m, 1H, CH_2-C*H*=CH_2), 5.15 – 5.04 (m, 2H, CH_2-CH=C*H_2*), 4.93 (d, *J* = 10.9 Hz, 1H, C*H*H Bn), 4.89 (d, *J* = 10.7 Hz, 1H, C*H*H Bn), 4.81 (d, *J* = 10.9 Hz, 1H, CH*H* Bn), 4.70 (d, *J* = 11.6 Hz, 1H, C*H*H Bn), 4.65 – 4.60 (m, 2H, 2x CH*H* Bn), 4.06 – 3.97 (m, 1H, H-1), 3.81 – 3.69 (m, 2H, H-2, H-3), 3.63 – 3.55 (m, 1H, H-5), 3.16 – 3.09 (m, 1H, H-4), 2.56 – 2.40 (m, 2H, C*H_2*-CH=CH_2), 1.23 (d, *J* = 6.1 Hz, 3H, H-6); ^{13}C NMR (101 MHz, $CDCl_3$) δ 138.9, 138.4 (C_q), 134.9 (CH_2-*C*H=CH_2), 131.2, 129.5, 129.3, 128.6, 128.6, 128.5, 128.2, 128.1, 127.9, 127.8, 124.9 (CH_{arom}), 117.0 (CH_2-CH=*C*H_2), 84.4 (C-4), 82.4, 80.6 (C-2, C-3), 75.6, 75.6 (CH_2 Bn), 73.8 (C-1), 73.2 (CH_2 Bn), 67.6 (C-5), 30.1 (*C*H_2-CH=CH_2), 18.5 (C-6); HRMS: $[M+NH_4]^+$ calcd for $C_{30}H_{34}O_4NH_4$ 476.27954, found 476.27873.

1-allyl-1-deoxy-2,3,4-tri-*O*-benzyl-α,β-L-rhamnopyranoside (10B)



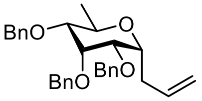
Title compound was prepared according to the general procedure for Ph_2SO/Tf_2O mediated glycosylations with donor **10** and Allyl-TMS, yielding compound **10B** (38 mg, 83 µmol, 83%, colourless oil, α:β 77:23); Data for the α-anomer: ^{1}H NMR (500 MHz, $CDCl_3$): δ 7.48 – 7.13 (m, 15H, CH_{arom}), 5.77 – 5.58 (m, 1H, CH_2-C*H*=CH_2), 5.05 – 4.91 (m, 2H, CH_2-CH=C*H₂*), 4.84 (d, J = 11.1 Hz, 1H, C*H*H Bn), 4.81 – 4.55 (m, 5H, 2x C*H*H Bn, 3x CH*H* Bn,), 4.01 (ddd, J = 8.2, 6.6, 3.4 Hz, 1H, H-1), 3.74 (dd, J = 7.9, 3.1 Hz, 1H, H-3), 3.67 (dd, J = 7.7, 6.1 Hz, 1H, H-5), 3.66 – 3.59 (m, 1H, H-2), 3.58 (t, J = 7.8 Hz, 1H, H-4), 2.34 (tdd, J = 8.2, 6.5, 1.4 Hz, 1H, C*H*H-CH=CH_2), 2.23 (dqd, J = 14.2, 6.9, 1.6 Hz, 1H, CH*H*-CH=CH_2), 1.33 (d, J = 6.2 Hz, 3H, H-6); ^{13}C NMR (126 MHz, CDCl3): δ 138.9, 138.6, 138.4 (C_q), 134.4 (CH_2-*C*H=CH_2), 128.6, 128.6, 128.5, 128.5, 128.2, 128.2, 128.0, 127.9, 127.8, 127.8, 127.7, 127.6 (CH_{arom}), 117.9 (CH_2-CH=*C*H_2), 80.3 (C-4), 78.1 (C-3), 75.3 (C-2), 74.8 (CH_2 Bn), 73.2 (C-1), 72.1, 71.8 (CH_2 Bn), 69.8 (C-5), 34.1 (*C*H_2-CH=CH_2), 18.2 (C-6); diagnostic signals for the β-anomer: 1H NMR (500 MHz, $CDCl_3$): δ 3.78 (dd, J = 2.7, 1.0 Hz, 1H, H-2), 3.36 – 3.28 (m, 2H, H-1, H-5), 2.50 – 2.39 (m, 1H, C*H*H-CH=CH_2); 13C NMR (126 MHz, CDCl3): δ 134.9 (CH_2-*C*H=CH_2), 117.3 (CH_2-CH=*C*H_2), 78.3 (C-1), 76.1 (C-5), 74.9 (C-2), 35.9 (*C*H_2-CH=CH_2), 19.6 (C-6); HRMS: $[M+Na]^+$ calcd for $C_{30}H_{34}NaO_4$ 481.2349, found 481.2355.

1-allyl-1-deoxy-2,3,4-tri-*O*-benzyl-α-L-fucopyranoside (11B)



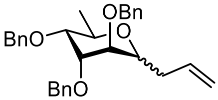
Title compound was prepared according to the general procedure for Ph_2SO/Tf_2O mediated glycosylations with donor **11** and Allyl-TMS, yielding compound **11B** (35 mg, 76 µmol, 76%, colourless oil, α:β >98:2); ^{1}H NMR (500 MHz, $CDCl_3$): δ 8.06 – 6.84 (m, 15H, CH_{arom}), 5.76 (ddt, J = 17.1, 10.2, 6.9 Hz, 1H, CH_2-C*H*=CH_2), 5.14 – 4.93 (m, 2H, CH_2-CH=C*H₂*), 4.80 – 4.53 (m, 5H, 3x C*H*H Bn, 2x CH*H* Bn), 4.52 (d, J = 11.8 Hz, 1H, CH*H* Bn), 4.06 (ddd, J = 8.5, 5.2, 2.4 Hz, 1H, H-1), 3.95 (dd, J = 6.7, 3.8 Hz, 1H, H-5), 3.82 – 3.70 (m, 3H, H-2, H-3, H-4), 2.40 (dddt, J = 14.7, 9.4, 6.8, 1.4 Hz, 1H, C*H*H-CH=CH_2), 2.31 (dddd, J = 13.4, 6.9, 4.1, 1.4 Hz, 1H, CH*H*-CH=CH_2), 1.29 (d, J = 6.7 Hz, 3H, H-6); 13C NMR (126 MHz, $CDCl_3$): δ 139.0, 138.7, 138.5 (C_q), 135.5 (CH_2-*C*H=CH_2), 128.5, 128.4, 128.3, 128.1, 127.9, 127.7, 127.7, 127.7, 127.6 (CH_{arom}), 117.9 (CH_2-CH=*C*H_2), 76.9 (C-3), 76.7 (C-4), 76.0 (C-2), 73.2, 73.1, 73.1(CH_2 Bn), 70.3, (C-1), 68.8 (C-5), 31.2 (*C*H_2-CH=CH_2), 14.5 (C-6); HRMS: $[M+Na]^+$ calcd for $C_{30}H_{34}NaO_4$ 481.2349, found 481.2347.

1-allyl-1,6-dideoxy-2,3,4-tri-*O*-benzyl-α-D-allopyranoside (12B)



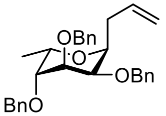
Title compound was prepared according to the general procedure for Ph$_2$SO/Tf$_2$O mediated glycosylations with donor **12** and Allyl-TMS, yielding compound **12B** (26 mg, 57 μmol, 57%, colourless oil, α:β >98:2); ^{1}H NMR (400 MHz, CDCl$_3$) δ 7.40 – 7.25 (m, 15H, CH$_{arom}$), 5.92 – 5.78 (m, 1H, CH$_2$-C*H*=CH$_2$), 5.14 – 4.99 (m, 2H, CH$_2$-CH=C*H$_2$*), 4.86 (d, *J* = 11.7 Hz, 1H, C*H*H Bn), 4.82 (d, *J* = 12.1 Hz, 1H, CH*H* Bn), 4.58 (s, 2H, CH$_2$ Bn), 4.55 (d, *J* = 11.7 Hz, 1H, C*H*H Bn), 4.40 (d, *J* = 11.7 Hz, 1H, CH*H* Bn), 4.19 (t, *J* = 2.6 Hz, 1H, H-3), 4.05 – 3.94 (m, 2H, H-1, H-5), 3.59 (dd, *J* = 6.0, 2.7 Hz, 1H, H-2), 3.11 – 2.99 (m, 2H, H-4, C*H*H-CH=CH$_2$), 2.58 – 2.48 (m, 1H, CH*H*-CH=CH$_2$), 1.22 (d, *J* = 6.2 Hz, 3H, H-6); ^{13}C NMR (101 MHz, CDCl$_3$) δ 139.2, 138.4, 138.1 (C$_q$), 136.8 (CH$_2$-CH=CH$_2$), 128.6, 128.5, 128.3, 128.3, 128.1, 127.9, 127.8, 127.8, 127.5, 127.4 (CH$_{arom}$), 116.4 (CH$_2$-CH=CH$_2$), 80.6 (C-4), 77.6 (C-2), 74.3 (C-1), 74.0 (CH$_2$ Bn), 73.7 (C-3), 71.4, 71.2 (CH$_2$ Bn), 63.6 (C-5), 31.8 (*C*H$_2$-CH=CH$_2$), 18.2 (C-6); HRMS: [M+NH$_4$]$^+$ calcd for $C_{30}H_{34}O_4NH_4$ 476.27954, found 476.27879.

1-allyl-1,6-dideoxy-2,3,4-tri-*O*-benzyl-α,β-D-altropyranoside (13B)



Title compound was prepared according to the general procedure for Ph$_2$SO/Tf$_2$O mediated glycosylations with donor **12** and Allyl-TMS, yielding compound **13B**. (31 mg, 67 μmol, 67%, colourless oil, α:β 89:11) Data for the α-anomer: ^{1}H NMR (400 MHz, CDCl$_3$) δ 7.37 – 7.26 (m, 15H, CH$_{arom}$), 5.84 (ddt, *J* = 17.1, 10.2, 6.9 Hz, 1H, CH$_2$-C*H*=CH$_2$), 5.13 – 5.02 (m, 2H, CH$_2$-CH=C*H$_2$*), 4.74 (d, *J* = 11.3 Hz, 1H, C*H*H Bn), 4.62 – 4.55 (m, 5H, 2x C*H*H Bn, 3x CH*H* Bn), 4.21 – 4.11 (m, 1H, H-5), 3.79 (dd, *J* = 6.8, 3.1 Hz, 1H, H-3), 3.72 – 3.62 (m, 2H, H-1, H-2), 3.52 (dd, *J* = 4.8, 3.1 Hz, 1H, H-4), 2.62 – 2.45 (m, 2H, C*H$_2$*-CH=CH$_2$), 1.19 (d, *J* = 6.8 Hz, 3H, H-6); ^{13}C NMR (101 MHz, CDCl$_3$) δ 138.5, 138.5, 138.4 (C$_q$), 135.4 (CH$_2$-CH=CH$_2$), 128.5, 128.5, 128.5, 128.1, 128.0, 128.0, 127.9, 127.8, 127.7 (CH$_{arom}$), 116.9 (CH$_2$-CH=CH$_2$), 77.6 (C-2), 77.3 (C-4), 77.3 (C-3), 74.0 (CH$_2$ Bn), 73.4 (C-1), 72.3, 71.7 (CH$_2$ Bn), 68.4 (C-5), 36.9 (*C*H$_2$-CH=CH$_2$), 13.1 (C-6); diagnostic peaks for the β-anomer: ^{1}H NMR (400 MHz, CDCl$_3$) δ 5.74 – 5.61 (m, 1H, CH$_2$-C*H*=CH$_2$), 2.39 (dt, *J* = 13.1, 6.9 Hz, 1H, C*H*H-CH=CH$_2$), 2.26 – 2.15 (m, 1H, CH*H*-CH=CH$_2$); ^{13}C NMR (101 MHz, CDCl$_3$) δ 135.1 (CH$_2$-CH=CH$_2$), 117.0 (CH$_2$-CH=CH$_2$), 34.1 (*C*H$_2$-CH=CH$_2$), 18.3 (C-6); HRMS: [M+NH$_4$]$^+$ calcd for $C_{30}H_{34}O_4NH_4$ 476.27954, found 476.27867.

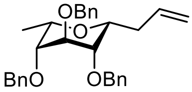
1-allyl-1,6-dideoxy-2,3,4-tri-*O*-benzyl-α-L-gulopyranoside (14B)

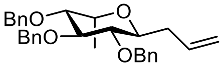


Title compound was prepared according to the general procedure for Ph$_2$SO/Tf$_2$O mediated glycosylations with donor **14** and Allyl-TMS, yielding compound **14B** (35 mg, 75 μmol, 75%, colourless oil, α:β >98:2); ^{1}H NMR (400 MHz, CDCl$_3$) δ 7.38 – 7.26 (m, 15H, CH$_{arom}$), 5.73 (ddt, *J*

= 17.1, 10.2, 7.0 Hz, 1H, CH$_2$-C*H*=CH$_2$), 5.08 – 4.97 (m, 2H, CH$_2$-CH=C*H$_2$*), 4.86 (d, *J* = 11.6 Hz, 1H, C*H*H Bn), 4.74 (s, 2H, CH$_2$ Bn), 4.67 (d, *J* = 11.8 Hz, 1H, C*H*H Bn), 4.61 (d, *J* = 11.7 Hz, 1H, CH*H* Bn), 4.58 (d, *J* = 11.8 Hz, 1H, CH*H* Bn), 4.28 – 4.20 (m, 1H, H-5), 3.91 (bs, 1H, H-4), 3.81 (t, *J* = 2.7 Hz, 1H, H-3), 3.78 – 3.67 (m, 2H, H-1, H-2), 2.57 (dt, *J* = 14.6, 7.5 Hz, 1H, C*H*H-CH=CH$_2$), 2.28 (dt, *J* = 14.1, 6.3 Hz, 1H, CH*H*-CH=CH$_2$), 1.20 (d, *J* = 6.8 Hz, 3H, H-6); ^{13}C NMR (101 MHz, CDCl$_3$) δ 138.9, 138.7, 138.6 (C$_q$), 135.6 (CH$_2$-*C*H=CH$_2$), 128.5, 128.4, 128.4, 128.2, 128.0, 127.8, 127.7, 127.6, 127.6 (CH$_{arom}$), 116.8 (CH$_2$-CH=*C*H$_2$), 78.1 (C-2), 77.2 (C-4), 75.7 (C-3) 73.7, 73.2, 73.2 (CH$_2$ Bn), 72.1 (C-1), 34.4 (*C*H$_2$-CH=CH$_2$), 13.5 (C-6), C-5 is invisible in the 13C-spectrum, but shows a cross-peak at 68.0 in the HSQC-spectrum; HRMS: [M+NH$_4$]$^+$ calcd for C$_{30}$H$_{34}$O$_4$NH$_4$ 476.27954, found 476.27877

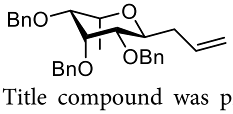
1-allyl-1,6-dideoxy-2,3,4-tri-*O*-benzyl-α,β-L-idopyranoside (15B)





Title compound was prepared according to the general procedure for Ph$_2$SO/Tf$_2$O mediated glycosylations with donor **15** and Allyl-TMS on 50 µmol scale, yielding compound **15B**. (11 mg, 24 µmol, 48%, colourless oil, α:β 21:79) Data for the β-anomer: ^{1}H NMR (400 MHz, CDCl$_3$) δ 7.66 – 7.02 (m, 15H, CH$_{arom}$), 5.79 – 5.65 (m, 1H, CH$_2$-C*H*=CH$_2$), 5.06 – 4.94 (m, 2H, CH$_2$-CH=C*H$_2$*), 4.61 – 4.53 (m, 2H, 2x C*H*H Bn), 4.41 (d, *J* = 12.3 Hz, 2H, 2x CH*H* Bn), 4.32 (s, 2H, CH$_2$ Bn), 3.77 (qd, *J* = 6.6, 1.7 Hz, 1H, H-5), 3.70 – 3.60 (m, 2H, H-1, H-3), 3.19 (q, *J* = 2.7, 2.2 Hz, 1H, H-2), 3.10 (t, *J* = 2.8 Hz, 1H, H-4), 2.57 – 2.48 (m, 1H, C*H*H-CH=CH$_2$), 2.33 – 2.24 (m, 1H, CH*H*-CH=CH$_2$), 1.21 (d, *J* = 6.6 Hz, 3H, H-6); ^{13}C NMR (101 MHz, CDCl$_3$) δ 138.4, 138.4, 138.1 (C$_q$), 135.5 (CH$_2$-*C*H=CH$_2$), 128.8, 128.7, 128.6, 128.4, 128.4, 128.1, 128.0, 127.9, 127.9, 127.8 (CH$_{arom}$), 116.7 (CH$_2$-CH=*C*H$_2$), 76.1 (C-1), 74.8 (C-4), 73.2 (C-2), 72.5, 72.3 (CH$_2$ Bn), 72.2 (C-5), 71.9 (CH$_2$ Bn), 70.5 (C-3), 35.6 (*C*H$_2$-CH=CH$_2$), 17.0 (C-6); diagnostic peaks for the α-anomer: ^{1}H NMR (400 MHz, CDCl$_3$) δ 5.88 – 5.79 (m, 1H, CH$_2$-C*H*=CH$_2$), 4.90 (d, *J* = 10.8 Hz, 1H, C*H*H Bn), 4.80 (d, *J* = 10.8 Hz, 1H, CH*H* Bn), 4.68 (d, *J* = 11.6 Hz, 1H, C*H*H Bn), 4.19 (p, *J* = 6.5 Hz, 1H, H-5), 3.24 (dd, *J* = 9.7, 8.7 Hz, 1H), 1.27 (d, *J* = 7.0 Hz, 3H, H-6); ^{13}C NMR (101 MHz, CDCl$_3$) δ 134.7 (CH$_2$-*C*H=CH$_2$), 117.5 (CH$_2$-CH=*C*H$_2$), 81.9, 80.6, 75.3, 73.2, 70.8, 70.0, 11.0 (C-6); HRMS: [M+NH$_4$]$^+$ calcd for C$_{30}$H$_{34}$O$_4$NH$_4$ 476.27954, found 476.27867.

1-allyl-1,6-dideoxy-2,3,4-tri-*O*-benzyl-α-L-talopyranoside (16B)



Title compound was prepared according to the general procedure for Ph$_2$SO/Tf$_2$O mediated glycosylations with donor 1**6** and Allyl-TMS, yielding compound **16B** (25 mg, 55 µmol, 55%, colourless oil, α:β >98:2); ^{1}H NMR (500 MHz, CDCl$_3$) δ 7.40 – 7.23 (m, 15H, CH$_{arom}$), 5.90 – 5.77 (m, 1H, CH$_2$-C*H*=CH$_2$), 5.09 (dq, *J* = 17.2, 1.6 Hz, 1H, CH$_2$-CH=C*H*H), 5.06 – 5.02 (m, 1H, CH$_2$-CH=CH*H*), 4.87 (d, *J* = 12.0 Hz, 1H, C*H*H Bn), 4.80 (d, *J* = 12.0 Hz, 1H, CH*H* Bn), 4.58 (s, 2H, CH$_2$ Bn), 4.54 (d, *J* = 11.5 Hz, 1H, C*H*H Bn), 4.38 (d, *J* = 11.5 Hz, 1H, CH*H* Bn), 4.22 (t, *J* = 2.6 Hz, 1H, H-3), 4.18 (p, *J* = 6.9 Hz, 1H, H-5), 4.07 – 4.00 (m, 1H, H-1), 3.51 (dd, *J* = 6.0, 2.7 Hz, 1H, H-4), 3.13 (dd, *J* = 9.4, 2.8 Hz, 1H, H-2), 2.61 (dddd, *J* = 13.1, 6.0, 3.2, 1.6 Hz, 1H, C*H*H=CH=CH$_2$), 2.18 (dt, *J* = 14.9, 7.8 Hz, 1H, CH*H*-CH=CH$_2$), 1.49 (d, *J* = 7.0 Hz, 3H, H-6);

^{13}C NMR (126 MHz, $CDCl_3$) δ 139.3, 138.5, 138.1 (C_q), 135.2 (CH_2-*C*H=CH_2), 128.5, 128.5, 128.3, 128.0, 127.9, 127.9, 127.8, 127.5, 127.4 (CH_{arom}), 116.8 (CH_2-CH=*C*H_2), 78.5 (C-2), 77.5 (C-4), 74.0 (CH_2 Bn), 73.8 (C-3), 71.3, 71.0 (CH_2 Bn), 70.5 (C-5), 66.7 (C-1), 36.1 (*C*H_2-CH=CH_2), 14.1 (C-6); HRMS: $[M+NH_4]^+$ calcd for $C_{30}H_{34}O_4NH_4$ 476.27954, found 476.27866.

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3

Chapter 3: Acceptor nucleophilicity – Glycosylation stereoselectivity mapping for all eight diastereomeric pyranosyl donors

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Introduction

Upon activation of a glycosyl donor in a glycosylation reaction, a mixture of different reactive intermediates is formed (***Figure 1***). Depending on the glycosyl donor, the activator, the acceptor (NuH) and external factors, the α-product, the β-product or a mixture thereof can be formed, through a S_N2 mechanism, featuring a covalent reactive intermediate or a S_N1-like mechanism, operating via an oxocarbenium ion intermediate.[1-4] Insight into the "extremes of the mechanistic spectrum" can help to better understand and eventually predict the stereochemical outcome of glycosylation reactions taking place somewhere along the mechanism continuum. The previous Chapter deals with the S_N1 side of the spectrum by determining the influence of the substitution pattern of the sugar ring on the conformational preference and reactivity of the intermediate oxocarbenium ions, using a combination of computational chemistry and glycosylation experiments with C- and D-nucleophiles. This Chapter will focus on the other end of the mechanistic spectrum by investigating the covalent intermediates and the influence of the reactivity of the acceptor on the S_N2 mechanism. For S_N1 reactions and the associated oxocarbenium ions, it is clear that the functional groups on C-2, C-3, C-4 and C-6 heavily influence the outcome,[5-7] with the stereochemistry of C-2 playing an all important role (*this thesis, Chapter 2).* To systematically map the influence of the ring substitution pattern of the donor in S_N2-type glycosylations, in the study of this Chapter all eight diastereomeric pyranosyl thiophenol donors[‡] were used (***Figure 2A***) while the reactive intermediates, formed upon activation were characterised using variable temperature (VT)-NMR. While VT-NMR has been used to detect many covalent species for the usual monosaccharides (predominantly triflates and oxosulfonium triflates)[8-15] the reactive intermediates for the more rare diastereomers have not yet been identified.

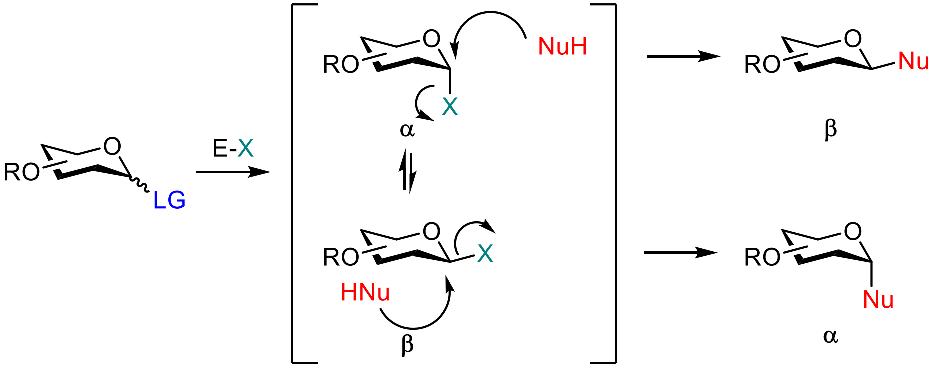


***Figure 1**: Equilibrium of reactive species in a glycosylation reaction,*

[‡] For the synthesis of the allose, altrose, gulose, idose and talose donor, see Chapter 2

After establishing of the structure of the species formed upon activation of the eight diastereomeric pyranosyl donors, the effect of the nucleophilicity of the acceptor on the stereoselectivity of the glycosylations was mapped. To this end the well-established set of fluorinated model alcohols (***Figure 2B***) was used. Of these, the most reactive acceptor -ethanol- has been shown to react with relatively stable covalent intermediates (generally the axially oriented α-triflates), while the weaker nucleophiles (such as trifluorethanol) require a more potent electrophile, such as a β-triflate or more dissociated oxocarbenium ion-triflate ion pair.[9, 10, 14, 16-19]

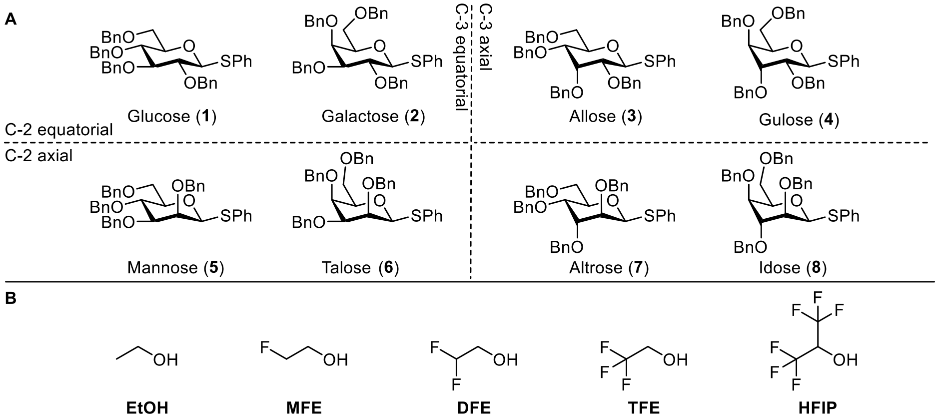


Figure 2: A: *Donors (1-8) divided by configuration and* ***B****: model acceptors (EtOH, MFE, DFE, TFE and HFIP) used in this study.*

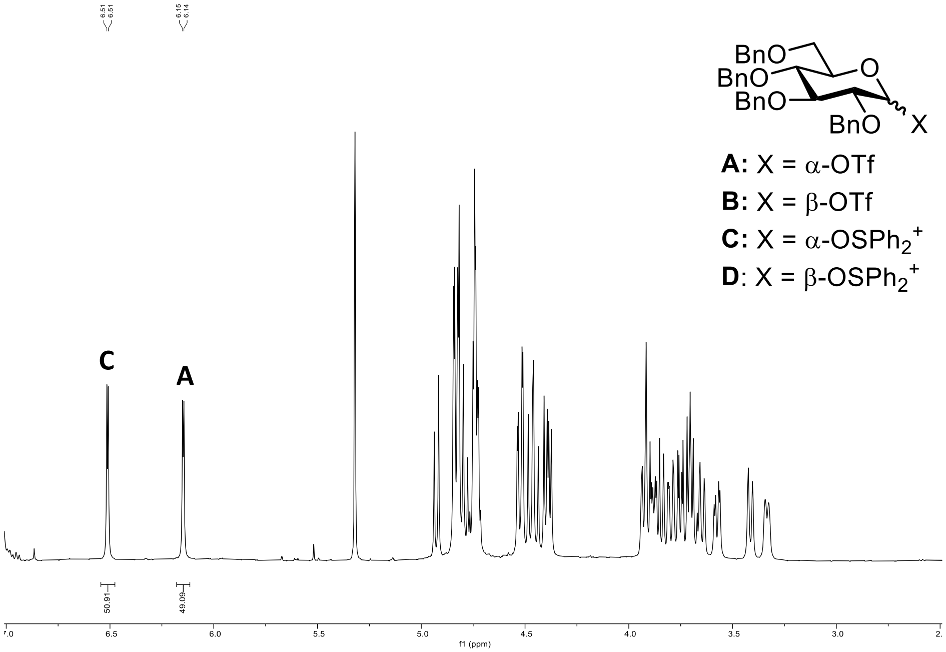
Results and discussion

Characterisation of reactive intermediates

To study the glycosylating properties of the glycosyl donors **1-8** their activation and the formation of reactive intermediates was studied by VT-NMR (***Figure* 3-6**). To this end, a mixture of the donor (1 eq) and Ph_2SO (1.3 eq) in CD_2Cl_2 (50 mM) was cooled to -80 °C, after which Tf_2O (1.3 eq) added. The reaction mixture was then allowed to warm to -60 °C after which the reactive species were characterized. To aid in the identification some experiments were repeated using 3 eq. Ph_2SO, promoting the formation of sulfoxonium triflate species. The results of the VT-NMR are summarized in ***Table 1***.

When glucose donor **1** was activated, a mixture of two species was formed (***Figure* 3**), which were identified as the α-triflate (**A**, H-1: 6.15 (d, *J* = 3.1 Hz)), previously reported in literature,[20, 21] and the α-oxosulfonium triflate (**C**, H-1: 6.51 (d, *J* = 3.4 Hz)). Galactose **2** gave three species upon activation: the α-triflate (**A**, H-1: 6.19 (d, *J* = 3.3 Hz)), the α-oxosulfonium triflate (**C**, H-1: 6.43 (d, *J* = 3.5 Hz)) and the β-oxosulfonium triflate (**D**, H-1: 5.50 (d, *J* = 7.9 Hz)), of which the α-triflate has previously been described.[21] Both allose (**3**) and gulose donor (**4**, ***Figure* 4**) gave the α- and β-oxosulfonium triflates upon activation (for allose: **C**, H-1: 6.13 (d, *J* = 3.7 Hz) and **D**, H-1: 5.79 (d, *J* = 7.8 Hz); for gulose: **C**, H-1: 6.21 (d, *J* = 3.6 Hz) and (**D**, H-1: 5.80 (d, *J* = 8.1 Hz)). The latter two donors provide significantly more of the β-oriented covalent species, which can be directly related to the axial C-3-substituent that destabilizes the α-oriented triflate and oxosulfonium triflate through 1,3-diaxial interactions. Activation of mannose donor (**5**, ***Figure* 5**), led to three species: the α-triflate (**A**, H-1: 6.10 (s)), the α-oxosulfonium triflate (**C**, H-1: 6.44 (s)) and the β-oxosulfonium triflate (**D**, H-1: 5.86 (s)). It has been argued that mannosyl β-triflates cannot be formed because of their instability, that results from the unfavourable orientation with respect to the ring oxygen and the C-2-substituent (the so called Δ2-effect). The formation of the β-oxosulfonium triflate however indicates that a role for these species in the glycosylation manifold should not *a priori* be ruled out. Of note, for a conformationally restricted mannose-type donor a β-oxosulfonium triflate has also been reported.[22] The α-triflate and α-oxosulfonium triflate have previously been characterised for the tetra-*O*-methyl donor.[23, 24] Talose (**6**, ***Figure* 5**), forms the α-triflate upon activation (**A**, H-1: 6.17 (s)) as well as an α-oxosulfonium triflate (**C**, H-1: 6.28 (s)). No β-oriented species could be identified from the mixture of this active donor. Altrose (**7**, ***Figure* 6**) also gave two α-oriented species upon activation: the α-triflate (**A**, H-1: 5.96 (s)) and the α-oxosulfonium triflate (**C**, H-1: 6.26 (s)). The activation of Idose (**8**, ***Figure* 6**) under the standard conditions led to the formation of a side product, which unfortunately could not be characterized. This may be due to the relatively high reactivity of the idose donor, resulting from the three axial ring substituents.[25] When three equivalents of Ph_2SO were used for the activation the α-triflate (**A**, H-1: 6.17 (s)) as well as the α-oxosulfonium triflate (**C**, H-1: 6.28 (s)) were formed

1H-NMR of activated donor 1



1H-NMR of activated donor 2

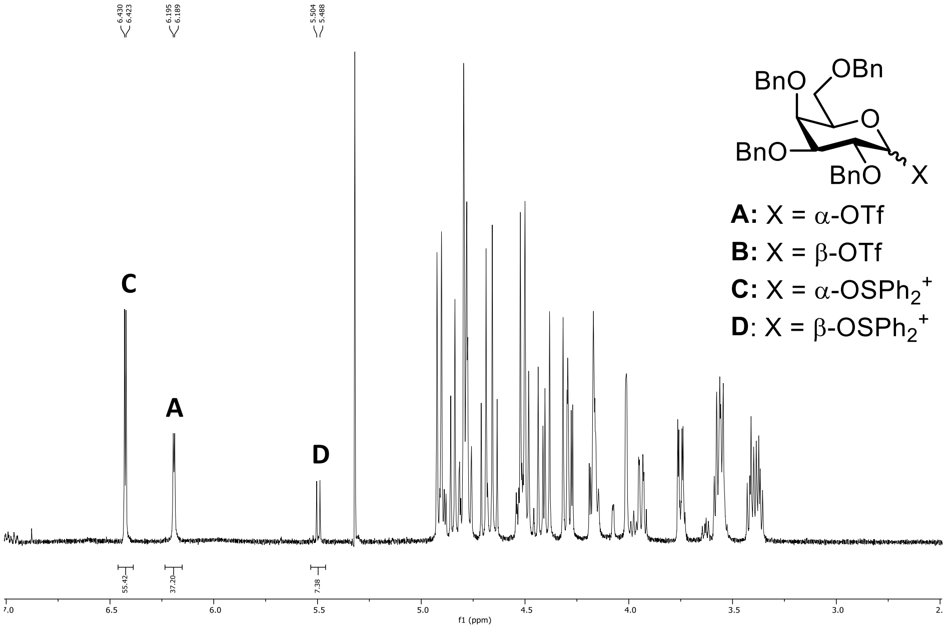
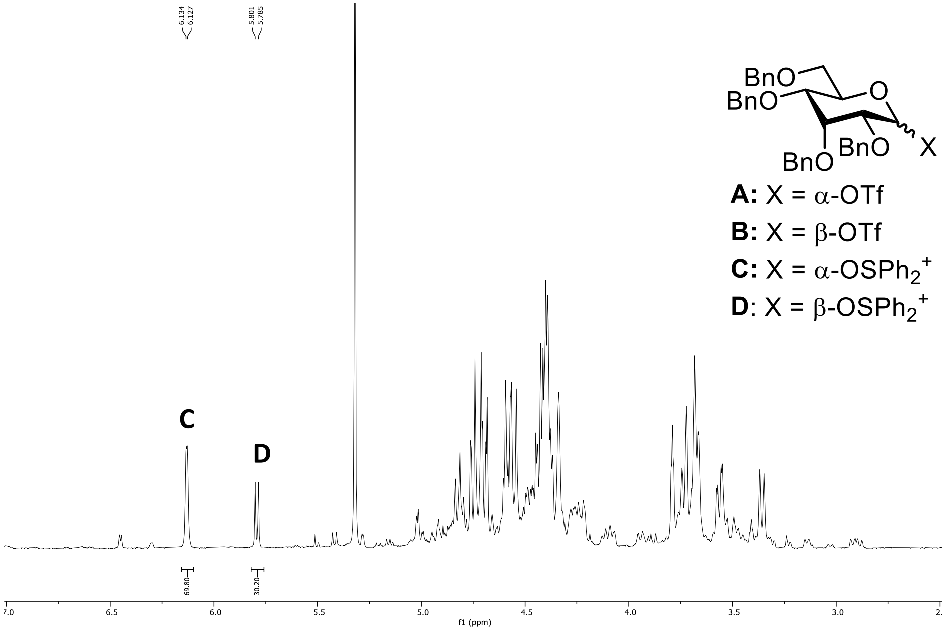


Figure 3: *Activated donors **1** and **2** at -60 ℃ in CD_2Cl_2*

1H-NMR of activated donor 3



1H-NMR of activated donor 4

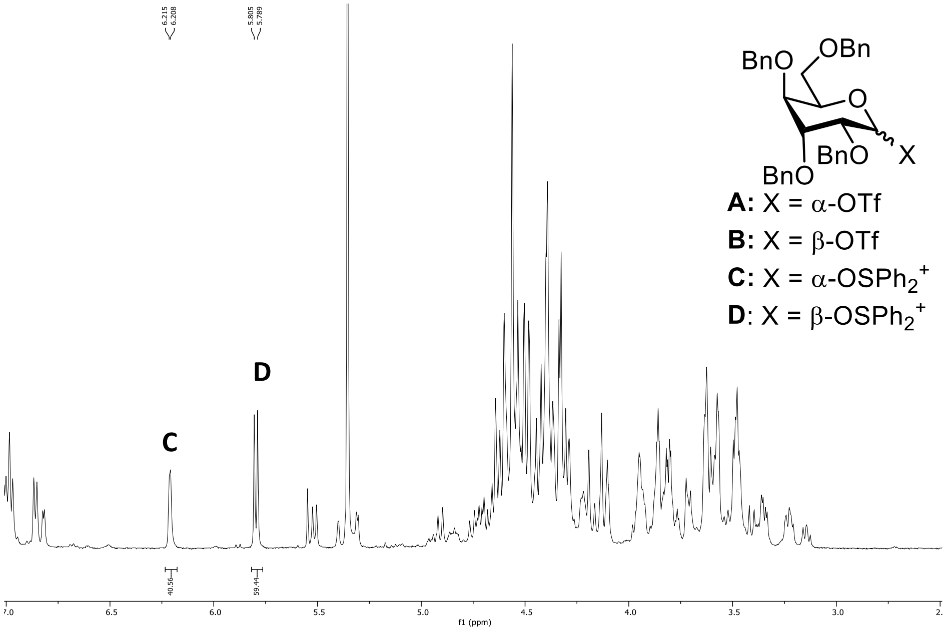
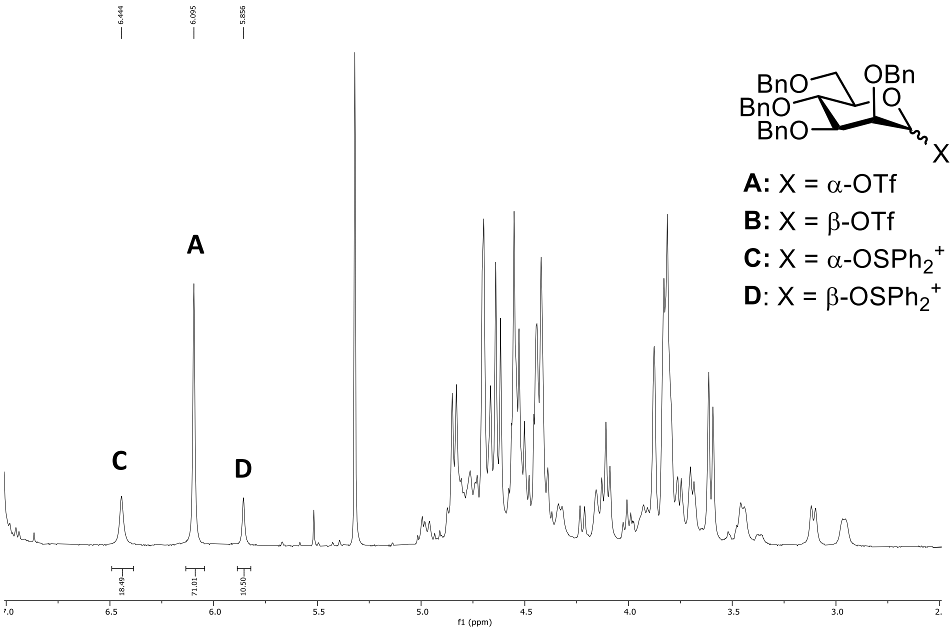


Figure 4: *Activated donors **3** and **4** at -60 °C in CD_2Cl_2*

1H-NMR of activated donor 5



1H-NMR of activated donor 6

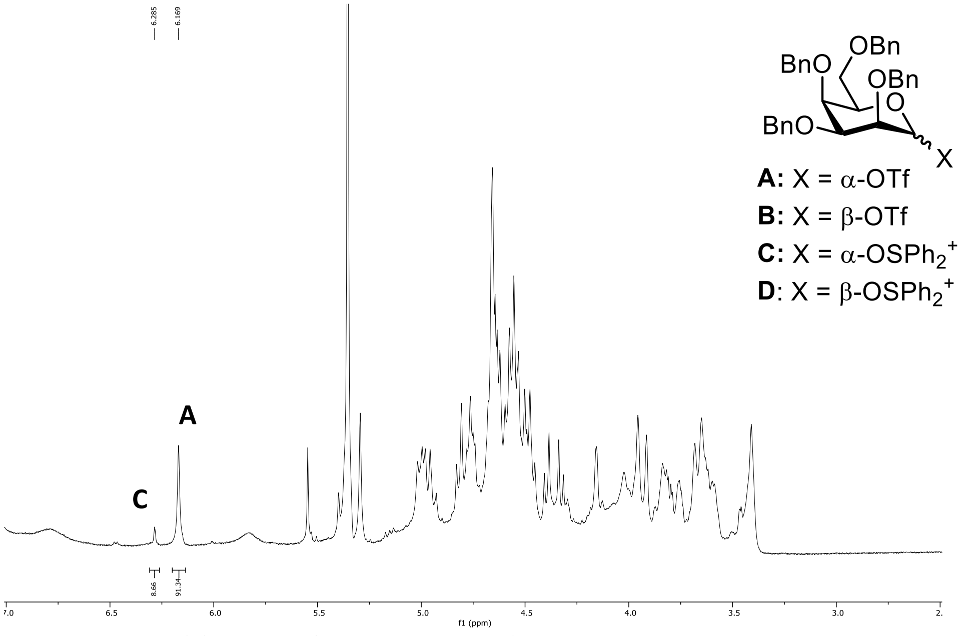
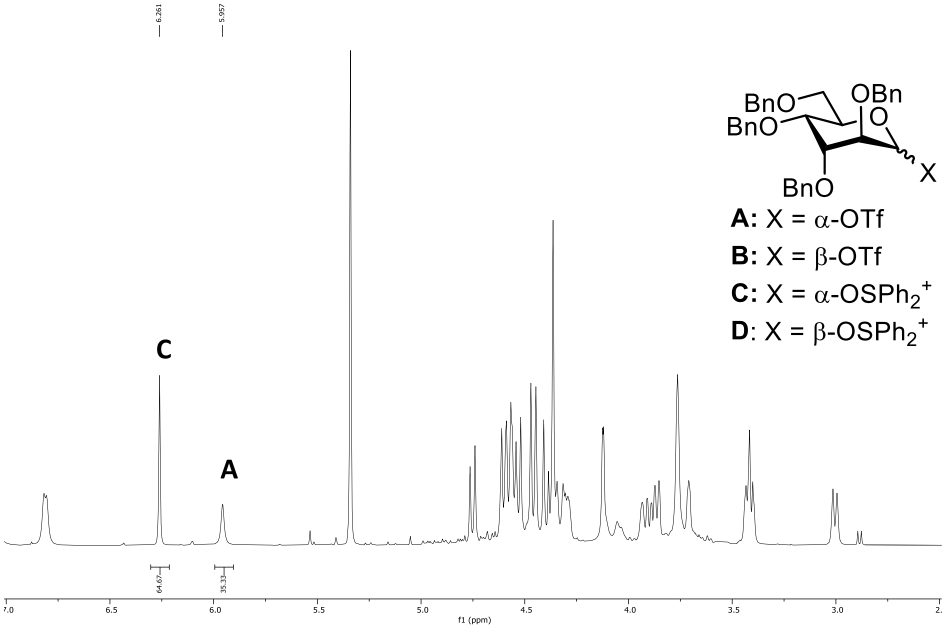


Figure 5: *Activated donors **5** and **6** at -60 °C in CD_2Cl_2*

1H-NMR of activated donor 7



1H-NMR of activated donor 8

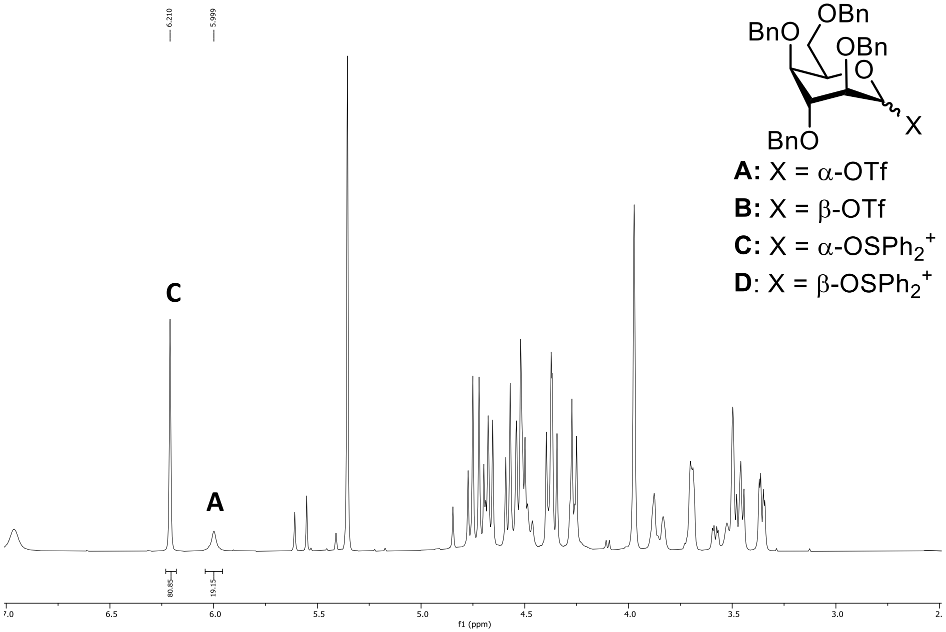


Figure 6: *Activated donors **7** and **8** at -60 ℃ in* CD_2Cl_2

Table 1: *Reactive species observed with VT-NMR at -60 ℃. n.d. = not detected*

Donor	H-1 : δ (multiplicity, J_{H1-H2})				ratio
	α-OTf (A)	**β-OTf (B)**	**α-OSPh$_2^+$ (C)**	**β-OSPh$_2^+$ (D)**	
Glucose (1)	6.15 (d, *J* = 3.1 Hz)	n.d.	6.51 (d, *J* = 3.4 Hz)	n.d.	A:C 49:51
Galactose (2)	6.19 (d, *J* = 3.3 Hz)	n.d.	6.43 (d, *J* = 3.5 Hz)	5.50 (d, *J* = 7.9 Hz)	A:C:D 37:55:7
Allose (3)	n.d.	n.d.	6.13 (d, *J* = 3.7 Hz)	5.79 (d, *J* = 7.8 Hz)	C:D 70:30
Gulose (4)	n.d.	n.d.	6.21 (d, *J* = 3.6 Hz)	5.80 (d, *J* = 8.1 Hz)	C:D 41:59
Mannose (5)	6.10 (s)	n.d.	6.44 (s)	5.86 (s)	A:C:D 71:18:11
Talose (6)	6.17 (s)	n.d.	6.28 (s)	n.d	A:C 91:9
Altrose (7)	5.96 (s)	n.d.	6.26 (s)	n.d	A:C 35:65
Idose (8)[a]	6.00 (s)	n.d.	6.21 (s)	n.d	A:C 19:81

a: 3 eq. of Ph_2SO were used, in VT-NMR with 1.3 eq. Ph_2SO only an yet unidentified decomposition product was found.

Reactions with *O*-nucleophiles

Next, all eight pyranosyl donors were glycosylated with five different acceptors of different nucleophilicity (EtOH, MFE, DFE, TFE and HFIP) to probe the relation between stereoselectivity of the glycosylation reaction and reactivity of the acceptor.[9, 10, 17, 18] The results of these glycosylations are summarized in ***Table 2***, together with the results of the glycosylation of the donors with the S_N1 model nucleophile TES-D (*This thesis, chapter 2*). In Table 2, the donors are organized by configuration of their C-2 and C-3 substituents to highlight the correlation between the orientation of these substituents and the reactivity-stereoselectivity trends. Of note, the selectivity of HFIP, the weakest *O*-nucleophile, differs significantly form the selectivity obtained with TES-D. TES-D gives *cis* selectivity with respect to the C-2-OBn (α when C-2-OBn is equatorial and β when C-2-OBn is axial), while the glycosylations of HFIP selectively provide the α-products, regardless of the stereochemistry of C-2. The differences between the results of the "S_N1 nucleophile" TES-D and HFIP suggest that reactions between a glycosyl donor and a weak *O*-nucleophile follow a different pathway than nucleophilic addition to an oxocarbenium ion. Another clear trend when looking at the stereoselectivity trends going from ethanol (EtOH) to 2,2,2-trifloroethanol (TFE) is observed for the donors having an equatorial C-3-OBn group (*i.e.* glucose, galactose, mannose and talose, **1**, **2**, **5** and **6** respectively): the stereoselectivity observed for these donors gradually changes as a function of acceptor nucleophilicity with the more nucleophilic acceptors giving more β-product and the less nucleophilic acceptors providing more α-product. When the C-3-OBn group is axial (as in the allose, gulose, altrose and idose donors **3**, **4**, **7** and **8**) no clear acceptor reactivity-stereoselectivity relationship was found. A potential mechanistic rationale for these observations is depicted in ***Figure 7***. For the donors with an equatorial C-3-OBn, the α-triflate or α-oxosulfonium triflate are more stable than the β-species, as revealed by the VT-NMR experiments. The α-species can be in equilibrium with the more reactive β-intermediates, that can form, as indicated by the observation of the galactose and mannose β-oxosulfonium triflates. The most reactive acceptors can substitute the α-triflate or α-oxosulfonium triflates to provide the β-product. With gradually decreasing acceptor reactivity, substitution of the more reactive β-intermediates will become more important, leading to the formation of more α-product (***Figure 7A***). In the donors having a C-3-OBn is axial, the difference in stability between the α-species and the β-species is smaller because of the 1,3-diaxial interactions between the α-(oxosulfonium) triflate on C-1 and the OBn-group on C-3.[26] However, in the S_N2-type substitution on the β-species, the trajectory for the incoming nucleophile is also hindered by the C-3-OBn group (***Figure 7B***). Thus, the 'conflicting' steric interactions lead to overall poor stereoselectivity in the glycosylation reactions.

Table 2: *Stereoselectivity of all eight pyranosyl donors with O-nucleophiles and TES-D. Selectivity is given as the α:β ratio in the glycosylation product. Eq = equatorial, Ax = axial n.d. = not determined*

Donor	C-2	C-3	TES-D	HFIP	TFE	DFE	MFE	EtOH
1 **Glc**	Eq	Eq	**1A** **>98:2** (70%)	**1F** **>98:2** (41%)	**1E** **75:25** (80%)	**1D** **48:52** (58%)	**1C** **36:64** (75%)	**1B** **15:85** (70%)
2 **Gal**	Eq	Eq	**2A** **>98:2** (86%)	**2F** **>98:2** (33%)	**2E** **87:13** (79%)	**2D** **66:34** (69%)	**2C** **31:69** (84%)	**2B** **17:83** (73%)
3 **All**	Eq	Ax	**3A** **>98:2** (74%)	**3F** **>98:2** (30%)	**3E** **50:50** (68%)	**3D** **58:42** (60%)	**3C** **55:45** (n.d.)[a]	**3B** **46:54** (45%)
4 **Gul**	Eq	Ax	**4A** **>98:2** (83%)	**4F** **>98:2** (39%)	**4E** **60:40** (85%)	**4D** **69:31** (83%)	**4C** **83:17** (85%)	**4B** **78:22** (94%)
5 **Man**	Ax	Eq	**5A** **3:97** (93%)	**5F** **>98:2** (39%)	**5E** **>98:2** (84%)	**5D** **80:20** (65%)	**5C** **60:40** (75%)	**5B** **33:67** (70%)
6 **Tal**	Ax	Eq	**6A** **<2:98** (51%)	**6F** **>98:2** (14%)	**6E** **90:10** (69%)	**6D** **86:14** (73%)	**6C** **80:20** (74%)	**6B** **68:32** (70%)
7 **Alt**	Ax	Ax	**7A** **20:80** (55%)	**7F** **>98:2** (16%)	**7E** **85:15** (73%)	**7D** **69:31** (64%)	**7C** **58:42** (60%)	**7B** **75:25** (79%)
8 **Ido**	Ax	Ax	**8A** **<2:98** (74%)	**8F** **>98:2** (22%)	**8E** **69:31** (66%)	**8D** **55:45** (72%)	**8C** **57:43** (72%)	**8B** **57:43** (76%)

For reactions with TES-D, see chapter 2. The stereoselectivity of donors ***1, 2*** *and* ***5*** *was previously published.*[19] *a: an accurate yield can't be determined because of poor separation of the glycosylated product from the hydrolysed donor*

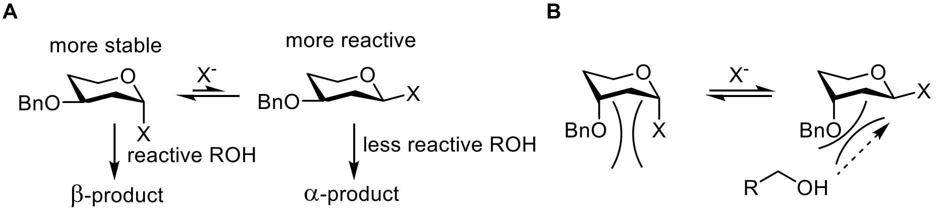


Figure 7: *The impact of the orientation of the C-3-OBn on the acceptor reactivity-stereoselectivity trends. A: For donors having an equatorial C-3-OBn the α-oriented intermediates are more stable, and the β-intermediates are more reactive. The most nucleophilic acceptors can react with the more prevalent former species, while less reactive acceptors need a stronger electrophile. Through a Curtin-Hammett type scenario, the reaction of the poor nucleophiles will shift to the substitution of the β-configured intermediates. B: The axial C-3-OBn destabilizes the α-triflate and oxosulfonium triflate, favoring the formation of the corresponding β-species, but also hinders nucleophilic attack of the incoming nucleophile on the β-species.*

Conclusion

After the investigation of the S_N1 side of the glycosylation as outlined in Chapter 2, the research of this chapter has characterized the covalent reactive species of all eight pyranosyl donors that play a role on the S_N2-side of the glycosylation reaction mechanism continuum. VT-NMR was used to characterise the reactive intermediates. In general, activation of the glycosyl donors leads to the preferential formation of α-triflates and α-oxosulfonium triflates. The galactose and mannose donors do provide a minor amount of the β-oxosulfonium triflate, while activation of the allose and especially the gulose donor, both having an axial C-3-group, leads to the generation of a significant amount of the equatorially oriented oxosulfonium species. Even though only minor amounts of the β-oxosulfonium triflates are formed, the existence of these species indicates that they may play a role in the glycosylation reactions of the different donors. Next, the eight pyranosyl donors were reacted with a set of model acceptors of gradually changing nucleophilicity. From the glycosylation with fluorinated acceptors, it becomes clear that, while S_N1 reactions are typically *1,2-cis* selective as observed by glycosylation with TES-D and supported by CEL-maps of the oxocarbenium ions, glycosylation of (very) weak *O*-nucleophiles always provide the α-product, regardless of the stereochemistry at C-2. This shows that the reactions of weak C/D or O-nucleophiles do not proceed via the same pathway. This discrepancy can be explained by the different nature of the nucleophiles and stereoelectronic effects that play a role in the transition states of the addition reactions to the oxocarbenium ions. The development of a stabilizing anomeric effect may promote the formation of the α-products and H-bonding effects between the nucleophile and donor species will also play a role in shaping the trajectory of the incoming O-nucleophiles. However, the acceptor reactivity-stereoselectivity trends observed here, can also be accounted for with S_N2-type product forming reaction pathways. For the donors having an equatorially oriented C-3-OBn group, a clear shift from β- to α-selectivity was observed with decreasing nucleophilicity of the acceptor. Through a Curtin-Hammett kinetic scenario, in which the weaker nucleophiles preferentially react with the less available but more reactive intermediates, the acceptor reactivity-stereoselectivity trends can be explained. The donors that carry an axial C-3-OBn group typically provide mixtures of anomers in a ratio that shows no clear correlation with the nucleophilicity of the acceptor. To better understand the stereochemical outcome of the glycosylations studied here, systematic computational studies into the nature of the different transition states as well as kinetic studies, supplemented by the establishment of kinetic isotope effects will prove valuable.

Experimental

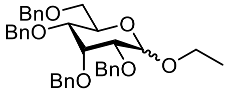
Procedure for VT-NMR experiments of glycosyl donors

A mixture of donor (30 µmol) and Ph_2SO (39 µmol or 90 µmol) was coevaporated with toluene, dissolved in 0.6 mL of CD_2Cl_2 under nitrogen atmosphere and transferred to an oven-dried NMR tube flushed with nitrogen gas and sealed with an NMR tube septum. The magnet was cooled to -80 °C, locked, and shimmed and the sample was measured prior to activation. In a separate cold bath (-80 °C) the sample was treated with Tf_2O (39 µmol) and shaken and recooled 3x. The cold sample was wiped dry and quickly inserted back in the cold magnet. The first ^{1}H NMR spectrum was immediately recorded. The sample was then reshimmed, and spectra were recorded in 10 °C intervals with at least 5 min of equilibration time for every temperature.

General procedure for Ph_2SO/Tf_2O mediated glycosylations

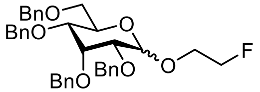
Donor (0.1 mmol, 1 eq), Ph_2SO (0.13 mmol, 1.3 eq) and TTBP (0.25 mmol, 2.5 eq) were coevaporated twice with toluene, dissolved in 2 mL DCM and stirred for 30 min at RT with 3 Å molecular sieves. The solution was cooled to -80 ^{0}C and Tf_2O (22 µL, 0.13 mmol, 2 eq) was added. The reaction mixture was allowed to warm to −60 ^{0}C and then recooled to −80 ^{0}C, after which the acceptor (0.2 mmol, 2 eq) in DCM (0.4 mL, 0.5 M) was added. The reaction mixture was allowed to warm to −60 ^{0}C for and stirred for 2 hr at that temperature. The reaction was quenched with 2 mL sat aq $NaHCO_3$, and the mixture was diluted with DCM. The solution was transferred to a separatory funnel, water was added, the layers were separated, and the water phase was extracted once more with DCM. The combined organic layers were dried over MgSO4, filtered, and concentrated in vacuo. Purification by silica gel flash column chromatography and/or sephadex LH-20 size-exclusion chromatography yielded the glycosylation product as a mixture of anomers.

Ethyl-2,3,4,6-tetra-O-benzyl-α,β-D-allopyranoside (3B)



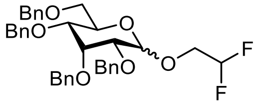
Title compound was prepared according to the general procedure for Ph_2SO/Tf_2O mediated glycosylations with donor **3** and ethanol, yielding compound **3B** (25 mg, 45 µmol, 45%, colourless oil, α:β = 46:54). An analytical amount was separated of both anomers was separated for characterisation. α-anomer: ^{1}H NMR (400 MHz, $CDCl_3$) δ, 7.35 – 7.15 (m, 20H, CH_{arom}), 4.97 (d, *J* = 12.3 Hz, 1H, C*H*H Bn), 4.92 (d, *J* = 4.0 Hz, 1H, H-1), 4.83 (d, *J* = 12.3 Hz, 1H, CH*H* Bn), 4.64 – 4.56 (m, 3H, C*H*H Bn, CH_2 Bn), 4.52 – 4.45 (m, 2H, C*H*H Bn, CH*H* Bn), 4.37 (d, *J* = 11.6 Hz, 1H, CH*H* Bn), 4.27 (dt, *J* = 10.1, 2.5 Hz, 1H, H-5), 4.18 (t, *J* = 2.8 Hz, 1H, H-3), 3.85 – 3.74 (m, 2H, C*H*H Et, H-6), 3.67 (dd, *J* = 10.5, 2.1 Hz, 1H, H-6), 3.60 – 3.49 (m, 2H, CH*H* Et, H-4), 3.43 (dd, *J* = 4.1, 2.8 Hz, 1H, H-2), 1.28 (t, *J* = 7.1 Hz, 3H, CH_3 Et) ^{13}C NMR (101 MHz, $CDCl_3$) δ 145.7, 139.7, 138.3, 138.2 (C_q), 131.2, 129.5, 128.5, 128.4, 128.4, 128.0, 128.0, 127.9, 127.9, 127.8, 127.8, 127.7, 127.1, 124.9 (CH_{arom}), 97.0 (C-1), 76.7 (C-2), 74.9 (C-4), 73.7, 73.5 (CH_2 Bn), 72.6 (C-3), 71.2, 71.2 (CH_2 Bn), 69.0 (C-6), 66.2 (C-5), 63.9 (CH_2 Et), 15.4 (CH_3 Et); β-anomer: ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.52 – 7.04 (m, 20H, CH_{arom}), 4.93 – 4.84 (m, 3H, 2x C*H*H Bn, H-1), 4.79 (d, *J* = 12.0 Hz, 1H, CH*H* Bn), 4.68 – 4.57 (m, 2H, C*H*H Bn, CH*H* Bn), 4.54 (d, *J* = 12.3 Hz, 1H, CH*H* Bn), 4.47 (d, *J* = 11.5 Hz, 1H, C*H*H Bn), 4.35 (d, *J* = 11.5 Hz, 1H, CH*H* Bn), 4.10 (t, *J* = 2.6 Hz, 1H, H-3), 4.06 (ddd, *J* = 9.8, 4.8, 1.9 Hz, 1H, H-5), 3.99 (dq, *J* = 9.5, 7.1 Hz, 1H, C*H*H Et), 3.76 (dd, *J* = 10.7, 1.9 Hz, 1H, H-6), 3.70 – 3.55 (m, 2H, CH*H* Et, H-6), 3.45 (dd, *J* = 9.8, 2.5 Hz, 1H, H-4), 3.24 (dd, *J* = 7.9, 2.7 Hz, 1H, H-2), 1.27 (t, *J* = 7.0 Hz, 3H, CH_3 Et) ^{13}C NMR (101 MHz, $CDCl_3$) δ 139.2, 139.0, 138.6, 138.0 (C_q), 128.5, 128.4, 128.4, 128.3, 128.0, 127.9, 127.9, 127.8, 127.7, 127.6, 127.6, 127.4 (CH_{arom}), 101.1 (C-1), 79.1 (C-2), 75.9 (C-4), 74.9 (C-3), 74.5, 73.6, 73.2 (CH_2 Bn), 72.5 (C-5), 71.6 9, CH_2 Bn), 69.6 (C-6), 65.5 (CH_2 Et), 15.6 (CH_3 Et); HRMS: $[M+NH_4]^+$ calcd for $C_{36}H_{40}O_6NH_4$ 586.31631, found 586.31478.

2-Fluoroethyl-2,3,4,6-tetra-O-benzyl-α,β-D-allopyranoside (3C)



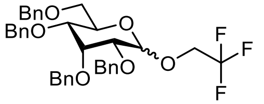
Title compound was prepared according to the general procedure for Ph_2SO/Tf_2O mediated glycosylations with donor **3** and 2-fluoroethanol, yielding compound **3C** (colourless oil, α:β = 55:45, contaminated with hydrolysed donor). Data reported for a 1:1 mixture: ^1H NMR (500 MHz, $CDCl_3$) δ 7.44 – 7.16 (m, 40H, CH_{arom}), 4.98 – 4.94 (m, 2H, H-1α, C*H*H Bn), 4.93 (d, *J* = 7.9 Hz, 1H, H-1β), 4.90 – 4.86 (m, 2H, 2x C*H*H Bn), 4.84 – 4.77 (m, 2H, 2x CH*H* Bn), 4.66 – 4.58 (m, 6H, 2x CH_2-C*H*HF, 4x C*H*H Bn/CH*H* Bn), 4.56 – 4.44 (m, 7H, 2x CH_2-CH*H*F, 5x C*H*H Bn/CH*H* Bn), 4.38 (d, *J* = 11.6 Hz, 1H, CH*H* Bn), 4.35 (d, *J* = 11.5 Hz, 1H, CH*H* Bn), 4.32 – 4.28 (m, 1H, H-5α), 4.18 (t, *J* = 2.8 Hz, 1H, H-3α), 4.14 – 4.03 (m, 3H, H-3β, H-5β, C*H*H-CH_2F), 3.97 – 3.87 (m, 1H, C*H*H-CH_2F), 3.86 – 3.71 (m, 4H, H-6α, H-6β, 2x CH*H*-CH_2F), 3.70 – 3.64 (m, 2H, H-6α, H-6β), 3.55 (dd, *J* = 9.9, 2.7 Hz, 1H, H-4α), 3.48 – 3.43 (m, 2H, H-2α, H-4β), 3.27 (dd, *J* = 7.9, 2.6 Hz, 1H, H-2β); ^{13}C NMR (126 MHz, $CDCl_3$) δ 139.6, 139.1, 138.9, 138.5, 138.2, 138.1, 138.0, 137.9, 137.8, 137.8 (C_q), 128.6, 128.6, 128.6, 128.5, 128.5, 128.5, 128.5, 128.5, 128.4, 128.3, 128.3, 128.1, 128.1, 128.1, 128.1, 128.0, 128.0, 128.0, 128.0, 127.9, 127.9, 127.9, 127.9, 127.8, 127.8, 127.7, 127.7, 127.6, 127.6, 127.5, 127.1 (CH_{arom}), 101.5 (C-1β), 97.6 (C-1α), 83.0 (d, *J* = 169.4 Hz, CH_2-*C*H_2F), 82.9 (d, *J* = 169.4 Hz, , CH_2-*C*H_2F) 78.9 (C-2β), 76.6 (C-2α), 75.7 (C-4β), 74.9 (C-3β), 74.8 (C-4α), 74.5, 73.7, 73.6, 73.6, 73.2 (CH_2 Bn), 72.6, 72.6 (C-3α, C-5β), 71.7, 71.3, 71.2 (CH_2 Bn), 69.4 (C-6β), 68.9 (C-6α, *C*H_2-CH_2F), 67.5 (d, *J* = 20.6 Hz, *C*H_2-CH_2F) 66.4 (C-5α); HRMS: $[M+NH_4]^+$ calcd for $C_{363}H_{39}FO_6NH_4$ 604.30689, found 604.30531.

2,2-difluoroethyl-2,3,4,6-tetra-O-benzyl-α,β-D-allopyranoside (3D)



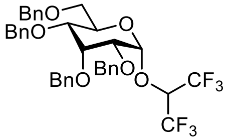
Title compound was prepared according to the general procedure for Ph_2SO/Tf_2O mediated glycosylations with donor **3** and 2,2-difluoroethanol, yielding compound **3D** (36 mg, 60 μmol, 60%, colourless oil, α:β = 58:42) Data reported for a 1:1 mixture: ^1H NMR (400 MHz, $CDCl_3$) δ 7.60 – 6.88 (m, 40H, CH_{arom}), 5.96 (tddd, *J* = 55.6, 7.4, 5.0, 3.6 Hz, 2H, 2x CH_2-C*H*F_2), 4.96 – 4.88 (m, 3H, H-1α, H-1β, C*H*H Bn), 4.86 – 4.76 (m, 3H, 2x C*H*H Bn, CH*H* Bn), 4.62 – 4.53 (m, 6H, 6x C*H*H Bn/CH*H* Bn), 4.52 – 4.44 (m, 4H, 4x C*H*H Bn/CH*H* Bn), 4.38 (d, *J* = 8.4 Hz, 1H, CH*H*Bn), 4.35 (d, *J* = 8.4 Hz, 1H, CH*H*Bn), 4.28 (ddd, *J* = 9.8, 3.4, 2.1 Hz, 1H, H-5α), 4.17 (t, *J* = 2.7 Hz, 1H, H-3α), 4.09 (t, *J* = 2.6 Hz, 1H, H-3β), 4.05 (ddd, *J* = 9.8, 4.5, 2.0 Hz, 1H, H-5β), 4.03 – 3.92 (m, 1H, C*H*H-$\mathrm{CHF_2}$), 3.90 – 3.71 (m, 5H, H-6α, H-6β, C*H*H-$\mathrm{CHF_2}$, 2x CH*H*-$\mathrm{CHF_2}$), 3.70 – 3.63 (m, 2H, H-6α, H-6β), 3.55 (dd, *J* = 9.9, 2.7 Hz, 1H, H-4α), 3.47 (dd, *J* = 9.8, 2.5 Hz, 1H, H-4β), 3.44 (dd, *J* = 4.0, 2.8 Hz, 1H, H-2α), 3.26 (dd, *J* = 7.9, 2.6 Hz, 1H, H-2β); ^{13}C NMR (101 MHz, $\mathrm{CDCl_3}$) δ 139.4, 139.0, 138.6, 138.3, 138.1, 137.9, 137.9 ($\mathrm{C_q}$), 128.6, 128.5, 128.5, 128.5, 128.3, 128.1, 128.1, 128.1, 128.0, 127.9, 127.9, 127.9, 127.9, 127.8, 127.8, 127.7, 127.6, 127.2 ($\mathrm{CH_{arom}}$), 117.3 – 111.7 (m, 2x $\mathrm{CH_2}$-$\mathrm{CHF_2}$) 101.8 (C-1β), 98.1 (C-1α), 78.8 (C-2β), 76.5 (C-2α), 75.5 (C-4β), 74.7 (C-4α), 74.6 (C-3β), 74.6, 73.7, 73.6, 73.6, 73.2 ($\mathrm{CH_2}$ Bn), 72.6 (C-5β), 72.4 (C-3α), 71.7, 71.5, 71.3 ($\mathrm{CH_2}$ Bn), 69.2 (C-6β), 68.7 (C-6α), 68.9 – 67.4 (m, 2x *C*$\mathrm{H_2}$-$\mathrm{CHF_2}$), 66.7 (C-5α); HRMS: $[\mathrm{M+NH_4}]^+$ calcd for $\mathrm{C_{36}H_{38}F_2O_6NH_4}$ 622.29747, found 622.29587.

2,2,2-trifluoroethyl-2,3,4,6-tetra-O-benzyl-α,β-D-allopyranoside (3E)



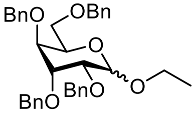
Title compound was prepared according to the general procedure for $\mathrm{Ph_2SO/Tf_2O}$ mediated glycosylations with donor **3** and 2,2,2-trifluoroethanol, yielding compound **3E** (43 mg, 68 μmol, 68%, colourless oil, α:β = 50:50). Data reported for a 1:1 mixture: ^{1}H NMR (400 MHz, $\mathrm{CDCl_3}$) δ 7.63 – 7.08 (m, 40H, $\mathrm{CH_{arom}}$), 5.04 – 4.97 (m, 3H, H-1α, H-1β, C*H*H Bn), 4.96 – 4.80 (m, 4H, 3x C*H*H Bn, CH*H*Bn), 4.68 – 4.49 (m, 9H, 4x C*H*H Bn, 5x CH*H* Bn), 4.42 (dd, *J* = 13.4, 11.5 Hz, 2H, 2x CH*H* Bn), 4.33 (dt, *J* = 10.4, 2.7 Hz, 1H, H-5α), 4.31 – 4.19 (m, 2H, H-3α, C*H*H-$\mathrm{CF_3}$), 4.15 (t, *J* = 2.6 Hz, 1H, H-3β), 4.12 – 4.02 (m, 2H, H-5β, C*H*H-$\mathrm{CF_3}$), 4.01 – 3.89 (m, 2H 2x CH*H*-$\mathrm{CF_3}$), 3.84 (dd, *J* = 10.6, 3.3 Hz, 1H, H-6α), 3.78 (dd, *J* = 10.8, 2.0 Hz, 1H, H-6β), 3.72 (ddd, *J* = 10.6, 3.3, 2.2 Hz, 2H, H-6α, H-6β), 3.63 (dd, *J* = 9.9, 2.7 Hz, 1H, H-4α), 3.57 – 3.49 (m, 2H, H-2α, H-4β), 3.33 (dd, *J* = 7.9, 2.6 Hz, 1H, H-2β); ^{13}C NMR (101 MHz, $\mathrm{CDCl_3}$) δ 139.4, 138.9, 138.6, 138.3, 138.1, 138.0, 137.9 ($\mathrm{C_q}$), 128.6, 128.5, 128.5, 128.3, 128.1, 128.0, 128.0, 127.9, 127.9, 127.9, 127.8, 127.8, 127.8, 127.8, 127.8, 127.8, 127.7, 127.6, 127.1 ($\mathrm{CH_{arom}}$), 101.6 (C-1β), 97.9 (C-1α), 78.6 (C-2β), 76.7(C-2α), 75.4 (C-4β), 74.7(C-3β), 74.6 ($\mathrm{CH_2}$ Bn), 74.3 (C-4α), 73.7, 73.6, 73.6, 73.2 ($\mathrm{CH_2}$ Bn), 72.7(C-5β), 72.5 (C-3α), 71.7, 71.5, 71.2 ($\mathrm{CH_2}$ Bn), 69.0 (C-6β), 68.6 (C-6α), 67.0 (C-5α), 66.3 (q, *J* = 34.8 Hz, *C*$\mathrm{H_2}$-$\mathrm{CF_3}$), 65.3 (q, *J* = 34.8 Hz, *C*$\mathrm{H_2}$-$\mathrm{CF_3}$); HRMS: $[\mathrm{M+NH_4}]^+$ calcd for $\mathrm{C_{36}H_{37}F_3O_6NH_4}$ 640.28805, found 640.28621.

1,1,1,3,3,3-hexafluoro-2-propyl-2,3,4,6-tetra-O-benzyl-α-D-allopyranoside (3F)



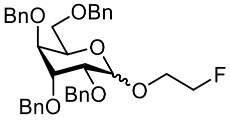
Title compound was prepared according to the general procedure for $\mathrm{Ph_2SO/Tf_2O}$ mediated glycosylations with donor **3** and 1,1,1,3,3,3-hexafluoropropan-2-ol, yielding compound **3F** (21 mg, 30 μmol, 30%, colourless oil, α:β = >98:2) ^{1}H NMR (400 MHz, $\mathrm{CDCl_3}$) δ 7.40 – 7.18 (m, 20H, $\mathrm{CH_{arom}}$), 5.22 (d, *J* = 4.0 Hz, 1H, H-1), 4.94 (d, *J* = 12.1 Hz, 1H, C*H*H Bn), 4.80 (d, *J* = 12.0 Hz, 1H, CH*H* Bn), 4.64 (d, *J* = 12.0 Hz, 1H, C*H*H Bn), 4.60 (d, *J* = 12.1 Hz, 1H, C*H*H Bn), 4.55 – 4.44 (m, 4H, C*H*$(\mathrm{CF_3})_2$, C*H*H Bn, 2x CH*H* Bn), 4.42 – 4.32 (m, 2H, H-5, CH*H* Bn), 4.18 (t, *J* = 2.6 Hz, 1H, H-3), 3.82 (dd, *J* = 10.7, 2.9 Hz, 1H, H-6), 3.65 (dd, *J* = 10.7, 2.1 Hz, 1H, H-6), 3.61 (dd, *J* = 10.0, 2.6 Hz, 1H, H-4), 3.50 (dd, *J* = 4.1, 2.6 Hz, 1H, H-2); ^{13}C NMR (101 MHz, CDCl$_3$) δ 139.2, 138.0, 137.9, 137.7 (C$_q$), 128.6, 128.5, 128.4, 128.4, 128.2, 128.2, 128.1, 128.0, 128.0, 127.9, 127.9, 127.9, 127.9, 127.8, 127.6, 127.2 (CH$_{arom}$), 99.0 (C-1), 76.5 (C-2), 73.9 (C-4), 73.8, 73.5 (CH$_2$ Bn), 72.0 (C-3), 71.4, 71.2 (CH$_2$ Bn), 68.2 (C-6), 67.9 (C-5); HRMS: [M+NH$_4$]$^+$ calcd for C$_{37}$H$_{36}$F$_6$O$_6$ 708.27543, found 708.27395.

Ethyl-2,3,4,6-tetra-*O*-benzyl-α-D-gulopyranoside (4B)



Title compound was prepared according to the general procedure for Ph$_2$SO/Tf$_2$O mediated glycosylations with donor **4** and ethanol, yielding compound **4B** (54 mg, 94 μmol, 94%, colourless oil, α:β = 78:22). Data for the α-anomer: ^{1}H NMR (500 MHz, CDCl$_3$) δ 7.38 – 7.22 (m, 18H, CH$_{arom}$), 7.14 – 7.08 (m, 2H, CH$_{arom}$), 4.90 (d, *J* = 3.3 Hz, 1H, H-1), 4.82 (d, *J* = 12.5 Hz, 1H, C*H*H Bn), 4.59 (d, *J* = 9.6 Hz, 1H, C*H*H Bn), 4.56 (d, *J* = 12.5 Hz, 1H, CH*H* Bn), 4.54 – 4.46 (m, 2H, C*H*H Bn, CH*H* Bn), 4.41 (d, *J* = 12.0 Hz, 1H, CH*H* Bn), 4.39 – 4.33 (m, 2H, H-5, C*H*H Bn), 4.29 (d, *J* = 11.9 Hz, 1H, CH*H* Bn), 3.85 – 3.77 (m, 1H, C*H*H Et), 3.77 (td, *J* = 3.6, 2.4 Hz, 2H, H-2, H-3), 3.64 – 3.53 (m, 2H, H-6, CH*H* Et), 3.52 (dd, *J* = 3.5, 1.4 Hz, 1H, H-4), 3.49 (dd, *J* = 9.7, 6.6 Hz, 1H, H-6), 1.29 (t, *J* = 7.1 Hz, 3H, CH$_3$ Et); ^{13}C NMR (126 MHz, CDCl$_3$) δ 139.1, 138.4, 138.1 (C$_q$), 128.5, 128.5, 128.4, 128.4, 128.3, 128.3, 128.2, 128.0, 128.0, 128.0, 127.9, 127.9, 127.9, 127.8, 127.7, 127.7, 127.7, 127.6, 127.5 (CH$_{arom}$), 97.0 (C-1), 75.3 (C-4), 73.5 (C-2, C-3), 73.4, 72.9, 72.8, 71.6 (CH$_2$ Bn), 69.2 (C-6), 65.5 (C-5), 64.0 (CH$_2$ Et), 15.3 (CH$_3$ Et); diagnostic peaks for the β-anomer: ^{1}H NMR (500 MHz, CDCl$_3$) δ 4.10 (td, *J* = 6.4, 1.5 Hz, 1H, H-5), 3.97 (dq, *J* = 9.4, 7.1 Hz, 1H, C*H*H Et), 3.73 (t, *J* = 3.5 Hz, 1H), 3.44 (dd, *J* = 3.7, 1.5 Hz, 1H), 1.25 (t, *J* = 7.1 Hz, 3H, CH$_3$ Et) ^{13}C NMR (126 MHz, CDCl$_3$) δ 100.9 (C-1), 76.4, 75.2, 74.8, 73.6, 72.6, 72.0 (C-5), 69.1 (C-6), 65.2 (CH$_2$ Et), 15.5 (CH$_3$ Et); HRMS: [M+NH$_4$]$^+$ calcd for C$_{36}$H$_{40}$O$_6$NH$_4$ 586.31631, found 586.31510.

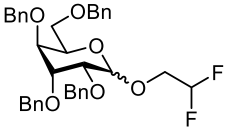
2-fluoroethyl-2,3,4,6-tetra-*O*-benzyl-α-D-gulopyranoside (4C)



Title compound was prepared according to the general procedure for Ph$_2$SO/Tf$_2$O mediated glycosylations with donor **4** and 2-fluoroethanol, yielding compound **4C** (50 mg, 85 μmol, 85%, colourless oil, α:β = 83:17). Data for the α-anomer: ^{1}H NMR (500 MHz, CDCl$_3$) δ 7.37 – 7.08 (m, 20H, CH$_{arom}$), 4.94 (d, *J* = 3.9 Hz, 1H, H-1), 4.83 (d, *J* = 12.4 Hz, 1H, C*H*H Bn), 4.67 (ddd, *J* = 5.3, 4.7, 2.6 Hz, 1H, CH$_2$-C*H*HF), 4.63 – 4.55 (m, 3H, CH$_2$-CH*H*F, C*H*H Bn, CH*H* Bn), 4.53 – 4.46 (m, 2H, C*H*H Bn, CH*H* Bn), 4.44 – 4.39 (m, 2H, H-5, CH*H* Bn), 4.37 (d, *J* = 11.9 Hz, 1H, C*H*H Bn), 4.31 (d, *J* = 12.0 Hz, 1H, CH*H* Bn), 3.92 (dddd, *J* = 29.9, 12.3, 4.9, 3.5 Hz, 1H, C*H*H-CH$_2$F), 3.86 – 3.76 (m, 3H, H-2, H-3, CH*H*-CH$_2$F), 3.59 – 3.52 (m, 2H, H-4, H-6), 3.48 (dd, *J* = 9.8, 6.5 Hz, 1H, H-6); ^{13}C NMR (126 MHz, CDCl$_3$) δ 139.0, 138.4, 138.3, 138.0 (C$_q$), 128.6, 128.5, 128.5, 128.4, 128.4, 128.4, 128.3, 128.3, 128.2, 128.2, 128.1, 128.1, 128.0, 128.0, 128.0, 127.9, 127.9, 127.8, 127.8, 127.8, 127.7, 127.6, 127.6, 127.5 (CH$_{arom}$), 97.7 (C-1), 83.1 (d, *J* = 169.0 Hz, CH$_2$-CH$_2$F) 75.2

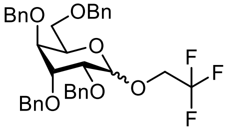
(C-4), 73.5 (C-2/C-3), 73.3, 73.0 (CH_2 Bn), 72.9 (C-2/C-3), 72.9, 71.7 (CH_2 Bn), 69.1 (C-6), 67.5 (d, *J* = 20.6 Hz, *C*H_2-CH_2F), 65.6 (C-5); diagnostic peaks for the β-anomer: ^{1}H NMR (500 MHz, $CDCl_3$) δ 4.88 – 4.85 (m, 2H, H-1, C*H*H Bn), 4.10 (ddd, *J* = 6.3, 5.3, 1.4 Hz, 1H, H-5), 3.74 (t, *J* = 3.4 Hz, 1H), 3.44 (dd, *J* = 3.7, 1.5 Hz, 1H); ^{13}C NMR (126 MHz, $CDCl_3$) δ 101.3 (C-1), 82.8 (d, *J* = 169.3 Hz, CH_2-*C*H_2F), 76.2, 75.0, 74.7, 72.1, 69.0, 68.5 (d, *J* = 20.3 Hz, *C*H_2-CH_2F); HRMS: $[M+NH_4]^+$ calcd for $C_{363}H_{39}FO_6NH_4$ 604.30689, found 604.30571.

2,2-difluoroethyl-2,3,4,6-tetra-*O*-benzyl-α-D-gulopyranoside (4D)



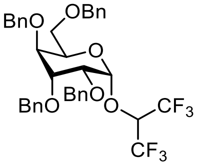
Title compound was prepared according to the general procedure for Ph_2SO/Tf_2O mediated glycosylations with donor **4** and 2,2-difluoroethanol, yielding compound **4D** (50 mg, 83 µmol, 83%, colourless oil, α:β = 69:31) Data for the α-anomer: ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.38 – 7.20 (m, 20H, CH_{arom}), 6.05 (tt, *J* = 55.8, 4.6 Hz, 1H, CH_2-C*H*F_2), 4.89 (d, *J* = 3.9 Hz, 1H, H-1), 4.80 (d, *J* = 12.4 Hz, 1H, C*H*H Bn), 4.56 (s, 2H, CH_2 Bn), 4.50 – 4.45 (m, 2H, C*H*H Bn, C*H*H Bn), 4.42 (d, *J* = 12.0 Hz, 1H, CH*H* Bn), 4.38 – 4.34 (m, 2H, H-5, C*H*H Bn), 4.32 – 4.28 (m, 1H, CH*H* Bn), 3.82 – 3.76 (m, 4H, H-2, H-3, C*H₂*-CHF_2), 3.55 – 3.51 (m, 2H, H-4, H-6), 3.45 (dd, *J* = 9.8, 6.1 Hz, 1H, H-6); ^{13}C NMR (126 MHz, $CDCl_3$) δ 138.8, 138.2, 138.1, 137.8 (C_q), 128.6, 128.5, 128.5, 128.4, 128.4, 128.2, 128.1, 128.1, 127.8, 127.7 (CH_{arom}), 114.7 (t, *J* = 241.0 Hz, CH_2-*C*HF_2), 98.4 (C-1), 75.1 (C-4), 73.4 (CH_2 Bn), 73.3 (C-3), 73.0, 72.9 (CH_2 Bn), 72.7 (C-5), 71.8 (C-6), 68.2 (t, *J* = 29.1 Hz, *C*H_2-CHF_2), 66.0 (C-5); diagnostic peaks for the β-anomer: ^{1}H NMR (500 MHz, $CDCl_3$) δ 4.90 (d, *J* = 8.1 Hz, 1H, H-1), 4.72 (d, *J* = 12.2 Hz, 1H, C*H*H Bn), 4.15 (td, *J* = 6.4, 1.5 Hz, 1H, H-5), 4.05 (dddd, *J* = 20.0, 11.6, 10.2, 3.3 Hz, 1H, C*H*H-CH_2F), 3.88 (dd, *J* = 4.5, 1.7 Hz, 1H), 3.77 (t, *J* = 3.4 Hz, 1H); ^{13}C NMR (126 MHz, $CDCl_3$) δ 101.7 (C-1), 76.1, 74.9, 74.6, 72.8, 72.7, 72.3, 68.9 – 68.4 (m, CH_2-CHF_2); HRMS: $[M+NH_4]^+$ calcd for $C_{36}H_{38}F_2O_6NH_4$ 622.29747, found 622.29587.

2,2,2-trifluoroethyl-2,3,4,6-tetra-*O*-benzyl-α-D-gulopyranoside (4E)



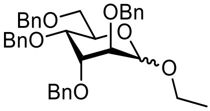
Title compound was prepared according to the general procedure for Ph_2SO/Tf_2O mediated glycosylations with donor **4** and 2,2,2-trifluoroethanol, yielding compound **4E** (53 mg, 85 µmol, 85%, colourless oil, α:β = 60:40). Data reported for a 1:1 mixture: ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.57 – 6.96 (m, 40H, CH_{arom}), 4.99 (d, *J* = 3.8 Hz, 1H, H-1α), 4.95 (d, *J* = 8.0 Hz, 1H, H-1β), 4.92 – 4.84 (m, 2H, 2x C*H*H Bn), 4.74 (d, *J* = 12.2 Hz, 1H, C*H*H Bn), 4.65 (d, *J* = 12.3 Hz, 1H, C*H*H Bn), 4.62 – 4.39 (m, 11H, H-5α, 3x C*H*H Bn, 7x CH*H* Bn), 4.34 (d, *J* = 2.1 Hz, 1H, CH_2 Bn), 4.23 (dq, *J* = 12.0, 8.7 Hz, 1H, C*H*H-CF_3), 4.14 (td, *J* = 6.4, 1.5 Hz, 1H, H-5β), 4.07 (dq, *J* = 12.4, 9.0 Hz, 1H, C*H*H-CF_3), 4.01 – 3.91 (m, 2H, 2x CH*H*-CF_3), 3.89 (t, *J* = 3.6 Hz, 1H, H-2α), 3.87 – 3.84 (m, 1H, H-3α), 3.77 (t, *J* = 3.5 Hz, 1H, H-3β), 3.66 – 3.57 (m, 5H, H-2β, H-4α, H-6α, 2x H-6β), 3.53 (dd, *J* = 9.8, 6.4 Hz, 1H, H-6α), 3.48 (dd, *J* = 3.8, 1.5 Hz, 1H, H-4β); ^{13}C NMR (126 MHz, $CDCl_3$) δ 138.9, 138.7, 138.3, 138.2, 138.2, 137.9, 137.8 (C_q), 128.6, 128.5, 128.5, 128.5, 128.5, 128.5, 128.4, 128.4, 128.3, 128.3, 128.2, 128.2, 128.1, 128.0, 128.0, 127.9, 127.8, 127.8, 127.7, 127.5 (CH$_{arom}$), 125.3, 125.0, 123.1, 122.8 (CH$_2$-*C*F$_3$), 101.5 (C-1β), 97.9 (C-1α), 75.9 (C-2β), 75.4 (C-4α), 74.9 (C-3β), 74.6 (C-4β), 73.6 (CH$_2$ Bn), 73.6 (C-2α), 73.5, 73.4, 73.1, 73.0 (CH$_2$ Bn), 72.9 (C-3α), 72.8 (CH$_2$ Bn), 72.4 (C-5β), 71.8 (CH$_2$ Bn), 68.9 (C-6α, C-6β), 66.3 (C-5α), 66.2 (q, *J* = 34.8 Hz, *C*H$_2$-CF$_3$), 65.2 (q, *J* = 34.7 Hz, *C*H$_2$-CF$_3$); HRMS: [M+NH$_4$]$^+$ calcd for $C_{36}H_{37}F_3O_6NH_4$ 640.28805, found 640.28617

1,1,1,3,3,3-hexafluoro-2-propyl-2,3,4,6-tetra-O-benzyl-α-D-gulopyranoside (4F)



Title compound was prepared according to the general procedure for Ph$_2$SO/Tf$_2$O mediated glycosylations with donor **4** and 1,1,1,3,3,3-hexafluoropropan-2-ol, yielding compound **4F** (27 mg, 39 μmol, 39%, colourless oil, α:β = >98:2) ^{1}H NMR (400 MHz, CDCl$_3$) δ 7.35 – 7.26 (m, 18H, CH$_{arom}$), 7.18 – 7.12 (m, 2H, CH$_{arom}$), 5.19 (d, *J* = 4.0 Hz, 1H, H-1), 4.89 (d, *J* = 11.9 Hz, 1H, C*H*H Bn), 4.65 (d, *J* = 12.1 Hz, 1H, C*H*H Bn), 4.56 – 4.38 (m, 8H, H-5, C*H*(CF$_3$)$_2$, 2x C*H*H Bn, 4x CH*H* Bn), 3.89 (dd, *J* = 4.0, 3.0 Hz, 1H, H-2), 3.86 – 3.80 (m, 1H, H-3), 3.66 (dd, *J* = 4.1, 1.6 Hz, 1H, H-4), 3.58 – 3.46 (m, 2H, 2x H-6); ^{13}C NMR (101 MHz, CDCl$_3$) δ 138.9, 138.2, 137.9, 137.8 (C$_q$), 128.6, 128.5, 128.3, 128.2, 128.2, 128.0, 127.8, 127.7, 127.7, 127.5 (CH$_{arom}$), 98.9 (C-1), 75.5 (C-4), 73.4 (CH$_2$ Bn), 73.3 (C-2), 73.2, 73.2 (CH$_2$ Bn), 73.0 – 71.9 (m, C-3, *C*H(CF$_3$)$_2$) 71.6 (CH$_2$ Bn), 68.5 (C-6), 67.0 (C-5); HRMS: [M+NH$_4$]$^+$ calcd for $C_{37}H_{36}F_6O_6$ 708.27543, found 708.27274.

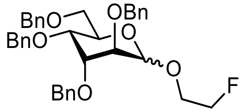
Ethyl-2,3,4,6-tetra-*O*-benzyl-α,β-D-altropyranoside (6B)



Title compound was prepared according to the general procedure for Ph$_2$SO/Tf$_2$O mediated glycosylations with donor **6** and ethanol, yielding compound **6B** (45 mg, 79 μmol, 79%, colourless oil, α:β = 75:25). Data for the α-anomer: ^{1}H NMR (500 MHz, CDCl$_3$) δ 7.42 – 7.12 (m, 20H, CH$_{arom}$), 4.83 (d, *J* = 2.0 Hz, 1H, H-1), 4.64 – 4.57 (m, 3H, 3x C*H*H Bn), 4.53 – 4.47 (m, 4H, C*H*H Bn, 3x CH*H* Bn), 4.44 (d, *J* = 11.8 Hz, 1H, CH*H* Bn), 4.27 (ddd, *J* = 8.0, 4.4, 3.0 Hz, 1H, H-5), 3.87 (dd, *J* = 8.5, 3.3 Hz, 1H, H-4), 3.84 – 3.78 (m, 1H, C*H*H Et), 3.77 (t, *J* = 4.0 Hz, 1H, H-3), 3.74 (dd, *J* = 4.7, 2.0 Hz, 1H, H-2), 3.69 (t, *J* = 3.8 Hz, 2H, 2x H-6), 3.50 – 3.45 (m, 1H, CH*H* Et), 1.22 (t, *J* = 7.1 Hz, 3H, CH$_3$ Et); ^{13}C NMR (126 MHz, CDCl$_3$) δ 138.7, 138.5, 138.3, 138.2 (C$_q$), 128.5, 128.4, 128.4, 128.4, 128.3, 128.3, 128.0, 127.9, 127.8, 127.8, 127.8, 127.6, 127.5 (CH$_{arom}$), 99.2 (C-1), 76.0 (C-4), 74.0 (C-3), 73.5 (CH$_2$ Bn), 72.9 (C-2), 72.7, 72.0, 71.7 (CH$_2$ Bn), 69.8 (C-6), 68.3 (C-5), 63.4 (CH$_2$ Et), 15.2 (CH$_3$ Et); ^{13}C-HMBC-GATED NMR (126 MHz, CDCl$_3$): δ 99.2 ($J_{H1\text{-}C1}$ = 165 Hz, α); diagnostic peaks for the β-anomer: ^{1}H NMR (500 MHz, CDCl$_3$) δ 4.82 – 4.77 (m, 2H, H-1, C*H*H Bn), 4.07 (ddd, *J* = 8.9, 5.9, 2.8 Hz, 1H, H-5), 3.97 (dq, *J* = 9.5, 7.1 Hz, 1H, C*H*H Et), 1.24 (t, *J* = 7.1 Hz, 3H, CH$_3$ Et); ^{13}C NMR (126 MHz, CDCl$_3$) δ 99.0 (C-1), 75.5, 73.9, 73.8, 73.6, 73.6, 73.4, 72.8, 71.8, 70.4, 65.1 (CH$_2$ Et), 15.4 (CH$_3$ Et); ^{13}C-HMBC-GATED NMR

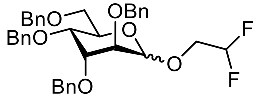
(126 MHz, $CDCl_3$): δ 99.0 (J_{H1-C1} = 155 Hz, β); HRMS: $[M+NH_4]^+$ calcd for $C_{36}H_{40}O_6NH_4$ 586.31631, found 586.31503.

2-Fluoroethyl-2,3,4,6-tetra-*O*-benzyl-α,β-D-altropyranoside (6C)



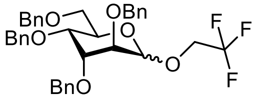
Title compound was prepared according to the general procedure for Ph_2SO/Tf_2O mediated glycosylations with donor **6** and 2-fluoroethanol, yielding compound **6C** (35 mg, 60 µmol, 60%, colourless oil, α:β = 58:42). Data reported for a 1:1 mixture: ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.58 – 6.94 (m, 40H, CH_{arom}), 4.93 – 4.90 (m, 2H, H-1α, H-1β), 4.85 (d, J = 12.6 Hz, 1H, C*H*H Bn), 4.67 – 4.59 (m, 7H, , 2x CH_2-C*H*HF, 5x C*H*H Bn/CH*H* Bn), 4.59 – 4.49 (m, 9H, 2x CH_2-CH*H*F, 7x C*H*H Bn/CH*H* Bn), 4.46 (d, J = 11.8 Hz, 1H, CH*H* Bn), 4.43 (d, J = 11.7 Hz, 1H, C*H*H Bn), 4.39 (d, J = 11.7 Hz, 1H, CH*H* Bn), 4.31 (dt, J = 8.1, 3.8 Hz, 1H, H-5α), 4.18 – 4.06 (m, 2H, H-5β, C*H*H-CH_2F), 4.02 – 3.88 (m, 2H, H-4α, C*H*H-CH_2F), 3.86 – 3.69 (m, 11H, H-2α, H-2β, H-3α, H-3β, H-4β, 2x H-6α, 2x H-6β, 2x CH*H*-CH_2F); ^{13}C NMR (126 MHz, $CDCl_3$) δ 138.7, 138.6, 138.4, 138.4, 138.1, 138.1 (C_q), 128.5, 128.5, 128.4, 128.4, 128.3, 128.1, 128.1, 128.0, 127.9, 127.9, 127.9, 127.9, 127.8, 127.8, 127.7, 127.7, 127.6, 127.6 (CH_{arom}), 99.6 (C-1α), 99.5 (C-1β), 83.0 (d, J = 168.9 Hz, CH_2-CH_2F), 82.9 (d, J = 169.1 Hz, CH_2-CH_2F), 75.5 (C-2α), 75.1 (C-2β, 73.9 (CH_2 Bn), 73.7 (C-3α), 73.6, 73.5 (CH_2 Bn), 73.4, 73.4 (C-3β, C-4β, C-5β), 72.9 (CH_2 Bn), 72.7 (C-4α), 72.7, 72.0, 71.8, 71.7 (CH_2 Bn), 70.2 (C-6β), 69.7 (C-6α), 68.6 (d, J = 19.8 Hz, *C*H_2-CH_2F), 68.4 (C-5α), 66.84 (d, J = 20.0 Hz, *C*H_2-CH_2F); ^{13}C-HMBC-GATED NMR (126 MHz, $CDCl_3$): δ 99.6 (J_{H1-C1} = 168 Hz, α), 99.5 (J_{H1-C1} = 161 Hz, β); HRMS: $[M+NH_4]^+$ calcd for $C_{363}H_{39}FO_6NH_4$ 604.30689, found 604.30606.

2,2-difluoroethyl-2,3,4,6-tetra-*O*-benzyl-α,β-D-altropyranoside (6D)



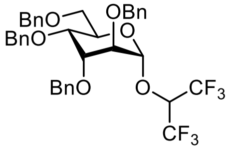
Title compound was prepared according to the general procedure for Ph_2SO/Tf_2O mediated glycosylations with donor **6** and 2,2-difluoroethanol, yielding compound **6D** (39 mg, 64 µmol, 64%, colourless oil, α:β = 69:31) Data for the α-anomer: ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.42 – 6.98 (m, 20H, CH_{arom}), 5.91 (dddd, J = 56.1, 55.2, 5.2, 3.3 Hz, 1H, CH_2-C*H*F_2), 4.85 (d, J = 1.4 Hz, 1H, H-1), 4.63 – 4.50 (m, 4H, 4x C*H*H Bn/ CH*H* Bn), 4.50 – 4.37 (m, 4H, 4x C*H*H Bn/ CH*H* Bn), 4.26 (dt, J = 8.8, 3.7 Hz, 1H, H-5), 3.91 – 3.83 (m, 2H, H-4, C*H*H-CHF_2), 3.77 – 3.74 (m, 2H, H-2, H-3), 3.70 – 3.64 (m, 3H, 2x H-6, CH*H*-CHF_2); ^{13}C NMR (126 MHz, $CDCl_3$) δ 138.5, 138.5, 138.3, 138.3, 137.9 (C_q), 128.6, 128.5, 128.4, 128.4, 128.0, 127.9, 127.9, 127.8 (CH_{arom}), 117.0 – 112.1 (m, CH_2-CHF_2) 100.1 (C-1), 75.4, 73.6 (C-2, C-3), 73.6, 72.8 (CH_2 Bn), 72.6 (C-4), 72.2, 71.8 (CH_2 Bn), 69.6 (C-6), 68.6 (C-5), 67.1 (dd, J = 29.6, 27.2 Hz, *C*H_2-CHF_2); ^{13}C-HMBC-GATED NMR (126 MHz, $CDCl_3$): δ 100.1 (J_{H1-C1} = 168 Hz, α); diagnostic peaks for the β-anomer: ^{1}H NMR (500 MHz, $CDCl_3$) δ 5.98 (dddd, J = 56.3, 55.0, 5.5, 3.0 Hz, 1H, CH_2-C*H*F_2), 4.90 (d, J = 1.4 Hz, 1H, H-1), 4.81 (d, J = 12.5 Hz, 1H, C*H*H Bn), 4.10 (ddd, J = 9.4, 5.8, 2.5 Hz, 1H, H-5), 4.08 – 4.00 (m, 1H, C*H*H-CHF_2); ^{13}C NMR (126 MHz, $CDCl_3$) δ 99.9 (C-1), 74.9, 73.9, 73.8, 73.5, 73.2, 73.0, 71.9, 70.0 (C-6); ^{13}C-HMBC-GATED NMR (126 MHz, $CDCl_3$): δ 99.9 (J_{H1-C1} = 160 Hz, β); HRMS: $[M+NH_4]^+$ calcd for $C_{36}H_{38}F_2O_6NH_4$ 622.29747, found 622.29581.

2,2,2-trifluoroethyl-2,3,4,6-tetra-*O*-benzyl-α,β-D-altropyranoside (6E)



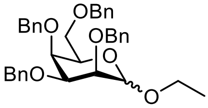
Title compound was prepared according to the general procedure for Ph_2SO/Tf_2O mediated glycosylations with donor **6** and 2,2,2-trifluoroethanol, yielding compound **6E** (46 mg, 73 µmol, 73%, colourless oil, α:β = 85:15). Data for the α-anomer: ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.38 – 7.25 (m, 20H, CH_{arom}), 4.94 (s, 1H, H-1), 4.67 – 4.59 (m, 3H, 3x C*H*H Bn), 4.58 – 4.50 (m, 4H, C*H*H Bn, 3x CH*H* Bn), 4.47 (d, *J* = 11.8 Hz, 1H, CH*H* Bn), 4.30 (ddd, *J* = 8.9, 4.3, 2.8 Hz, 1H, H-5), 4.06 (dq, *J* = 12.3, 9.0 Hz, 1H, C*H*H-CF_3), 3.95 – 3.86 (m, 2H, H-4, CH*H*-CF_3), 3.83 – 3.79 (m, 2H, H-2, H-3), 3.76 – 3.70 (m, 2H, 2x H-6); ^{13}C NMR (126 MHz, $CDCl_3$) δ 138.4, 138.3, 138.3, 137.8 (C_q), 128.6, 128.4, 128.4, 128.1, 128.0, 127.9, 127.8, 127.8, 127.7 (CH_{arom}), 124.1 (q, *J* = 278.3 Hz, CH_2-*C*F_3), 99.7 (C-1), 75.1 (C-2/C-3), 73.6 (CH_2 Bn), 73.6 (C-2/C-3), 72.8 (CH_2 Bn), 72.5 (C-4), 72.2, 71.8 (CH_2 Bn), 69.4 (C-6), 68.7 (C-5), 64.36 (q, *J* = 34.5 Hz, *C*H_2-CF_3); ^{13}C-HMBC-GATED NMR (126 MHz, $CDCl_3$): δ 99.7 (J_{H1-C1} = 169 Hz, α); diagnostic peaks for the β-anomer: ^{1}H NMR (500 MHz, $CDCl_3$) δ 4.96 (d, *J* = 1.4 Hz, 1H, H-1), 4.82 (d, *J* = 12.5 Hz, 1H, C*H*H Bn), 4.42 (d, *J* = 11.7 Hz, 1H, CH*H* Bn), 4.24 (dq, *J* = 12.4, 8.9 Hz, 1H, C*H*H-CF_3); ^{13}C NMR (126 MHz, $CDCl_3$) δ 99.6 (C-1), 74.6, 73.8, 73.8, 73.7, 73.6, 73.1, 73.0, 72.0, 70.0 (C-6); ^{13}C-HMBC-GATED NMR (126 MHz, $CDCl_3$): δ 99.7 (J_{H1-C1} = 162 Hz, β); HRMS: $[M+NH_4]^+$ calcd for $C_{36}H_{37}F_3O_6NH_4$ 640.28805, found 640.28612

1,1,1,3,3,3-hexafluoro-2-propyl-2,3,4,6-tetra-O-benzyl-α-D-altropyranoside (6F)



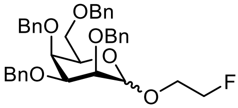
Title compound was prepared according to the general procedure for Ph_2SO/Tf_2O mediated glycosylations with donor **6** and 1,1,1,3,3,3-hexafluoropropan-2-ol, yielding compound **6F** (11 mg, 16 µmol, 16%, colourless oil, α:β = >98:2) ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.36 – 7.27 (m, 18H, CH_{arom}), 7.21 (ddt, *J* = 8.4, 5.3, 2.2 Hz, 2H, CH_{arom}), 5.05 (s, 1H, H-1), 4.64 (d, *J* = 12.1 Hz, 1H, C*H*H Bn), 4.58 – 4.49 (m, 4H, C*H*$(CF_3)_2$, 3x C*H*H Bn), 4.48 – 4.39 (m, 3H, 3x CH*H* Bn), 4.35 – 4.29 (m, 2H, H-5, CH*H* Bn), 3.96 (dd, *J* = 9.4, 3.1 Hz, 1H, H-4), 3.80 (dd, *J* = 4.3, 1.6 Hz, 1H, H-2), 3.78 – 3.73 (m, 2H, H-3, H-6), 3.66 (dd, *J* = 10.9, 2.3 Hz, 1H, H-6); ^{13}C NMR (101 MHz, $CDCl_3$) δ 138.2 (C_q), 130.5, 128.9, 128.7, 128.6, 128.5, 128.5, 128.5, 128.4, 128.4, 128.4, 128.3, 128.2, 128.2, 128.0, 128.0, 128.0, 127.9, 127.9, 127.9, 127.7 (CH_{arom}), 100.7 (C-1), 74.3 (C-2), 73.6 (CH_2 Bn), 73.1 (C-3), 72.9, 72.3, 72.0 (CH_2 Bn), 72.0 (C-4), 69.1 (C-5), 69.0 (C-6); ^{13}C-HMBC-GATED NMR (101 MHz, $CDCl_3$): δ 100.7 (J_{H1-C1} = 173 Hz, α); HRMS: $[M+NH_4]^+$ calcd for $C_{37}H_{36}F_6O_6$ 708.27543, found 708.27387.

Ethyl-2,3,4,6-tetra-*O*-benzyl-α,β-D-talopyranoside (7B)



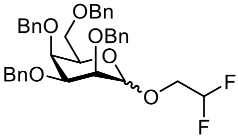
Title compound was prepared according to the general procedure for Ph_2SO/Tf_2O mediated glycosylations with donor **7** and ethanol, yielding compound **7B** (40 mg, 70 μmol, 70%, colourless oil, α:β = 68:32) Data for the α-anomer: ^1H NMR (400 MHz, $CDCl_3$) δ 7.44 – 7.23 (m, 20H, CH_{arom}), 5.04 – 4.99 (m, 2H, H-1, C*H*H Bn), 4.92 (d, *J* = 12.6 Hz, 1H, C*H*H Bn), 4.85 – 4.76 (m, 2H, 2x CH*H* Bn), 4.62 – 4.57 (m, 3H, C*H*H Bn, CH_2 Bn), 4.54 – 4.51 (m, 1H, CH*H* Bn), 4.02 (td, *J* = 6.3, 1.9 Hz, 1H, H-5), 3.96 (p, *J* = 1.4 Hz, 1H, H-3), 3.83 – 3.72 (m, 5H, H-2, H-4, 2x H-6, C*H*H Et), 3.50 (dq, *J* = 9.8, 6.9 Hz, 1H, CH*H* Et), 1.21 (t, *J* = 7.1 Hz, 3H, CH_3 Et); ^{13}C NMR (101 MHz, $CDCl_3$) δ 139.2, 138.9, 138.6, 138.4 (C_q), 128.5, 128.4, 128.4, 128.3, 128.3, 128.2, 128.1, 127.9, 127.2 (CH_{arom}), 99.0 (C-1), 77.6, 74.6 (C-2, C-4), 73.8, 73.7 (CH_2 Bn), 73.5 (C-3), 73.2, 71.3 (CH_2 Bn), 70.8 (C-5), 69.6 (C-6), 63.2 (CH_2 Et), 15.1 (CH_3 Et); ^{13}C-HMBC-GATED NMR (101 MHz, $CDCl_3$): δ 99.0 ($J_{H1\text{-}C1}$ = 169 Hz, α); diagnostic peaks for the β-anomer: ^1H NMR (400 MHz, $CDCl_3$) δ 4.45 (d, *J* = 12.2 Hz, 1H, CH*H* Bn), 4.42 (d, *J* = 1.3 Hz, 1H, H-1), 4.08 (dt, *J* = 9.3, 7.1 Hz, 1H, C*H*H Et), 3.93 (dt, *J* = 3.1, 1.2 Hz, 1H), 3.59 (td, *J* = 5.4, 4.7, 2.2 Hz, 1H, H-5), 3.44 (t, *J* = 3.1 Hz, 1H), 1.30 (t, *J* = 7.1 Hz, 3H, CH_3 Et); ^{13}C NMR (101 MHz, $CDCl_3$) δ 102.4 (C-1), 79.0, 75.3, 74.8, 74.6, 72.6, 70.8, 69.8 (C-6), 64.9 (CH_2 Et), 15.3 (CH_3 Et); ^{13}C-HMBC-GATED NMR (101 MHz, $CDCl_3$): δ 102.4 ($J_{H1\text{-}C1}$ = 154 Hz, β) HRMS: $[M+NH_4]^+$ calcd for $C_{36}H_{40}O_6NH_4$ 586.31631, found 586.31493.

2-fluoroethyl-2,3,4,6-tetra-*O*-benzyl-α,β-D-talopyranoside (7C)



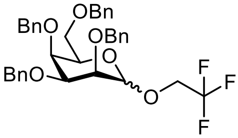
Title compound was prepared according to the general procedure for Ph_2SO/Tf_2O mediated glycosylations with donor **7** and 2-fluoroethanol, yielding compound **7C** (43 mg, 74 μmol, 74%, colourless oil, α:β = 80:20) Data for the α-anomer: ^1H NMR (500 MHz, $CDCl_3$) δ 7.45 – 6.98 (m, 20H, CH_{arom}), 5.01 (d, *J* = 1.8 Hz, 1H, H-1), 4.96 (d, *J* = 11.9 Hz, 1H, C*H*H Bn), 4.86 (d, *J* = 12.5 Hz, 1H, C*H*H Bn), 4.78 – 4.70 (m, 2H, 2x CH*H* Bn), 4.57 – 4.51 (m, 4H, C*H*H Bn, CH_2 Bn, CH_2-C*H*HF), 4.49 – 4.44 (m, 2H, CH*H* Bn, CH_2-CH*H*F), 3.98 (td, *J* = 6.2, 1.9 Hz, 1H, H-5), 3.91 (dt, *J* = 2.7, 1.4 Hz, 1H, H-3), 3.89 – 3.79 (m, 2H, H-2, C*H*H-CH_2F), 3.79 – 3.76 (m, 1H, H-4), 3.75 – 3.62 (m, 3H, 2x H-6, CH*H*-CH_2F); ^{13}C NMR (126 MHz, $CDCl_3$) δ 139.1, 138.7, 138.4, 138.3 (C_q), 128.5, 128.4, 128.4, 128.4, 128.3, 128.3, 128.2, 128.2, 128.1, 128.1, 128.0, 127.9, 127.8, 127.8, 127.7, 127.6, 127.6, 127.5, 127.4, 127.3, 127.2, 127.2 (CH_{arom}), 99.5 (C-1), 82.6 (d, *J* = 169.6 Hz, CH_2-*C*H_2F), 77.4 (C-4), 74.3 (C-2), 73.8, 73.6 (CH_2 Bn), 73.3 (C-3), 73.3, 71.3 (CH_2 Bn), 70.9 (C-5), 69.6 (C-6), 66.6 (d, *J* = 19.7 Hz, *C*H_2-CH_2F); ^{13}C-HMBC-GATED NMR (126 MHz, $CDCl_3$): δ 99.5 ($J_{H1\text{-}C1}$ = 170 Hz, α); diagnostic peaks for the β-anomer: ^1H NMR (500 MHz, $CDCl_3$) δ 5.06 (d, *J* = 12.8 Hz, 1H, C*H*H Bn), 4.16 – 4.02 (m, 1H, C*H*H-CF_2), 3.55 (t, *J* = 5.7 Hz, 1H), 3.39 (t, *J* = 3.1 Hz, 1H); ^{13}C NMR (126 MHz, $CDCl_3$) δ 102.1 (C-1), 83.0 (d, *J* = 169.0 Hz, CH_2-*C*H_2F), 81.4, 79.2, 75.3, 74.4, 72.4, 68.21 (d, *J* = 19.8 Hz, *C*H_2-CH_2F); HRMS: $[M+NH_4]^+$ calcd for $C_{363}H_{39}FO_6NH_4$ 604.30689, found 604.30540.

2,2-difluoroethyl-2,3,4,6-tetra-*O*-benzyl-α,β-D-talopyranoside (7D)



Title compound was prepared according to the general procedure for Ph$_2$SO/Tf$_2$O mediated glycosylations with donor **7** and 2,2-fluoroethanol, yielding compound **7D** (44 mg, 73 μmol, 73%, colourless oil, α:β = 86:14) Data for the α-anomer: ^{1}H NMR (400 MHz, CDCl$_3$) δ 7.60 – 6.98 (m, 20H, CH$_{arom}$), 5.88 (tdd, *J* = 55.4, 4.8, 3.5 Hz, 1H, CH$_2$-C*H*F$_2$), 4.99 (d, *J* = 1.9 Hz, 1H, H-1), 4.95 (d, *J* = 11.9 Hz, 1H, C*H*H Bn), 4.85 (d, *J* = 12.4 Hz, 1H, C*H*H Bn), 4.77 – 4.67 (m, 2H, 2x CH*H* Bn), 4.55 – 4.43 (m, 4H, 2x CH$_2$ Bn), 3.95 (td, *J* = 6.1, 1.9 Hz, 1H, H-5), 3.89 (p, *J* = 1.4 Hz, 1H, H-3), 3.82 – 3.72 (m, 4H, H-2, H-3, H-6, C*H*H-CHF$_2$), 3.72 – 3.64 (m, 2H, H-6, CH*H*-CHF$_2$); ^{13}C NMR (101 MHz, CDCl$_3$) δ 139.0, 138.6, 138.3, 138.2 (C$_q$), 128.5, 128.5, 128.3, 128.2, 128.2, 128.2, 127.9, 127.8, 127.7, 127.6, 127.5, 127.3 (CH$_{arom}$), 114.1 (t, *J* = 240.9 Hz, CH$_2$-*C*HF$_2$) 100.1 (C-1), 77.1, 74.0 (C-2, C-3), 73.8, 73.6, 73.4 (CH$_2$ Bn), 73.2 (C-4), 71.4 (C-5), 71.4 (CH$_2$ Bn), 69.5 (C-6), 66.9 (t, *J* = 28.1 Hz, *C*H$_2$-CHF$_2$); ^{13}C-HMBC-GATED NMR (101 MHz, CDCl$_3$): δ 100.1 (J_{H1-C1} = 171 Hz, α); diagnostic peaks for the β-anomer: ^{1}H NMR (400 MHz, CDCl$_3$) δ 6.10 – 5.78 (m, 1H, CH$_2$-C*H*F$_2$), 4.45 – 4.42 (m, 2H, H-1, CH*H* Bn), 4.39 (d, *J* = 12.2 Hz, 1H), 4.07 (dddd, *J* = 23.5, 11.8, 9.3, 2.7 Hz, 1H, C*H*H-CHF$_2$), 3.56 (dt, *J* = 6.9, 3.5 Hz, 1H), 3.39 (t, *J* = 3.1 Hz, 1H); ^{13}C NMR (101 MHz, CDCl$_3$) δ 102.1 (C-1), 75.5, 74.6, 74.2, 72.3, 70.8; ^{13}C-HMBC-GATED NMR (101 MHz, CDCl$_3$): δ 102.1 (J_{H1-C1} = 156 Hz, β); HRMS: [M+NH$_4$]$^+$ calcd for C$_{36}$H$_{38}$F$_2$O$_6$NH$_4$ 622.29747, found 622.29554.

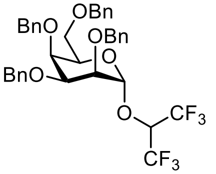
2,2,2-trifluoroethyl-2,3,4,6-tetra-*O*-benzyl-α,β-D-talopyranoside (7E)



Title compound was prepared according to the general procedure for Ph$_2$SO/Tf$_2$O mediated glycosylations with donor **7** and 2,2,2-fluoroethanol, yielding compound **7E** (43 mg, 43 μmol, 43%, colourless oil, α:β = 90:10) Data for the α-anomer: ^{1}H NMR (400 MHz, CDCl$_3$) δ 7.55 – 6.96 (m, 20H, CH$_{arom}$), 5.04 (d, *J* = 1.9 Hz, 1H, H-1), 4.95 (d, *J* = 11.8 Hz, 1H, C*H*H Bn), 4.85 (d, *J* = 12.4 Hz, 1H, C*H*H Bn), 4.77 – 4.69 (m, 2H, 2x CH*H* Bn), 4.55 – 4.50 (m, 3H, C*H*H Bn, CH$_2$ Bn), 4.47 (d, *J* = 11.9 Hz, 1H, CH*H* Bn), 4.01 – 3.90 (m, 3H, H-3, H-5, C*H*H-CF$_3$), 3.88 – 3.78 (m, 2H, H-2, CH*H*-CF$_3$), 3.76 – 3.66 (m, 3H, H-4, 2x H-6); ^{13}C NMR (101 MHz, CDCl$_3$) δ 138.9, 138.4, 138.2, 138.2 (C$_q$), 128.5, 128.5, 128.5, 128.4, 128.3, 128.2, 128.2, 128.2, 127.9, 127.8, 127.7, 127.7, 127.5, 127.4, 127.3 (CH$_{arom}$), 99.7 (C-1), 76.9 (c-4), 73.8(C-2, CH$_2$ Bn), 73.6, 73.5(CH$_2$ Bn), 73.0(C-3), 71.6 (C-5), 71.4 (CH$_2$ Bn), 69.4 (C-6), 64.2 (q, *J* = 34.8 Hz, *C*H$_2$-CF$_3$); ^{13}C-HMBC-GATED NMR (101 MHz, CDCl$_3$): δ 99.7 (J_{H1-C1} = 172 Hz, α); diagnostic peaks for the β-anomer: ^{1}H NMR (400 MHz, CDCl$_3$) δ 4.38 (d, *J* = 12.1 Hz, 1H, CH*H* Bn), 4.21 (dq, *J* = 12.4, 8.9 Hz, 1H, C*H*H-CF$_3$), 3.57 (dt, *J* = 6.5, 3.2 Hz, 1H), 3.42 – 3.38 (m, 1H); ^{13}C NMR (101 MHz, CDCl$_3$) δ 75.6, 70.9, 69.5, a cross-peak for (H-1, C-1) is visible at (4.50, 101.4) in the HSQC spectrum; ^{13}C-

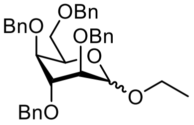
HMBC-GATED NMR (101 MHz, CDCl$_3$): δ 101.4 ($J_{H1\text{-}C1}$ = 157 Hz, β); HRMS: [M+NH$_4$]$^+$ calcd for $C_{36}H_{37}F_3O_6NH_4$ 640.28805, found 640.28619.

1,1,1,3,3,3-hexafluoro-2-propyl-2,3,4,6-tetra-O-benzyl-α-D-talopyranoside (7F)



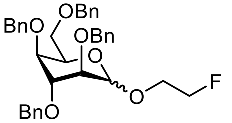
Title compound was prepared according to the general procedure for Ph$_2$SO/Tf$_2$O mediated glycosylations with donor **7** and 1,1,1,3,3,3-hexafluoropropan-2-ol, yielding compound **7F** (10 mg, 14 µmol, 14%, colourless oil, α:β = >98:2) ^{1}H NMR (500 MHz, CDCl$_3$) δ 7.39 – 7.20 (m, 20H, CH$_{arom}$), 5.22 (d, *J* = 1.7 Hz, 1H, H-1), 4.96 (d, *J* = 11.8 Hz, 1H, C*H*H Bn), 4.81 (d, *J* = 12.4 Hz, 1H, C*H*H Bn), 4.76 – 4.70 (m, 2H, 2x CH*H* Bn), 4.54 (s, 2H, CH$_2$ Bn), 4.52 – 4.44 (m, 3H, C*H*(CF$_3$)$_2$), 4.03 (td, *J* = 6.2, 1.8 Hz, 1H, H-5), 3.95 (p, *J* = 1.4 Hz, 1H, H-4), 3.85 (dt, *J* = 3.0, 1.3 Hz, 1H, H-2), 3.74 – 3.65 (m, 3H, H-3, 2x H-6); ^{13}C NMR (126 MHz, CDCl$_3$) δ 138.8, 138.2, 138.0, 138.0 (C$_q$), 128.6, 128.5, 128.5, 128.4, 128.3, 127.9, 127.8, 127.7, 127.6, 127.4 (CH$_{arom}$), 101.2 (C-1), 76.5 (C-3), 73.8, 73.7, 73.6 (CH$_2$ Bn), 73.4 (C-2), 72.6 (C-4), 72.4 (C-5), 71.5 (CH$_2$ Bn), 69.0 (C-6); ^{13}C-HMBC-GATED NMR (126 MHz, CDCl$_3$): δ 101.2 ($J_{H1\text{-}C1}$ = 175 Hz, α); HRMS: [M+NH$_4$]$^+$ calcd for $C_{37}H_{36}F_6O_6$ 708.27543, found 708.27354.

Ethyl-2,3,4,6-tetra-*O*-benzyl-α,β-D-idopyranoside (8B)



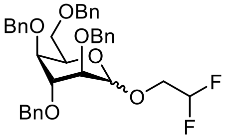
Title compound was prepared according to the general procedure for Ph$_2$SO/Tf$_2$O mediated glycosylations with donor **8** and ethanol, yielding compound **8B** (44 mg, 76 µmol, 76%, colourless oil, α:β = 57:43). Data reported for a 1:1 mixture: ^{1}H NMR (400 MHz, CDCl$_3$) δ 7.43 – 7.13 (m, 40H, CH$_{arom}$), 4.85 (d, *J* = 5.4 Hz, 1H, H-1α), 4.79 (d, *J* = 11.5 Hz, 1H, C*H*H Bn), 4.77 – 4.70 (m, 3H, H-1β, C*H*H Bn, C*H*H Bn), 4.68 – 4.60 (m, 5H, 5x C*H*H Bn/CH*H* Bn), 4.58 – 4.46 (m, 8H, 8x C*H*H Bn/CH*H* Bn), 4.21 (dt, *J* = 7.0, 4.6 Hz, 1H, H-5α), 4.13 (dt, *J* = 7.4, 4.8 Hz, 1H, H-5β), 3.97 (dq, *J* = 9.5, 7.0 Hz, 1H, C*H*H Et), 3.91 – 3.84 (m, 2H, C*H*H Et, H-6β), 3.83 – 3.77 (m, 3H), 3.77 – 3.72 (m, 1H, H-6α), 3.71 – 3.65 (m, 2H), 3.60 – 3.51 (m, 2H), 3.51 – 3.44 (m, 3H), 1.23 (t, *J* = 7.1 Hz, 6H, 2x CH$_3$ Et); ^{13}C NMR (101 MHz, CDCl$_3$) δ 138.7, 138.5, 138.3, 138.3, 138.3 (C$_q$), 128.5, 128.5, 128.4, 128.2, 128.1, 128.1, 128.1, 128.0, 128.0, 127.9, 127.9, 127.8, 127.8, 127.8, 127.7, 127.7 (CH$_{arom}$), 100.1 (C-1α), 98.9 (C-1β), 80.1, 79.2, 77.8, 75.8, 75.6, 74.3, 74.1 (C-5β), 73.9, 73.8, 73.7, 73.5, 73.4, 73.2, 72.7, 70.0 (C-5α), 69.9 (C-6β), 68.4 (C-6α), 64.4, 64.3 (2x CH$_2$ Et), 15.4, 15.1 (2x CH$_3$ Et); ^{13}C-HMBC-GATED NMR (101 MHz, CDCl$_3$): δ 100.1 ($J_{H1\text{-}C1}$ = 165 Hz, α), 98.9 ($J_{H1\text{-}C1}$ = 161 Hz, β); HRMS: [M+NH$_4$]$^+$ calcd for $C_{36}H_{40}O_6NH_4$ 586.31631, found 586.31458.

2-fluoroethy-2,3,4,6-tetra-*O*-benzyl-α,β-D-idopyranoside (8C)



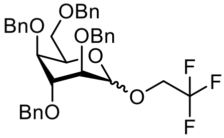
Title compound was prepared according to the general procedure for Ph$_2$SO/Tf$_2$O mediated glycosylations with donor **8** and 2-fluoroethanol, yielding compound **8C** (42 mg, 72 µmol, 72%, colourless oil, α:β = 57:43). Data reported for a 1:1 mixture: ^{1}H NMR (400 MHz, CDCl$_3$) δ 7.57 – 6.84 (m, 40H, CH$_{arom}$), 4.95 (d, *J* = 5.0 Hz, 1H, H-1α), 4.87 – 4.78 (m, 5H, H-1β, 4x C*H*H Bn/CH*H* Bn), 4.76 – 4.61 (m, 8H, 6x C*H*H Bn/CH*H* Bn, 2x CH$_2$-C*H*HF), 4.61 – 4.47 (m, 8H, 6x C*H*H Bn/CH*H* Bn, 2x CH$_2$-CH*H*F), 4.26 (dt, *J* = 7.1, 4.4 Hz, 1H, H-5α), 4.22 – 4.08 (m, 2H, H-5β, C*H*H-CH$_2$F), 4.07 – 3.95 (m, 1H, C*H*H-CH$_2$F), 3.92 (dd, *J* = 10.1, 7.8 Hz, 1H, H-6β), 3.88 – 3.75 (m, 6H,, H-3α, H-3β, H-6α, H-6β, 2x CH*H*-CH$_2$F), 3.76 – 3.67 (m, 2H, H-4α, H-6β), 3.63 – 3.54 (m, 2H, H-2α, H-2β), 3.54 (dd, *J* = 5.4, 3.9 Hz, 1H, H-4β); ^{13}C NMR (101 MHz, CDCl$_3$) δ 138.7, 138.5, 138.4, 138.3, 138.3, 138.2, 138.2 (C$_q$), 128.5, 128.5, 128.4, 128.3, 128.2, 128.2, 128.1, 128.0, 127.9, 127.9, 127.9, 127.9, 127.8, 127.8, 127.7, 127.7, 127.7 (CH$_{arom}$), 100.8 (C-1α), 99.7 (C-1α), 83.0 (d, *J* = 169.0 Hz, CH$_2$-*C*H$_2$F), 82.8 (d, *J* = 169.4 Hz, CH$_2$-*C*H$_2$F), 79.4 (C-2β), 78.8 (C-3β), 77.5 (C-4α), 75.9 (C-2α), 75.2 (C-3α, C-4β), 74.2 (C-5β), 74.1, 73.8, 73.7, 73.6, 73.5, 73.4, 73.2, 72.7 (CH$_2$ Bn), 69.9 (C-5α), 69.7 (C-6β), 68.6 (C-6α), 68.0 (d, *J* = 19.8 Hz, *C*H$_2$-CH$_2$F), 67.5 (d, *J* = 19.9 Hz, *C*H$_2$-CH$_2$F); ^{13}C-HMBC-GATED NMR (101 MHz, CDCl$_3$): δ 100.8 ($J_{H1\text{-}C1}$ = 167 Hz, α), 99.7 ($J_{H1\text{-}C1}$ = 162 Hz, β); HRMS: [M+NH$_4$]$^+$ calcd for $C_{363}H_{39}FO_6NH_4$ 604.30689, found 604.30571.

2,2-difluoroethy-2,3,4,6-tetra-*O*-benzyl-α,β-D-idopyranoside (8D)



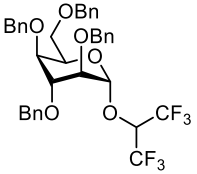
Title compound was prepared according to the general procedure for Ph$_2$SO/Tf$_2$O mediated glycosylations with donor **8** and 2,2-difluoroethanol, yielding compound **8D** (44 mg, 72 µmol, 72%, colourless oil, α:β = 55:45) Data reported for a 1:1 mixture: ^{1}H NMR (500 MHz, CDCl$_3$) δ 7.53 – 7.06 (m, 40H, CH$_{arom}$), 6.11 – 5.84 (m, 2H, 2x CH$_2$-C*H*F$_2$), 4.93 (d, *J* = 4.7 Hz, 1H, H-1α), 4.82 (d, *J* = 2.4 Hz, 1H, H-1β), 4.80 – 4.45 (m, 16H, 8x CH$_2$ Bn), 4.24 (dt, *J* = 7.2, 4.2 Hz, 1H, H-5α), 4.14 (ddd, *J* = 8.1, 4.8, 3.4 Hz, 1H, H-5β), 4.12 – 4.02 (m, 1H, C*H*H-CHF$_2$), 3.99 – 3.85 (m, 2H, H-6β, C*H*H-CHF$_2$), 3.85 – 3.83 (m, 1H, H-3α), 3.82 – 3.72 (m, 5H, H-3β, H-6α, H-6β, 2x CH*H*-CHF$_2$), 3.70 – 3.67 (m, 2H, H-4α, H-6α), 3.58 – 3.54 (m, 2H, H-2αβ), 3.51 (dd, *J* = 5.0, 3.6 Hz, 1H, H-4β); ^{13}C NMR (126 MHz, CDCl$_3$) δ 138.5, 138.4, 138.1, 138.1, 138.0, 138.0 (C$_q$), 128.5, 128.5, 128.5, 128.4, 128.3, 128.2, 128.2, 128.1, 128.0, 128.0, 127.9, 127.9, 127.8, 127.8, 127.8, 127.7 (CH$_{arom}$), 116.8 – 112.1 (m, 2x CH$_2$-*C*HF$_2$) 101.4 (C-1α), 100.0 (C-1β), 78.9 (C-2α), 78.5 (C-3α), 77.3 (C-4α), 75.4 (C-2β), 74.9 (C-3β), 74.7 (C-4β), 74.3 (C-5β), 74.0, 73.8, 73.8, 73.5, 73.5, 73.4, 73.1, 72.6 (CH$_2$ Bn), 69.9 (C-6β), 69.5 (C-6α), 68.6 (C-5α); ^{13}C-HMBC-GATED NMR (101 MHz, CDCl$_3$): δ 101.4 ($J_{H1\text{-}C1}$ = 168 Hz, α), 100.0 ($J_{H1\text{-}C1}$ = 162 Hz, β); HRMS: [M+NH$_4$]$^+$ calcd for $C_{36}H_{38}F_2O_6NH_4$ 622.29747, found 622.29604.

2,2,2-trifluoroethy-2,3,4,6-tetra-*O*-benzyl-α,β-D-idopyranoside (8E)



Title compound was prepared according to the general procedure for Ph_2SO/Tf_2O mediated glycosylations with donor **8** and 2,2,2-trifluoroethanol, yielding compound **8E** (41 mg, 66 μmol, 66%, α:β = 69:31) Data for the α-anomer: ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.40 – 7.24 (m, 20H, CH_{arom}), 4.99 (d, *J* = 4.6 Hz, 1H, H-1), 4.79 (dd, *J* = 11.5, 10.0 Hz, 2H, CH_2 Bn), 4.71 – 4.60 (m, 3H, 3x C*H*H Bn), 4.59 – 4.51 (m, 3H, 3x CH*H* Bn), 4.23 (dt, *J* = 7.1, 4.2 Hz, 1H, H-5), 4.13 – 4.05 (m, 1H, C*H*H-CF_3), 3.98 – 3.89 (m, 1H, CH*H*-CF_3), 3.84 (dd, *J* = 7.2, 5.7 Hz, 1H, H-3), 3.78 – 3.73 (m, 1H, H-6), 3.70 – 3.65 (m, 2H, H-4, H-6), 3.59 (dd, *J* = 7.2, 4.7 Hz, 1H, H-2); ^{13}C NMR (126 MHz, $CDCl_3$) δ 138.4, 138.1, 138.1, 138.0 (C_q), 128.6, 128.5, 128.5, 128.5, 128.3, 128.1, 128.0, 128.0, 127.9, 127.9, 127.7 (CH_{arom}), 101.0 (C-1), 78.4, 78.3 (C-2, C-3), 77.2 (C-4), 74.0, 73.8, 73.5, 73.2 (CH_2 Bn), 70.0 (C-5), 68.6 (C-6), 64.6 (q, *J* = 34.5 Hz, *C*H-CF_3); ^{13}C-HMBC-GATED NMR (126 MHz, $CDCl_3$): δ 101.0 ($J_{H1\text{-}C1}$ = 169 Hz, α); diagnostic peaks for the β-anomer: ^{1}H NMR (500 MHz, $CDCl_3$) δ 4.89 (d, *J* = 2.5 Hz, 1H, H-1), 3.51 (dd, *J* = 5.2, 3.7 Hz, 1H); ^{13}C NMR (126 MHz, $CDCl_3$) δ 99.7 (C-1), 74.4, 73.6, 72.7, 69.4 (C-6), 68.2 – 67.3 (m, 2x *C*H_2-CHF_2); ^{13}C-HMBC-GATED NMR (126 MHz, $CDCl_3$): δ 99.7 ($J_{H1\text{-}C1}$ = 163 Hz, β); HRMS: $[M+NH_4]^+$ calcd for $C_{36}H_{37}F_3O_6NH_4$ 640.28805, found 640.28690.

1,1,1,3,3,3-hexafluoro-2-propyl-2,3,4,6-tetra-O-benzyl-α-D-idopyranoside (8F)



Title compound was prepared according to the general procedure for Ph_2SO/Tf_2O mediated glycosylations with donor **8** and 1,1,1,3,3,3-hexafluoropropan-2-ol, yielding compound **8F** (15 mg, 22 μmol, 22%, colourless oil, α:β = >98:2) ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.40 – 7.20 (m, 20H, CH_{arom}), 5.16 (d, *J* = 4.2 Hz, 1H, H-1), 4.76 (t, *J* = 11.4 Hz, 2H, CH_2 Bn), 4.67 (d, *J* = 11.7 Hz, 1H, C*H*H Bn), 4.65 – 4.59 (m, 2H, C*H*$(CF_3)_2$, C*H*H Bn), 4.57 (d, *J* = 11.5 Hz, 1H, CH*H* Bn), 4.54 (d, *J* = 11.8 Hz, 1H, CH*H* Bn), 4.52 (d, *J* = 3.1 Hz, 2H, CH_2 Bn), 4.26 (td, *J* = 6.2, 3.6 Hz, 1H, H-5), 3.81 (dd, *J* = 7.1, 5.1 Hz, 1H, H-3), 3.72 – 3.68 (m, 3H, H-4, 2x H-6), 3.65 (dd, *J* = 7.1, 4.2 Hz, 1H, H-2); ^{13}C NMR (126 MHz, $CDCl_3$) δ 138.3, 138.1, 138.1, 137.6 (C_q), 129.6, 129.3, 128.9, 128.7, 128.6, 128.6, 128.6, 128.5, 128.5, 128.4, 128.3, 128.2, 128.1, 128.0, 127.9, 127.8, 127.8, 127.8, 127.7, 127.7 (CH_{arom}), 101.6 (C-1), 78.1 (C-3), 77.6 (C-2), 73.8, 73.8, 73.6, 73.3 (CH_2 Bn), 70.1 (C-5), 68.2 (C-6), a cross-peak for (H-4, C-4) is visible at (3.70, 76.2) in the HSQC spectrum; ^{13}C-HMBC-GATED NMR (126 MHz, $CDCl_3$): δ 101.6 ($J_{H1\text{-}C1}$ = 173 Hz, α); HRMS: $[M+NH_4]^+$ calcd for $C_{37}H_{36}F_6O_6$ 708.27543, found 708.27396.

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4

Chapter 4: How configuration and protecting group pattern influence glycosyl acceptor reactivity

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Introduction

Typically, the optimization of glycosylation reactions in the context of oligosaccharide total synthesis is done in a target-oriented approach and despite decades of research no universal guidelines exist to ensure general stereoselective and high yielding glycosylations.[1-5] Many different protocols for the synthesis of oligosaccharides have been developed, with most of them taking the same approach (***Figure 1***). First, a donor with a latent leaving group (LG) is activated with an activator (E-X) to form an activated donor. This electrophile then reacts with a nucleophile, the acceptor, in the glycosylation reaction, forming a glycosidic bond.[6] Not surprisingly, the outcome of a glycosylation reaction, in terms of both stereoselectivity and yield, is dependent on many variables. Both external factors such as temperature, solvent, concentration and activator as well as inherent properties of the donor and the acceptor play a determining role.[7]

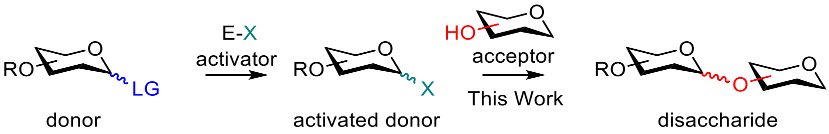
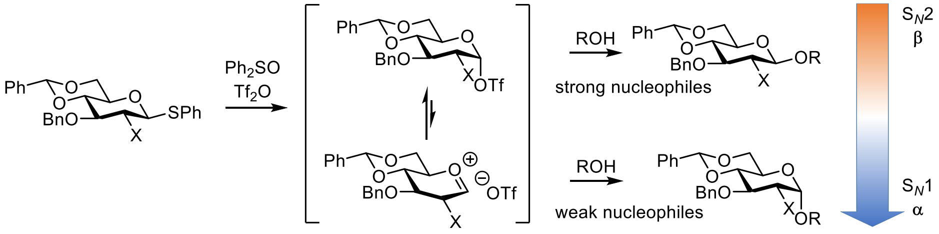


Figure 1: *A typical synthesis of a disaccharide*

Two important parameters are the reactivity of the donor,[8-10] as well as the nucleophilicity of the acceptor.[8, 11-14] Donor reactivity has been thoroughly investigated: countless relative reactivity values of thioglycosides have been determined,[15-17] various reactive species have been observed and characterized by variable temperature NMR,[18] and the reactivity of oxocarbenium-like intermediates has been probed via a combination of experiments, computational chemistry and spectroscopy.[14, 19, 20] Thanks to systematic mechanistic studies, the effect of both stereochemistry and protecting group pattern on the reactivity of the donor is relatively well understood. On the other hand, factors influencing the reactivity of the acceptor are less well understood, because systematic studies regarding the reactivity of the acceptor in the glycosylation reaction are much more scarce. Quite often acceptors with multiple variations are compared, making it unclear which structural modification is responsible for the difference in reactivity.[21] By carefully choosing a set of acceptors and changing the structure in a systematic way, it is possible to determine the effect of a single variation in the stereochemistry or protecting group pattern on the reactivity of the acceptor. This work investigates the reactivity of glycosyl acceptors of C-2, C-3, or C-4 hydroxyls of D-glucose, D-mannose, D-galactose, L-rhamnose and L-fucose acceptors, having different protecting group patterns of ether and ester groups. In order to limit steric effects when comparing different ether/ester protecting groups, sterically similar benzyl and benzoyl groups were used.

Model "stripped" carbohydrate-like acceptors and glycerol alcohols are probed for comparison. The glycerol acceptors in this series resemble typical carbohydrate acceptors as they are cyclic and secondary alcohols, flanked by protected alcohols. However, unlike carbohydrate acceptors, they are not chiral, eliminating the effect of double stereodifferentiation in the glycosylation reaction.

The method used for measuring the reactivity of the acceptors is based on the stereoselective outcome in a glycosylation reaction with the acceptors and two donors: phenyl 2,3-di-*O*-benzyl-4,6-*O*-benzylidene-1-thio-β-D-glucopyranoside (**Donor A**) and phenyl 2-deoxy-2-azido-3-*O*-benzyl-4,6-*O*-benzylidene-1-thio-β-D-glucopyranoside (**Donor B**). Recently the stereoselectivity of glycosylation reactions of these donors was reported to be a measure for the reactivity of the acceptor.[13] More nucleophilic acceptors, provide β-selective glycosylations, while less nucleophilic acceptors lead to α-selectivity. The mechanism to explain the change in stereoselectivity is shown in ***Figure 2***. Both thioglycoside donors form an α-triflate upon activation with Ph_2SO and Tf_2O. More nucleophilic acceptors react with this triflate in an S_N2 like mechanism, while less nucleophilic acceptors react with the corresponding β-triflate or an oxocarbenium ion-like species to form the α-product.[12] **Donor B** shows higher β-selectivity with the same acceptor than **Donor A** because the electron-withdrawing azide on C-2 stabilises the anomeric triflate rendering the S_N2 substitution of the α-triflate more predominant.[8]



	CH_3CH_2OH	CH_2FCH_2OH	CHF_2CH_2OH	CF_3CH_2OH	
Donor A: X = OBn	**1 : 10**	**1 : 2.8**	**5 : 1**	**>20 : 1**	(α/β)
Donor B: X = N_3	**<1 : 20**	**1 : 6.7**	**2.9 : 1**	**>20 : 1**	

Figure 2: *Glycosylation mechanisms and the relation between stereoselectivity of* ***donor A*** *and* ***Donor B*** *and nucleophilicity of the acceptor*

Results and discussion

Stereoselectivity

In this study, 60 acceptors were reacted with **Donor A** and **Donor B**. The acceptors can be divided in six groups based on their configuration. The results of the glucose series (acceptors **1**-**12**), are reported in ***Table 1***, the mannose series (**13-23**) in ***Table 2***, the galactose series (**24-35)** in ***Table 3***, the rhamnose series (**36-42**) in ***Table 4***, the fucose series (**43-50**) in ***Table 5*** and the model acceptors (**51-60)** in ***Table 6***. When analysing these results, several trends became clear. In the previous study,[13] the reactivity of glucosyl C-4-hydroxy groups was thoroughly investigated (***Table 1***). It was found that the protecting groups on the C-6-position and on the C-3-position have an effect on the reactivity, with the protecting group on the C-3-position having a larger influence, due to the closer proximity. When both positions are changed from benzyl ethers to benzoyl esters, the deactivating effects work in concert leading the following order of reactivity of the glucosyl C-4-OH acceptors: **1** > **2** >**3** > **4**. A similar effect is found for the mannosyl C-4-OH (***Table 2*** acceptors **13-16**). Also, in this series the protecting group on the C-3-position has a larger influence on the reactivity of the acceptor than the protecting group on the 6-position, and again the effects of the C-3/C-6 benzyl/benzoyl groups are additive, leading to the order of reactivity for the mannosyl C-4-OH acceptors **13** > **14** > **15** > **16.** Of note, the mannosyl C-4-OH acceptors are all more reactive than their glucosyl C-4-OH equivalents.

The axial galactosyl C-4-OH is significantly less reactive (***Table 3*** acceptor **24**). When the protection groups on the C-6-position or the C-3-position of the galactose acceptors are changed from benzyl ethers to benzoyl esters (acceptors **25** and **26** respectively) the reactivity does not change significantly. Only when all protecting groups are changed to benzoyl esters, a significant effect is found and the reactivity decreases to provide highly α-selective glycosylations (acceptor **27**). The C-4-hydroxyls of D- and L-rhamnose and D- and L-fucose (acceptors **36**, **37**, **43**, **44**, ***Table 4*** and ***Table 5***) were used to investigate double stereodifferention effects in this glycosylation system. Although there are minor differences in stereoselectivity between the D- and L-isomers, the configuration of the acceptor seems to be more important than the absolute stereochemistry. The D-rhamnose and fucose acceptors have similar reactivity as their mannose and galactose counterparts, which is in line with what was previously found for C-4-OH glucose and C-4-OH 6-deoxyglucose acceptors.[13]

Regarding the reactivity of the C-3-hydroxyls, it is remarkable that the glycosylation with the glucose C-3-OH (acceptor **5**) is much more β-selective than the mannosyl, galactosyl, rhamnosyl and fucosyl C-3-OH (acceptor **17**, **28**, **38**, and **45** respectively), which all provide similar stereoselectivity. The main structural difference that distinguishes the glucosyl C-3-OH from the other alcohols, is that this alcohol has two equatorially oriented neighboring groups, while in mannose, galactose, rhamnose and fucose one of the neighboringing groups is axial, suggesting that this is important for the reactivity of the acceptor. Another difference is that benzoylation of the 2- and 4-position of glucose (acceptors **6** and **7**) has a similar effect on the reactivity and that the effects are additive (acceptor **8**). While the glycosylation of all per-benzoylated acceptors (acceptors **20**, **31**, **41** and **48**) show great α-selectivity, the effects of single benzoyl group (as in mannosyl acceptors **18** and **19**, galactosyl acceptors **29** and **30**, rhamnosyl acceptors **39** and **40** and fucosyl acceptors **46** and **47**), depends strongly on which position it is placed. In mannose and rhamnose, benzoylation of the equatorial C-4-OH significantly diminishes the reactivity (acceptors **18** and **39**) while benzoylation of the axial C-2-alcohol has little effect on the reactivity (acceptors **19** and **40**). This effect was also observed for the galactosyl and fucosyl acceptors were benzoylation of the axial C-4-OH (acceptors **29** and **46**) has a lower effect on the reactivity of the free alcohol than benzoylation of the equatorial C-2-OH (acceptors **30** and **47**). These results show that the electron withdrawing effect of the benzoate esters critically depends on the orientation of this protecting group relative to the free OH-group.

The results of the glycosylations with the C-2-OH acceptors show the same trend. The reactivity of the equatorial alcohols (acceptors **9**, **12**, **32**, **35**, **49**, **50**) is higher than that of the axial alcohols (acceptors **21** and **42**). Substitution of benzyl groups for benzoyl groups also decreases the reactivity of the glucosyl, mannosyl and galactosyl C-2-OH (acceptors **9-11, 21-23** and **32-34**). When regarding the reactivity of α-OMe *vs* β-OMe acceptors (**9** *vs* **12**, **32** *vs* **35** and **49** *vs* **50**) it becomes clear that alcohols next to equatorial ethers are more reactive than those next to one axial ether, in line with the reactivity trend revealed above for the C-3-OH acceptors. Furthermore, the β-OMe acceptors **12**, **35** and **50** have a similar reactivity as the other acceptors having the free alcohol next to two equatorial ethers (acceptors **1, 5, 13, 36, 37, 50**) and the α-OMe acceptors **9** and **32** react in a similar fashion to the other acceptors having one axial and one equatorial ether (acceptors **17**, **28**, **38** and **45**), again showing that the configuration of functional groups next to the alcohol is important for the reactivity with acceptors alcohols next to only equatorial benzyl ethers being more nucleophilic than those next to an axial benzyl ethers. From all the tested acceptors, only acceptor **49** shows a higher β-selectivity than what could be expected based on the above-described configuration-reactivity trends between.

Finally, two sets of model acceptors were introduced to 'isolate' the effect of the different neighboring groups and serve as benchmark to aid in (future) calculations to get more quantitative grip on the relative reactivity of the tested acceptors and provide a mechanistic explanation for the reactivity differences between acceptors. The first set consists of 'stripped' carbohydrate acceptors with a single substituent next to the alcohol. The experimental data obtained with these nucleophiles show that the same reactivity trends found for the carbohydrate acceptors above: equatorial acceptors are more reactive than axial acceptors (**51**, **53** and **55** *vs* **56**), alcohols next to equatorial benzyl ethers are more nucleophilic than those next to axial benzyl ethers (**51** and **55** vs **53**) and equatorial esters decrease the nucleophilicity much more than axial esters as compared to corresponding ethers (**51** *vs* **52** and **53** *vs* **54**). The second set of model acceptors consist of four glycerol C-2-OH acceptors, which were designed to investigate the effect of different protecting groups on non-chiral cyclic acceptors containing a secondary alcohol next to two protected oxygen atoms. Not surprisingly, the reactivity of the glyceroyl alcohols in the acceptors is heavily dependent on the protecting groups. The isopropylidene protected acceptor (**59**) is the most reactive, followed by the *cis*-benzylidene protected acceptor (**58**), the *trans*-benzylidene protected acceptor (**57**) and finally the carbonate protected acceptor (**60**)

Table 1: *Glucose acceptors and their stereoselectivities with* ***donor A*** *and* ***donor B****. a: results are taken from ref 13*

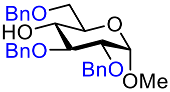
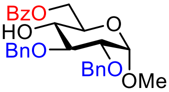
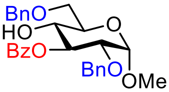
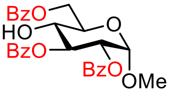
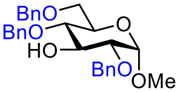
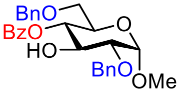
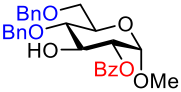
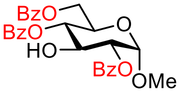
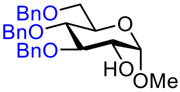
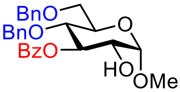
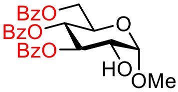
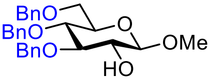
Acceptor	structure	Donor A		Donor B	
		Product (yield)	**α:β**	**Product** (yield)	**α:β**
1[a]		**1A** (82%)	**1:1**	**1B** (88%)	**1:7**
2[a]		**2A** (92%)	**4:1**	**2B** (67%)	**1:1.1**
3[a]		**3A** (95%)	**>20:1**	**3B** (77%)	**6.7:1**
4[a]		**4A** (91%)	**>20:1**	**4B** (69%)	**>20:1**
5[a]		**5A** (78%)	**1:2.7**	**5B** (70%)	**<1:20**
6		**6A** (98%)	**2.6:1**	**6B** (99%)	**1:5**
7		**7A** (99%)	**1.8:1**	**7B** (93%)	**1:4**
8[a]		**8A** (100%)	**>20:1**	**8B** (83%)	**>20:1**
9[a]		**9A** (76%)	**9:1**	**9B** (66%)	**1.6:1**
10		**10A** (78%)	**>20:1**	**10B** (82%)	**6:1**
11[a]		**11A** (85%)	**>20:1**	**11B** (92%)	**13:1**
12		**12A** (96%)	**1:1.9**	**12B** (78%)	**1:6**

***Table 2:** Mannose acceptors and their stereoselectivities with **donor A** and **donor B**. a: results are taken from ref 13*

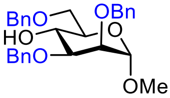
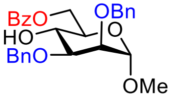
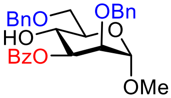
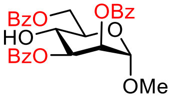
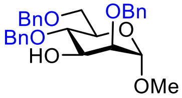
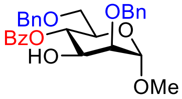
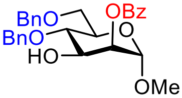
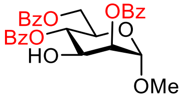
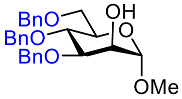
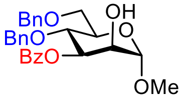
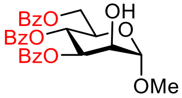
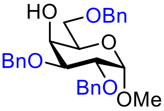
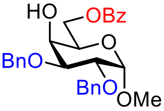
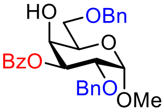
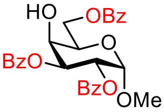
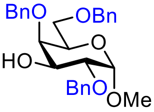
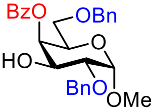
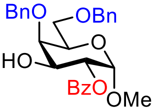
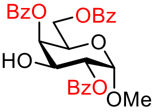
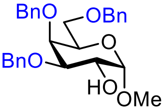
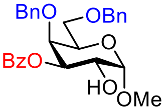
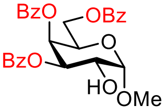
Acceptor	structure	Donor A		Donor B	
		Product (yield)	**α:β**	**Product** (yield)	**α:β**
13[a]		**13A** (76%)	**1:2**	**13B** (72%)	**<1:20**
14		**14A** (76%)	**1.3:1**	**14B** (92%)	**1:8**
15		**15A** (62%)	**9:1**	**15B** (93%)	**1.5:1**
16		**16A** (66%)	**>20:1**	**16B** (98%)	**10:1**
17[a]		**17A** (82%)	**8:1**	**17B** (70%)	**1.1:1**
18		**18A** (87%)	**>20:1**	**18B** (87%)	**>20:1**
19		**19A** (82%)	**10:1**	**19B** (93%)	**1:1**
20[a]		**20A** (100%)	**>20:1**	**20B** (100%)	**>20:1**
21[a]		**21A** (95%)	**>20:1**	**21B** (65%)	**7:1**
22		**22A** (76%)	**>20:1**	**22B** (51%)	**7:1**
23		**23A** (77%)	**>20:1**	**23B** (51%)	**>20:1**

***Table 3**: Galactose acceptors and their stereoselectivities with **donor A** and **donor B**. a: results are taken from ref 13*

Acceptor	structure	Donor A		Donor B	
		Product (yield)	**α:β**	**Product** (yield)	**α:β**
24[a]		**24A** (72%)	**12:1**	**24B** (86%)	**3:1**
25		**25A** (85%)	**>20:1**	**25B** (100%)	**3:1**
26		**26A** (78%)	**11:1**	**26B** (67%)	**3:1**
27		**27A** (70%)	**>20:1**	**27B** (100)	**>20:1**
28[a]		**28A** (85%)	**6:1**	**28B** (88%)	**1:1.3**
29		**29A** (76%)	**16:1**	**29B** (60%)	**1.3:1**
30		**30A** (84%)	**>20:1**	**30B** (82%)	**13:1**
31[a]		**31A** (83%)	**>20:1**	**31B** (90%)	**11:1**
32[a]		**32A** (87%)	**10:1**	**32B** (73%)	**1:1.3**
33		**33A** (89%)	**>20:1**	**33B** (51%)	**3:1**
34		**34A** (88%)	**>20:1**	**34B** (87%)	**6:1**

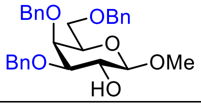
35		**35A** (83%)	**1.5:1**	**35B** (86%)	**1:10**

Table 4**: Rhamnose acceptors and their stereoselectivities with **donor A** and **donor B

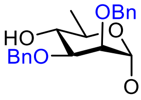
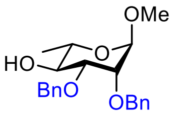
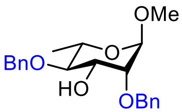
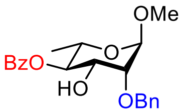
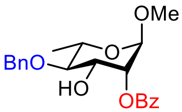
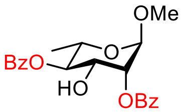
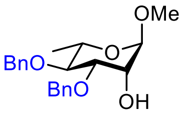
Acceptor	structure	**Donor A**		**Donor B**	
		Product (yield)	**α:β**	**Product** (yield)	**α:β**
36		**36A** (89%)	**1:2.4**	**36B** (75%)	**<1:20**
37		**37A** (90%)	**1.7:1**	**37B** (99%)	**1:10**
38		**38A** (100%)	**7:1**	**38B** (68%)	**1.4:1**
39		**39A** (69%)	**>20:1**	**39B** (50%)	**12:1**
40		**40A** (66%)	**6:1**	**40B** (55%)	**1:1**
41		**41A** (83%)	**>20:1**	**41B** (100%)	**12:1**
42		**42A** (59%)	**>20:1**	**42A** (77%)	**3:1**

Table 5: *Fucose acceptors and their stereoselectivities with **donor A** and **donor B***

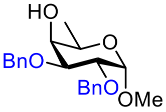
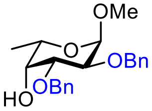
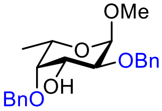
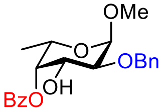
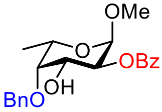
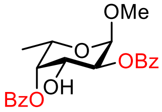
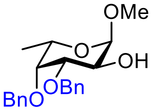
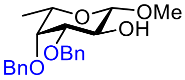
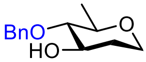
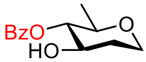
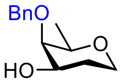
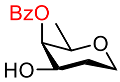
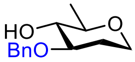
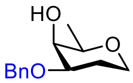
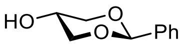
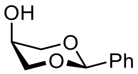
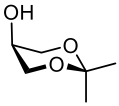
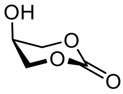
Acceptor	structure	**Donor A**		**Donor B**	
		Product (yield)	**α:β**	**Product** (yield)	**α:β**
43		**43A** (98%)	**>20:1**	**43B** (100%)	**1.3:1**
44		**44A** (85%)	**14:1**	**44B** (100%)	**3:1**
45		**45A**(100%)	**3.2:1**	**45B** (88%)	**1:2**
46		**46A** (100%)	**>20:1**	**46B** (100%)	**2:1**
47		**47A** (100%)	**>20:1**	**47B** (92%)	**9:1**
48		**48A** (100%)	**>20:1**	**48B** (100%)	**>20:1**
49		**49A** (55%)	**1:1**	**49B** (95%)	**1:5.5**
50		**50A** (86%)	**1:1.2**	**50B** (93%)	**<1:20**

Table 6: *Model acceptors and their stereoselectivities with* ***donor A*** *and* ***donor B***

Acceptor	structure	**Donor A**		**Donor B**	
		Product (yield)	**α:β**	**Product** (yield)	**α:β**
51		**51A** (81%)	**1:1.6**	**51B** (85%)	**1:13**
52		**52A** (53%)	**5:1**	**52B** (60%)	**1.4:1**
53		**53A** (97%)	**4:1**	**53B** (60%)	**1:1.4**
54		**54A** (100%)	**8:1**	**54B** (100%)	**1.5:1**
55		**55A** (98%)	**1:1.6**	**55B** (97%)	**1:16**
56		**56A** (100%)	**11:1**	**56B** (93%)	**1.4:1**
57		**57A** (100%)	**6:1**	**57B** (100%)	**2.9:1**
58		**58A** (79%)	**1.6:1**	**58B** (31%)	**1:3**
59		**59A** (96%)	**1:1**	**59B** (100%)	**1:10**
60		**60A** (97%)	>20:1	**60B** (99%)	>20:1

Structure-reactivity relationships

In order to reveal structure-reactivity relationships for the large collection of acceptors, they were divided in groups based on their configuration and protecting group pattern and their reactivity of acceptors plotted as percentage β-product formed with both **donor A** and **donor B**.

Figure 3 shows the importance of configuration on the reactivity of the acceptor. Equatorial acceptors are generally more reactive than axial acceptors (light blue circles and blue squares bar vs black triangles). Furthermore, the orientation of the group next to the alcohol is important for the reactivity of the acceptor. When the nucleophilic alcohol only has equatorial neighbours (light blue circles) the acceptor is more nucleophilic than an acceptor with an axial neighbour (blue squares)

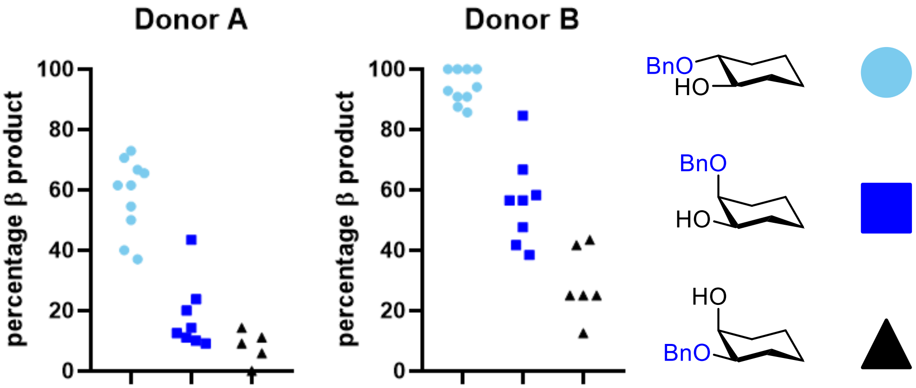


***Figure 3**: Configuration vs reactivity (measured as percentage β-product for **Donor A** and **Donor B**) of glycosyl acceptors. Light blue circles: equatorial alcohol acceptors with only equatorial neighboring OBn and OMe groups, i.e. acceptors **1, 5, 12, 13, 35, 36, 37, 50, 51** and **55**. Blue squares: equatorial alcohol with one axial neighboring OBn or OMe group, i.e. acceptors **9, 17, 28, 32, 38, 45, 49** and **53.** Black triangles: axial alcohols, i.e. acceptors **21, 24, 42, 43, 44** and **56**.*

Figure 4 shows the effect of the orientation of a benzoyl group on the reactivity of the acceptors. When the neighboring benzoyl is axial (red diamonds) the effect on the reactivity is smaller than that of an equatorial benzoyl (yellow triangles). Benzyl protected acceptors with one axial neighboring OBn or OMe group (blue circles) and acceptors with one axial and one equatorial benzoyl group (green inverted triagles) are provided as a reference.

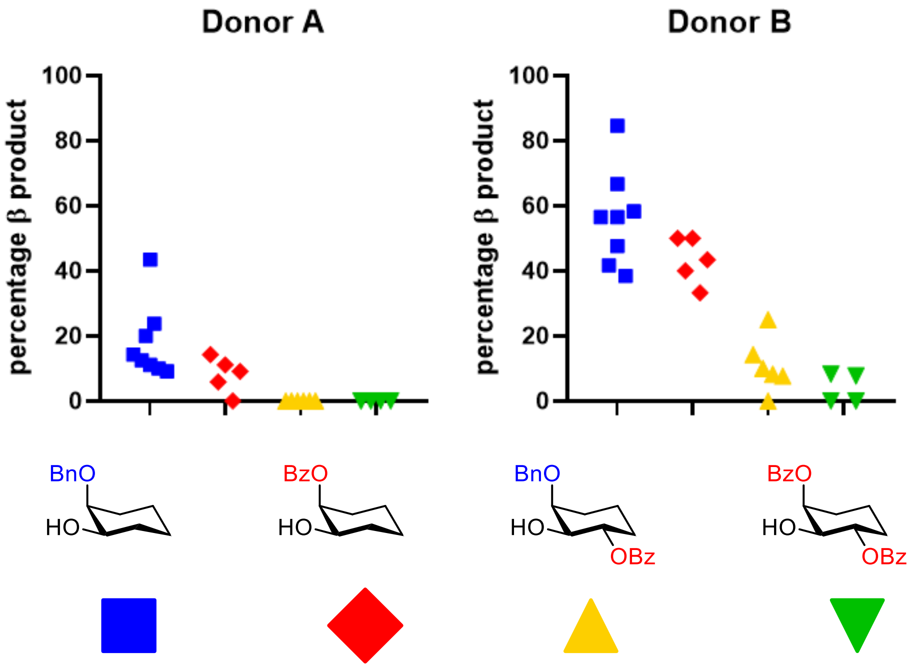


Figure 4: *Protecting group pattern vs reactivity (measured as percentage β-product for* ***Donor A*** *and* ***Donor B****) of glycosyl acceptors. Blue circles: equatorial alcohol acceptors with one axial neighboring OBn or OMe group, i.e. acceptors* ***9, 17, 28, 32, 38, 45, 49*** *and* ***53.*** *Red diamonds: equatorial alcohol acceptors with one axial neighboring OBz group, i.e. acceptors* ***19, 29, 40, 46*** *and* ***54.*** *Yellow triangles: equatorial alcohol acceptors with one axial neighboring OBn or OMe group and one equatorial neighboring OBz group, i.e. acceptors* ***10, 18, 30, 34, 40*** *and* ***47****. Green triangles: equatorial alcohol acceptors with one axial and one equatorial neighboring OBz group, i.e. acceptors* ***20, 31, 41*** *and* ***48****.*

Proton affinity

Next, a method was sought to establish acceptor reactivity in a more quantitiative manner. To this end the proton affinity of the model acceptors **59**-**68** and partially fluorinated ethanols was calculated. The computed proton affinity (ΔH_{PA}) is defined as the enthalpy for the reaction described in ***equation 1*** in the gas phase.

$$ROH \rightarrow RO^{-} + H^{+} \ (1)$$

The proton affinity of a given alcohol serves as a measure for the electron density of the alcohol, and thus relates to the nucleophilicity of the acceptor alcohols. First the proton affinities were computed for ethanol, 2-fluoroethanol, 2,2-difluoroethanol and 2,2,2-

trifluoroethanol and compared to experimental values from literature.[23-25] For each acceptor and the corresponding alkoxide the enthalpy of the lowest energy conformer was computed at DLPNO-CCSD(T)/CBS(3/4,def2)[26-29] //DLPNO-MP2/def2-TZVP[26-28, 30, 31] at T=298.15K using ORCA5.0.1.[32] This general purpose method[33] has recently been shown to provide energies similar to the 'golden standard', canonical CCSD(T) calculations, for carbohydrate conformations.[34] First the ΔH_{PA} of the fluorinated ethanol derivates were computed at both DLPNO-CCSD(T) and canonical CCSD(T) level, and compared to the experimental value to gauge the accuracy of the method. The DLPNO-CCSD(T) computations provided excellent agreement with both computed canonical CCDT(T) calculations and experimental values (***Table 7***).

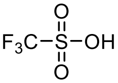
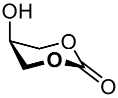
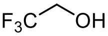
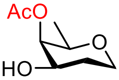
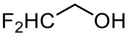
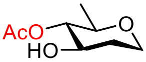
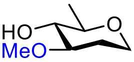
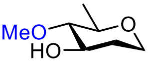
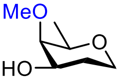
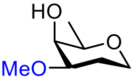
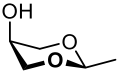
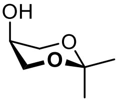
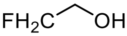
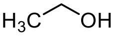
Table 7: *calculated proton affinities of ethanol acceptors compared to their experimental values from literature*

Acceptor	Calculated ΔH_{PA} DLNPO-CCDS(T) (Kcal/mol)	Calculated ΔH_{PA} CCDS(T) (Kcal/mol)	experimental ΔH_{PA} (Kcal/mol)
Ethanol	379.1	379.4	379.1 ± 1.0[23]
MFE	372.1	372.5	370.9 ± 2.9[24]
DFE	366.6	367.0	366.2 ± 2.2[25]
TFE	361.4	361.7	361.4 ± 2.4[25]

Next the proton affinities for the other acceptors were calculated. In these computations, the relatively large benzyl, benzoyl and benzylidene protecting groups were replaced for smaller but electronically similar methyl, acetyl and ethylidene groups. For ease of comparison, the proton affinities are shown as the relative proton affinity to triflic acid ($\Delta\Delta H_{PA}$), which can be defined by ***equation 2.*** The results of these calculations are depicted in ***Table 8*** and listed in order of increasing relative proton affinity.

$$\Delta\Delta H_{PA}\,(ROH) = \Delta H_{PA}\,(ROH) - \Delta H_{PA}\,(TfOH)\ (2)$$

Table 8: *Proton affinity vs stereoselectivity for the studied model acceptors.*

Acceptor	structure	$\Delta\Delta H_{PA}$ (Kcal/mol)	Percentage β Donor A	Percentage β Donor B
TfOH	 $F_3C-S(=O)_2-OH$	0	0[b]	0[b]
60		58.3	0	0
TFE		64.4	0	0
61		68.0	14[a]	26[a]
62		68.7	11[a]	40 [a]
DFE		69.4	17	26
63		69.5	17[a]	42[a]
64		69.6	62[a]	94[a]
65		70.5	62[a]	93[a]
66		70.9	20[a]	58[a]
67		71.4	8[a]	42[a]
68		76.0	38[a]	75[a]
59		76.2	50	91
MFE		74.9	74	87
EtOH		81.9	91	100

[a]Stereoselectivity based on experimental data from benzyl, benzoyl or benzylidene protected analogues, see above. [b]Determined by NMR at – 40 °C

The correlation between proton-affinity and reactivity of the acceptor (as measured by the percentage of β-product in a glycosylation reaction with **Donor A** or **Donor B**) is plotted in ***Figure 5A-C***. When the proton affinity of all acceptors is plotted agains the β-selectivity of the acceptors, a coefficient of determination (R^2) of 0.57 was obtained for the reactions with both **Donor A** and **Donor B** (***Figure 5A***). When only the data was used obtained for the simpler non-chiral alcohols (*i.e.* **59**, **60**, **61**, **68**, EtOH, MFE, DFE and TFE) the value for R^2 was much higher (0.85 for **Donor A** and 0.92 for **Donor B**), indicating a good correlation between the calculated proton affinity and the reactivity of the acceptor (***Figure 5B***). There is no correlation between the proton affinity of the chiral 'stripped carbohydrate' acceptors and the stereoselectivity of the reactions ($R^2 < 0.01$, ***Figure 5C***), showing that reactivity of these acceptors in the glycosylations with donors **A** and **B** is not solely determined by the electron density of the alcohol, as determined by the ΔH_{PA}, but rather by the more complex interplay of both steric and electronic factors. Although the computations listed in ***Table 8*** show that the method used to compute the proton affinity can accurately reconstitute this parameter for simple alcohols in the gas phase, it is not surprising that there is poorer correlation with the reactivity of the more complex alcohols in solution.

Another recent study has attempted to describe acceptor reactivity with a parameter (Aka) relating to the reaction rate of acceptors with 3,4-dihydropyran (DHP) under acidic conditions.[22] The authors found relatively good correlations between this parameter, the reactivity of the donor and the outcome of the glycosylation reaction. So for future research it would be interesting to measure the Aka of this set of acceptors and investigate if the same trends can be found as described in this work.

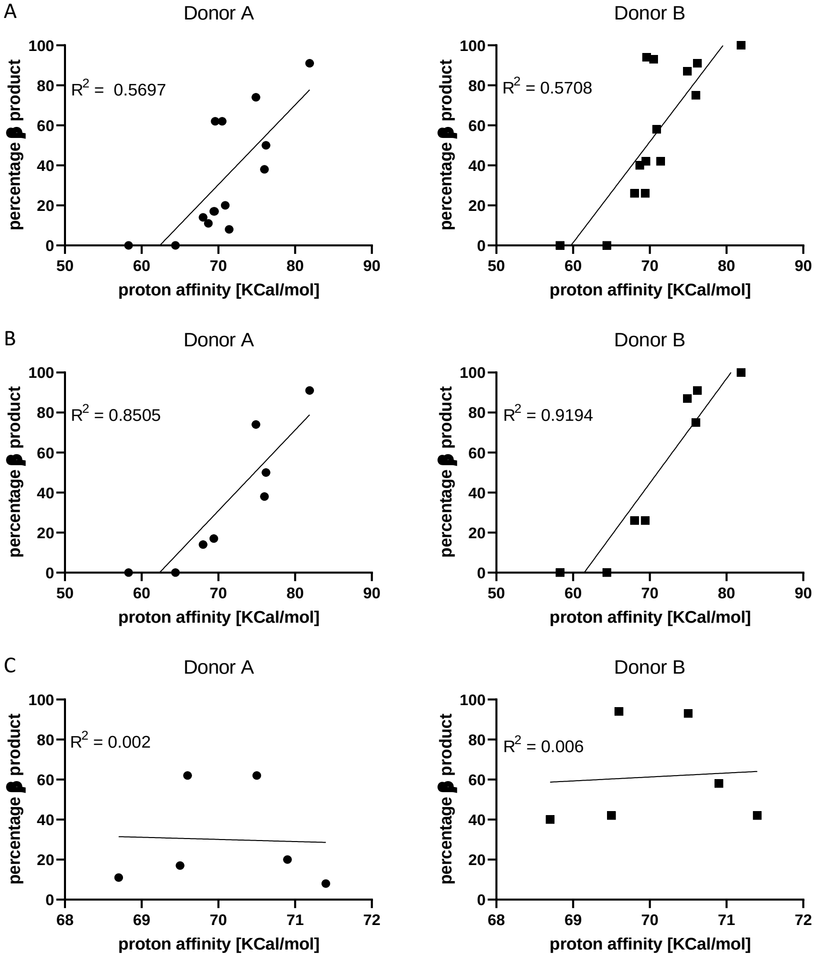


Figure 5: *Calculated proton affinity vs experimental stereoselectivity with* R^2 *displayed for A: all acceptors for which proton affinity was calculated; B: for the set of non-chiral acceptors and C: 'stripped carbohydrate-like' acceptors. Acceptor* ***60*** *was excluded for the calculation of* R^2 *because of non-linearity of the graph in that area, since the amount of β-product can not be lower than 0%, and acceptors with a higher proton affinity already show full α-selectivity. Experimental values of β-selectivity are based on benzyl, benzoyl and benzylidene protected acceptors, the calculated proton affinity is based on methyl, acetyl and ethylidene protected analogues.*

Conclusions

In conclusion, structure-reactivity relationships for a large set of glycosyl acceptors have been established, based on the stereoselectivity of these acceptors in glycosylations with two conformationally restricted glucosyl donors. The reactivity-stereoselectivity correlation is based on the premise that reactive acceptors predominantly provide the β-product via an S_N2 like mechanism in which a covalent anomeric α-triflate is displaced, while less reactive acceptors give more α-product via a glycosylation proceeding with more S_N1 like character. In total, 60 acceptors were tested, and this systematic series of nucleophiles has revealed several factors that influence the reactivity of the acceptor. With regards to configuration, equatorial acceptors are more reactive than axial alcohols. Also, the configuration of the protected alcohols next to the OH-group are important, and acceptors in which the neighboring protected alcohols take up an equatorial position, are more reactive than acceptors in which one of the flanking protected alcohols is axial. The protecting group pattern also plays an important role, since switching benzyl ethers to sterically similar benzoyl esters decreases the reactivity of the acceptor. However, it is important to note that the configuration of the ester is also important, and substituting an axial ether for an ester has significantly less effect on the reactivity of the acceptor than substituting an equatorial ether for an ester. To better understand the stereoelectronic effects of exerted by the different configuration and protecting group patterns, a set of model acceptors was introduced to serve as a benchmark for computational studies. Proton affinities were calculated in an attempt to explain differences in reactivity, and for simple non-chiral alcohol nucleophiles relatively good correlation was found between calculated proton affinity and reactivity. For the more complex, chiral carbohydrate-like acceptors, the differences in proton affinity proved to be relatively small, and these could not fully account for the experimentally observed differences in reactivity. Overall, this has shown that proton affinity is important for the reactivity of acceptors, but other factors may also contribute and future research efforts will focus on the investigation of steric and hydrogen bonding effects.

Experimental

Calculation of proton affinities

Spartan'14[35] was used to construct a conformer library of the neutral acceptor by a Monte-Carlo search. Each conformation was optimzed and evaluated using the MMFF[36] force field, and the 100 lowest energy structures were included in the conformer library. The conformer library of the corresponding anion was constructed by converting all hydroxyl conformers in the neutral conformer library to the corresponding alkoxide conformer. All conformers in both libraries were optimized using ORCA5.0.1[32] by DFT at B3LYP-D3(BJ)/def2-TZVP(-f)[26, 37-40] level of theory, utilizing the TighSCF and Defgrid2 keywords. All conformers with a $\Delta E < 1$ kcal mol^{-1} were re-optimized by WFT at DLPNO-MP2/def2-TZVP[26-28, 30, 31] level of theory. Final single point energies of all re-optimized structures were computed by WFT at DLPNO-CCSD(T)/CBS(3/4,def2)[26-31] level of theory, utilizing the TightSCF, Defgrid2 and NormalPNO keywords. This method has been shown to provide energies similar to canonical CCSD(T) for diverse systems,[34] aswell as for carbohydrate conformations specifically.[33] The final enthalpy of each conformer was constructed as DLPNO-MP2/def2-TZVP//DLPNO-CCSD(T)/CBS(3/4,def2) at T=298.15K. ΔH_{PA} was derived by equation 1.

$$\Delta H_{PA} = H_{alkoxide} - H_{alcohol} \ (1)$$

The ΔH_{PA} was expressed as $\Delta\Delta H_{PA}$, relative to the lowest computed ΔH_{PA} in this study; triflic acid.

General experimental procedures

All chemicals were of commercial grade and used as received unless stated otherwise. Dichloromethane (DCM) was stored over activated 4 Å molecular sieves for at least 24 h before use. Trifluoromethanesulfonic anhydride (Tf_2O) was distilled over P_2O_5 and stored at -20°C under a nitrogen atmosphere. Overnight temperature control was achieved by a FT902 Immersion Cooler (Julabo). Flash column chromatography was performed on silica gel 60 Å (0.04 – 0.063 mm, Screening Devices B.V.). Size-exclusion chromatography was performed on Sephadex (LH-20, GE Healthcare Life Sciences) by isocratic elution with DCM/MeOH (1/1, v/v). Thin-layer chromatography (TLC) analysis was conducted on TLC silica gel 60 plates (Kieselgel 60 F254, Merck) with UV detection by (254 nm) and by spraying with 20% sulfuric acid in ethanol or by spraying with a solution of $(NH_4)_6Mo_7O_{24}\cdot H_2O$ (25 g/L) and $(NH_4)_4Ce(SO4)_4\cdot 2H_2O$ (10 g/L) in 10% aq. sulfuric acid followed by charring at ±250 °C. High-resolution mass spectrometry (HRMS) was performed on a Thermo Finnigan LTQ Orbitrap mass spectrometer equipped with an electrospray ion source in positive-ion mode (source voltage 3.5 kV, sheath gas flow 10, capillary temperature 275 °C) with resolution R = 60.000 at *m/z* 400 (mass range of 150-4000) and dioctylphtalate (m/z=391.28428) as lock mass, or on a Waters Synapt G2-Si (TOF) equipped with an electrospray ion source in positive mode (source voltage 3.5 kV) and LeuEnk (m/z = 556.2771). as internal lock mass. 1H and 13C NMR spectra were recorded on Bruker AV-400, Bruker DMX-400, and Bruker AV-500 NMR instruments. Chemical shifts (δ) are given in parts per million (ppm) relative to tetramethylsilane as an internal standard or the residual signal of the deuterated solvent. Coupling constants (*J*) are given in Hertz (Hz). All presented 13C-APT spectra are proton-decoupled. NMR peak assignments were made using COSY and HSQC. When necessary, additional NOESY, HMBC and HMBC-GATED experiments were used to further elucidate the structure. The anomeric product ratios were based on careful analysis of the crude reaction mixture and the purified reaction product by integration of representative 1H NMR signals. IR spectra were recorded on a Shimadzu FTIR-8300 IR spectrometer and are reported in cm-1. Specific rotations were measured on a Propol automatic polarimeter or an Anton-Paar MCP-100 modular circular polarimeter at 589 nm unless otherwise stated.

Acceptor **58** was purchased from Sigma Aldrich and used without further purification. Acceptors **26**,[41] **44**,[42] **57**,[43] **59**[43] and **60**[44] and donors **A**[12] and **B**[8] were synthesized according to literature procedures

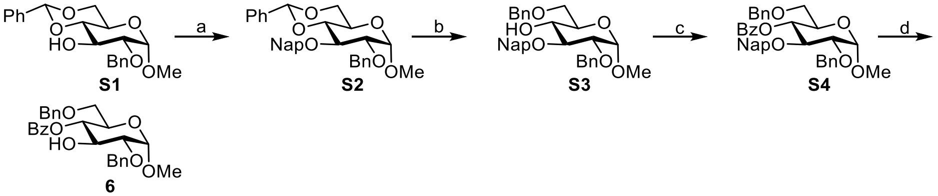
General procedure for Ph_2SO/Tf_2O meditated glycosylations

Donor (0.1 mmol, 1 eq), Ph_2SO (0.13 mmol, 1.3 eq) and TTBP (0.25 mmol, 2.5 eq) were coevaporated twice with toluene, dissolved in 2 mL DCM and stirred for 30 min at RT with 3A molecular sieves. The solution was cooled to -80 ^{0}C and Tf_2O (22 µL, 0.13 mmol, 2 eq) was added. The reaction mixture was allowed to warm to −60 ^{0}C and then recooled to −78 ^{0}C, after which the acceptor (0.2 mmol, 2 eq) in DCM (0.4 mL, 0.5 M) was added. The reaction mixture was allowed to warm to −40 ^{0}C for and stirred between 1-24 hr at that temperature. The reaction was quenched with 2 mL sat aq $NaHCO_3$ or 0.3 mL 1M Et_3N in DCM, and the mixture was diluted with DCM. The solution was transferred to a separatory funnel, water was added, the layers were separated, and the water phase was extracted once more with DCM. The combined organic layers were dried over MgSO4, filtered, and concentrated in vacuo. Purification by silica gel flash column chromatography and/or sephadex LH-20 size-exclusion chromatography yielded the glycosylation product as a mixture of anomers.

Preparations of acceptors

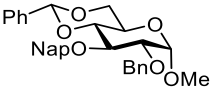
Glucose acceptors

Preparation of acceptor **6**



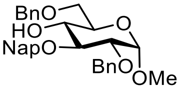
***Scheme S1**: preparation of acceptor (**6**): reagents and conditions: a) NapBr, NaH, DMF 100%; b) TES-H, TFA, DCM, 0^{0}C 84% c) BzCl, pyridine, 76% d) DDQ, DCM/H_2O (9:1), 90%*

Methyl 2-*O*-benzyl-4,6-*O*-benzylidene-3-*O*-(2-naphthyl)methyl-α-D-glucopyranoside (S2)



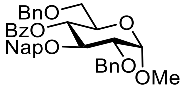
methyl 2-*O*-benzyl-4,6-*O*-benzylidene-3-*O*-(2-naphthyl)methyl-α-D-glucopyranoside[45] (**S1**, 1.50 g, 4.03 mmol) was dissolved in DMF and cooled to 0 °C. NaH (60% dispersion in mineral oil, 241 mg, 6.04 mmol, 1.5 eq) was added and after 15 minutes 2-(Bromomethyl)naphthalene (1.11 g, 5.03 mmol, 1.25 eq) was added. The reaction mixture was allowed to warm to room temperature. When TLC showed full conversion, the reaction mixture was quenched with 0.1 M HCl, diluted with EtOAc and washed with sat. aq. $NaHCO_3$ and brine. The organic phase is dried with $MgSO_4$ and concentrated under reduced pressure. The residue is purified over silica (10%→40% EtOAc in pentane) yielding the product as a white wax in quantitative yield. ^1H NMR (400 MHz, $CDCl_3$) δ 7.84 – 7.74 (m, 3H, CH_{arom}), 7.72 – 7.66 (m, 1H, CH_{arom}), 7.53 – 7.46 (m, 3H, CH_{arom}), 7.46 – 7.42 (m, 2H, CH_{arom}), 7.39 – 7.27 (m, 8H, CH_{arom}), 5.57 (s, 1H, C*H*Ph), 5.07 (d, *J* = 11.7 Hz, 1H, C*H*H Bn/Nap), 5.00 (d, *J* = 11.6 Hz, 1H, CH*H* Bn/Nap), 4.87 (d, *J* = 12.1 Hz, 1H, C*H*H Bn/Nap), 4.72 (d, *J* = 12.2 Hz, 1H, CH*H* Bn/Nap), 4.61 (d, *J* = 3.7 Hz, 1H, H-1), 4.27 (dd, *J* = 10.1, 4.7 Hz, 1H, H-6), 4.10 (t, *J* = 9.3 Hz, 1H, H-3), 3.84 (td, *J* = 9.9, 4.7 Hz, 1H, H-5), 3.71 (t, *J* = 10.2 Hz, 1H, H-6), 3.66 – 3.56 (m, 2H, H-2, H-4), 3.40 (s, 3H, CH_3 OMe); ^{13}C NMR (101 MHz, $CDCl_3$) δ 138.2, 137.5, 136.3, 133.4, 133.1 (C_q), 129.1, 128.6, 128.4, 128.2, 128.1, 128.1, 128.1, 127.7, 126.8, 126.3, 126.2, 126.0, 125.8 (CH_{arom}), 101.5 (CHPh), 99.3 (C-1), 82.2 (C-4), 79.4 (C-2), 78.7 (C-3), 75.5, 73.9 (CH_2 Bn/Nap), 69.2 (C-6), 62.5 (C-5), 55.5 (CH_3 OMe); HRMS: $[M+NH_4]^+$ calcd for $C_{32}H_{32}O_6NH_4$ 530.25371, found 530.25279.

Methyl 2,6-di-*O*-benzyl-3-*O*-(2-naphthyl)methyl-α-D-glucopyranoside (S3)



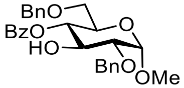
methyl 2-*O*-benzyl-4,6-*O*-benzylidene-3-*O*-(2-naphthyl)methyl-α-D-glucopyranoside (**S2**, 1.48 g, 2.89 mmol) and TES-H (2.15 mL, 28.9 mmol, 10 eq) were dissolved in DCM and cooled to 0 °C. After 15 min of stirring TFA (4.60 mL 28.9 mmol, 10 eq) was added dropwise. When TLC showed full conversion, the reaction was quenched with sat. aq. $NaHCO_3$. The organic phase was dried with Na_2SO_4 and concentrated under reduced pressure. The residue was purified over silica (25% EtOAc in pentane) to obtain the title compound as colourless oil Yield: 1.25 g, 2.43 mmol, 84%. ^1H NMR (400 MHz, $CDCl_3$) δ 7.86 – 7.79 (m, 4H, CH_{arom}), 7.48 (ddd, *J* = 9.3, 6.1, 1.6 Hz, 3H, CH_{arom}), 7.39 – 7.25 (m, 10H, CH_{arom}), 5.15 (d, *J* = 11.7 Hz, 1H, C*H*H Bn/Nap), 4.91 (d, *J* = 11.7 Hz, 1H, CH*H* Bn/Nap), 4.78 (d, *J* = 12.1 Hz, 1H, C*H*H Bn/Nap), 4.68 (d, *J* = 12.1 Hz, 1H, CH*H* Bn/Nap), 4.65 (d, *J* = 3.6 Hz, 1H, H-1), 4.59 (d, *J* = 12.2 Hz, 1H, C*H*H Bn/Nap), 4.53 (d, *J* = 12.2 Hz, 1H, CH*H* Bn/Nap), 3.84 (dd, *J* = 9.6, 8.5 Hz, 1H, H-3), 3.73 – 3.62 (m, 4H, H-4, H-5, H-6, H-6), 3.57 (dd, *J* = 9.5, 3.6 Hz, 1H, H-2), 3.39 (s, 3H, CH_3 OMe), 2.37 (d, *J* = 2.3 Hz, 1H, OH); ^{13}C NMR (101 MHz, $CDCl_3$) δ 138.2, 138.1, 136.3, 133.5, 133.1 (C_q), 128.6, 128.5, 128.5, 128.3, 128.1, 127.8, 127.8, 127.8, 126.9, 126.3, 126.1, 126.0 (CH_{arom}), 98.3 (C-1), 81.5 (C-3), 79.7 (C-2), 75.6, 73.7, 73.3 (CH_2 Bn/Nap), 70.9, 70.0 (C-4, C-5), 69.6 (C-6), 55.4 (CH_3 OMe); HRMS: $[M+NH_4]^+$ calcd for $C_{32}H_{34}O_6NH_4$ 532.26936, found 532.26839.

Methyl 4-*O*-benzoyl-2,6-di-*O*-benzyl-3-*O*-(2-naphthyl)methyl-α-D-glucopyranoside (S4)



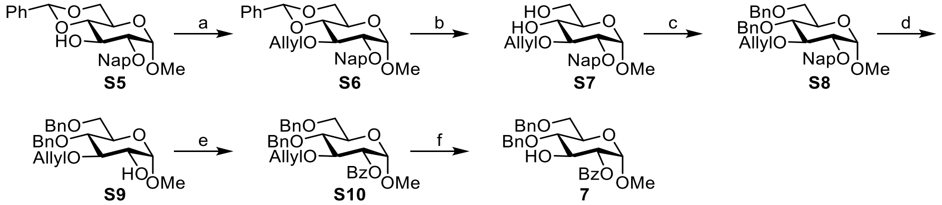
Methyl 2,6-di-*O*-benzyl-3-*O*-(2-naphthyl)methyl-α-D-glucopyranoside (**S3**, 1.20 g, 2.33 mmol) was dissolved in 5 mL pyridine, after which benzoyl chloride (0.406 mL, 3.50 mmol, 1.5 eq) was added. When TLC indicated full conversion, the reaction mixture was diluted with diethyl ether, washed with 1M aq. HCl, sat. aq. NaHCO$_3$ and brine. The organic phase was dried with sodium sulfate and concentrated under reduced pressure. The residue was purified with silica chromatography (15% EtOAc in pentane) to yield the title compound as colourless oil. Yield: 1.10 g, 1.78 mmol, 76%. ^{1}H NMR (400 MHz, CDCl$_3$) δ 7.88 – 7.81 (m, 2H, CH$_{arom}$), 7.66 – 7.62 (m, 1H, CH$_{arom}$), 7.60 – 7.57 (m, 2H, CH$_{arom}$), 7.50 (ddt, *J* = 8.7, 7.3, 1.3 Hz, 1H, CH$_{arom}$), 7.45 (d, *J* = 8.4 Hz, 1H, CH$_{arom}$), 7.41 – 7.28 (m, 9H, CH$_{arom}$), 7.24 – 7.12 (m, 6H, CH$_{arom}$), 5.33 (dd, *J* = 10.3, 9.2 Hz, 1H, H-4), 4.99 (d, *J* = 11.6 Hz, 1H, C*H*H Bn/Nap), 4.85 (d, *J* = 12.1 Hz, 1H, C*H*H Bn/Nap), 4.79 (d, *J* = 11.7 Hz, 1H, CH*H* Bn/Nap), 4.71 (d, *J* = 12.1 Hz, 1H, CH*H* Bn/Nap), 4.68 (d, *J* = 3.6 Hz, 1H, H-1), 4.46 (s, 2H, CH$_2$ Bn/Nap), 4.11 (t, *J* = 9.4 Hz, 1H, H-3), 3.96 (ddd, *J* = 10.2, 5.1, 2.7 Hz, 1H, H-5), 3.71 (dd, *J* = 9.6, 3.6 Hz, 1H, H-2), 3.55 (dd, *J* = 10.8, 2.7 Hz, 1H, H-6), 3.49 (dd, *J* = 10.8, 5.1 Hz, 1H, H-6), 3.44 (s, 3H, CH$_3$ OMe); ^{13}C NMR (101 MHz, CDCl$_3$) δ 165.4 (C=O), 138.1, 137.9, 135.8, 133.2 (C$_q$, 133.2 (CH$_{arom}$), 132.9, 129.8(C$_q$), 129.8, 128.6, 128.4, 128.3, 128.3, 128.1, 128.1, 128.0, 127.8, 127.7, 127.6, 126.9, 126.3, 125.9, 125.7 (CH$_{arom}$), 98.4 (C-1), 79.8 (C-2), 79.1 (C-3), 75.5 (CH$_2$ Bn/Nap), 73.7 (2xCH$_2$ Bn/Nap), 71.0 (C-4), 69.1 (C-6), 69.1 (C-5), 55.6 (CH$_3$ OMe); HRMS: [M+NH$_4$]$^+$ calcd for C$_{39}$H$_{38}$O$_7$NH$_4$ 636.29558, found 636.29453.

Methyl 4-*O*-benzoyl-2,6-di-*O*-benzyl-α-D-glucopyranoside (6)



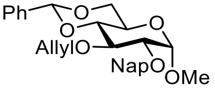
Methyl 4-*O*-benzoyl-2,6-di-*O*-benzyl-3-*O*-(2-naphthyl)methyl-α-D-glucopyranoside (**S4**, 1.05 g, 1.70 mmol) was dissolved in 20 mL 19:1 DCM/water, after which DDQ (770 mg, 3.39 mmol, 2 eq) was added. When TLC indicated full conversion, the organic phase was diluted with DCM, washed twice with sat. aq. NaHCO$_3$, dried with sodium sulfate and concentrated under reduced pressure. The residue was purified with silica chromatography (15%→25% EtOAc in pentane) to yield the title compound as a colourless oil. Yield: 731 mg, 1,53 mmol, 90%. $[\alpha]_D^{25}$ = 55.6° (c = 0.73, CHCl$_3$); IR (thin film): 698, 713, 1027, 1043, 1097, 1269, 1452, 1724; ^{1}H NMR (400 MHz, CDCl$_3$) δ 8.03 – 7.96 (m, 2H, CH$_{arom}$), 7.59 – 7.53 (m, 1H, CH$_{arom}$), 7.45 – 7.28 (m, 7H, CH$_{arom}$), 7.24 – 7.10 (m, 5H, CH$_{arom}$), 5.24 (dd, *J* = 10.2, 9.3 Hz, 1H, H-4), 4.77 (d, *J* = 12.2 Hz, 1H, C*H*H Bn), 4.70 (d, *J* = 12.2 Hz, 1H, CH*H* Bn), 4.67 (d, *J* = 3.5 Hz, 1H, H-1), 4.52 (d, *J* = 12.1 Hz, 1H, C*H*H Bn), 4.45 (d, *J* = 12.1 Hz, 1H, CH*H* Bn), 4.17 (td, *J* = 9.4, 2.8 Hz, 1H, H-3), 3.99 (ddd, *J* = 10.2, 4.6, 2.7 Hz, 1H, H-5), 3.61 – 3.50 (m, 3H, H-2, H-6, H-6), 3.40 (s, 3H, CH$_3$ OMe), 2.59 (d, *J* = 3.2 Hz, 1H, OH); ^{13}C NMR (101 MHz, CDCl$_3$) δ 166.2 (C=O), 138.0, 137.7 (C$_q$), 133.4, 130.0 (CH$_{arom}$), 129.7 (C$_q$), 128.7, 128.5, 128.3, 128.3, 128.2, 127.8, 127.6 (CH$_{arom}$), 97.9 (C-1), 79.5 (C-2), 73.7 , 73.5 (CH$_2$ Bn), 71.7, 71.7 (C-3, C-4), 68.7 (C-6), 68.6 (C-5), 55.6 (CH$_3$ OMe); HRMS: [M+Na]$^+$ calcd for C$_{28}$H$_{30}$O$_7$Na 501.18837, found 501.18733.

Preparation of acceptor 7



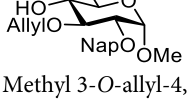
***Scheme S2**: preparation of acceptor 7: reagents and conditions: a) AllylBr, NaH, DMF, 94%; b) pTsOH•H_2O, MeOH, 50 °C, quant.; c) BnBr, NaH, DMF, 95%; d) DDQ, DCM/H2O (9:1), 80%; e) BzCl, pyridine, 87%; f) $Pd(PPh_3)_4$, DMBA, MeOH, 40 °C, 90%.*

Methyl 3-*O*-allyl-4,6-*O*-benzylidene-2-*O*-(2-naphtyl)methyl-α-D-glucopyranoside (S6)



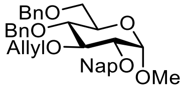
Methyl 4,6-*O*-benzylidene-2-*O*-(2-naphtyl)methyl-α-D-glucopyranoside[46] (**S5**, 9.3 g, 22.0 mmol, 1 eq) was dissolved in 75 ml DMF and stirred at 0 °C until the sugar was fully dissolved. To the solution was added NaH (60 % dispersion in mineral oil, 0.48 g, 33 mmol, 1.5 eq) and the mixture was stirred for another 15 min before slowly adding AllylBr (2.9 ml, 33 mmol, 1.5 eq) and the reaction was stirred at RT until TLC indicated full conversion. The reaction mixture was quenched with H_2O and extracted with Et_2O. The organic layer was washed twice with H_2O. The organic layer was dried over $MgSO_4$, filtered and concentrated under reduced pressure. Purification was performed on flash column chromatography (10% EtOAc in pentane) to provide the title compound as an oil. Yield: 9.58 g, 20.7 mmol, 94%. ^1H NMR (400 MHz, $CDCl_3$) δ 7.89 – 7.77 (m, 4H, CH_{arom}), 7.60 – 7.46 (m, 5H, CH_{arom}), 7.41 – 7.31 (m, 3H, CH_{arom}), 6.01 (ddt, *J* = 17.2, 10.4, 5.7 Hz, 1H, CH_2-C*H*=CH_2), 5.52 (s, 1H, C*H*Ph), 5.34 (dq, *J* = 17.2, 1.7 Hz, 1H, CH_2-CH=C*H*H), 5.19 (dq, *J* = 10.4, 1.3 Hz, 1H, CH_2-CH=CH*H*), 5.02 (d, *J* = 12.0 Hz, 1H, C*H*H Nap), 4.87 (d, *J* = 12.4 Hz, 1H, CH*H* Nap), 4.57 (d, *J* = 3.7 Hz, 1H, H-1), 4.43 (ddt, *J* = 12.7, 5.8, 1.4 Hz, 1H, C*H*H-CH=CH_2), 4.34 (ddt, *J* = 12.6, 5.7, 1.4 Hz, 1H, CH*H*-CH=CH_2), 4.24 (dd, *J* = 10.1, 4.8 Hz, 1H, H-6), 3.96 (t, *J* = 9.2 Hz, 1H, H-3), 3.80 (td, *J* = 9.9, 4.7 Hz, 1H, H-5), 3.67 (t, *J* = 10.3 Hz, 1H, H-6), 3.57 – 3.50 (m, 2H, H-2, H-4), 3.40 (s, 3H, CH_3 OMe); ^{13}C NMR (101 MHz, $CDCl_3$) δ 137.5, 135.8 (C_q), 135.4 (CH_2-*C*H=CH_2), 133.3, 133.2 (C_q), 129.0, 128.4, 128.4, 128.1, 127.9, 127.2, 126.3, 126.2 (CH_{arom}), 117.0 (CH_2-CH=*C*H_2), 101.4 (CHPh), 99.4 (C-1), 82.2 (C-4), 78.9 (C-2), 78.2 (C-3), 74.2 (*C*H_2-CH=CH_2), 74.1(CH_2 Nap), 69.2 (C-6), 62.4 (C-5), 55.5 (CH_3 OMe); HRMS: $[M+Na]^+$ calcd for $C_{28}H_{30}O_6Na$ 485.19346, found 485.19269.

Methyl 3-*O*-allyl-2-*O*-(2-naphtyl)methyl-α-D-glucopyranoside (S7)



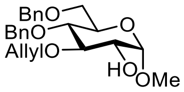
Methyl 3-*O*-allyl-4,6-*O*-benzylidene-2-*O*-(2-naphtyl)methyl-α-D-glucopyranoside (**S6**, 9.57 g, 20.7 mmol, 1 eq) was dissolved in 100 ml MeOH and stirred at RT for 15 min. To the solution was added pTsOH·H_2O (0.39 g, 2.07 mmol, 0.1 eq) and the mixture was stirred for 1 h at 50 °C after which TLC indicated full conversion. The reaction mixture was set to cool down to RT and was quenched with TEA (2.3 ml, 6.18 mmol, 0.25 eq). Solvents were evaporated under reduced pressure and purification was performed on flash column chromatography (3/2 pentane/EtOAc) to provide the title compound as a solid. Yield: 7.8 g, 20.7 mmol, quant. ^{1}H NMR (400 MHz, CDCl$_3$) δ 7.86 – 7.76 (m, 4H, CH$_{arom}$), 7.53 – 7.43 (m, 3H, CH$_{arom}$), 5.99 (ddt, *J* = 17.3, 10.4, 5.8 Hz, 1H, CH$_2$-C*H*=CH$_2$), 5.31 (dq, *J* = 17.2, 1.6 Hz, 1H, CH$_2$-CH=C*H*H), 5.19 (dq, *J* = 10.4, 1.4 Hz, 1H, CH$_2$-CH=CH*H*), 4.89 (d, *J* = 12.3 Hz, 1H, C*H*H Nap), 4.78 (d, *J* = 12.3 Hz, 1H, CH*H* Nap), 4.57 (d, *J* = 3.5 Hz, 1H, H-1), 4.50 (ddt, *J* = 12.6, 5.5, 1.5 Hz, 1H, C*H*H-CH=CH$_2$), 4.28 (ddt, *J* = 12.6, 5.9, 1.3 Hz, 1H, CH*H*-CH=CH$_2$), 3.80 – 3.75 (m, 2H, H-6, H-6), 3.71 (dd, *J* = 9.5, 8.7 Hz, 1H, H-3), 3.60 (dt, *J* = 9.8, 3.7 Hz, 1H, H-5), 3.52 (ddd, *J* = 9.9, 8.7, 3.0 Hz, 1H, H-4), 3.47 (dd, *J* = 9.5, 3.5 Hz, 1H, H-2), 3.35 (s, 3H, CH$_3$ OMe), 3.07 (d, *J* = 3.2 Hz, 1H, 4-OH), 2.36 (t, *J* = 6.2 Hz, 1H, 6-OH); ^{13}C NMR (101 MHz, CDCl$_3$) δ 135.5 (C$_q$), 135.2 (CH$_2$-CH=CH$_2$), 133.2, 133.1 (C$_q$), 128.3, 127.9, 127.7, 126.9, 126.3, 126.1, 125.9 (CH$_{arom}$), 117.2 (CH$_2$-CH=*C*H$_2$), 98.3 (C-1), 81.0 (C-3), 79.6 (C-2), 74.3 (*C*H$_2$-CH=CH$_2$), 73.3 (CH$_2$ Nap), 70.8 (C-5), 70.2 (C-4), 62.2 (C-6), 55.3 (CH$_3$ OMe); HRMS: [M+NH$_4$]$^+$ calcd for C$_{21}$H$_{26}$O$_6$NH$_4$ 392.20676, found 392.20584.

Methyl 3-*O*-allyl-4,6-di-*O*-benzyl-2-*O*-(2-naphtyl)methyl-α-D-glucopyranoside (S8)



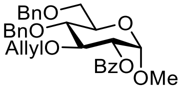
Methyl 3-*O*-allyl-2-*O*-(2-naphtyl)methyl-α-D-glucopyranoside (**S7**, 7.7 g, 20.56 mmol, 1 eq) was dissolved in 75 ml DMF and stirred at 0 °C until the sugar was fully dissolved. To the solution was added NaH (60% dispersion in mineral oil, 2.47 g, 61.69 mmol, 3 eq) and the reaction was stirred for 30 min at 0 °C after which BnBr (7.33 ml, 61.69 mmol, 3 eq) was slowly added. After 30 min the temperature was increased to RT. Once TLC indicated full conversion the reaction mixture was quenched with water and extracted twice with Et$_2$O. The combined organic layers were dried over MgSO$_4$, filtered and concentrated under reduced pressure. Purification was performed on flash column chromatography (9/1 pentane/EtOAc) to provide the title compound as an oil. Yield: 10.85 g, 19.55 mmol, 95%. ^{1}H NMR (400 MHz, CDCl$_3$) δ 7.85 – 7.78 (m, 4H, CH$_{arom}$), 7.55 – 7.42 (m, 3H, CH$_{arom}$), 7.35 – 7.23 (m, 8H, CH$_{arom}$), 7.21 – 7.15 (m, 2H, CH$_{arom}$), 6.03 (ddt, *J* = 17.3, 10.4, 5.6 Hz, 1H, CH$_2$-C*H*=CH$_2$), 5.33 (dq, *J* = 17.2, 1.7 Hz, 1H, CH$_2$-CH=C*H*H), 5.18 (dq, *J* = 10.4, 1.3 Hz, 1H, CH$_2$-CH=C*H*H), 4.94 (d, *J* = 12.3 Hz, 1H, C*H*H Bn), 4.84 (d, *J* = 8.2 Hz, 1H, C*H*H Nap), 4.81 (d, *J* = 9.9 Hz, 1H, CH*H* Bn), 4.62 – 4.56 (m, 2H, H-1, C*H*H Bn), 4.53 – 4.42 (m, 3H, CH*H* Bn, CH*H* Nap, C*H*H-CH=CH$_2$), 4.34 (ddt, *J* = 12.4, 5.7, 1.4 Hz, 1H, CH*H*-CH=CH$_2$), 3.86 (t, *J* = 9.3 Hz, 1H, H-3), 3.77 – 3.65 (m, 2H, H-5, H-6), 3.64 – 3.52 (m, 3H, H-2, H-4, H-6), 3.35 (s, 3H, CH$_3$ OMe); ^{13}C NMR (101 MHz, CDCl$_3$) δ 138.4, 138.0, 135.8 (C$_q$), 135.4 (CH$_2$-CH=CH$_2$), 133.3, 133.2 (C$_q$), 128.4, 128.4, 128.3, 128.1, 128.0, 127.8, 127.8, 127.1, 126.2, 126.1, 126.1 (CH$_{arom}$), 116.7 (CH$_2$-CH=*C*H$_2$), 98.3 (C-1), 81.8 (C-3), 79.6 (C-2), 77.7 (C-4), 75.2 (CH$_2$ Nap), 74.5 (*C*H$_2$-CH=CH$_2$), 73.6, 73.6 (CH$_2$ Bn), 70.1 (C-5), 68.5 (C-6), 55.2 (CH$_3$ OMe); HRMS: [M+NH$_4$]$^+$ calcd for C$_{35}$H$_{38}$O$_6$NH$_4$ 572.30066, found 572.29941.

Methyl 3-*O*-allyl-4,6-di-*O*-benzyl-α-D-glucopyranoside (S9)



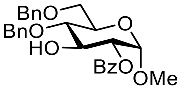
Methyl 3-*O*-allyl-4,6-di-*O*-benzyl-2-*O*-(2-naphtyl)methyl-α-D-glucopyranoside (**S8**, 2.77 g, 5.0 mmol, 1 eq) was dissolved in 40 ml 9/1 DCM/H_2O and stirred at RT until the sugar was fully dissolved. To the solution was added DDQ (2.27 g, 10.0 mmol, 2 eq) and the reaction was stirred for 60 min at RT after which TLC indicated full conversion. The reaction mixture was quenched with aq. Bicarb solution and extracted with DCM. The organic layer was washed twice with aq. Bicarb solution. The organic layer was dried over $MgSO_4$, filtered and concentrated under reduced pressure. Purification was performed on flash column chromatography (7/3 pentane/EtOAc) to provide the title compound as an oil. Yield: 1.67 g, 4.01 mmol, 80%. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.37 – 7.26 (m, 8H, CH$_{arom}$), 7.18 (dd, *J* = 7.6, 1.9 Hz, 2H, CH$_{arom}$), 5.98 (ddt, *J* = 17.3, 10.4, 5.7 Hz, 1H, CH$_2$-C*H*=CH$_2$), 5.30 (dq, *J* = 17.3, 1.7 Hz, 1H, CH$_2$-CH=C*H*H), 5.17 (dt, *J* = 10.3, 1.5 Hz, 1H, CH$_2$-CH=CH*H*), 4.83 – 4.78 (m, 2H, H-1, C*H*H Bn), 4.64 (d, *J* = 12.2 Hz, 1H, C*H*H Bn), 4.56 – 4.45 (m, 2H, 2x CH*H* Bn), 4.41 – 4.29 (m, 2H, C*H*$_2$-CH=CH$_2$,), 3.76 – 3.70 (m, 2H, H-5, H-6), 3.69 – 3.63 (m, 2H, H-2, H-6), 3.63 – 3.54 (m, 2H, H-3, H-4), 3.41 (s, 3H, CH$_3$ OMe), 2.14 (d, *J* = 7.7 Hz, 1H, OH); ^{13}C NMR (101 MHz, $CDCl_3$) δ 138.3, 138.0 (C$_q$), 135.3 (CH$_2$-*C*H=CH$_2$), 128.5, 128.0, 127.8, 127.8 (CH$_{arom}$), 117.1 (CH$_2$-CH=*C*H$_2$), 99.5 (C-1), 82.9 (C-3), 77.5 (C-4), 75.0 (CH$_2$ Bn), 74.3 (*C*H$_2$-CH=CH$_2$), 73.7 (CH$_2$ Bn), 72.8 (C-2), 70.2 (C-5), 68.6 (C-6), 55.3 (CH$_3$ OMe). Data is in agreement with literature.[47]

Methyl 3-*O*-allyl-2-*O*-benzoyl-4,6-di-*O*-benzyl-α-D-glucopyranoside (S10)



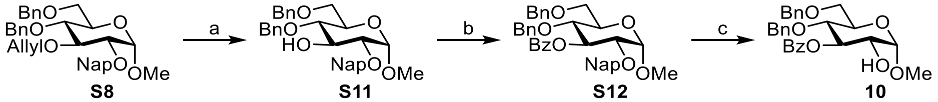
Methyl 3-*O*-allyl-4,6-di-*O*-benzyl-α-D-glucopyranoside (**S9**, 1.60 g, 3.86 mmol, 1 eq) was dissolved in 30 ml pyridine and stirred at 0 °C until the sugar was fully dissolved. To the solution was added BzCl (0.58 ml, 5.02 mmol, 1.3 eq) and the reaction was stirred for 30 min at 0 °C after which the temperature was increased to RT. Once TLC indicated full conversion the reaction mixture was diluted with DCM and washed twice with 1M HCl and with sat. aq. $NaHCO_3$. The organic layer was dried over $MgSO_4$, filtered and concentrated under reduced pressure. Purification was performed on flash column chromatography (9/1 pentane/EtOAc) to provide the title compound as a light-yellow oil. Yield: 1.74 g, 3.36 mmol, 87%. ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.15 – 8.07 (m, 2H, CH$_{arom}$), 7.63 – 7.53 (m, 1H, CH$_{arom}$), 7.46 (dd, *J* = 8.4, 7.1 Hz, 2H, CH$_{arom}$), 7.40 – 7.18 (m, 10H, CH$_{arom}$) , 5.84 (ddt, *J* = 17.2, 10.3, 5.7 Hz, 1H, CH$_2$-C*H*=CH$_2$), 5.18 (dq, *J* = 17.2, 1.6 Hz, 1H, CH$_2$-CH=C*H*H), 5.10 – 5.02 (m, 3H, H-1, H-2, CH$_2$-CH=CH*H*), 4.85 (d, *J* = 10.8 Hz, 1H, C*H*H Bn), 4.66 (d, *J* = 12.1 Hz, 1H, C*H*H Bn), 4.56 – 4.51 (m, 2H, 2x CH*H* Bn), 4.28 (dd, *J* = 5.8, 1.4 Hz, 2H, C*H*$_2$-CH=CH$_2$), 4.03 (t, *J* = 9.1 Hz, 1H, H-3), 3.85 – 3.79 (m, 1H, H-5), 3.79 – 3.68 (m, 3H, H-4, 2x H-6), 3.35 (s, 3H, CH$_3$ OMe); ^{13}C NMR (101 MHz, $CDCl_3$) δ 166.0 (C=O), 138.3, 138.1, 134.9 (C$_q$), 133.3 (CH$_2$-*C*H=CH$_2$), 129.9, 128.5, 128.5, 128.1, 128.0, 127.9, 127.8 (CH$_{arom}$), 117.0 (CH$_2$-CH=*C*H$_2$), 97.3 (C-1), 79.9 (C-3), 77.9 (C-4), 75.2 (CH$_2$ Bn), 74.4 (*C*H$_2$-CH=CH$_2$), 74.2 (C-2), 73.6 (CH$_2$ Bn), 70.3 (C-5), 68.5 (C-6), 55.3 (CH$_3$ OMe); HRMS: $[M+NH_4]^+$ calcd for $C_{31}H_{34}O_7NH_4$ 536.26428, found 536.26337.

Methyl 2-*O*-benzoyl-4,6-di-*O*-benzyl-α-D-glucopyranoside (7)



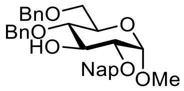
Methyl 2-*O*-benzoyl-3-*O*-allyl-4,6-di-*O*-benzyl-α-D-glucopyranoside (**S10**, 1.65 g, 3.18 mmol, 1 eq) and DMBA (1.00 g, 6.36 mmol, 2 eq) were dissolved in 20 ml MeOH and flushed for 30 min with N_2. To the solution was added $Pd(PPh_3)_4$ (0.18 g, 0.16 mmol, 0.05 eq) and the mixture was heated for 1h at 40 °C, after which TLC indicated full conversion. The mixture was diluted in EtOAc and washed with saturated Bicarb sol. The aqueous layer was extracted three times with EtOAc. The combined organic layers were dried over $MgSO_4$, filtered and concentrated under reduced pressure. Purification was performed on flash column chromatography (8/2 pentane/EtOAc) to provide the title compound as a yellow oil. Yield: 1.27 g, 2.66 mmol, 84%. ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.12 – 8.03 (m, 2H, CH_{arom}), 7.61 – 7.52 (m, 1H, CH_{arom}), 7.50 – 7.20 (m, 12H, CH_{arom}), 5.05 (d, *J* = 3.7 Hz, 1H, H-1), 4.98 (dd, *J* = 10.0, 3.7 Hz, 1H, H-2), 4.79 (d, *J* = 11.3 Hz, 1H, C*H*H Bn), 4.69 (d, *J* = 12.1 Hz, 1H, C*H*H Bn), 4.61 (d, *J* = 11.2 Hz, 1H, CH*H* Bn), 4.55 (d, *J* = 12.1 Hz, 1H, CH*H* Bn), 4.25 (ddd, *J* = 9.7, 8.5, 2.8 Hz, 1H, H-3), 3.87 – 3.76 (m, 2H, H-5, H-6), 3.77 – 3.69 (m, 1H, H-6), 3.68 (dd, *J* = 9.9, 8.8 Hz, 1H, H-4), 3.37 (s, 3H,CH_3 OMe), 2.30 (d, *J* = 3.5 Hz, 1H, OH); ^{13}C NMR (101 MHz, $CDCl_3$) δ 166.4 (C=O), 138.3, 138.0, 133.4 (C_q), 130.0, 129.7, 128.6, 128.5, 128.5, 128.0, 128.0, 128.0, 127.8 (CH_{arom}), 97.2 (C-1), 78.1 (C-4), 74.9 (CH_2 Bn), 74.1 (C-2), 73.7 (CH_2 Bn), 72.3 (C-3), 70.0 (C-5), 68.5 (C-6), 55.4 (CH_3 OMe). Data is in agreement with literature.[48]

Preparation of acceptor **10**



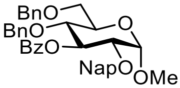
***Scheme S3**: preparation of acceptor **10**: reagents and conditions: a) $Pd(PPh_3)_4$, DMBA, MeOH, 40 °C, 83%; b) BzCl, pyridine, 86%; c) DDQ, DCM/H2O (9:1), 68%.*

Methyl 4,6-di-*O*-benzyl-2-*O*-(2-naphtyl)methyl-α-D-glucopyranoside (S11)



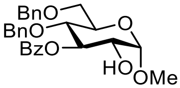
Methyl 3-*O*-allyl-4,6-*O*-benzyl-2-*O*-(2-naphtyl)methyl-α-D-glucopyranoside (**S8**, 2.77 g, 5.0 mmol, 1 eq) and DMBA (1.57 g, 10.0 mmol, 2 eq) were dissolved in 20 ml MeOH and flushed for 30 min with N_2. To the solution was added $Pd(PPh_3)_4$ (0.29 g, 0.25 mmol, 0.05 eq) and the mixture was heated for 1h at 40 °C, after which TLC indicated full conversion. The mixture was diluted with EtOAc and washed with saturated Bicarb sol. The aqueous layer was extracted three times with EtOAc. The combined organic layers were dried over $MgSO_4$, filtered and concentrated under reduced pressure. Purification was performed on flash column chromatography (8/2 pentane/EtOAc) to provide the title compound as a yellow oil. Yield: 2.12 g, 4.13 mmol, 83%. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.87 – 7.75 (m, 4H, CH_{arom}), 7.55 – 7.43 (m, 3H, CH_{arom}), 7.34 – 7.22 (m, 8H, CH_{arom}), 7.20 (dd, *J* = 7.8, 1.8 Hz, 2H, CH_{arom}), 4.87 (d, *J* = 12.3 Hz, 1H, C*H*H Bn/Nap), 4.86 – 4.76 (m, 2H, C*H*H Bn/Nap, CH*H* Bn/Nap), 4.64 (d, *J* = 3.5 Hz, 1H, H-1), 4.59 (d, *J* = 12.1 Hz, 1H, C*H*H Bn/Nap), 4.51 (d, *J* = 11.2 Hz, 1H, CH*H* Bn/Nap), 4.46 (d, *J* = 12.2 Hz, 1H, CH*H* Bn/Nap), 4.10 (td, *J* = 9.2, 2.1 Hz, 1H, H-3), 3.75 – 3.66 (m, 2H, H-5, H-6), 3.67 – 3.58 (m, 1H, H-6), 3.55 (dd, *J* = 10.2, 8.2 Hz, 1H, H-4), 3.45 (t, *J* = 9.6, 3.5 Hz, 1H, H-2), 3.32 (s, 3H, CH_3 OMe), 2.51 (d, *J* = 2.2 Hz, 1H, OH); ^{13}C NMR (101 MHz, $CDCl_3$) δ 138.5, 137.9, 135.4, 133.2, 133.2 (C_q), 128.5, 128.4, 128.4, 128.0, 127.9, 127.8, 127.7, 127.1, 126.3, 126.2, 125.9 (CH_{arom}), 97.6 (C-1), 79.5 (C-2), 77.5 (C-4), 74.6 (CH_2 Bn/Nap), 73.7 (C-3), 73.5, 73.3 (CH_2 Bn/Nap), 69.7 (C-5), 68.5 (C-6), 55.3 (CH_3 OMe); HRMS: $[M+NH_4]^+$ calcd for $C_{32}H_{34}O_6NH_4$ 532.26936, found 532.843.

Methyl 3-*O*-benzoyl-4,6-di-*O*-benzyl-2-*O*-(2-naphtyl)methyl-α-D-glucopyranoside (S12)



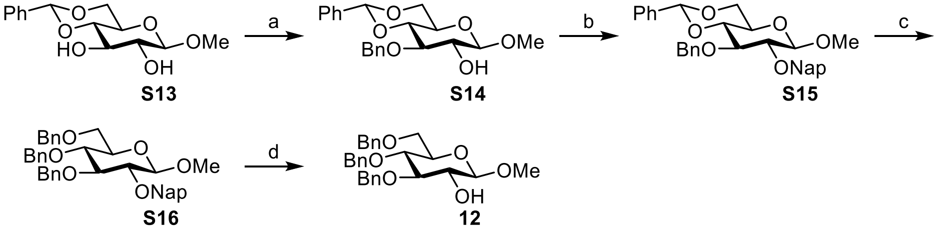
Methyl 4,6-di-*O*-benzyl-2-*O*-(2-naphtyl)methyl-α-D-glucopyranoside (**S11**, 2.00 g, 3.9 mmol, 1 eq) was dissolved in 30 ml pyridine and stirred at 0 °C until the sugar was fully dissolved. To the solution was added BzCl (0.59 ml, 5.10 mmol, 1.3 eq) and the reaction was stirred for 30 min at 0 °C after which the temperature was increased to RT. Once TLC indicated full conversion the reaction mixture was diluted with EtOAc and washed twice with 1M HCl and once with sat. aq. $NaHCO_3$. The organic layer was dried over $MgSO_4$, filtered and concentrated under reduced pressure. Purification was performed on flash column chromatography (9/1 pentane/EtOAc) to provide the title compound as a light-yellow oil. Yield: 2.06 g, 3.35 mmol, 86%. ^1H NMR (400 MHz, $CDCl_3$) δ 8.03 – 7.94 (m, 2H, CH_{arom}), 7.76 – 7.70 (m, 1H, CH_{arom}), 7.67 – 7.60 (m, 2H, CH_{arom}), 7.60 – 7.52 (m, 2H, CH_{arom}), 7.46 – 7.35 (m, 4H, CH_{arom}), 7.35 – 7.25 (m, 6H, CH_{arom}), 7.14 – 7.08 (m, 3H, CH_{arom}), 7.01 – 6.96 (m, 2H, CH_{arom}), 5.83 (dd, *J* = 10.0, 8.8 Hz, 1H, H-3), 4.80 (d, *J* = 3.5 Hz, 1H), 4.75 (d, *J* = 12.7 Hz, 1H, C*H*H Bn/Nap), 4.68 (d, *J* = 12.4 Hz, 1H, CH*H* Bn/Nap), 4.63 (d, *J* = 12.1 Hz, 1H, C*H*H Bn/Nap), 4.51 – 4.43 (m, 2H, C*H*H Bn/Nap, CH*H* Bn/Nap), 4.35 (d, *J* = 10.7 Hz, 1H, CH*H* Bn/Nap), 3.89 – 3.73 (m, 3H, H-4, H-5, H-6), 3.70 – 3.62 (m, 2H, H-2, H-6), 3.41 (s, 3H, CH_3 OMe); ^{13}C NMR (101 MHz, $CDCl_3$) δ 165.5 (C=O), 137.8, 137.6, 135.2, 133.1, 133.1 (C_q), 133.0 (CH_{arom}), 130.4 (C_q), 129.8, 128.5, 128.4, 128.3, 128.3, 128.2, 128.1, 127.9, 127.9, 127.7, 126.9, 126.1, 126.0 (CH_{arom}), 97.9 (C-1), 77.1 (C-2), 76.1 (C-4), 74.5 (CH_2 Bn/Nap), 74.3 (C-3), 73.7, 72.8 (CH_2 Bn/Nap), 69.8 (C-5), 68.3 (C-6), 55.4 (CH_3 OMe); HRMS: $[M+NH_4]^+$ calcd for $C_{39}H_{38}O_7NH_4$ 636.29558, found 636.29410.

Methyl 3-O-benzoyl-4,6-di-O-benzyl-α-D-glucopyranoside (10)



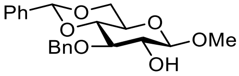
Methyl 3-*O*-benzoyl-4,6-di-*O*-benzyl-2-*O*-(2-naphtyl)methyl-α-D-glucopyranoside (**S11**, 2.0 g, 3.23 mmol, 1 eq) was dissolved in 30 ml 9/1 DCM/H_2O and stirred at RT until the sugar was fully dissolved. To the solution was added DDQ (1.47 g, 6.46 mmol, 2 eq) and the reaction was stirred for 60 min at RT after which TLC indicated full conversion. The reaction mixture was quenched with aq. Bicarb solution and extracted with DCM. The organic layer was washed twice with aq. Bicarb solution. The organic layer was dried over $MgSO_4$, filtered and concentrated under reduced pressure. Purification was performed on flash column chromatography (7/3 pentane/EtOAc) to provide the title compound as an oil. Yield: 0.901 g, 1.88 mmol, 68%. ^1H NMR (400 MHz, $CDCl_3$) δ 8.10 – 8.02 (m, 2H, CH_{arom}), 7.62 – 7.52 (m, 1H, CH_{arom}), 7.48 – 7.27 (m, 8H, CH_{arom}), 7.14 (dd, *J* = 5.0, 2.0 Hz, 3H, CH_{arom}), 7.14 (dd, *J* = 5.0, 2.0 Hz, 3H, CH_{arom}), 7.05 – 6.97 (m, 2H, CH_{arom}), 5.55 (dd, *J* = 9.9, 7.4, Hz, 1H, H-3), 4.86 (d, *J* = 3.8 Hz, 1H, H-1), 4.68 (d, *J* = 12.1 Hz, 1H, C*H*H Bn), 4.57 (d, *J* = 10.8 Hz, 1H, C*H*H Bn), 4.53 (d, *J* = 12.1 Hz, 1H, CH*H* Bn), 4.44 (d, *J* = 10.8 Hz, 1H, CH*H* Bn), 3.90 – 3.83 (m, 2H, H-4, H-5), 3.83 – 3.73 (m, 2H, H-2, H-6), 3.71 (dd, *J* = 10.4, 1.2 Hz, 1H, H-6), 3.45 (s, 3H, CH$_3$ OMe), 2.21 (d, *J* = 11.3 Hz, 1H, OH); ^{13}C NMR (101 MHz, CDCl$_3$) δ 166.9 (C=O), 137.9, 137.7(C$_q$), 133.2 (CH$_{arom}$), 130.1 (C$_q$), 129.9, 128.6, 128.5, 128.4, 128.2, 128.0, 127.9, 127.8 (CH$_{arom}$), 99.7 (C-1), 76.7 (C-3), 75.6 (C-4), 74.8, 73.8 (CH$_2$ Bn), 71.8 (C-2), 70.4 (C-5), 68.3 (C-6), 55.6 (CH$_3$ OMe). Data is in agreement with literature.[49]

preparation of acceptor **12**



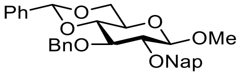
***Scheme S4**: preparation of acceptor **12**: reagents and conditions: a) i: DBTO, toluene, reflux, ii: CsF, BnBr, DMF, 58% over 2 steps; b) NapBr, NaH, DMF, 96%; c) i: PTSA, MeOH, 60 ^{o}C, ii: BnBr, NaH, DMF, 91% over 2 steps; d) DDQ, DCM/H2O (9:1), 75%.*

Methyl 3-*O*-benzyl-4,6-*O*-benzylidene-β-D-glucopyranoside (S14)



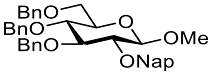
Methyl 4,6-*O*-benzylidene-β-D-glucopyranoside[50] (**S13**, 1.60 g, 5.67 mmol) and di-n-butyltin oxide (1.83 g, 7.37 mmol, 1.3 eq) were refluxed in a Dean-Stark setup for 2 hr, after which the solvent was removed under reduced pressure. The residue was dissolved in DMF. Benzyl bromide (0.88 mL, 7.37 mmol, 1.3 eq) and CsF (1.12 g, 7.37 mmol) were added and the reaction mixture was stirred overnight, after which it was diluted with water and extracted twice with diethyl ether. Combined organic phases were dried and concentrated under reduced pressure. The residue was recrystallized from EA/pentane, yielding the title compound as white solid. Yield: 1.22 g, 3.28 mmol, 58%. ^{1}H NMR (400 MHz, CDCl$_3$) δ 7.52 – 7.46 (m, 2H, CH$_{arom}$), 7.42 – 7.26 (m, 8H, CH$_{arom}$), 5.58 (s, 1H, C*H*Ph), 4.98 (d, *J* = 11.6 Hz, 1H, C*H*H Bn), 4.79 (d, *J* = 11.6 Hz, 1H, CH*H* Bn), 4.37 (dd, *J* = 10.5, 5.0 Hz, 1H, H-6), 4.33 (d, *J* = 7.7 Hz, 1H, H-1), 3.81 (t, *J* = 10.3 Hz, 1H, H-6), 3.75 – 3.64 (m, 2H, H-3, H-4), 3.57 (s, 4H, H-2, CH$_3$ OMe), 3.50 – 3.42 (m, 1H, H-5), 2.49 (d, *J* = 2.2 Hz, 1H, OH); ^{13}C NMR (101 MHz, CDCl$_3$) δ 138.4, 137.3 (C$_q$), 129.2, 128.6, 128.4, 128.2, 128.0, 126.1 (CH$_{arom}$), 104.3 (C-1), 101.4 (CHPh), 81.6 (C-4), 80.3 (C-3), 74.8 (CH$_2$ Bn, 74.3 (C-2), 68.8 (C-6), 66.5 (C-5), 57.6 (CH$_3$ OMe). Spectra in agreement with literature.[51]

Methyl 3-*O*-benzyl-4,6-*O*-benzylidene-2-*O*-(2-naphtyl)methyl-β-D-glucopyranoside (S15)



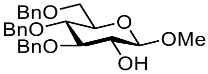
Methyl 3-*O*-benzyl-4,6-*O*-benzylidene-β-D-glucopyranoside (**S14**, 1.20 g, 3.22 mmol) and NapBr (1.07 g, 4.83 mmol, 1.5 eq) were dissolved in DMF, after which NaH (60% dispersion in mineral oil, 193 mg, 4.83 mmol, 1.5 eq) was added. After completion of the reaction, water was added to quench the excess reagent. The formed precipitate was collected by filtration, washed with water and with pentane and dried under vacuum, yielding the title compound as white solid. Yield: 1.59 g, 3.10 mmol, 96%. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.84 (dtd, *J* = 11.7, 6.3, 3.3 Hz, 4H, CH_{arom}), 7.52 (dtd, *J* = 10.9, 6.9, 6.3, 3.0 Hz, 5H, CH_{arom}), 7.46 – 7.35 (m, 5H, CH_{arom}), 7.33 – 7.26 (m, 4H, CH_{arom}), 5.62 (s, 1H, C*H*Ph), 5.08 (d, *J* = 11.2 Hz, 1H, C*H*H Bn/Nap), 5.01 – 4.93 (m, 2H, C*H*H Bn/Nap, CH*H* Bn/Nap), 4.86 (d, *J* = 11.4 Hz, 1H, CH*H* Bn/Nap), 4.51 (d, *J* = 7.7 Hz, 1H, H-1), 4.42 (dd, *J* = 10.5, 5.0 Hz, 1H, H-6), 3.88 – 3.80 (m, 2H, H-4, H-6), 3.74 (t, *J* = 9.2 Hz, 1H, H-3), 3.55 (dd, *J* = 8.6, 7.7 Hz, 1H, H-2), 3.48 (td, *J* = 9.6, 5.0 Hz, 1H, H-6); ^{13}C NMR (101 MHz, $CDCl_3$) δ 138.5, 137.3, 135.9, 133.3, 133.0 (C_q), 129.0, 128.3, 128.3, 128.1, 128.1, 128.0, 127.7, 127.7, 126.8, 126.2, 126.0, 125.9 (CH_{arom}), 105.3 (C-1), 101.2 (CHPh), 82.2 (C-2), 81.6 (C-3), 80.8 (C-4), 75.3, 75.2 (CH_2 Bn, CH_2 Nap), 68.8 (C-6), 66.0 (C-5), 57.5 (CH_3 OMe). Spectra in agreement with literature.[52]

Methyl 3,4,6-tri-*O*-benzyl-2-*O*-(2-naphtyl)methyl-β-D-glucopyranoside (S16)



Methyl 3-*O*-benzyl-4,6-*O*-benzylidene-2-*O*-(2-naphtyl)methyl-β-D-glucopyranoside (**S15**, 1.55 g, 3.02 mmol) was dissolved with PTSA-H_2O (58 mg, 0.30 mmol, 0.1 eq) and heated to 50 °C. After TLC indicates full conversion, the reaction mixture was quenched with triethylamine (0.06 mL, 0.45 mmol, 0.15 eq) and concentrated under reduced pressure. The residue was dissolved in DMF and treated with benzyl bromide (1.08 mL, 9.07 mmol, 3 eq) and sodium hydride (60% dispersion in mineral oil, 0.36 g, 9.07 mmol, 3 eq). After 1 hr, the reaction was quenched with water and extracted twice with diethyl ether. Combined organic phases were dried with $MgSO_4$ and concentrated. The residue was purified over silica (10% EtOAc in pentane) to obtain the title compound as colourless oil that slowly solidifies. Yield: 1.66 g, 2.74 mmol, 91%. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.90 – 7.79 (m, 4H, CH_{arom}), 7.57 – 7.48 (m, 3H, CH_{arom}), 7.44 – 7.38 (m, 4H, CH_{arom}), 7.38 – 7.30 (m, 10H, CH_{arom}), 7.25 – 7.20 (m, 2H, CH_{arom}), 5.15 (d, *J* = 11.2 Hz, 1H, C*H*H Bn/Nap), 5.02 (d, *J* = 11.0 Hz, 1H, C*H*H Bn/Nap), 4.94 (d, *J* = 11.2 Hz, 1H, CH*H* Bn/Nap), 4.91 – 4.85 (m, 2H, C*H*H Bn/Nap, CH*H* Bn/Nap), 4.70 (d, *J* = 12.2 Hz, 1H, C*H*H Bn/Nap), 4.65 – 4.57 (m, 2H, 2x CH*H* Bn/Nap), 4.42 (d, *J* = 7.8 Hz, 1H, H-1), 3.83 (dd, *J* = 10.7, 2.0 Hz, 1H, H-6), 3.79 – 3.75 (m, 1H, H-6), 3.75 – 3.65 (m, 5H, H-3, H-4, CH_3 OMe), 3.60 – 3.52 (m, 2H, H-2, H-5); ^{13}C NMR (101 MHz, $CDCl_3$) δ 138.7, 138.3, 138.2, 136.1, 133.4, 133.1 (C_q), 128.5, 128.5, 128.2, 128.1, 128.1, 127.9, 127.9, 127.9, 127.8, 127.7, 127.7, 126.9, 126.4, 126.1, 125.9 (CH_{arom}), 104.9 (C-1), 84.8 (C-4), 82.4 (C-2), 78.0 (C-3), 75.8, 75.1 (CH_2 Bn/Nap), 75.0 (C-5), 74.9, 73.6 (CH_2 Bn/Nap), 69.0 (C-6), 57.3 (CH_3 Me); HRMS: $[M+NH_4]^+$ calcd for $C_{39}H_{40}O_6NH_4$ 622.31631, found 622.31478.

Methyl 3,4,6-tri-*O*-benzyl-β-D-glucopyranoside (12)

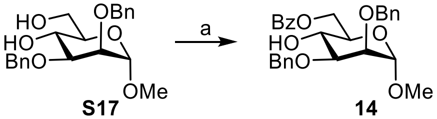


Methyl 3,4,6-tri-*O*-benzyl-2-*O*-(2-naphtyl)methyl-β-D-glucopyranoside (**S16**, 1.63 g, 2.70 mmol) and DDQ (1.23 g, 5.40 mmol, 2 eq) were dissolved in 30 mL 9:1 DCM/H_2O and vigorously stirred. When TLC showed full conversion, the reaction mixture was diluted with DCM and washed twice with sat. aq. $NaHCO_3$. The organic phase was dried with $MgSO_4$ and concentrated under reduced pressure. The residue was purified over silica (20% EtOAc in pentane) to give the titel compound as white solid. Yield: 945 mg, 2.03 mmol, 75%. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.45

– 7.30 (m, 13H, CH_{arom}), 7.25 – 7.17 (m, 2H, CH_{arom}), 4.97 (d, *J* = 11.3 Hz, 1H, C*H*H Bn), 4.93 – 4.84 (m, 2H, C*H*H Bn, CH*H* Bn), 4.68 (d, *J* = 12.2 Hz, 1H, C*H*H Bn), 4.64 – 4.53 (m, 2H, CH*H* Bn), 4.23 (d, *J* = 7.3 Hz, 1H, H-1), 3.81 (dd, *J* = 10.8, 2.2 Hz, 1H, H-6), 3.76 (dd, *J* = 10.8, 4.5 Hz, 1H, H-6), 3.71 – 3.58 (m, 6H, H-2, H-3, H-4, CH_3 OMe), 3.54 (ddt, *J* = 9.4, 4.6, 2.4 Hz, 1H, H-5), 2.49 (d, *J* = 2.1 Hz, 1H, OH); ^{13}C NMR (101 MHz, $CDCl_3$) δ 138.6, 138.1, 138.1 (C_q), 128.5, 128.5, 128.4, 128.0, 128.0, 127.9, 127.8, 127.8, 127.7 (CH_{arom}), 103.7 (C-1), 84.5 (C-4), 77.6 (C-3), 75.2 (CH_2 Bn), 75.2 (C-2), 75.1 (CH_2 Bn), 74.6 (C-5), 73.6 (CH_2 Bn), 68.8 (C-6), 57.2 (CH_3 OMe). Spectra in agreement with literature.[53]

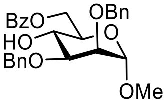
Mannose acceptors

Preparation of acceptor **14**



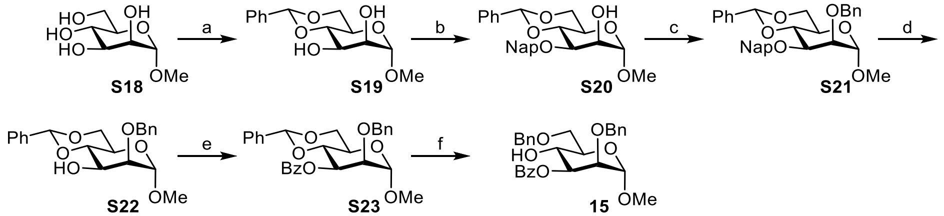
Scheme S5*: preparation of acceptor* ***14****: reagents and conditions a) BzCl, pyridine, DCM, 0 °C, 83%*

methyl 6-*O*-benzoyl-2,3-di-*O*-benzyl-α-D-mannopyranoside (14)



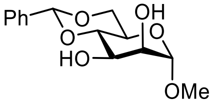
methyl 2,3-di-*O*-benzyl-α-D-mannopyranoside[54] (**S17,** 1.51 g, 4.03 mmol) and pyridine (1.63 mL, 20.2 mmol, 5 eq) were dissolved in 12 mL DCM and cooled to 0°C, after which benzoyl chloride (0.492 mL, 4.23 mmol, 1.05 eq) was added dropwise as a 1.6 M solution in DCM. The reaction was allowed to warm to RT overnight and diluted with DCM, washed with 1M aq. HCl and sat. aq. $NaHCO_3$. The organic phase was sodium sulfate and concentrated under reduced pressure. The residue was purified with silica chromatography (20% EA in pentane) to yield the title compound (1.60 g, 3.34 mmol, 83%) as a colourless oil. ^1H NMR (400 MHz, $CDCl_3$) δ 8.08 – 8.00 (m, 2H, CH_{arom}), 7.53 (ddt, *J* = 8.7, 7.0, 1.3 Hz, 1H, CH_{arom}), 7.40 – 7.25 (m, 12H, CH_{arom}), 4.82 (d, *J* = 1.7 Hz, 1H, H-1), 4.70 – 4.59 (m, 5H, H-6, H-6, C*H*H Bn, CH_2 Bn), 4.51 (d, *J* = 11.7 Hz, 1H, CH*H* Bn), 4.11 (t, *J* = 9.7 Hz, 1H, H-4), 3.86 (dt, *J* = 9.8, 3.6 Hz, 1H, H-5), 3.81 (dd, *J* = 3.1, 1.8 Hz, 1H, H-2), 3.75 (dd, *J* = 9.5, 3.1 Hz, 1H, H-3), 3.37 (s, 3H, CH_3 OMe), 2.61 (s, 1H, OH); ^{13}C NMR (101 MHz, $CDCl_3$) δ 166.8 (C=O), 138.2 (C_q), 138.1 (CH_{arom}), 133.1 (C_q), 130.1, 129.9, 128.6, 128.5, 128.4, 128.0, 127.9, 127.8, 127.8 (CH_{arom}), 99.1 (C-1), 79.6 (C-3), 74.1 (C-2), 72.7, 71.9 (CH_2 Bn), 70.8 (C-5), 66.6 (C-4), 64.2 (C-6), 55.0 (CH_3 OMe); Spectra in agreement with literature.[55]

Preparation of acceptor **15**



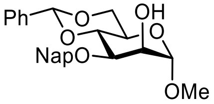
Scheme S6: *preparation of acceptor **15**: reagents and conditions: a) PhCH(OMe)$_2$, HBF$_4$•Et$_2$O, DMF 96%; b) i) Bu$_2$SnO, toluene, reflux 3h; ii) NapBr, CsF, DMF, 79%; c) BnBr, NaH, DMF, 90%; d) DDQ, DCM/H2O (9:1), 80%; e) BzCl, pyridine 83%; f) TES-H, TFA, DCM, 0 °C, 92%.*

Methyl 4,6-*O*-benzylidene-α-D-mannopyranoside (S19)



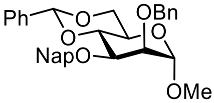
Methyl-α-D-mannopyranoside (**S18**, 3.88 g, 20.0 mmol, 1 eq) was dissolved in 20 ml DMF and stirred until the sugar was fully dissolved. To the solution was added benzaldehyde dimethyl acetal (3.22 ml, 21.4 mmol, 1.07 eq) and HBF$_4$·Et$_2$O (32.74 ml, 20.0 mmol, 1 eq), the mixture was stirred for 4h at RT after which TLC indicated full conversion. The reaction mixture was quenched with TEA. Solvents were evaporated under reduced pressure and purification was performed on flash column chromatography (3/2pentane/EtOAc) to provide the title compound as a solid. Yield: 5.00 g, 17.8 mmol, 89%. ^{1}H NMR (400 MHz, CDCl$_3$) δ 7.52 – 7.46 (m, 2H, CH$_{arom}$), 7.40 – 7.35 (m, 3H, CH$_{arom}$), 5.56 (s, 1H, C*H*Ph), 4.73 (d, *J* = 1.4 Hz, 1H, H-1), 4.31 – 4.25 (m, 1H, H-6), 4.04 (dd, *J* = 9.4, 3.6 Hz, 1H, H-3), 4.00 (dd, *J* = 3.5, 1.5 Hz, 1H, H-2), 3.91 (t, *J* = 9.2 Hz, 1H, H-4), 3.84 – 3.77 (m, 2H, H-5, H-6), 3.39 (s, 3H, CH$_3$ OMe); ^{13}C NMR (101 MHz, CDCl$_3$) δ 137.3 (C$_q$), 129.4, 128.6, 128.5, 128.5, 126.7, 126.4, 126.2 (CH$_{arom}$), 102.4 (CHPh), 101.4 (C-1), 79.0 (C-4), 70.9 (C-2), 68.9 (C-6), 68.8 (C-3), 63.0 (C-5), 55.2 (OMe). Data in agreement with literature.[56]

Methyl 4,6-*O*-benzylidene-3-*O*-(2-naphtyl)methyl-α-D-mannopyranoside (S20)



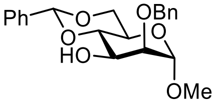
Methyl 4,6-*O*-benzylidene-α-D-mannopyranoside (**S19**, 5.44 g, 19.3 mmol) and di-n-butyltin(IV) oxide (6.24 g, 25.06 mmol, 1.3 eq) were dissolved in 100 ml toluene and refluxed for 3 hours, after which solvents where evaporated under reduced pressure. To the crude mixture was added NapBr (5.54 g, 25.06 mmol, 1.3 eq) and CsF (3.81 g, 25.06 mmol, 1.3 eq) and dissolved in 100 ml DMF. The reaction was stirred overnight at RT. The reaction mixture was diluted in Et$_2$O and washed twice with H$_2$O. The organic layer was dried over MgSO$_4$, filtered and concentrated under reduced pressure. Purification was performed on flash column chromatography (3/1 pentane/EtOAc) to provide the title compound as a light-yellow oil. Yield: 6.47 g, 15.2 mmol, 79%.^{1}H NMR (400 MHz, CDCl$_3$) δ 7.85 – 7.78 (m, 3H, CH$_{arom}$), 7.75 – 7.70 (m, 1H, CH$_{arom}$), 7.55 – 7.44 (m, 5H, CH$_{arom}$), 7.42 – 7.35 (m, 3H, CH$_{arom}$), 5.63 (s, 1H, C*H*Ph), 4.98 (d, *J* = 12.1 Hz, 1H, C*H*H Nap), 4.88 (d, *J* = 12.2 Hz, 1H, CH*H* Nap), 4.75 (d, *J* = 1.5 Hz, 1H, H-1), 4.28 (dd, *J* = 9.7, 4.3 Hz, 1H, H-6), 4.13 (t, *J* = 9.3 Hz, 1H, H-4), 4.07 (dt, *J* = 3.3, 1.6 Hz, 1H, H-2), 3.94 (dd, *J* = 9.6, 3.4 Hz, 1H, H-3), 3.90 – 3.84 (m, 1H, H-6), 3.81 (ddd, *J* = 10.3, 9.0, 4.2 Hz, 1H, H-5), 3.35 (s, 3H, CH_3 OMe), 2.78 (d, *J* = 1.6 Hz, 1H, OH); ^{13}C NMR (101 MHz, $CDCl_3$) δ 137.6, 135.4, 133.2, 133.1 (C_q), 129.0, 128.3, 128.3, 128.0, 127.7, 126.6, 126.2, 126.2, 126.0, 125.8 (CH_{arom}), 101.7 (CHPh), 101.2 (C-1), 78.9 (C-4), 75.6 (C-3), 72.9 (CH_2 Nap), 69.9 (C-2), 68.9 (C-6), 63.3 (C-5), 54.9 (CH_3 OMe). Data in agreement with literature.[57]

Methyl 2-*O*-benzyl-4,6-*O*-benzylidene-3-*O*-(2-naphtyl)methyl-α-D-mannopyranoside (S21)



Methyl 4,6-*O*-benzylidene-3-*O*-(2-naphtyl)methyl-α-D-mannopyranoside (**S20**, 5.09 g, 15.2 mmol) was dissolved in 75 ml DMF and stirred at 0 °C until the sugar was fully dissolved. To the solution was added NaH (60% dispersion in mineral oil, 0.92 g, 23.0 mmol, 1.5 eq) and the reaction was stirred for 30 min at 0 °C after which BnBr (2.73 ml, 23.0 mmol, 1.5 eq) was slowly added. After 30 min the temperature was increased to RT. Once TLC indicated full conversion, the reaction mixture was quenched with water and extracted twice with Et_2O. The combined organic layers were dried over $MgSO_4$, filtered and concentrated under reduced pressure. Purification was performed on flash column chromatography (8/2 pentane/EtOAc) to provide the title compound as an oil. Yield: 5.55 g, 13.77 mmol, 90%. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.85 – 7.75 (m, 3H, CH_{arom}), 7.74 – 7.64 (m, 1H), 7.59 – 7.27 (m, 14H, CH_{arom}), 5.67 (s, 1H, C*H*Ph), 4.93 (d, *J* = 12.3 Hz, 1H, C*H*H Bn/Nap), 4.87 – 4.75 (m, 3H, CH*H* Bn/Nap, CH_2 Bn/Nap), 4.70 (d, *J* = 1.7 Hz, 1H, H-1), 4.31 – 4.24 (m, 2H, H-4, H-6), 3.99 (dd, *J* = 10.0, 3.3 Hz, 1H, H-3), 3.90 (t, *J* = 10.3 Hz, 1H, H-6), 3.86 (dd, *J* = 3.3, 1.7 Hz, 1H, H-2), 3.77 (ddd, *J* = 10.4, 9.1, 4.7 Hz, 1H, H-5), 3.30 (s, 3H, CH_3 OMe); ^{13}C NMR (101 MHz, $CDCl_3$) δ 138.2, 137.8, 136.2, 133.4, 133.0 (C_q), 129.0, 128.5, 128.3, 128.2, 128.1, 128.0, 127.9, 127.7, 126.2, 126.2, 126.1, 125.8, 125.7 (CH_{arom}), 101.7 (CHPh), 100.5 (C-1), 79.2 (C-4), 76.3 (C-3), 76.2 (C-2), 73.7, 72.9 (CH_2 Bn, CH_2 Nap), 69.0 (C-6), 64.1 (C-5), 54.9 (CH_3 OMe).

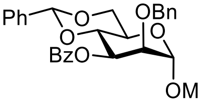
Methyl 2-*O*-benzyl-4,6-*O*-benzylidene-α-D-mannopyranoside (S22)



Methyl 2-*O*-benzyl-4,6-*O*-benzylidene-3-*O*-(2-naphtyl)methyl-α-D-mannopyranoside. (**S21**, 1.72 g, 3.36 mmol) was dissolved in 25 ml 9/1 DCM/H_2O and stirred at RT until the sugar was fully dissolved. To the solution was added DDQ (1.52 g, 6.71 mmol, 2 eq) and the reaction was stirred for 60 min at RT after which TLC indicated full conversion. The reaction mixture was quenched with sat. aq. Bicarb solution and extracted with DCM. The organic layer was washed twice with sat. aq. Bicarb solution, dried over $MgSO_4$, filtered and concentrated under reduced pressure. Purification was performed on flash column chromatography (8/2 pentane/EtOAc) to provide the title compound as an oil. Yield: 1.00 g, 2.69 mmol, 80%. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.53 – 7.45 (m, 2H, CH_{arom}), 7.41 – 7.28 (m, 8H, CH_{arom}), 5.56 (s, 1H, C*H*Ph), 4.77 – 4.72 (m, 2H, H-1, C*H*H Bn), 4.68 (d, *J* = 11.7 Hz, 1H, CH*H* Bn), 4.26 (dd, *J* = 9.3, 3.9 Hz, 1H, H-6), 4.07 (ddd, *J* =

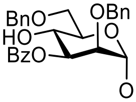
9.9, 7.9, 3.7 Hz, 1H, H-5), 3.90 (t, *J* = 9.4 Hz, 1H, H-4), 3.86 – 3.82 (m, 2H, H-2, H-6), 3.81 – 3.72 (m, 1H, H-3), 3.36 (s, 3H, CH_3 OMe), 2.39 (d, *J* = 8.0 Hz, 1H, OH); ^{13}C NMR (101 MHz, $CDCl_3$) δ 137.7, 137.4 (C_q), 129.2, 128.7, 128.3, 128.2, 128.0, 126.4 (CH_{arom}), 102.2 (CHPh), 99.5 (C-1), 79.6 (C-4), 78.5 (C-2), 73.8 (CH_2 Bn), 68.9 (C-6), 68.8 (C-5), 63.4 (C-3), 55.1 (CH_3 OMe). Data in agreement with literature[58]

Methyl 3-*O*-benzoyl-2-*O*-benzyl-4,6-*O*-benzylidene-α-D-mannopyranoside (S23)



Methyl 2-*O*-benzyl-4,6-*O*-benzylidene-α-D-mannopyranoside (**S22**, 0.95 g, 2.55 mmol) was dissolved in 10 ml pyridine and stirred at 0 °C until the sugar was fully dissolved. To the solution was added BzCl (0.39 ml, 3.32 mmol, 1.3 eq) and the reaction was stirred at RT until TLC indicated full conversion. The reaction mixture was diluted in DCM and washed twice with aq. 1M HCl and twice with aq. Bicarb solution. The organic layer was dried over $MgSO_4$, filtered and concentrated under reduced pressure. Purification was performed on flash column chromatography (8/2 pentane/EtOAc) to provide the title compound as an oil. Yield: 1.28 g, 2.54 mmol, 63%. ^1H NMR (400 MHz, $CDCl_3$) δ 8.10 – 8.03 (m, 2H, CH_{arom}), 7.60 – 7.52 (m, 1H, CH_{arom}), 7.47 – 7.40 (m, 4H, CH_{arom}), 7.23 – 7.17 (m, 3H, CH_{arom}) 7.35 – 7.26 (m, 5H, CH_{arom}), 5.62 (s, 1H, C*H*Ph), 5.55 (dd, *J* = 10.4, 3.4 Hz, 1H, H-3), 4.77 (d, *J* = 1.6 Hz, 1H, H-1), 4.64 (s, 2H, CH_2 Bn), 4.35 (dd, *J* = 10.6, 9.1 Hz, 1H, H-4), 4.32 – 4.28 (m, 1H, H-6), 4.09 (dd, *J* = 3.5, 1.6 Hz, 1H, H-2), 4.00 – 3.89 (m, 2H, H-5, H-6), 3.40 (s, 3H, CH_3 OMe); ^{13}C NMR (101 MHz, $CDCl_3$) δ 165.9 (C=O), 137.6, 137.4 (C_q), 133.2 (CH_{arom}), 130.1 (C_q), 129.9, 129.0, 128.5, 128.5, 128.3, 128.0, 126.3 (CH_{arom}), 101.8 (CHPh), 100.2 (C-1), 76.5 (C-2, C-4), 73.9 (CH_2 Bn), 71.3 (C-3), 69.0 (C-6), 64.1 (C-5), 55.2 (CH_3 OMe). Data in agreement with literature.[59]

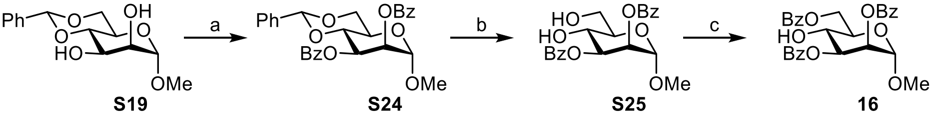
Methyl 3-*O*-benzoyl-2,6-di-*O*-benzyl-α-D-mannopyranoside (15)



Methyl 3-*O*-benzoyl-2-*O*-benzyl-4,6-*O*-benzylidene-α-D-mannopyranoside (**S23**, 0.54 g, 1.13 mmol) was dissolved in 20 ml anhydrous DCM and stirred at 0 °C until the sugar was fully dissolved. To the solution was added TES-H (1.8 ml, 11.3 mmol, 10 eq) and the mixture was stirred for another 15 min before slowly adding TFA (0.84 ml, 11.3 mmol, 10 eq) and the reaction was stirred at 0 °C until TLC indicated full conversion. The reaction mixture was quenched with aq. Bicarb solution and extracted with DCM. The organic layer was washed twice with aq. Bicarb solution. The organic layer was dried over $MgSO_4$, filtered and concentrated under reduced pressure. Purification was performed on flash column chromatography (8/2 pentane/EtOAc) to provide the title compound as an oil. Yield: 0.49 g, 1.03 mmol, 92 %. ^1H NMR (400 MHz, $CDCl_3$) δ 8.09 – 8.02 (m, 2H, CH_{arom}), 7.61 – 7.55 (m, 1H, CH_{arom}), 7.47 – 7.41 (m, 2H, CH_{arom}), 7.38 – 7.32 (m, 4H, CH_{arom}), 7.32 – 7.26 (m, 3H, CH_{arom}), 7.20 (tt, *J* = 3.9, 2.4 Hz, 3H, CH_{arom}), 5.36 (dd, *J* = 9.9, 3.3 Hz, 1H, H-3), 4.79 (d, *J* = 1.7 Hz, 1H, H-1), 4.70 – 4.64 (m, 3H, C*H*H Bn, CH_2 Bn), 4.60 (d, *J* = 11.9 Hz, 1H, CH*H* Bn), 4.26 (t, *J* = 9.0 Hz, 1H, H-4), 3.94 (dd, *J* = 3.3, 1.8 Hz, 1H, H-2), 3.90 – 3.74 (m, 3H, H-5, 2x H-6), 3.40 (s, 3H, CH_3 OMe), 2.67 (s, 1H, OH); ^{13}C NMR (101 MHz,

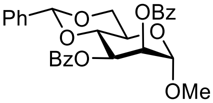
$CDCl_3$) δ 166.7 (C=O), 138.1, 137.9 (C_q), 133.3 , 130.0 (CH_{arom}), 129.9 (C_q), 128.5, 128.4, 127.8 (CH_{arom}), 99.2 (C-1), 75.9 (C-2), 74.8 (C-3), 73.8, 73.3 (CH_2 Bn), 71.3 (C-5), 70.7 (C-6), 67.8 (C-4), 55.1 (CH_3 OMe). Data in agreement with literature[60]

Preparation of acceptor **16**



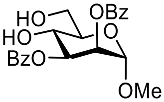
Scheme S7: *preparation of acceptor* ***16****: reagents and conditions: a) BzCl, pyridine, 95%; b) pTsOH•H₂O, MeOH, 50 °C, 62%; c) BzCl, pyridine, DCM, 0 °C, 38%.*

Methyl 2,3-di-*O*-benzoyl-4,6-*O*-benzylidene-α-D-mannopyranoside (S24)



Methyl 4,6-*O*-benzylidene-α-D-mannopyranoside (**S19**, 1.04 g, 3.68 mmol) was dissolved in 20 ml pyridine and stirred at 0 °C until the sugar was fully dissolved. To the solution was added BzCl (1.28 ml, 11.04 mmol, 3.0 eq) and the reaction was stirred for 30 min at 0 °C after which the temperature was increased to RT. Once TLC indicated full conversion the reaction mixture was diluted with EtOAc and washed twice with sat. aq. $NaHCO_3$. The organic layer was dried over $MgSO_4$, filtered and concentrated under reduced pressure. Purification was performed on flash column chromatography (9/1 pentane/EtOAc) to provide the title compound as a light-yellow oil. Yield: 1.73 g, 3.51 mmol, 95%. ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.13 – 8.07 (m, 2H, CH_{arom}), 7.94 – 7.88 (m, 2H, CH_{arom}), 7.61 – 7.55 (m, 1H, CH_{arom}), 7.50 – 7.40 (m, 5H, CH_{arom}), 7.32 – 7.24 (m, 5H, CH_{arom}), 5.83 (dd, *J* = 10.3, 3.6 Hz, 1H, H-3), 5.72 (dd, *J* = 3.6, 1.6 Hz, 1H, H-2), 5.67 (s, 1H, C*H*Ph), 4.88 (d, *J* = 1.6 Hz, 1H, H-1), 4.42 – 4.32 (m, 2H, H-4, H-6), 4.10 (td, *J* = 9.8, 4.7 Hz, 1H, H-5), 3.96 (t, *J* = 10.3 Hz, 1H, H-6), 3.42 (s, 3H, CH_3 OMe); ^{13}C NMR (101 MHz, $CDCl_3$) δ 165.4 (C=O), 137.1 (C_q), 133.5, 133.0, 129.8, 129.7 (CH_{arom}), 129.7, 129.4, 129.0, 128.6, 128.5, 128.4, 128.4, 128.4, 128.2, 128.2, 126.2, 126.2 (CH_{arom}), 101.9 (CH Ph), 99.6 (C-1), 76.8 (C-4), 70.9 (C-2), 69.0 (C-3), 68.8 (C-6), 63.8 (C-5), 55.3 (CH_3 OMe). Data in agreement with literature.[61]

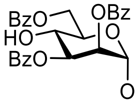
Methyl 2,3-di-*O*-benzoyl-α-D-mannopyranoside (S25)



Methyl 2,3-di-*O*-benzoyl-4,6-*O*-benzylidene-α-D-mannopyranoside (**S24**, 1.65 g, 3.36 mmol, 1 eq) was dissolved in 25 ml MeOH and stirred at RT for 15 min. To the solution was added pTsOH·H_2O (64.0 mg, 0.34 mmol, 0.1 eq) and the mixture was stirred for 1h at 50 °C after which TLC indicated full conversion. The reaction mixture was set to cool down to RT and was quenched with TEA (0.25 ml, 0.8 mmol, 0.25 eq). Solvents were evaporated under reduced pressure and purification was performed on flash column chromatography (3/2 pentane/EtOAc) to provide the title compound as a solid. Yield: 0.842 g, 2.10 mmol, 62%. ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.07 (dd, *J* = 8.4, 1.4 Hz, 2H, CH_{arom}), 7.91 (dd, *J* = 8.4, 1.4 Hz, 2H, CH_{arom}), 7.65 – 7.58

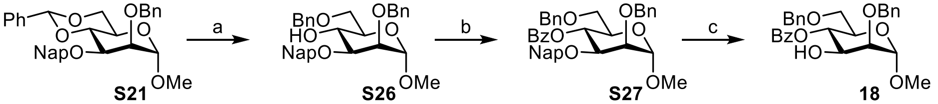
(m, 1H, CH_{arom}), 7.55 – 7.45 (m, 3H, CH_{arom}) 7.38 – 7.31 (m, 2H, CH_{arom}), 5.64 – 5.49 (m, 2H, H-2, H-3), 4.90 (d, *J* = 1.4 Hz, 1H, H-1), 4.33 (t, *J* = 9.4 Hz, 1H, H-4), 3.98 (dd, *J* = 3.8, 1.1 Hz, 2H, 2x H-6), 3.85 (dt, *J* = 9.7, 3.7 Hz, 1H, H-5), 3.47 (s, 3H, CH_3 OMe); ^{13}C NMR (101 MHz, $CDCl_3$) δ 167.0, 165.6 (C=O), 133.7, 133.6, 129.9, 129.9 (CH_{arom}), 129.5, 129.3 (C_q), 128.7, 128.5 (CH_{arom}), 98.8 (C-1), 73.2 (C-3), 72.4 (C-5), 70.67 (C-2), 67.0 (C-4), 62.4 (C-6), 55.4 (CH_3 OMe). Data in agreement with literature.[62]

Methyl 2,3,6-tri-*O*-benzoyl-α-D-mannopyranoside (16)



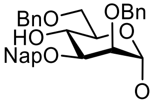
Methyl 2,3-di-*O*-benzoyl-α-D-mannopyranoside (**S25**, 800 mg, 1.99 mmol) and pyridine (0.80 mL, 9.94 mmol, 5 eq) were dissolved in 7 mL DCM and cooled to 0 °C. Benzoyl chloride (0.24 mL, 2.09 mmol, 1.05 eq) was added over 15 minutes, after which the reaction mixture was allowed to warm to RT. After 16 hr stirring, the reaction mixture was diluted with dichloromethane and washed twice with 1M HCl and with sat. aq. $NaHCO_3$. The organic phase was dried with $MgSO_4$ and concentrated under reduced pressure. The residue was purified by silica chromatography (5% EtOAc in pentane), yielding the title compound as colourless oil. Yield: 0.38 g, 0.76 mmol, 38 %. ^1H NMR (400 MHz, $CDCl_3$) δ 8.14 (dd, *J* = 8.4, 1.3 Hz, 2H, CH_{arom}), 7.98 (dd, *J* = 8.3, 1.3 Hz, 2H, CH_{arom}), 7.92 (dd, *J* = 8.4, 1.3 Hz, 2H, CH_{arom}), 7.65 – 7.60 (m, 1H, CH_{arom}), 7.59 – 7.54 (m, 1H, CH_{arom}), 7.53 – 7.49 (m, 1H, CH_{arom}), 7.48 – 7.44 (m, 2H, CH_{arom}), 7.39 – 7.30 (m, 4H, CH_{arom}), 5.70 – 5.58 (m, 2H, H-2, H-3), 4.93 (s, 1H, H-1), 4.91 (dd, *J* = 12.2, 4.0 Hz, 1H, H-6), 4.65 (dd, *J* = 12.0, 2.2 Hz, 1H, H-6), 4.28 (dd, *J* = 10.7, 8.5 Hz, 1H, H-4), 4.10 (ddd, *J* = 9.9, 3.9, 2.2 Hz, 1H, H-5), 3.50 (s, 3H, CH_3 OMe); ^{13}C NMR (101 MHz, $CDCl_3$) δ 167.1, 166.9, 165.5 (C=O), 133.5, 133.5, 133.4, 130.0, 129.9, 129.9 (CH_{arom}), 129.6, 129.4 (C_q), 128.7, 128.6, 128.5 (CH_{arom}), 98.8 (C-1), 72.8 (C-2), 71.3 (C-5), 70.6 (C-3), 66.5 (C-4), 63.5 (C-6), 55.5 (CH_3 OMe). Data in agreement with literature.[63]

Preparation of acceptor **18**



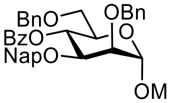
Scheme S8*: preparation of acceptor* ***18****: reagents and conditions: a) TES-H TFA, DCM, 0 °C, 92%; b) BzCl, pyridine, 55%; c) DDQ, DCM/H_2O 9:1, 77%*

Methyl 2,6-di-*O*-benzyl-3-*O*-(2-naphtyl)methyl-α-D-mannopyranoside (S26)



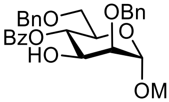
Methyl 2-*O*-benzyl-4,6-*O*-benzylidene-3-*O*-(2-naphtyl)methyl-α-D-mannopyranoside (**S21**, 3.33 g, 6.50 mmol) was dissolved in 40 ml anhydrous DCM and stirred at 0 °C until the sugar was fully dissolved. To the solution was added TES-H (10.38 ml, 65 mmol, 10 eq) and the mixture was stirred for another 15 min before slowly adding TFA (4.84 ml, 65 mmol, 10 eq). The reaction was kept at 0 °C until TLC indicated full conversion. The reaction mixture was quenched with sat. aq. NaHCO$_3$ and extracted with DCM. The organic layer was washed twice with sat. aq. NaHCO$_3$. The organic layer was dried over MgSO$_4$, filtered and concentrated under reduced pressure. Purification was performed on flash column chromatography (7/3 pentane/EtOAc) to provide the title compound as an oil. Yield: 2.42 g, 4.70z mmol, 72%. ^{1}H NMR (400 MHz, CDCl$_3$) δ 7.87 – 7.75 (m, 4H, CH$_{arom}$), 7.51 – 7.42 (m, 3H, CH$_{arom}$), 7.38 – 7.25 (m, 12H, CH$_{arom}$), 4.79 (d, *J* = 1.7 Hz, 1H, H-1), 4.75 – 4.69 (m, 2H, 2x CH*H* Bn/Nap), 4.67 – 4.61 (m, 3H, C*H*H Bn/Nap, 2x CH*H* Bn/Nap), 4.59 (d, *J* = 12.1 Hz, 1H, CH*H* Bn/Nap), 4.15 – 4.04 (m, 1H, H-4), 3.83 – 3.76 (m, 3H, H-2, 2x H-6) 3.76 – 3.70 (m, 2H, H-3, H-5), 3.34 (s, 3H,CH$_3$ OMe), 2.63 – 2.58 (m, 1H, OH); ^{13}C NMR (101 MHz, CDCl$_3$) δ 138.3, 138.2, 135.8, 133.3, 133.0 (C$_q$), 128.4, 128.4, 128.3, 128.0, 127.9, 127.8, 127.8, 127.7, 127.6, 126.5, 126.3, 126.0, 125.8 (CH$_{arom}$), 99.2 (C-1), 79.7 (C-3), 73.9 (C-2), 73.6, 72.7, 71.9 (CH$_2$ Bn, CH$_2$ Nap), 71.4 (C-5), 70.5 (C-6), 68.0 (C-4), 54.9 (CH$_3$ OMe); HRMS: [M+NH$_4$]$^+$ calcd for C$_{32}$H$_{34}$O$_6$NH$_4$ 532.26936, found 532.26887.

Methyl 4-*O*-benzoyl-2,6-di-*O*-benzyl-3-*O*-(2-naphtyl)methyl-α-D-mannopyranoside (S27)



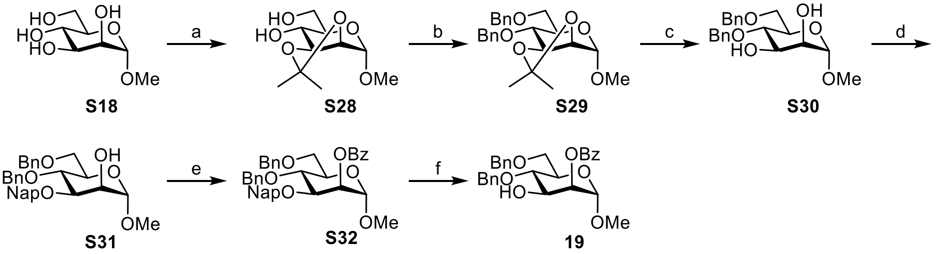
Methyl 2,6-di-*O*-benzyl-3-*O*-(2-naphtyl)methyl-α-D-mannopyranoside (**S27**, 2.30 g, 4.47 mmol) was dissolved in 25 ml pyridine and stirred at 0 °C until the sugar was fully dissolved. To the solution was added BzCl (0.70 ml, 5.81 mmol, 1.3 eq) and the reaction was stirred for 30 min at 0 °C after which the temperature was increased to RT. Once TLC indicated full conversion the reaction mixture was diluted with EtOAc and washed twice with 1M HCl and with sat. aq. NaHCO$_3$. The organic layer was dried over MgSO$_4$, filtered and concentrated under reduced pressure. Purification was performed on flash column chromatography (9/1 pentane/EtOAc) to provide the title compound as a light-yellow oil. Yield: 1.53 g, 2.46 mmol, 55%. ^{1}H NMR (400 MHz, CDCl$_3$) δ 7.97 – 7.91 (m, 2H, CH$_{arom}$), 7.77 – 7.71 (m, 1H, CH$_{arom}$), 7.56 (dd, *J* = 16.2, 7.5 Hz, 4H, CH$_{arom}$), 7.47 – 7.34 (m, 6H, CH$_{arom}$), 7.34 – 7.27 (m, 3H, CH$_{arom}$), 7.26 – 7.14 (m, 7H, CH$_{arom}$), 5.66 (t, *J* = 9.8 Hz, 1H, H-4), 4.86 – 4.80 (m, 2H, H-1, C*H*H Bn/Nap), 4.76 (d, *J* = 12.5 Hz, 1H, CH*H* Bn/Nap), 4.71 (d, *J* = 12.5 Hz, 1H, C*H*H Bn/Nap), 4.55 (d, *J* = 12.5 Hz, 1H, CH*H* Bn/Nap), 4.51 (d, *J* = 2.7 Hz, 2H, CH$_2$ Bn/Nap), 4.01 – 3.91 (m, 2H, H-3, H-6), 3.88 (dd, *J* = 3.3, 1.8 Hz, 1H, H-2), 3.68 (dd, *J* = 10.8, 6.2 Hz, 1H, H-6), 3.62 (dd, *J* = 10.8, 2.9 Hz, 1H, H-5), 3.37 (s, 3H, CH$_3$ OMe); ^{13}C NMR (101 MHz, CDCl$_3$) δ 165.7 (C=O), 138.3, 138.2, 135.6, 133.2 (C$_q$), 133.1 (CH$_{arom}$), 133.0, 130.1 (C$_q$), 129.9, 128.5, 128.4, 128.3, 128.2, 128.1, 127.9, 127.8, 127.7, 127.7, 127.4, 126.5, 126.1, 125.9, 125.9 (CH$_{arom}$), 99.5 (C-1), 76.8 (C-3), 74.0 (C-2), 73.6, 73.0, 71.8 (CH$_2$ Bn, CH$_2$ Nap), 70.7 (C-5), 70.1 (C-6), 69.5 (C-4), 55.1 (OMe); HRMS: [M+NH$_4$]$^+$ calcd for C$_{39}$H$_{38}$O$_7$NH$_4$ 636.29461, found 636.29461.

Methyl 4-*O*-benzoyl-2,6-di-*O*-benzyl-α-D-mannopyranoside (18)



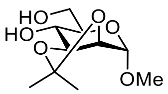
Methyl 4-*O*-benzoyl-2,6-di-*O*-benzyl-3-*O*-(2-naphtyl)methyl-α-D-mannopyranoside (**S27**, 1.45 g, 2.34 mmol) was dissolved in 20 ml 9/1 DCM/H$_2$O and stirred at RT until the sugar was fully dissolved. To the solution was added DDQ (1.06 g, 4.69 mmol, 2 eq) and the reaction was stirred for 60 min at RT after which TLC indicated full conversion. The reaction mixture was diluted with DCM and washed twice with sat. aq. $NaHCO_3$. The organic layer was dried over $MgSO_4$, filtered and concentrated under reduced pressure. Purification was performed on flash column chromatography (9/1 pentane/EtOAc) to provide the title compound as an oil. Yield: 0.86 g, 1.80 mmol, 77%. $[\alpha]_D^{25}$ = +22.9° (*c = 0.6*, $CHCl_3$); IR (thin film): 416, 699, 716, 750, 1037, 1060, 1106, 1270, 1731, 2350; ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.02 – 7.95 (m, 2H, CH_{arom}), 7.59 – 7.49 (m, 1H, CH_{arom}), 7.46 – 7.29 (m, 7H, CH_{arom}), 7.24 – 7.10 (m, 5H, CH_{arom}), 5.38 (t, *J* = 9.9 Hz, 1H, H-4), 4.87 (d, *J* = 1.5 Hz, 1H, H-1), 4.77 (d, *J* = 11.8 Hz, 1H, C*H*H Bn), 4.61 (d, *J* = 11.8 Hz, 1H, CH*H* Bn), 4.57 (d, *J* = 12.1 Hz, 1H, C*H*H Bn), 4.50 (d, *J* = 12.1 Hz, 1H, CH*H* Bn), 4.07-3.95 (m, 2H, H-3, H-5), 3.79 (dd, *J* = 3.7, 1.6 Hz, 1H, H-2), 3.70 – 3.58 (m, 2H, 2x H-6), 3.41 (s, 3H, CH_3 OMe), 2.45 (d, *J* = 10.6 Hz, 1H, OH); ^{13}C NMR (101 MHz, $CDCl_3$) δ 166.6 (C=O), 138.0, 137.6 (C_q), 133.2, 129.9 (CH_{arom}), 129.8 (C_q), 128.6, 128.4, 128.3, 128.1, 128.0, 127.6, 127.54 (CH_{arom}), 98.2 (C-1), 78.2 (C-2), 73.6, 73.2 (CH_2 Bn), 71.0 (C-4), 70.1, 69.8 (C-3, C-5), 69.4 (C-6), 55.2(CH_3 OMe); HRMS: $[M+NH_4]^+$ calcd for $C_{28}H_{30}O_7NH_4$ 496.23298, found 496.23176.

Preparation of acceptor **19**



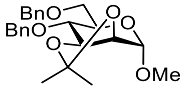
***Scheme S9**: preparation of acceptor **19**: reagents and conditions: a) 2,2-dimethoxypropane, PTSA, acetone, water, 54%; b) BnBr, NaH, DMF, 64%; c) TFA, H_2O, $CHCl_3$, quant; d) i: Bu_2SnO, toluene reflux, ii: NapBr, CsF, DMF, 74%; e) BzCl, pyridine, 94%; f) DDQ, DCM/H_2O (9:1), 74%*

Methyl 2,3-*O*-isopropylidene-α-D-mannopyranoside (S28)



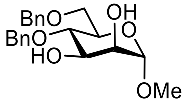
Methyl α-D-mannopyranoside (**S18**, 3.88 g, 20.0 mmol), 2,2-dimethoxypropane (36.8 ml, 300 mmol, 15 eq) and pTsOH·H_2O (0.38 g, 2 mmol, 0.1 eq) were dissolved in 40 ml Acetone and stirred at RT for 15 min. To the solution was added 80 ml H_2O and the mixture was stirred for 4h at RT. The reaction mixture was quenched with aq. Bicarb sol. Solvents were evaporated under reduced pressure and purification was performed on flash column chromatography (1/1 pentane/EtOAc) to provide the title compound as a solid. Yield: 2.48 g, 10.59 mmol, 53 %. ^{1}H NMR (400 MHz, $CDCl_3$) δ 4.92 (s, 1H, H-1), 4.21-4.09 (m, 2H, H-2, H-3), 3.86 (t, *J* = 3.2 Hz, 2H, 2x H-6), 3.74 (dd, *J* = 9.6, 5.9 Hz, 1H, H-4), 3.60 (dt, *J* = 9.5, 4.0 Hz, 1H, H-5), 3.39 (s, 3H, CH_3 OMe), 3.19 (s, 1H, 4-OH), 2.43 (s, 1H, 6-OH), 1.53 (s, 3H, CH_3 isopropylidene), 1.35 (s, 3H, CH_3 isopropylidene); ^{13}C NMR (101 MHz, $CDCl_3$) δ 109.5 (C_q isopropylidene), 98.2 (C-1), 78.5, 75.6 (C-2, C-3), 69.6 (C-5), 68.8 (C-4), 61.7 (C-6), 54.9 (CH_3 OMe), 27.9 (CH_3 isopropylidene), 26.1 (CH_3 isopropylidene). Data in agreement with literature.[64]

Methyl 4,6-di-*O*-benzyl-2,3-*O*-isopropylidene-α-D-mannopyranoside (S29)



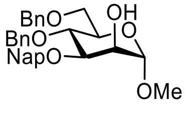
Methyl 2,3-*O*-isopropylidene-α-D-mannopyranoside (**S28**, 0.50 g, 2.13 mmol) was dissolved in 20 ml DMF and stirred at 0 °C until the sugar was fully dissolved. To the solution was added NaH (60% dispersion in mineral oil, 0.26 g, 6.40 mmol, 3 eq) and the reaction was stirred for 30 min at 0 °C after which BnBr (0.76 ml, 6.40 mmol, 3 eq) was slowly added. After 30 min the temperature was increased to RT. Once TLC indicated full conversion the reaction mixture was quenched with water and extracted twice with Et_2O. The combined organic layers were dried over $MgSO_4$, filtered and concentrated under reduced pressure. Purification was performed on flash column chromatography (19/1 pentane/EtOAc) to provide the title compound as an oil. Yield: 0.62 g, 1.49 mmol, 70%. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.39 – 7.22 (m, 10H, CH_{arom}), 4.95 (d, *J* = 0.8 Hz, 1H, H-1), 4.86 (d, *J* = 11.5 Hz, 1H, C*H*H Bn), 4.63 (d, *J* = 12.2 Hz, 1H, C*H*H Bn), 4.58 – 4.52 (m, 2H, 2x CH*H* Bn), 4.30 (dd, *J* = 6.9, 5.9 Hz, 1H, H-3), 4.13 (dd, *J* = 5.8, 0.9 Hz, 1H, H-2), 3.79 – 3.65 (m, 3H, H-5, 2x H-6), 3.56 (dd, *J* = 9.9, 6.9 Hz, 1H, H-4), 3.39 (s, 3H, CH_3 OMe), 1.51 (s, 3H, CH_3 isopropylidene)), 1.37 (s, 3H, CH_3 isopropylidene); ^{13}C NMR (101 MHz, $CDCl_3$) δ 138.4, 138.3 (C_q), 128.3, 128.2, 127.9, 127.6, 127.6, 127.5 (CH_{arom}), 109.4 (C_q isopropylidene), 98.3 (C-1), 78.9 (C-3), 75.8 (C-2), 75.8 (C-4), 73.5, 72.8 (CH_2 Bn), 69.3 (C-6), 68.3 (C-5), 54.9 (CH_3 OMe), 27.9 (CH_3 isopropylidene), 26.3 (CH_3 isopropylidene). Data in agreement with literature[65]

Methyl 4,6-di-*O*-benzyl-α-D-mannopyranoside (S30)



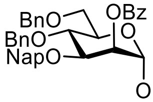
Methyl 2,3-*O*-isopropylidene-4,6-di-*O*-benzyl-α-D-mannopyranoside (**S29**, 0.55 g, 1.33 mmol) was dissolved in 10 ml $CHCl_3$ and stirred until the sugar was fully dissolved. To the solution was added TFA (0.82 ml, 10.62 mmol, 8.0 eq) and H_2O (0.07 ml, 3.58 mmol, 2.7 eq), the reaction was stirred for 4h at RT. Once TLC indicated full conversion the reaction mixture was quenched with TEA, the reaction mixture was concentrated under reduced pressure. Purification was performed on flash column chromatography (1/1 pentane/EtOAc) to provide the title compound as a solid. Yield: 0.50 g, 1.33 mmol, quant. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.43 – 7.23 (m, 10H, CH_{arom}), 4.75 (s, *J* = 1.1 Hz, 1H, H-1), 4.74 – 4.65 (m, 2H, 2x C*H*H Bn), 4.59 – 4.52 (m, 2H, 2x CH*H* Bn), 3.97 – 3.87 (m, 2H, H-2, H-5), 3.78 (dd, 1H, H-6), 3.75 – 3.69 (m, 3H, H-3, H-4, H-6), 3.36 (s, 3H, CH_3 OMe), 2.37 (s, 2H, 2-OH, 3-OH); ^{13}C NMR (101 MHz, $CDCl_3$) δ 138.4, 138.1 (C_q), 128.7, 128.5, 128.1, 128.1, 128.1, 127.9 (CH_{arom}), 100.7 (C-1), 75.9 (C-4), 74.7, 73.7 (CH_2 Bn), 71.9 (C-5), 71.1 (C-2), 70.7 (C-3), 68.9 (C-6), 55.1 (CH_3 OMe). Data in agreement with literature.[66]

Methyl 4,6-di-*O*-benzyl-3-*O*-(2-naphtyl)methyl-α-D-mannopyranoside (S31)



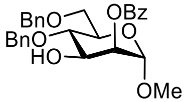
Methyl 4,6-di-*O*-benzyl-α-D-mannopyranoside (**S30**, 1.94 g, 5.18 mmol) and dibutyltin(IV) oxide (1.68 g, 6.74 mmol, 1.3 eq) were dissolved in 75 ml toluene and refluxed for 3 hours, after which solvents where evaporated under reduced pressure. The residue was dissolved in DMF and NapBr (1.49 g, 6.74 mmol, 1.3 eq) and CsF (1.02 g, 6.74 mmol, 1.3 eq) were added. The reaction was stirred overnight at RT. The reaction mixture was diluted with Et_2O and washed twice with H_2O. The organic layer was dried over $MgSO_4$, filtered and concentrated under reduced pressure. Purification was performed on flash column chromatography (3/1 pentane/EtOAc) to provide the title compound as a light-yellow oil. Yield: 1.98 g, 3.85 mmol, 74%. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.86 – 7.70 (m, 4H, CH$_{arom}$), 7.51 – 7.42 (m, 3H, CH$_{arom}$), 7.38 – 7.26 (m, 8H, CH$_{arom}$), 7.19 – 7.13 (m, 2H, CH$_{arom}$), 4.89 – 4.79 (m, 4H, H-1, 2x C*H*H Bn/Nap, CH*H* Bn/Nap), 4.66 (d, *J* = 12.1 Hz, 1H, C*H*H Bn/Nap), 4.55 (d, *J* = 9.6 Hz, 1H, CH*H* Bn/Nap), 4.52 (d, *J* = 8.3 Hz, 1H, CH*H* Bn/Nap), 4.07 (t, *J* = 1.7 Hz, 1H, H-2), 3.92 (dd, *J* = 9.1, 3.1 Hz, 1H, H-3), 3.87 (t, *J* = 8.9 Hz, 1H, H-4), 3.80 – 3.67 (m, 3H, H-5, 2x H-6), 3.36 (s, 3H, CH_3 OMe), 2.50 (d, *J* = 2.2 Hz, 1H, OH); ^{13}C NMR (101 MHz, $CDCl_3$) δ 138.4, 138.3 , 135.4, 133.3, 133.1 (C$_q$), 128.4, 128.4, 128.0, 127.9, 127.8, 127.7, 127.7, 126.7, 126.3, 126.1, 125.9 (CH$_{arom}$), 100.4 (C-1), 80.3 (C-3), 75.2 (CH_2 Bn/Nap), 74.4 (C-4), 73.6, 72.1 (CH_2 Bn/Nap), 71.1 (C-5), 69.1 (C-6), 68.5 (C-5), 55.0 (CH_3 OMe); HRMS: $[M+NH_4]^+$ calcd for $C_{32}H_{34}O_6$ 532.26936, found 532.26888.

Methyl 2-*O*-benzoyl-4,6-di-*O*-benzyl-3-*O*-(2-naphtyl)methyl-α-D-mannopyranoside (S32)



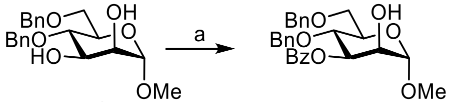
Methyl 4,6-di-*O*-benzyl-3-*O*-(2-naphtyl)methyl-α-D-mannopyranoside (**S31**, 1.90 g, 3.69 mmol) was dissolved in 20 ml pyridine and stirred at 0 °C until the sugar was fully dissolved. To the solution was added BzCl (0.56 ml, 4.8 mmol, 1.3 eq) and the reaction was stirred for 30 min at 0 °C after which the temperature was increased to RT. Once TLC indicated full conversion the reaction mixture was diluted with EtOAc and washed twice with 1M HCl and once with sat. aq. $NaHCO_3$. The organic layer was dried over $MgSO_4$, filtered and concentrated under reduced pressure. Purification was performed on flash column chromatography (9/1 pentane/EtOAc) to provide the title compound as a light-yellow oil. Yield: 2.15 g, 3.47 mmol, 94%. ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.13 – 8.06 (m, 2H, CH$_{arom}$), 7.83 – 7.74 (m, 2H, CH$_{arom}$), 7.71 (d, *J* = 8.4 Hz, 1H, CH$_{arom}$), 7.65 – 7.60 (m, 1H, CH$_{arom}$), 7.59 – 7.52 (m, 1H, CH$_{arom}$), 7.46 – 7.23 (m, 14H, CH$_{arom}$), 7.18 (ddd, *J* = 6.0, 2.5, 1.5 Hz, 2H, CH$_{arom}$), 5.67 (dd, *J* = 2.9, 2.0 Hz, 1H, H-2), 4.95 – 4.89 (m, 2H, 2x C*H*H Bn/Nap), 4.88 (d, *J* = 1.9 Hz, 1H, H-1) 4.77 – 4.69 (m, 2H, C*H*H Bn/Nap, CH*H* Bn/Nap), 4.60 – 4.48 (m, 2H, 2x CH*H* Bn/Nap), 4.15 (dd, *J* = 9.2, 2.9 Hz, 1H, H-3), 4.10 (t, *J* = 9.2 Hz, 1H, H-4), 3.90 (dd, *J* = 10.5, 3.9 Hz, 1H, H-6), 3.85 (dt, *J* = 9.2, 2.8 Hz, 1H, H-5), 3.80 (dd, *J* = 10.5, 1.7 Hz, 1H, H-6), 3.39 (s, 3H, CH_3 OMe); ^{13}C NMR (101 MHz, $CDCl_3$) δ 165.8 (C=O), 138.5, 138.4, 135.5, 133.3 (CH$_{arom}$), 133.2 (C$_q$), 132.9 (CH$_{arom}$), 130.0 (C$_q$), 129.9, 128.4, 128.4, 128.3, 128.0, 127.9, 127.9, 127.6, 127.5, 127.5, 126.7, 126.0, 125.9, 125.8 (CH$_{arom}$), 98.9 (C-1), 78.2 (C-3), 75.3 (CH_2 Bn/Nap), 74.3 (C-4), 73.5, 71.5(CH_2 Bn/Nap), 71.5 (C-5), 69.1 (C-6), 68.9 (C-2), 55.0 (CH_3 OMe); HRMS: $[M+Na]^+$ calcd for $C_{39}H_{38}O_7NH_4$ 636.29558, found 636.29475.

Methyl 2-*O*-benzoyl-4,6-di-*O*-benzyl-α-D-mannopyranoside (19)



Methyl 2-*O*-benzoyl-4,6-di-*O*-benzyl-3-*O*-(2-naphtyl)methyl-α-D-mannopyranoside. (**S32**, 2.05 g, 3.31 mmol) was dissolved in 25 ml 9/1 DCM/H_2O and stirred at RT until the sugar was fully dissolved. To the solution was added DDQ (1.50 g, 6.63 mmol, 2 eq) and the reaction was stirred for 60 min at RT after which TLC indicated full conversion. The reaction mixture was quenched with aq. Bicarb solution and extracted with DCM. The organic layer was washed twice with aq. Bicarb solution. The organic layer was dried over $MgSO_4$, filtered and concentrated under reduced pressure. Purification was performed on flash column chromatography (9/1 pentane/EtOAc) to provide the title compound as an oil. Yield: 1.17 g, 2.44 mmol, 74%. ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.03 (dd, *J* = 8.3, 1.3 Hz, 2H, CH_{arom}), 7.60 – 7.52 (m, 1H, CH_{arom}), 7.44 – 7.18 (m, 12H, CH_{arom}), 5.35 (dd, *J* = 3.4, 1.8 Hz, 1H, H-2), 4.85 (d, *J* = 1.8 Hz, 1H, H-1), 4.80 (d, *J* = 11.1 Hz, 1H, C*H*H Bn), 4.75 (d, *J* = 12.0 Hz, 1H, C*H*H Bn), 4.63 (d, *J* = 11.1 Hz, 1H, CH*H* Bn), 4.56 (d, *J* = 11.9 Hz, 1H, CH*H* Bn), 4.24 (dd, *J* = 9.4, 3.4 Hz, 1H, H-3), 3.99 (t, *J* = 9.6 Hz, 1H, H-4), 3.91 (dd, *J* = 10.9, 3.9 Hz, 1H, H-6), 3.85 – 3.74 (m, 2H, H-5, H-6), 3.39 (s, 3H, CH_3 OMe) 2.24 (s, 1H, OH);^{13}C NMR (101 MHz, $CDCl_3$) δ 166.3 (C=O), 138.4, 138.3 (C_q), 133.3, 130.0 (CH_{arom}), 129.7 (C_q), 128.5, 128.5, 128.4, 128.1, 127.9, 127.6, 127.6 (CH_{arom}), 98.6 (C-1), 75.8 (C-4), 74.9, 73.6 (CH_2 Bn), 72.9 (C-2), 71.3 (C-5), 70.6 (C-3), 69.1 (C-6), 55.2 (CH_3 OMe). Data in agreement with literature.[67]

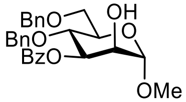
Preparation of acceptor **22**



S30 **22**

*Scheme **S10**: preparation of acceptor **22**: reagents and conditions: a) BzCl, 2-aminoethyl diphenylborinate, Dipea, ACN, 61%*

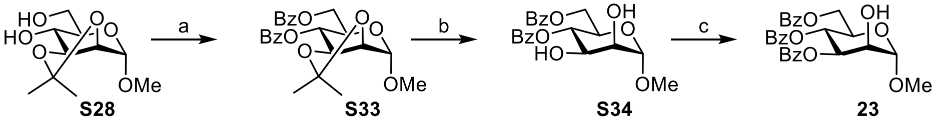
Methyl 3-*O*-benzoyl-4,6-di-*O*-benzyl-α-D-mannopyranoside (22)



Methyl 4,6-di-*O*-benzyl-α-D-mannopyranoside (**S30**, 0.51 g, 1.27 mmol) and 2-aminoethyl diphenylborinate (0.03 g, 0.12 mmol, 0.1 eq) where dissolved in 10 ml anhydrous CH_3CN. To the solution was added DIPEA (0.31 ml, 1.80 mmol, 1.5 eq) and BzCl (0.21 ml, 1.80 mmol, 1.5 eq) the mixture was stirred for 4 hours, after which TLC indicated full conversion. The mixture was diluted in EtOAc and washed with H_2O. The aqueous layer was extracted twice with EtOAc. The combined organic layers were dried over $MgSO_4$, filtered and concentrated under reduced pressure. Purification was performed on flash column chromatography (9/1 pentane/EtOAc) to provide the title compound as a yellow oil. Yield: 0.35 g, 0.74 mmol, 61%. ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.11 – 8.00 (m, 2H, CH_{arom}), 7.64 – 7.54 (m, 1H, CH_{arom}), 7.50 – 7.42 (m, 3H, CH_{arom}), 7.39 – 7.28 (m, 5H, CH_{arom}), 7.20 – 7.12 (m, 3H, CH_{arom}), 7.09 – 6.99 (m, 2H, CH_{arom}), 5.50 (dd, *J*

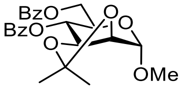
= 9.6, 3.1 Hz, 1H, H-3), 4.79 (d, *J* = 1.9 Hz, 1H, H-1), 4.70 (d, *J* = 12.1 Hz, 1H, C*H*H Bn), 4.64 (d, *J* = 10.9 Hz, 1H, C*H*H Bn), 4.55 (d, *J* = 12.1 Hz, 1H, CH*H* Bn), 4.48 (d, *J* = 10.9 Hz, 1H, CH*H* Bn), 4.21 – 4.12 (m, 2H, H-2, H-4), 3.88 (ddt, *J* = 10.5, 4.4, 2.1 Hz, 1H, H-5), 3.82 (dd, *J* = 10.7, 3.9 Hz, 1H, H-6), 3.73 (dd, *J* = 10.6, 2.0 Hz, 1H, H-6), 3.42 (s, 3H, CH_3 OMe); ^{13}C NMR (101 MHz, $CDCl_3$) δ 165.7 (C=O), 138.1, 137.8 (C_q), 133.3 (CH_{arom}), 130.0 (C_q), 129.8, 129.8, 128.7, 128.6, 128.5, 128.4, 128.1, 128.0, 127.8, 127.8, 127.1 (CH_{arom}), 100.9 (C-1), 75.1 (C-3), 74.9, 73.7 (CH_2 Bn), 73.0 (C-4), 71.2 (C-5), 69.7 (C-2), 68.6 (C-6), 55.2 (CH_3 OMe). Data in agreement with literature.[67]

Preparation of acceptor **23**



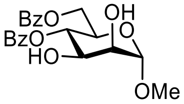
***Scheme S11**: preparation of acceptor **23**: reagents and conditions: a) BzCl, pyridine, 96%; b) acetic acid, reflux, 85%; c) BzCl, 2-aminoethyl diphenylborinate, Dipea, ACN, 55%*

Methyl 4,6-di-*O*-benzoyl-2,3-*O*-isopropylidene-α-D-mannopyranoside (S33)



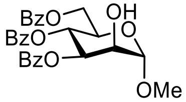
Methyl 2,3-*O*-isopropylidene-α-D-mannopyranoside (**S28**, 0.43 g, 1.84 mmol) was dissolved in 20 ml pyridine and stirred at 0 °C until the sugar was fully dissolved. To the solution was added BzCl (0.75 ml, 6.40 mmol, 3.0 eq) and the reaction was stirred for 30 min at 0 °C after which the temperature was increased to RT. Once TLC indicated full conversion the reaction mixture was diluted with EtOAc and washed twice with 1M HCl and with sat. aq. $NaHCO_3$. The organic layer was dried over $MgSO_4$, filtered and concentrated under reduced pressure. Purification was performed on flash column chromatography (9/1 pentane/EtOAc) to provide the title compound as a light-yellow oil. Yield: 0.78 g, 1.77 mmol, 96%. ^{1}H NMR (400 MHz, $CDCl_3$) 8.07 – 7.97 (m, 4H, CH_{arom}), 7.58 – 7.49 (m, 2H, CH_{arom}), 7.45 – 7.34 (m, 4H, CH_{arom}), 5.42 (dd, *J* = 10.3, 7.6 Hz, 1H, H-4), 5.03 (s, 1H, H-1), 4.54 (dd, *J* = 12.0, 3.1 Hz, 1H, H-6), 4.47 – 4.34 (m, 2H, H-3, H-6), 4.23 (dd, *J* = 5.5, 0.8 Hz, 1H, H-2), 4.18 – 4.09 (m, 1H, H-5), 3.44 (s, 3H, CH_3 OMe), 1.64 (s, 3H, CH_3 isopropylidene), 1.37 (s, 3H, CH_3 isopropylidene). ^{13}C NMR (101 MHz, $CDCl_3$) δ 166.3, 165.7 (C=O), 133.4, 133.1, 130.0 (CH_{arom}), 129.9 (C_q), 129.7 (CH_{arom}), 129.5 C_q), 128.5, 128.5 (CH_{arom}), 110.3 (C_q isopropylidene), 98.3 (C-1), 76.1 (C-3), 75.9 (C-2), 70.7 (C-4), 66.4 (C-5), 63.8 (C-6), 55.3 (CH_3 OMe), 27.9 (CH_3 isopropylidene), 26.5 (CH_3 isopropylidene). Data in agreement with literature.[68]

Methyl 4,6-di-*O*-benzoyl-α-D-mannopyranoside (S34)



Methyl 2,3-*O*-isopropylidene-4,6-di-*O*-benzoyl-α-D-mannopyranoside (**S33**, 0.73 g, 1.65mmol) was dissolved in 10 ml Acetic acid and refluxed for 1 h. Once TLC indicated full conversion the reaction mixture was cooled down to RT and concentrated under reduced pressure. Purification was performed on flash column chromatography (3/2 pentane/EtOAc) to provide the title compound as a solid. Yield: 0.56 g, 1.40 mmol, 85 %. ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.09 – 7.95 (m, 4H, CH_{arom}), 7.62 – 7.49 (m, 2H, CH_{arom}), 7.48 – 7.35 (m, 4H, CH_{arom}), 5.39 (dd, *J* = 10.1, 9.3 Hz, 1H, H-4), 4.86 (d, *J* = 1.6 Hz, 1H, H-1), 4.60 (dd, *J* = 11.9, 2.7 Hz, 1H, H-6), 4.46 (dd, *J* = 11.9, 5.9 Hz, 1H, H-6), 4.22 (ddd, *J* = 10.2, 5.9, 2.7 Hz, 1H, H-5), 4.11 (dd, *J* = 9.4, 3.6 Hz, 1H, H-3), 4.03 (dd, *J* = 3.5, 1.7 Hz, 1H, H-2), 3.44 (s, 3H, CH_3 OMe); ^{13}C NMR (101 MHz, $CDCl_3$) δ 167.4, 166.4 (C=O), 133.8, 133.2, 130.1 (CH_{arom}), 129.8 (C_q), 129.8 (CH_{arom}), 129.2 (C_q), 128.7, 128.5 (CH_{arom}), 100.6 (C-1), 71.5 (C-4), 70.7 (C-2), 70.6 (C-3), 67.9 (C-5), 63.9 (C-6), 55.4 (CH_3 OMe). Data in agreement with literature.[68]

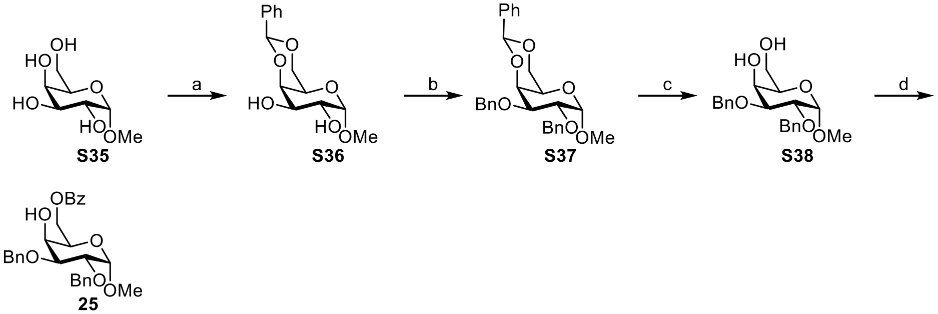
Methyl 3,4,6-tri-*O*-benzoyl-α-D-mannopyranoside (23)



Methyl 4,6-di-*O*-benzoyl-α-D-mannopyranoside (**S34**, 0.45 g, 1.20 mmol) and 2-aminoethyl diphenylborinate (0.03 g, 0.13 mmol, 0.1 eq) where dissolved in 10 ml anhydrous CH_3CN. To the solution was added DIPEA (0.27 ml, 1.52 mmol, 1.2 eq) and BzCl (0.18 ml, 1.52 mmol, 1.2 eq) the mixture was stirred for 4 hours, after which TLC indicated full conversion. The mixture was diluted in EtOAc and washed with H_2O. The aqueous layer was extracted twice with EtOAc. The combined organic layers were dried over $MgSO_4$, filtered and concentrated under reduced pressure. Purification was performed on flash column chromatography (9/1 pentane/EtOAc) to provide the title compound as a yellow oil. Yield: 0.35 g, 0.70 mmol, 55%. ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.11 – 8.00 (m, 2H, CH_{arom}), 7.95 (ddt, *J* = 11.8, 7.0, 1.4 Hz, 4H, CH_{arom}), 7.61 – 7.45 (m, 3H, CH_{arom}), 7.43 – 7.31 (m, 6H, CH_{arom}), 5.93 (t, *J* = 10.0 Hz, 1H, H-4), 5.67 (dd, *J* = 10.0, 3.2 Hz, 1H, H-3), 4.89 (d, *J* = 1.8 Hz, 1H, H-1), 4.60 (dd, *J* = 12.0, 3.0 Hz, 1H, H-6), 4.49 (dd, *J* = 12.0, 5.5 Hz, 1H, H-6), 4.44 – 4.28 (m, 2H, H-2, H-5), 3.50 (s, 3H, CH_3 OMe), 2.35 (s, 1H, OH); ^{13}C NMR (101 MHz, $CDCl_3$) δ 166.3, 165.7, 165.6 (C=O), 133.5, 133.5, 133.2 (C_q), 129.9, 129.9, 129.9, 129.8, 129.3, 129.2, 128.6, 128.6, 128.5, 128.5 (CH_{arom}), 100.8 (C-1), 72.7 (C-3), 69.5 (C-2), 68.7 (C-5), 67.1 (C-4), 63.7 (C-6), 55.5 (CH_3 OMe). Data in agreement with literature.[67]

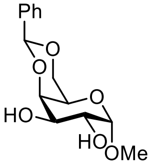
Galactose acceptors

Preparation of acceptor **25**



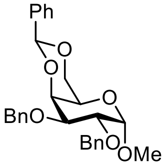
Scheme S12: *preparation of acceptor **25**: reagents and conditions: a) PhCH(OMe)$_2$, HBF$_4$-Et$_2$O, DMF, 89%; b) BnBr, NaH, DMF, 65%; c) PTSA, MeOH, 50 °C, 94%; d) BzCl, pyridine, DCM, 0 °C, 48%*

Methyl 4,6-*O*-benzylidene-α-D-galactopyranoside (S36)



Methyl-α-D-galactopyranoside (**S35**, 4.85 g, 25.0 mmol) was dissolved in 25 ml DMF and stirred until the sugar was fully dissolved. To the solution was added benzaldehyde dimethyl acetal (4.03 ml, 26.75 mmol, 1.07 eq) and HBF$_4$-Et$_2$O (3.43 ml, 25.0 mmol, 1 eq), the mixture was stirred for 4h at RT after which TLC indicated full conversion. The reaction mixture was quenched with TEA (4.2 ml, 50.0 mmol, 2 eq). Solvents were evaporated under reduced pressure and purification was performed on flash column chromatography (3/2pentane/EtOAc) to provide the title compound as a solid. Yield: 6.3 g, 22.3 mmol, 89%. ^{1}H NMR (400 MHz, CDCl$_3$) δ 8.01 – 7.33 (m, 5H, CH$_{arom}$), 5.55 (s, 1H, C*H*Ph), 4.91 (d, *J* = 3.2 Hz, 1H, H-1), 4.31 – 4.22 (m, 2H, H-2, H-6), 4.06 (d, *J* = 1.8 Hz, 1H, H-6), 3.99 – 3.88 (m, 2H, H-3, H-5), 3.68 (d, *J* = 1.6 Hz, 1H, H-4), 3.45 (s, 3H, CH$_3$ OMe); ^{13}C NMR (101 MHz, CDCl$_3$) δ 137.7 (C$_q$), 129.1, 128.2, 126.3 (CH$_{arom}$), 101.2 (CHPh), 100.4 (C-1), 76.0 (C-2), 69.7 (C-3), 69.6 (C-5), 69.4 (C-6), 62.7 (C-4), 55.7 (OMe). Data in agreement with literature.[69]

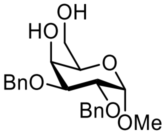
Methyl 2,3-di-*O*-benzyl-4,6-*O*-benzylidene-α-D-galactopyranoside (S37)



Methyl 4,6-di-*O*-benzylidene-α-D-galactopyranoside. (**S36**, 7.0 g, 24.8 mmol) was dissolved in 75 ml DMF and stirred at 0 °C until the sugar was fully dissolved. To the solution was added NaH

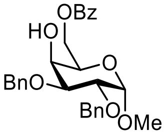
(60% dispersion in mineral oil, 2.98 g, 74.39 mmol, 3 eq) and the reaction was stirred for 30 min at 0 °C after which BnBr (8.84 ml, 74.39 mmol, 3 eq) was slowly added. After 30 min the temperature was increased to RT. Once TLC indicated full conversion the reaction mixture was quenched with water and extracted twice with Et_2O. The combined organic layers were dried over $MgSO_4$, filtered and concentrated under reduced pressure. Purification was performed on flash column chromatography (8/2 pentane/EtOAc) to provide the title compound as an oil. Yield: 11.47 g, 16.12 mmol, 65%. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.56 – 7.22 (m, 15H, CH_{arom}), 5.48 (s, 1H, C*H*Ph), 4.88 (d, *J* = 12.0 Hz, 1H, C*H*H Bn), 4.84 (d, *J* = 12.4 Hz, 1H, C*H*H Bn), 4.78 – 4.72 (m, 2H, CH*H* Bn, H-1), 4.68 (d, *J* = 12.0 Hz, 1H, CH*H* Bn), 4.21 (dd, *J* = 12.4, 1.6 Hz, 1H, H-6), 4.18 (dd, *J* = 3.5, 1.2 Hz, 1H, H-4), 4.06 (dd, *J* = 10.1, 3.5 Hz, 1H, H-3), 4.03 – 3.99 (m, 1H, H-6), 3.99 – 3.94 (m, 1H, H-2), 3.58 (q, *J* = 1.6 Hz, 1H, H-5), 3.38 (s, 3H, CH_3 OMe);^{13}C NMR (101 MHz, $CDCl_3$) δ 138.9, 138.7, 137.9 (C_q), 129.0, 128.5, 128.2, 128.2, 127.8, 127.8, 127.7, 126.5 (CH_{arom}), 101.2 (CHPh), 99.6 (C-1), 76.2 (C-2), 75.6 (C-3), 74.9 (C-4), 73.9 (CH_2 Bn), 72.3 (CH_2 Bn), 69.5 (C-6), 62.5 (C-5), 55.6 (CH_3 OMe). Data in agreement with literature.[70]

Methyl 2,3-di-*O*-benzyl-α-D-galactopyranoside (S38)



Methyl 2,3-di-*O*-benzyl-4,6-*O*-benzylidene-α-D-galactopyranoside (**S37**, 2.31 g, 5.0 mmol) was dissolved in 30 ml MeOH and stirred at RT for 15 min. To the solution was added pTsOH·H_2O (95.1 mg, 0.50 mmol, 0.1 eq) and the mixture was stirred for 1h at 50 °C after which TLC indicated full conversion. The reaction mixture was set to cool down to RT and was quenched with TEA. Solvents were evaporated under reduced pressure and purification was performed on flash column chromatography (3/2pentane/EtOAc) to provide the title compound as a solid. Yield: 1.75 g, 4.70 mmol, 94%. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.38 – 7.27 (m, 10H, CH_{arom}), 4.80 (dd, *J* = 11.8, 2.8 Hz, 2H, 2x C*H*H Bn), 4.72 – 4.63 (m, 3H, H-1, 2x CH*H* Bn), 4.03 (s, 1H, H-4), 3.90 – 3.84 (m, 3H, H-2, H-3, H-6), 3.79 – 3.71 (m, 2H, H-5, H-6), 3.37 (s, 3H, CH_3 OMe); ^{13}C NMR (101 MHz, $CDCl_3$) δ 138.3, 138.1 (C_q), 128.6, 128.5, 128.1, 128.0, °127.9 (CH_{arom}), 98.7 (C-1), 77.4 (C-2), 75.7 (C-3), 73.6, 73.0 (CH_2 Bn), 69.1 (C-4), 69.0 (C-5), 63.0 (C-6), 55.4 (CH_3 OMe). Data in agreement with literature.[71]

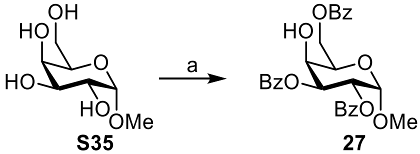
Methyl 6-*O*-benzoyl-2,3-di-*O*-benzyl-α-D-galactopyranoside (25)



Methyl 2,3-di-*O*-benzyl-α-D-galactopyranoside (**S38**, 0.75 g, 2.00 mmol) and pyridine (0.81 mL, 10.0 mmol, 5 eq) were dissolved in 6 mL DCM and cooled to 0 °C, after which BzCl (0.25 mL, 2.10 mmol, 1.05 eq) was added over 15 min. The reaction mixture was allowed to warm to RT overnight, before being diluted with DCM and washed with 1M HCl and sat. aq. $NaHCO_3$. The organic phase was dried with $MgSO_4$ and concentrated under reduced pressure. The residue was purified over silica (10% EtOAc in pentane) to yield the title compound as colourless oil. Yield:

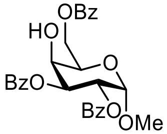
468 mg, 0.96 mmol, 48% ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.05 – 8.00 (m, 2H, CH_{arom}), 7.59 – 7.54 (m, 1H, CH_{arom}), 7.43 (dd, *J* = 8.3, 7.1 Hz, 2H, CH_{arom}), 7.39 – 7.27 (m, 10H, CH_{arom}), 4.87 – 4.78 (m, 2H, 2x C*H*H Bn), 4.71 (d, *J* = 11.6 Hz, 1H, CH*H* Bn), 4.69 – 4.65 (m, 2H, H-1, CH*H* Bn), 4.55 (dd, *J* = 11.5, 5.0 Hz, 1H, H-6), 4.49 (dd, *J* = 11.5, 7.4 Hz, 1H, H-6), 4.10 – 4.01 (m, 2H, H-4, H-5), 3.91 (dd, *J* = 9.7, 3.0 Hz, 1H, H-3), 3.86 (dd, *J* = 9.8, 3.3 Hz, 1H, H-2), 3.37 (s, 3H, CH_3 OMe), 2.55 (s, 1H, OH); ^{13}C NMR (101 MHz, $CDCl_3$) δ 166.5 (C=O), 138.4, 138.1 (C_q), 133.2 (CH_{arom}), 130.0 (C_q), 129.8, 128.7, 128.6, 128.5, 128.2, 128.1, 128.0, 128.0 (CH_{arom}), 98.6 (C-1), 77.5 (C-3), 75.7 (C-2), 73.7, 73.2 (CH_2 Bn), 68.0, 67.6 (C-4, C-5), 64.1 (C-6), 55.4 (CH_3 OMe). Spectra in agreement with literature.[72]

Preparation of acceptor **27**



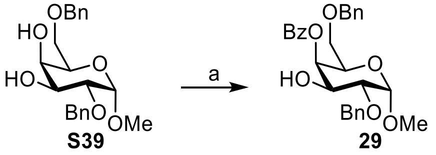
***Scheme S13**: preparation of acceptor **27**: reagents and conditions: a) BzCl, pyridine, 63%*

Methyl 2,3,6-tri-*O*-benzoyl-α-D-galactopyranoside (27)



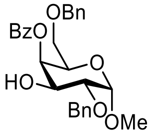
Methyl-α-D-galactopyranoside (**S35**, 0.78 g, 4.0 mmol) was dissolved in 20 ml pyridine and stirred at 0 °C until the sugar was fully dissolved. To the solution was added BzCl (2.14 ml, 18.4 mmol, 4.6 eq) over a 30 min time frame and the reaction was stirred for 4 h at RT after which TLC indicated full conversion. The reaction mixture was quenched with H_2O and extracted with Toluene. The organic layer was washed twice with aq. 1M HCl solution and once with aq. Bicarb solution. The organic layer was dried over $MgSO_4$, filtered and concentrated under reduced pressure. Purification was performed on flash column chromatography (9/1 pentane/EtOAc → 8/2 pentane/EtOAc) to provide the title compound as an oil. Yield: 1.28 g, 2.54 mmol, 63%. ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.16 – 7.88 (m, 6H, CH_{arom}), 7.58 (ddt, *J* = 8.8, 6.9, 1.3 Hz, 1H, CH_{arom}), 7.54 – 7.48 (m, 2H, CH_{arom}), 7.47 – 7.42 (m, 2H, CH_{arom}), 7.37 (td, *J* = 7.8, 1.6 Hz, 4H, CH_{arom}) 5.76 (dd, *J* = 10.7, 3.0 Hz, 1H, H-3), 5.69 (dd, *J* = 10.7, 3.5 Hz, 1H, H-2), 5.22 (d, *J* = 3.6 Hz, 1H, H-1), 4.68 (dd, *J* = 11.5, 5.8 Hz, 1H, H-6), 4.57 (dd, *J* = 11.4, 6.9 Hz, 1H, H-6), 4.41 (d, *J* = 1.8 Hz, 1H, H-4), 4.36 (t, *J* = 6.3 Hz, 1H, H-5), 3.45 (s, 3H, CH_3 OMe), 2.68 (s, 1H, OH); ^{13}C NMR (101 MHz, $CDCl_3$) δ 166.6, 166.2, 165.9 (C=O), 133.6, 133.4, 133.4, 129.9, 129.9, 129.8 (CH_{arom}), 129.7, 129.5, 129.4 (C_q), 128.6, 128.5 (CH_{arom}), 97.7 (C-1), 70.9 (C-3), 69.0 (C-2), 68.3 (C-4), 67.8 (C-5), 63.5 (C-6), 55.6 (CH_3 OMe). Data in agreement with literature.[73]

Preparation of acceptor **29**



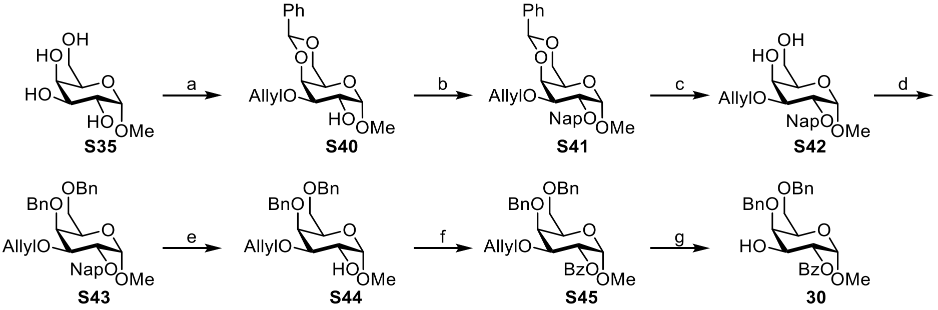
***Scheme S14**: preparation of acceptor **29**: reagents and conditions: a) Benzoyl cyanide, DMAP, DCM, - 78 °C, 65%*

Methyl 4-*O*-benzoyl-2,6-di-*O*-benzyl-α-D-galactopyranoside (29)



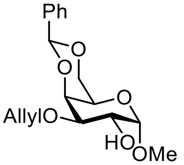
Methyl 2,6-di-*O*-benzyl-α-D-galactopyranoside[74] (**S39**, 1.30 g, 3.47 mmol) was dissolved in 20 ml anhydrous DCM. The solution was cooled down to -78 °C and BzCN (0.46 g, 3.47 mmol, 1 eq) and DMAP (43.4 mg, 0.35 mmol, 0.1 eq) were added. After 4 h TLC indicated full conversion and the reaction was quenched with aq. NH_4Cl, filtered over a celite pad and extracted with DCM. The organic phase was washed twice with aq. $Na_2S_2O_3$. The organic layer was dried over $MgSO_4$, filtered and concentrated under reduced pressure. Purification was performed on flash column chromatography (3/1 pentane/EtOAc) to provide the title compound as an oil. Yield: 1.08 g, 2.26 mmol, 65%. $[\alpha]_D^{25}$ = +46.5° (c = 0.60, $CHCl_3$); IR (thin film): 412, 699, 714, 738, 985, 1027, 1046, 1097, 1177, 1193, 1272, 1313, 1349, 1452, 1720; ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.09 – 7.98 (m, 2H, CH_{arom}), 7.65 – 7.51 (m, 1H, CH_{arom}), 7.48 – 7.40 (m, 2H, CH_{arom}), 7.42 – 7.25 (m, 5H, CH_{arom}), 7.26 – 7.13 (m, 4H, CH_{arom}), 5.66 (dd, *J* = 3.6, 1.3 Hz, 1H, H-4), 4.81 (d, *J* = 3.5 Hz, 1H, H-1), 4.74 (d, *J* = 12.0 Hz, 1H, C*H*H Bn), 4.68 (d, *J* = 12.0 Hz, 1H, CH*H* Bn), 4.50 (d, *J* = 11.8 Hz, 1H, C*H*H Bn), 4.40 (d, *J* = 11.8 Hz, 1H, CH*H* Bn), 4.27 (dt, *J* = 10.0, 3.2 Hz, 1H, H-3), 4.17 (td, *J* = 6.1, 1.3 Hz, 1H, H-5), 3.82 (dd, *J* = 10.0, 3.5 Hz, 1H, H-2), 3.55 (d, *J* = 6.2 Hz, 2H, 2x H-6), 3.40 (s, 3H, CH_3 OMe), 2.41 (d, *J* = 3.0 Hz, 1H, OH); ^{13}C NMR (101 MHz, $CDCl_3$) δ 166.4 (C=O), 138.0, 137.8 (C_q), 133.3, 130.0 (CH_{arom}), 129.9 (C_q), 128.6, 128.5, 128.4, 128.3, 128.2, 127.7 (CH_{arom}), 98.2 (C-1), 76.8 (C-2), 73.6 73.2 (CH_2 Bn), 71.4 (C-4), 68.9 (C-6), 68.5 (C-3), 68.2 (C-5), 55.6 (CH_3 OMe); HRMS: $[M+Na]^+$ calcd for $C_{28}H_{30}O_7$ 501.18837, found 501.18754.

Preparation of acceptor **30**



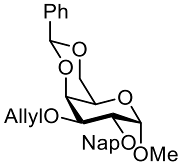
***Scheme S15**: preparation of acceptor **30**: reagents and conditions: a) i: DBTO, toluene reflux, ii: allyl bromide, TBAI, toluene, 75 °C, iii: $PhCH(OCH_3)_2$, PTSA, acetonitrile, 60 °C, 300 mbar, 27% over 3 steps; b) NapBr, NaH, DMF, 81%; c) PTSA, MeOH, 50 °C, 82%; d) BnBr, NaH, DMF, 86%; e) DDQ, DCM/H_2O (9:1), 79%; f) BzCl, pyridine, 90%; g) $Pd(Ph_3P)_4$, DMBA, MeOH, 40 °C, quant*

Methyl 3-*O*-allyl-4,6-*O*-benzylidene-α-D-galactopyranoside (S40)



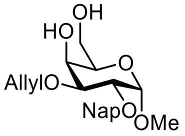
Methyl α-D-galactopyranoside (**S35**, 9.71 g, 50 mmol) and di-n-butyltin oxide (13.7 g, 55 mmol, 1.1 eq) were refluxed in toluene for 3 hr, while water was removed with a Dean-Stark trap. After this, the reaction mixture was cooled to 60 °C and TBAI (20.3 g, 55 mmol, 1.1 eq) and allyl bromide (5.18 mL, 60 mmol, 1.2 eq) were added. The reaction mixture was stirred overnight at this temperature and subsequently concentrated under reduced pressure. Silica chromatography (4% MeOH in DCM) yields impure Methyl 3-*O*-allyl-α-D-galactopyranoside (9.9 g, max. 42.3 mmol, 85%) as red oil. This was dissolved in acetonitrile with PTSA-H_2O (0.80 g, 4.23 mmol, ca. 0.1 eq) and benzaldehyde dimethyl acetal (8.92 mL, 59.2 mmol, ca. 1.4 eq). The reaction mixture was heated to 60 °C at 300 mbar until TLC showed full conversion. The reaction was then concentrated under reduced pressure. The residue was dissolved in EtOAc and washed with sat. aq. $NaHCO_3$. The organic phase was dried with $MgSO_4$ and concentrated under reduced pressure. Recrystallisation from EA/pentane yields the title compound as yellowish solid. Yield: 4.3 g, 13.3 mmol, 27% based on **S35**. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.59 – 7.48 (m, 2H, CH$_{\text{arom}}$), 7.45 – 7.30 (m, 3H, CH$_{\text{arom}}$), 5.99 (ddt, *J* = 17.3, 10.3, 5.8 Hz, 1H, CH$_2$-C*H*=CH$_2$), 5.57 (s, 1H, C*H*Ph), 5.35 (dq, *J* = 17.3, 1.6 Hz, 1H, CH$_2$-CH=C*H*H), 5.23 (dq, *J* = 10.3, 1.3 Hz, 1H, CH$_2$-CH=CH*H*), 4.97 (d, *J* = 3.7 Hz, 1H, H-1), 4.34 (dd, *J* = 3.5, 1.2 Hz, 1H, H-4), 4.30 (dd, *J* = 12.5, 1.6 Hz, 1H, H-6), 4.30 – 4.21 (m, 1H, C*H*H-CH=CH$_2$), 4.24 – 4.14 (m, 2H, H-2, CH*H*-CHCH$_2$), 4.10 (dd, *J* = 12.5, 1.8 Hz, 1H, H-6), 3.76 (dd, *J* = 10.1, 3.5 Hz, 1H, H-3), 3.68 (q, *J* = 1.6 Hz, 1H, H-5), 3.48 (s, 3H, CH$_3$ OMe); ^{13}C NMR (101 MHz, $CDCl_3$) δ 137.8 (C$_q$), 135.0(CH$_2$-*C*H=CH$_2$), 129.0, 128.2, 126.4 (CH$_{\text{arom}}$), 117.7 CH$_2$-CH=*C*H$_2$), 101.1 (CHPh), 100.2 (C-1), 76.1 (C-3), 73.7 (C-4), 70.6 (*C*H$_2$-CH=CH$_2$), 69.6 (C-6), 68.0 (C-2), 62.9 (C-5), 55.7 (CH$_3$ OMe). Spectra in agreement with literature.[75]

Methyl 3-*O*-allyl-4,6-*O*-benzylidene-2-*O*-(2-naphtyl)methyl-α-D-galactopyranoside (S41)



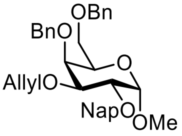
Methyl 3-*O*-allyl-4,6-*O*-benzylidene-α-D-galactopyranoside (**S40**, 4.25 g, 13.18 mmol) was dissolved in 50 ml DMF and stirred at 0 °C until the sugar was fully dissolved. To the solution was added NaH (60 % dispersion in mineral oil, 0.69 g, 17.14 mmol, 1.3 eq) and the mixture was stirred for another 15 min before slowly adding NapBr (3.79 g, 17.14 mmol, 1.3 eq) and the reaction was stirred at RT until TLC indicated full conversion. The reaction mixture was quenched with H_2O and extracted with Et_2O. The organic layer was washed twice with H_2O. The organic layer was dried over $MgSO_4$, filtered and concentrated under reduced pressure. Purification was performed on flash column chromatography (8/2 pentane/EtOAc) to provide the title compound as an oil. Yield: 4.85 g, 10.48 mmol, 81%. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.85 – 7.77 (m, 4H, CH_{arom}), 7.55 – 7.43 (m, 5H, CH_{arom}), 7.35 – 7.28 (m, 3H, CH_{arom}), 6.07 – 5.92 (m, 1H, CH_2-C*H*=CH_2), 5.53 (s, 1H, C*H*Ph), 5.36 (dq, *J* = 17.2, 1.6 Hz, 1H, CH_2-CH=C*H*H), 5.20 (dq, *J* = 10.4, 1.4 Hz, 1H, CH_2-CH=CH*H*), 5.06 – 4.97 (m, 1H, C*H*H Nap), 4.82 (d, *J* = 12.2 Hz, 1H, CH*H* Nap), 4.77 (d, *J* = 3.5 Hz, 1H, H-1), 4.35 – 4.24 (m, 2H, H-4, CH_2-CH=CH_2), 4.21 (dd, *J* = 12.5, 1.6 Hz, 1H, H-6), 4.08 (dd, *J* = 10.1, 3.6 Hz, 1H, H-2), 4.03 (dd, *J* = 12.5, 1.8 Hz, 1H, H-6), 3.95 (dd, *J* = 10.2, 3.4 Hz, 1H, H-3), 3.62 (d, *J* = 1.5 Hz, 1H, H-5), 3.39 (s, 3H, CH_3 OMe); ^{13}C NMR (101 MHz, $CDCl_3$) δ 137.9, 136.1 (C_q), 135.4 (CH_2-CH=CH_2), 133.3, 133.1 (C_q), 129.0, 128.2, 128.0, 127.8, 127.0, 126.5, 126.2, 126.1, 126.0 (CH_{arom}), 117.2 (CH_2-CH=CH_2), 101.3 (CHPh), 99.6 (C-1), 75.6 (C-3), 75.5 (C-2), 75.1 (C-4), 74.0 (CH_2 Nap), 71.6 (CH_2-CH=CH_2), 69.5 (C-6), 62.7 (C-5), 55.7 (CH_3 OMe); HRMS: $[M+NH_4]^+$ calcd for $C_{28}H_{30}O_6NH_4$ 480.23806, found 480.23749.

Methyl 3-*O*-allyl-2-*O*-(2-naphtyl)methyl-α-D-galactopyranoside (S42)



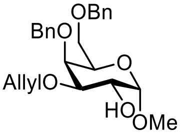
Methyl 3-*O*-allyl-4,6-di-*O*-benzylidene-2-*O*-(2-naphtyl)methyl-α-D-galactopyranoside (**S41**, 4.76 g, 10.3 mmol) was dissolved in 50 ml MeOH and stirred at RT for 15 min. To the solution was added pTsOH·H_2O (0.20 g, 1.03 mmol, 0.1 eq) and the mixture was stirred for 1h at 50 °C after which TLC indicated full conversion. The reaction mixture was set to cool down to RT and was quenched with TEA. Solvents were evaporated under reduced pressure and purification was performed on flash column chromatography (1/1 pentane/EtOAc) to provide the title compound as a solid. Yield: 3.17 g, 8.46 mmol, 82 %. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.86 – 7.77 (m, 4H, CH_{arom}), 7.54 – 7.43 (m, 3H, CH_{arom}), 5.96 (ddt, *J* = 17.3, 10.4, 5.7 Hz, 1H, CH_2-C*H*=CH_2), 5.33 (dq, *J* = 17.2, 1.6 Hz, 1H, CH_2-CH=C*H*H), 5.22 (dq, *J* = 10.3, 1.3 Hz, 1H, CH_2-CH=CH*H*), 4.95 (d, *J* = 12.3, 1H, C*H*H Nap), 4.81 (d, *J* = 12.3 Hz, 1H, CH*H* Nap), 4.69 (d, *J* = 3.3 Hz, 1H, H-1), 4.29 (ddt, *J* = 12.7, 5.4, 1.5 Hz, 1H, C*H*H-CH=CH_2), 4.22 (ddt, *J* = 12.7, 5.9, 1.4 Hz, 1H, CH*H*-CH=CH_2), 4.10 (dd, *J* = 3.1, 1.3 Hz, 1H, H-4), 3.91 (dd, *J* = 12.7, 6.9 Hz, 1H, H-6), 3.87 – 3.80 (m, 2H, H-2, H-3), 3.80 – 3.76 (m, 2H, H-5, H-6), 3.38 (s, 3H, CH_3 OMe), 2.72 (s, 1H, OH), 2.37 (s, 1H, OH); ^{13}C NMR (101 MHz, $CDCl_3$) δ 135.9 (C_q), 134.7(CH_2-*C*H=CH_2), 133.3, 133.2 (C_q), 128.3, 128.0, 127.8, 126.9, 126.3, 126.1, 126.1 (CH_{arom}), 117.6 (CH_2-CH=*C*H_2), 98.7 (C-1), 76.9 (C-3), 75.5 (C-2), 73.8 (CH_2 Nap), 71.8 (*C*H_2-CH=CH_2), 69.2 (C-4), 69.0 (C-5), 63.2 (C-6), 55.5 (CH_3 OMe); HRMS: $[M+Na]^+$ calcd for $C_{21}H_{26}O_6Na$ 397.16216, found 397.16144.

Methyl 3-*O*-allyl-4,6-di-*O*-benzyl-2-*O*-(2-naphtyl)methyl-α-D-galactopyranoside (S43)



Methyl 3-*O*-allyl-2-*O*-(2-naphtyl)methyl-α-D-galactopyranoside (**S42**, 2.62 g, 7.0 mmol, 1 eq) was dissolved in 40 ml DMF and stirred at 0 °C until the sugar was fully dissolved. To the solution was added NaH (60% dispersion in mineral oil, 0.84 g, 21.0 mmol, 3 eq) and the reaction was stirred for 30 min at 0 °C after which BnBr (2.49 ml, 21.0 mmol, 3 eq) was slowly added. After 30 min the temperature was increased to RT. Once TLC indicated full conversion the reaction mixture was quenched with water and extracted twice with Et_2O. The combined organic layers were dried over $MgSO_4$, filtered and concentrated under reduced pressure. Purification was performed on flash column chromatography (9/1 pentane/EtOAc) to provide the title compound as an oil. Yield: 3.35 g, 6.02 mmol, 86%. ^1H NMR (400 MHz, $CDCl_3$) δ 7.85 – 7.76 (m, 4H, CH_{arom}), 7.55 – 7.42 (m, 3H, CH_{arom}), 7.38 – 7.21 (m, 10H, CH_{arom}) , 5.99 (ddt, *J* = 17.3, 10.5, 5.3 Hz, 1H, CH_2-C*H*=CH_2), 5.37 (dq, *J* = 17.2, 1.8 Hz, 1H, CH_2-CH=C*H*H), 5.20 (dq, *J* = 10.4, 1.5 Hz, 1H, CH_2-CH=CH*H*), 4.98 (d, *J* = 12.3 Hz, 1H, C*H*H Bn), 4.94 (d, *J* = 11.4 Hz, 1H, C*H*H Nap), 4.84 (d, *J* = 12.3 Hz, 1H, CH*H* Bn), 4.67 (d, *J* = 3.6 Hz, 1H, H-1), 4.56 (d, *J* = 11.4 Hz, 1H, CH*H* Nap), 4.47 (d, *J* = 11.8 Hz, 1H, C*H*H Bn), 4.39 (d, *J* = 11.8 Hz, 1H, CH*H* Bn), 4.32 (ddt, *J* = 13.0, 5.1, 1.6 Hz, 1H, C*H*H-CH=CH_2), 4.23 (ddt, *J* = 13.0, 5.4, 1.6 Hz, 1H, CH*H*-CH=CH_2), 4.03 (dd, *J* = 10.1, 3.7 Hz, 1H, H-2), 3.93 (d, *J* = 2.8 Hz, 1H, H-4), 3.89 (t, *J* = 6.5 Hz, 1H, H-5), 3.84 (dd, *J* = 10.1, 2.9 Hz, 1H, H-3), 3.51 (d, *J* = 6.5 Hz, 2H, 2x H-6), 3.36 (s, 3H, CH_3 OMe); ^{13}C NMR (101 MHz, $CDCl_3$) δ 138.8, 138.1, 136.2 (C_q), 135.3 (CH_2-*C*H=CH_2), 133.4, 133.2 (C_q), 128.5, 128.4, 128.3, 128.2, 128.1, 127.9, 127.8, 127.8, 127.7, 126.9, 126.2, 126.1, 125.9 (CH_{arom}), 116.6 (CH_2-CH=*C*H_2), 98.9 (C-1), 78.7 (C-3), 76.4 (C-2), 75.0 (C-4), 74.8 (CH_2 Nap), 73.8 (CH_2 Bn), 73.6 (CH_2 Bn), 72.0 (*C*H_2-CH=CH_2), 69.3 (C-5), 69.2 (C-6), 55.5 (CH_3 OMe); HRMS: $[M+NH_4]^+$ calcd for $C_{35}H_{38}O_6$ 572.30066, found 572.29988.

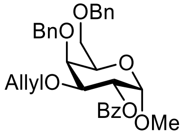
Methyl 3-*O*-allyl-4,6-di-*O*-benzyl-α-D-galactopyranoside (S44)



Methyl 3-*O*-allyl-4,6-di-*O*-benzyl-2-*O*-(2-naphtyl)methyl-α-D-galactopyranoside (**S43**, 1.66 g, 3.0 mmol) was dissolved in 30 ml 9/1 DCM/H_2O and stirred at RT until the sugar was fully dissolved. To the solution was added DDQ (1.36 g, 3.0 mmol, 2 eq) and the reaction was stirred for 60 min at RT after which TLC indicated full conversion. The reaction mixture was quenched with aq. Bicarb solution and extracted with DCM. The organic layer was washed twice with aq.

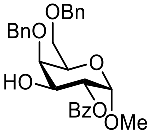
Bicarb solution. The organic layer was dried over MgSO$_4$, filtered and concentrated under reduced pressure. Purification was performed on flash column chromatography (7/3 pentane/EtOAc) to provide the title compound as an oil. Yield: 0.973 g, 2.36 mmol, 79%. ^{1}H NMR (400 MHz, CDCl$_3$) δ 7.41 – 7.17 (m, 10H, CH$_{\text{arom}}$), 5.94 (ddt, *J* = 17.2, 10.4, 5.6 Hz, 1H, CH$_2$-C*H*=CH$_2$), 5.32 (dq, *J* = 17.2, 1.6 Hz, 1H, CH$_2$-CH=C*H*H), 5.20 (dq, *J* = 10.4, 1.4 Hz, 1H, CH$_2$-CH=CH*H*), 4.87 (d, *J* = 11.4 Hz, 1H, C*H*H Bn), 4.84 (d, *J* = 3.9 Hz, 1H, H-1), 4.56 (d, *J* = 11.4 Hz, 1H, CH*H* Bn), 4.52 (d, *J* = 11.7 Hz, 1H, C*H*H Bn), 4.44 (d, *J* = 11.7 Hz, 1H, CH*H* Bn), 4.18 (ddt, *J* = 12.7, 5.5, 1.5 Hz, 1H, C*H*H-CH=CH$_2$), 4.17 – 4.07 (m, 2H, H-2, CH*H*-CH=CH$_2$), 3.95 (dd, *J* = 2.9, 1.3 Hz, 1H, H-4), 3.90 (t, *J* = 2.7 Hz, 1H, H-5), 3.64 – 3.52 (m, 3H, H-3, 2x H-6), 3.42 (s, 3H, CH$_3$ OMe), 2.22 (d, *J* = 7.1 Hz, 1H, OH); ^{13}C NMR (101 MHz, CDCl$_3$) δ 138.6, 138.0 (C$_q$), 134.7 (CH$_2$-*C*H=CH$_2$), 128.6, 128.4, 128.3, 127.9, 127.9, 127.8 (CH$_{\text{arom}}$), 117.4 (CH$_2$-CH=*C*H$_2$), 99.7 (C-1), 79.1 (C-3), 74.7 (CH$_2$ Bn), 73.7 (C-4), 73.7 (CH$_2$ Bn), 71.2 (*C*H$_2$-CH=CH$_2$), 69.7 (C-5), 69.1 (C-6), 68.9 (C-2), 55.6 (OMe); HRMS: [M+Na]$^+$ calcd for $C_{24}H_{30}O_6Na$ 437.19346, found 437.19295.

Methyl 3-*O*-allyl-2-*O*-benzoyl-4,6-di-*O*-benzyl-α-D-galactopyranoside (S45)



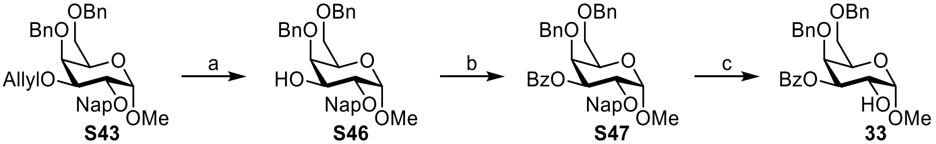
Methyl 3-*O*-allyl-4,6-di-*O*-benzyl-α-D-galactopyranoside (**S44**, 0.92 g, 2.22 mmol) was dissolved in 25 ml pyridine and stirred at 0 °C until the sugar was fully dissolved. To the solution was added BzCl (0.35 ml, 2.89 mmol, 1.3 eq) and the reaction was stirred for 30 min at 0 °C after which the temperature was increased to RT. Once TLC indicated full conversion the reaction mixture was diluted with EtOAc and washed twice with 1M HCl and once with sat. aq. NaHCO$_3$. The organic layer was dried over MgSO$_4$, filtered and concentrated under reduced pressure. Purification was performed on flash column chromatography (9/1 pentane/EtOAc) to provide the title compound as a light-yellow oil. Yield: 1.04 g, 2.0 mmol, 90%. ^{1}H NMR (400 MHz, CDCl$_3$) δ 8.12 – 8.05 (m, 2H, CH$_{\text{arom}}$), 7.61 – 7.52 (m, 1H, CH$_{\text{arom}}$), 7.49 – 7.40 (m, 2H, CH$_{\text{arom}}$), 7.39 – 7.24 (m, 10H, CH$_{\text{arom}}$), 5.94 – 5.79 (m, 1H, CH$_2$-C*H*=CH$_2$), 5.49 (dd, *J* = 10.2, 3.7 Hz, 1H, H-2), 5.28 (dq, *J* = 17.2, 1.7 Hz, 1H, CH$_2$-CH=C*H*H), 5.14 (dq, *J* = 10.4, 1.4 Hz, 1H, CH$_2$-CH=CH*H*), 5.10 (d, *J* = 3.7 Hz, 1H, H-1), 4.97 (d, *J* = 11.5 Hz, 1H, C*H*H Bn), 4.60 (d, *J* = 11.5 Hz, 1H, CH*H* Bn), 4.52 (d, *J* = 11.7 Hz, 1H, C*H*H Bn), 4.44 (d, *J* = 11.7 Hz, 1H, CH*H* Bn), 4.17 (d, *J* = 5.5 Hz, 1H, C*H*$_2$-CH=CH$_2$), 4.06 – 3.95 (m, 3H, H-3, H-4, H-5), 3.68 – 3.57 (m, 2H, 2x H-6), 3.35 (s, 3H, CH$_3$ OMe); ^{13}C NMR (101 MHz, CDCl$_3$) δ 166.2 (C=O), 138.6, 138.1 (C$_q$), 134.8 (CH$_2$-*C*H=CH$_2$), 133.1 (CH$_{\text{arom}}$), 130.3 (C$_q$), 129.9, 128.6, 128.5, 128.4, 128.4, 128.0, 127.9, 127.8 (CH$_{\text{arom}}$), 117.2 (CH$_2$-CH=*C*H$_2$), 97.7 (C-1), 76.6 (C-4), 74.9 (CH$_2$ Bn), 74.7 (C-3), 73.7 (CH$_2$ Bn), 71.9 (*C*H$_2$-CH=CH$_2$) 71.9 (C-2), 69.4 (C-5), 69.1 (C-6), 55.5 (CH$_3$ OMe); HRMS: [M+NH$_4$]$^+$ calcd for $C_{31}H_{34}O_7NH_4$ 536.26428, found 536.26380.

Methyl 2-*O*-benzoyl-4,6-di-*O*-benzyl-α-D-galactopyranoside (30)



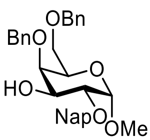
Methyl 2-*O*-benzoyl-3-*O*-allyl-4,6-di-*O*-benzyl-α-D-galactopyranoside (**S45**, 0.95 g, 1.83 mmol) and DMBA (0.57 g, 3.66 mmol, 2 eq) were dissolved in 20 ml MeOH and flushed for 30 min with N_2. To the solution was added $Pd(PPh_3)_4$ (0.11 g, 0.09 mmol, 0.05 eq) and the mixture was heated for 1h at 40 °C, after which TLC indicated full conversion. The mixture was diluted in EtOAc and washed with saturated Bicarb sol. The aqueous layer was extracted three times with EtOAc. The combined organic layers were dried over $MgSO_4$, filtered and concentrated under reduced pressure. Purification was performed on flash column chromatography (8/2 pentane/EtOAc) to provide the title compound as a yellow oil. Yield: 0.88 g, 1.83 mmol, quant. $[\alpha]_D^{25}$ = +168.6° (*c* = *0.6*, $CHCl_3$); IR (thin film): 698, 714, 1048, 1103, 1280, 1717; ^1H NMR (400 MHz, $CDCl_3$) δ 8.10 – 8.05 (m, 2H, CH_{arom}), 7.59 – 7.53 (m, 1H, CH_{arom}), 7.46 – 7.39 (m, 2H, CH_{arom}), 7.39 – 7.27 (m, 10H, CH_{arom}), 5.25 (dd, *J* = 10.3, 3.7 Hz, 1H, H-2), 5.02 (d, *J* = 3.7 Hz, 1H, H-1), 4.73 (s, 1H, CH_2 Bn), 4.58 (d, *J* = 11.7 Hz, 1H, C*H*H Bn), 4.50 (d, *J* = 11.7 Hz, 1H, CH*H* Bn), 4.17 (ddd, *J* = 10.3, 9.3, 3.5 Hz, 1H, H-3), 4.10 – 4.04 (m, 1H, H-5), 4.02 (dd, *J* = 3.6, 1.2 Hz, 1H, H-4), 3.75 – 3.59 (m, 2H, 2x H-6), 3.38 (s, 3H, CH_3 OMe), 2.17 (d, *J* = 9.4 Hz, 1H, OH); ^{13}C NMR (101 MHz, $CDCl_3$) δ 167.0 (C=O), 138.2, 137.9 (C_q), 133.4, 130.1 (CH_{arom}), 129.9 (C_q), 128.7, 128.6, 128.5, 128.2, 128.1, 128.0, 128.0 (CH_{arom}), 97.8 (C-1), 77.7 (C-4), 75.6 (CH_2 Bn), 73.7 (CH_2 Bn), 72.9 (C-2), 69.0, 68.9 (C-3, C-5), 68.7 (C-6), 55.6 (CH_3 OMe); HRMS: $[M+NH_4]^+$ calcd for $C_{28}H_{30}O_7NH_4$ 496.23298, found 496.23242.

Preparation of acceptor **33**



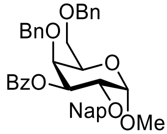
***Scheme S16**: preparation of acceptor **33**: reagents and conditions: a) $Pd(Ph_3P)_4$, DMBA, methanol, 40 °C, 95%; b) BzCl, pyridine, 97%; c) DDQ, DCM/H_2O (9:1), 84%*

Methyl 4,6-di-*O*-benzyl-2-*O*-(2-naphtyl)methyl-α-D-galactopyranoside (S46)



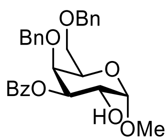
3-*O*-allyl-4,6-di-*O*-benzyl-2-*O*-(2-naphtyl)methyl-α-D-galactopyranoside (**S43** 1.59 g, 2.87 mmol) and DMBA (0.90 g, 5.73 mmol, 2 eq) where dissolved in 50 ml MeOH and flushed for 30 min with N_2. To the solution was added $Pd(PPh_3)_4$ (0.17 g, 0.14 mmol, 0.05 eq) and the mixture was heated for 1h at 40 °C, after which TLC indicated full conversion. The mixture was diluted in EtOAc and washed with saturated aq. Bicarb sol. The aqueous layer was extracted three times with EtOAc. The combined organic layers were dried over $MgSO_4$, filtered and concentrated under reduced pressure. Purification was performed on flash column chromatography (17/3 pentane/EtOAc) to provide the title compound as a yellow oil. Yield: 1.40 g, 2.72 mmol, 95%. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.86 – 7.78 (m, 4H, CH_{arom}), 7.53 – 7.46 (m, 3H, CH_{arom}), 7.35 – 7.22 (m, 5H, CH_{arom}), 4.88 (d, *J* = 12.2 Hz, 1H, C*H*H Bn/Nap), 4.85 – 4.76 (m, 2H, CH*H* Bn/Nap, C*H*H Bn/Nap), 4.69 (d, *J* = 3.5 Hz, 1H, H-1), 4.60 (d, *J* = 11.5 Hz, 1H, CH*H* Bn/Nap), 4.51 (d, *J* = 11.8 Hz, 1H, C*H*H Bn/Nap), 4.42 (d, *J* = 11.8 Hz, 1H, CH*H* Bn/Nap), 4.08 (ddd, *J* = 10.0, 4.9, 3.2 Hz, 1H, H-3), 3.98 – 3.91 (m, 2H, H-4, H-5), 3.84 (dd, *J* = 10.0, 3.5 Hz, 1H, H-2), 3.55 (d, *J* = 6.4 Hz, 2H, 2x H-6), 3.32 (s, 3H, CH_3 OMe), 2.26 (d, *J* = 4.9 Hz, 1H, OH); ^{13}C NMR (101 MHz, $CDCl_3$) δ 138.5, 138.0, 135.7, 133.3, 133.3 (C_q), 128.5, 128.5, 128.3, 128.1, 127.9, 127.8, 127.2, 126.3, 126.2, 126.1 (CH_{arom}), 98.1 (C-1), 77.5 (C-2), 76.8 (C-4), 75.3, 73.6, 73.3 (CH_2 Bn, CH_2 Nap), 70.4 (C-3), 69.2 (C-5), 69.1 (C-6), 55.5 (CH_3 OMe). HRMS: $[M+Na]^+$ calcd for $C_{32}H_{34}O_6Na$ 537.22531, found 537.22250.

Methyl 3-*O*-benzoyl-4,6-di-*O*-benzyl-2-*O*-(2-naphtyl)methyl-α-D-galactopyranoside (S47)



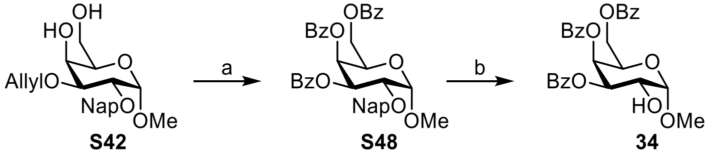
Methyl 4,6-di-*O*-benzyl-2-*O*-(2-naphtyl)methyl-α-D-galactopyranoside (**S46**, 1.30 g, 2.53 mmol) was dissolved in 25 ml pyridine and stirred at 0 °C until the sugar was fully dissolved. To the solution was added BzCl (0.38 ml, 3.28 mmol, 1.3 eq) and the reaction was stirred for 30 min at 0 °C after which the temperature was increased to RT. Once TLC indicated full conversion the reaction mixture was diluted with EtOAc and washed twice with 1M HCl. The organic layer was dried over $MgSO_4$, filtered and concentrated under reduced pressure. Purification was performed on flash column chromatography (9/1 pentane/EtOAc) to provide the title compound as a light-yellow oil. Yield: 1.51 g, 2.45 mmol, 97%. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.96 (dd, *J* = 8.3, 1.4 Hz, 2H, CH_{arom}), 7.82 – 7.75 (m, 1H, CH_{arom}), 7.75 – 7.65 (m, 3H, CH_{arom}), 7.55 (ddt, *J* = 8.7, 7.1, 1.3 Hz, 1H, CH_{arom}), 7.49 – 7.41 (m, 2H, CH_{arom}), 7.41 – 7.37 (m, 3H, CH_{arom}), 7.36 – 7.24 (m, 5H, CH_{arom}), 7.20 – 7.08 (m, 5H, CH_{arom}), 5.59 (dd, *J* = 10.6, 3.1 Hz, 1H, H-3), 4.83 (d, *J* = 3.7 Hz, 2H, H-1, CH_2 Bn/Nap), 4.62 (d, *J* = 11.4 Hz, 1H, C*H*H Bn/Nap), 4.51 (d, *J* = 11.9 Hz, 1H, C*H*H Bn/Nap), 4.45 – 4.36 (m, 2H, 2x CH*H* Bn/Nap), 4.24 (dd, *J* = 10.5, 3.6 Hz, 1H, H-2), 4.16 (dd, *J* = 3.1, 1.3 Hz, 1H, H-4), 4.12 (t, *J* = 6.5, 1.3 Hz, 1H, H-5), 3.55 (dd, *J* = 6.6, 1.2 Hz, 2H, 2x H-6), 3.43 (s, 3H, CH_3 OMe); ^{13}C NMR (101 MHz, $CDCl_3$) δ 165.9 (C=O), 138.0, 138.0, 135.7, 133.3 (C_q), 133.2 (CH_{arom}), 133.2, 130.0 (C_q), 129.9, 128.5, 128.4, 128.3, 128.1, 128.1, 127.8, 127.8, 127.0, 126.2, 126.1, 126.0 (CH_{arom}), 98.6 (C-1), 75.7 (C-4), 75.3 (CH_2 Bn/Nap), 74.3 (C-2), 73.5, 73.4 (CH_2 Bn/Nap), 73.0 (C-3), 68.9 (C-5), 68.7 (C-6), 55.6 (CH_3 OMe); HRMS: $[M+NH_4]^+$ calcd for $C_{39}H_{38}O_7NH_4$ 636.29558, found 636.29474.

Methyl 3-*O*-benzoyl-4,6-di-*O*-benzyl-α-D-galactopyranoside (33)



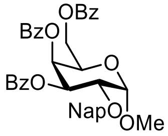
Methyl 3-*O*-benzoyl-4,6-di-*O*-benzyl-2-*O*-(2-naphtyl)methyl-α-D-galactopyranoside (**S47**, 1.45 g, 2.34 mmol) was dissolved in 25 ml 9/1 DCM/H_2O and stirred at RT until the sugar was fully dissolved. To the solution was added DDQ (1.06 g, 4.69 mmol, 2 eq) and the reaction was stirred for 60 min at RT after which TLC indicated full conversion. The reaction mixture was quenched with aq. Bicarb solution and extracted with DCM. The organic layer was washed twice with aq. Bicarb solution. The organic layer was dried over $MgSO_4$, filtered and concentrated under reduced pressure. Purification was performed on flash column chromatography (3/1 pentane/EtOAc) to provide the title compound as a solid. Yield: 0.94 g, 1.96 mmol, 84%. $[\alpha]_D^{25}$= +97.9° (c = 0.60, $CHCl_3$); IR (thin film): 698, 738, 1027, 1056, 1070, 1094, 1124, 1149, 1273, 1315, 1352, 1452, 1717; ^1H NMR (400 MHz, $CDCl_3$) δ 8.10 – 8.03 (m, 2H, CH_{arom}), 7.57 (ddt, *J* = 8.7, 7.1, 1.3 Hz, 1H, CH_{arom}), 7.48 – 7.38 (m, 2H, CH_{arom}), 7.39 – 7.18 (m, 10H, CH_{arom}), 5.39 (dd, *J* = 10.4, 3.0 Hz, 1H, H-3), 4.89 (d, *J* = 3.9 Hz, 1H, H-1), 4.77 (d, *J* = 11.4 Hz, 1H, C*H*H Bn), 4.54 (d, *J* = 9.1 Hz, 1H, C*H*H Bn), 4.51 (d, *J* = 8.7 Hz, 1H, CH*H* Bn), 4.44 (d, *J* = 11.8 Hz, 1H, CH*H* Bn), 4.27 (ddd, *J* = 11.3, 10.4, 3.9 Hz, 1H, H-2), 4.13 – 4.04 (m, 2H, H-4, H-5), 3.60 (d, *J* = 6.6 Hz, 2H, 2x H-6), 3.46 (s, 3H, CH_3 OMe), 2.03 (d, *J* = 11.2 Hz, 1H, OH); ^{13}C NMR (101 MHz, $CDCl_3$) δ 166.7 (C=O), 138.12, 137.9 (C_q), 133.4, 130.0 (CH_{arom}), 129.9 (C_q), 128.6, 128.6, 128.5 128.1, 127.9, 127.9 (CH_{arom}), 99.9 (C-1), 75.6 (C-4), 75.3 (CH_2 Bn), 74.4 (C-3), 73.6 (CH_2 Bn), 69.5 (C-5), 68.7 (C-6), 68.1 (C-2), 55.7 (CH_3 OMe); HRMS: $[M+Na]^+$ calcd for 501.18837, found 501.18772.

Preparation of acceptor **34**



***Scheme S17**: preparation of acceptor **34**: reagents and conditions: a) i) Pd(Ph_3P)$_4$, DMBA, methanol, 40 °C, ii: BzCl, pyridine, 89% over 2 steps; b) DDQ, DCM/H_2O (9:1), 61%*

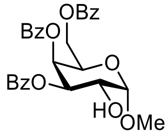
Methyl 3,4,6-tri-*O*-benzoyl-2-*O*-(2-naphtyl)methyl-α-D-galactopyranoside (S48)



Methyl 3-*O*-allyl-2-*O*-(2-naphtyl)methyl-α-D-galactopyranoside (**S42**, 0.5 g, 1.34 mmol) and DMBA (0.42 g, 2.67 mmol, 2 eq) were dissolved in 25 ml MeOH and flushed for 30 min with N_2. To the solution was added Pd(PPh_3)$_4$ (0.08 g, 0.07 mmol, 0.05 eq) and the mixture was heated for 1h at 40 °C, after which TLC indicated full conversion. The mixture conventrated under reduced pressure and the crude intermediate was dissolved in 25 ml pyridine and stirred at 0 °C until it was dissolved. To the solution was added BzCl (0.63 ml, 5.36 mmol, 4 eq) and stirred for 30 min at 0 °C, after which the temperature was increased to RT. The reaction was stirred overnight and diluted in DCM, once TLC indicated full conversion. The organic layer was washed three times with 1M aq. HCl and once with sat. aq. Bicarb. The combined organic layers were dried over $MgSO_4$, filtered and concentrated under reduced pressure. Purification was performed on flash column chromatography (4/1 pentane/EtOAc) to provide the slightly impure title compound as a yellow oil. Yield: 0.772 g, 1.19 mmol, 89% over 2 steps. ^1H NMR (400 MHz, $CDCl_3$) δ 8.02 –

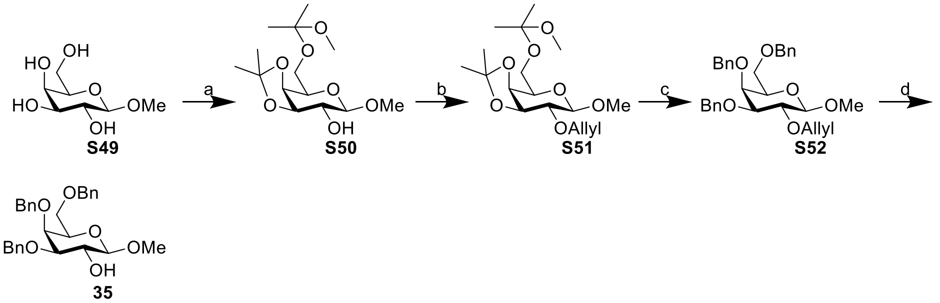
7.95 (m, 2H), 7.90 – 7.84 (m, 2H), 7.82 – 7.76 (m, 3H), 7.72 – 7.66 (m, 3H), 7.60 – 7.51 (m, 3H), 7.50 – 7.45 (m, 3H), 7.40 (dd, *J* = 8.7, 7.0 Hz, 3H), 7.35 – 7.26 (m, 7H), 5.92 (d, *J* = 3.4 Hz, 1H, H-4), 5.81 (dd, *J* = 10.4, 3.4 Hz, 1H, H-3), 4.96 (d, *J* = 3.6 Hz, 1H, H-1), 4.86 (d, *J* = 12.5 Hz, 1H, C*H*H Nap), 4.81 (d, *J* = 12.5 Hz, 1H, CH*H* Nap), 4.59 – 4.46 (m, 2H, H-5, H-6), 4.35 – 4.24 (m, 1H, H-6), 4.22 (dd, *J* = 10.5, 3.4 Hz, 1H, H-2), 3.50 (s, 3H, CH_3 OMe); ^{13}C NMR (101 MHz, $CDCl_3$) δ 166.2, 165.6, 165.5 (C=O), 135.4, 135.2, 134.4, 133.5, 133.3, 133.2, 133.2 (C_q), 130.8, 130.7, 130.3, 129.9, 129.8, 129.8, 129.7, 129.6, 129.5, 129.3, 129.0, 128.6, 128.6, 128.5, 128.4, 128.0, 127.9, 127.2, 126.3, 126.2, 126.1 (CH_{arom}), 98.7 (C-1), 73.4 (CH_2 Nap), 73.4 (C-2), 70.3 (C-3), 69.7 (C-4), 66.9 (C-5), 62.8 (C-6), 55.8 (CH_3 OMe); HRMS: $[M+NH_4]^+$ calcd for $C_{39}H_{34}O_9NH_4$ 664.25411, found 664.25339.

Methyl 3,4,6-tri-*O*-benzoyl-α-D-galactopyranoside (34)



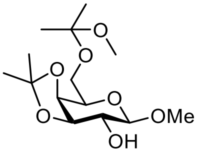
Methyl 3,4,6-tri-*O*-benzyl-2-*O*-(2-naphtyl)methyl-α-D-galactopyranoside (0.82 g, 1.27 mmol) was dissolved in 25 ml 9/1 DCM/H_2O and stirred at RT until the sugar was fully dissolved. To the solution was added DDQ (0.58 g, 2.54 mmol, 2 eq) and the reaction was stirred for 60 min at RT after which TLC indicated full conversion. The reaction mixture was quenched with aq. Bicarb solution and extracted with DCM. The organic layer was washed twice with aq. Bicarb solution. The organic layer was dried over $MgSO_4$, filtered and concentrated under reduced pressure. Purification was performed on flash column chromatography (4/1 pentane/EtOAc) to provide the title compound as a solid. Yield: 0.39 g, 0.78 mmol, 62%. ^1H NMR (400 MHz, $CDCl_3$) δ 8.12 – 8.04 (m, 2H, CH_{arom}), 8.05 – 7.98 (m, 2H, CH_{arom}), 7.90 – 7.83 (m, 2H, CH_{arom}), 7.62 (ddt, *J* = 8.7, 7.1, 1.3 Hz, 1H, CH_{arom}), 7.60 – 7.51 (m, 1H, CH_{arom}), 7.53 – 7.44 (m, 3H, CH_{arom}), 7.46 – 7.37 (m, 2H, CH_{arom}), 7.35 – 7.26 (m, 2H, CH_{arom}), 5.91 (dd, *J* = 3.4, 1.3 Hz, 1H, H-4), 5.59 (dd, *J* = 10.3, 3.4 Hz, 1H, H-3), 5.05 (d, *J* = 3.8 Hz, 1H, H-1), 4.58 (dd, *J* = 11.0, 7.0 Hz, 1H, H-6), 4.50 (ddd, *J* = 6.8, 5.4, 1.3 Hz, 1H, H-5), 4.36 (dd, *J* = 11.0, 5.6 Hz, 1H, H-6), 4.28 (td, *J* = 10.7, 3.8 Hz, 1H, H-2), 3.54 (s, 3H, CH_3 OMe), 2.19 (d, *J* = 11.0 Hz, 1H, OH); ^{13}C NMR (101 MHz, $CDCl_3$) δ 166.4, 166.2, 165.7 (C=O), 133.7, 133.4, 133.3, 130.0, 129.9 (CH_{arom}), 129.8 (C_q), 129.5, 128.7, 128.6, 128.4 (CH_{arom}), 99.9 (C-1), 71.5 (C-3), 69.4 (C-4), 68.1 (C-2), 67.3 (C-5), 62.7 (C-6), 55.9 (CH_3 OMe). Data in agreement with literature.[76]

Preparation of acceptor **35**



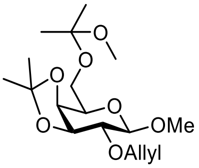
***Scheme S18**: preparation of acceptor **35**: reagents and conditions: a) 2,2-dimethoxypropane, PTSA, 78%; b) allyl bromide, NaH, DMF, 71%; c) i: PTSA, MeOH, 50 °C, ii: BnBr, NaH, DMF, 76% over 2 steps; d) $Pd(Ph_3P)_4$, DMBA, MeOH, 85%*

Methyl 3,4-*O*-isopropylidene-6-(1’-methoxy-1’-methyl)ethyl-β-D-galactopyranoside (S50)



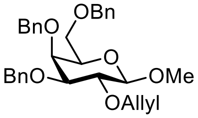
Methyl β-D-galactopyranoside (**S49**, 3.88 g, 20 mmol) was suspended in 2,2-dimethoxypropane (49 mL, 400 mmol, 20 eq) and PTSA-H_2O (380 mg, 2 mmol, 0.1 eq) was added. The reaction mixture was stirred for 72 hr before being quenched with triethylamine (0.42 mL, 3 mmol, 0.15 eq) and concentrated under reduced pressure. The residue was purified over silica (20% → 40% acetone in pentane with 1% triethylamine), to provide the title compound as colourless oil. Yield: 4.79 g, 15.6 mmol, 78%. ^{1}H NMR (400 MHz, $CDCl_3$) δ 4.18 (dd, *J* = 5.5, 2.2 Hz, 1H, H-4), 4.11 (d, *J* = 8.2 Hz, 1H, H-1), 4.07 (dd, *J* = 7.3, 5.4 Hz, 1H, H-3), 3.87 (td, *J* = 6.1, 2.1 Hz, 1H, H-5), 3.72 (d, *J* = 6.1 Hz, 2H, 2x H-6), 3.60 – 3.50 (m, 4H, H-2, CH_3 OMe), 3.24 (s, 3H, CH_3 OMe), 2.80 (d, *J* = 2.3 Hz, 1H, OH), 1.52 (s, 3H, CH_3 isopropylidene), 1.38 – 1.36 (m, 6H, 2x CH_3 isopropylidene), 1.34 (s, 3H, CH_3 isopropylidene) ^{13}C NMR (101 MHz, $CDCl_3$) δ 110.2 (C_q isopropylidene), 103.3 (C-1), 100.2 (C_q isopropylidene), 78.9 (C-3), 73.8 (C-2, C-4), 72.6 (C-5), 60.4 (C-6), 56.9, 48.6 (CH_3 OMe), 28.2, 26.3, 24.5, 24.5 (CH_3 isopropylidene). Spectra in agreement with literature[77]

Methyl 2-*O*-allyl-3,4-*O*-isopropylidene-6-(1’-methoxy-1’-methyl)ethyl-β-D-galactopyranoside (S51)



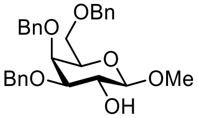
Methyl 3,4-O-isopropylidene-6-(1’-methoxy-1’-methyl)ethyl-β-D-galactopyranoside (**S50)** 4.75 g, 15.5 mmol) was dissolved in DMF and allyl bromide (2 mL, 23.3 mmol, 1.5 eq) and sodium hydride (60% dispersion in mineral oil, 0.93 g, 23.3 mmol, 1.5 eq) were added. When TLC shows full conversion, the reaction was quenched with water. The aquatic phase was extracted twice with diethyl ether. Combined organic phases were dried with $MgSO_4$ and concentrated under reduced pressure. The residue was purified over silica (10% acetone in pentane with 1% triethylamine) to provide the title compound as colourless oil. Yield: 3.79g, 10.9 mmol, 71%. ^{1}H NMR (400 MHz, $CDCl_3$) δ 5.94 (ddt, *J* = 17.3, 10.4, 5.8 Hz, 1H, CH$_2$-C*H*=CH$_2$), 5.30 (dq, *J* = 17.2, 1.7 Hz, 1H, CH$_2$-CH=C*H*H), 5.18 (dq, *J* = 10.4, 1.3 Hz, 1H, CH$_2$-CH=CH*H*), 4.33 – 4.21 (m, 2H, C*H*$_2$-CH=CH$_2$), 4.18 (d, *J* = 8.1 Hz, 1H, H-1), 4.17 – 4.15 (m, 1H, H-4), 4.11 (dd, *J* = 6.8, 5.5 Hz, 1H, H-3), 3.82 (td, *J* = 6.2, 2.0 Hz, 1H, H-5), 3.70 (dd, *J* = 6.0, 0.9 Hz, 2H, 2x H-6), 3.53 (s, 3H, CH$_3$ OMe), 3.34 (dd, *J* = 8.0, 6.8 Hz, 1H, H-2), 3.24 (s, 3H, CH$_3$ OMe), 1.51 (s, 3H, CH$_3$ isopropylidene), 1.37 (s, 3H, CH$_3$ isopropylidene), 1.36 (s, 3H, CH$_3$ isopropylidene), 1.33 (s, 3H, CH$_3$ isopropylidene) ^{13}C NMR (101 MHz, $CDCl_3$) δ 134.9 (CH$_2$-CH=CH$_2$), 117.3 (CH$_2$-CH=*C*H$_2$), 109.8 (C$_q$ isopropylidene), 103.6 (C-1), 100.1 (C$_q$ isopropylidene), 79.6 (C-2), 79.1 (C-3), 73.9 (C-4), 72.5 (*C*H$_2$-CH=CH$_2$), 72.1 (C-5), 60.4 (C-6), 56.6, 48.5 (CH$_3$ OMe), 27.9, 26.3, 24.4, 24.4 (CH$_3$ isopropylidene). Spectra in agreement with literature.[78]

Methyl 2-*O*-allyl-3,4,6-tri-*O*-benzyl-β-D-galactopyranoside (S52)



Methyl 2-*O*-allyl-3,4-*O*-isopropylidene-6-(1'-methoxy-1'-methyl)ethyl-β-D-galactopyranoside (**S51**, 1.5 g, 4.33 mmol) and PTSA-H_2O (82 mg, 0.43 mmol, 0.1 eq) were dissolved in methanol and heated to 50 °C. When TLC shows full removal of isopropylidenes, the reaction is quenched with Et_3N (0.12 mL, 0.87 mmol, 0.2 eq) and concentrated under reduced pressure. After residual methanol and water were removed by azeotropic distillation with toluene, the residue was dissolved in DMF. Benzyl bromide (2.31 mL, 19.5 mmol, 4.5 eq) and NaH (60% dispersion in mineral oil, 779 mg, 19.5 mmol, 4.5 eq) were added. When TLC shows full conversion, the reaction was quenched with water and extracted with diethyl ether. The organic phase was dried with Na_2SO_4 and concentrated under reduced pressure. The residue was purified over silica (10% EtOAc in pentane), yielding the title compound as colourless oil. Yield: 1.67 g, 3.30 mmol, 76% over 2 steps. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.41 – 7.21 (m, 15H, CH$_{arom}$), 5.97 (ddt, *J* = 17.3, 10.4, 5.8 Hz, 1H, CH$_2$-C*H*=CH$_2$), 5.28 (dt, *J* = 17.3, 1.7 Hz, 1H, CH$_2$-CH=C*H*H), 5.15 (dq, *J* = 10.3, 1.3 Hz, 1H, CH$_2$-CH-CH*H*), 4.92 (d, *J* = 11.7 Hz, 1H, C*H*H Bn), 4.76 (d, *J* = 11.9 Hz, 1H, C*H*H Bn), 4.70 (d, *J* = 11.9 Hz, 1H, CH*H* Bn), 4.61 (d, *J* = 11.7 Hz, 1H, CH*H* Bn), 4.44 (d, *J* = 11.8 Hz, 1H, C*H*H Bn), 4.43 – 4.33 (m, 2H, C*H*H-CH=CH$_2$, CH*H* Bn), 4.28 – 4.18 (m, 2H, H-1, CH*H*-CH=CH$_2$), 3.86 (dd, *J* = 3.0, 1.0 Hz, 1H, H-4), 3.67 (dd, *J* = 9.7, 7.6 Hz, 1H, H-2), 3.60 – 3.56 (m, 2H, 2x H-6), 3.55 – 3.49 (m, 4H, H-5, CH$_3$ OMe), 3.46 (dd, *J* = 9.8, 2.9 Hz, 1H, H-3); ^{13}C NMR (101 MHz, $CDCl_3$) δ 138.8, 138.7, 138.1 (C$_q$), 135.5 (CH$_2$-*C*H=CH$_2$), 128.6, 128.5, 128.4, 128.3, 128.0, 127.9, 127.7, 127.7, 127.6 (CH$_{arom}$), 116.8 (CH$_2$-CH=*C*H$_2$), 104.9 (C-1), 82.2 (C-3), 79.4 (C-2), 74.5, 74.1 (CH$_2$ Bn), 73.7 (*C*H$_2$-CH=CH$_2$), 73.6 (C-4), 73.5 (C-5), 73.2 (CH$_2$ Bn), 69.0 (C-6), 57.1 (CH$_3$ OMe); HRMS: $[M+NH_4]^+$ calcd for $C_{31}H_{36}O_6NH_4$ 522.28501, found 522.28412.

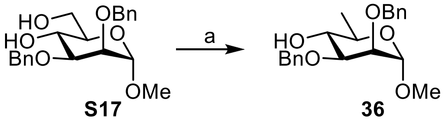
Methyl 3,4,6-tri-*O*-benzyl-β-D-galactopyranoside (35)



Methyl 2-*O*-allyl-3,4,6-tri-*O*-benzyl-β-D-galactopyranoside (**S52**, 1.6 g, 3.17 mmol) and DMBA (990 mg, 6.34 mmol, 2 eq) were dissolved in methanol and heated to 40 °C. After degassing with N_2 for 30 min, $Pd(Ph_3P)_4$ (183 mg, 0.159 mmol, 0.05 eq) was added. When TLC shows full conversion, the reaction mixture concentrated under reduced pressure. The residue was dissolved in diethyl ether and washed twice with sat. aq. $NaHCO_3$. The organic phase was dried with Na_2SO_4 and concentrated under reduced pressure. The residue was purified over silica (30% EA in pentane), yielding the title compound as yellowish powder. Yield: 1.25 g, 2.69 mmol, 85%. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.69 – 6.98 (m, 15H, CH_{arom}), 4.88 (d, *J* = 11.6 Hz, 1H, C*H*H Bn) 4.72 (d, *J* = 11.9 Hz, 1H, C*H*H Bn), 4.66 – 4.57 (m, 2H, 2x CH*H* Bn), 4.48 (d, *J* = 11.7 Hz, 1H, C*H*H Bn), 4.43 (d, *J* = 11.8 Hz, 1H, CH*H* Bn), 4.18 (d, *J* = 7.6 Hz, 1H, H-1), 4.00 – 3.89 (m, 2H, H-2, H-4), 3.66 – 3.56 (m, 3H, H-5, 2x H-6), 3.52 (s, 3H, CH_3 OMe), 3.43 (dd, *J* = 9.8, 2.8 Hz, 1H, H-3), 2.50 (d, *J* = 2.0 Hz, 1H, OH) ^{13}C NMR (101 MHz, $CDCl_3$) δ 138.6, 138.1, 137.9 (C_q), 128.6, 128.5, 128.3, 128.3, 128.0, 127.9, 127.8, 127.7 (CH_{arom}), 104.2 (C-1), 82.1 (C-3), 74.6 (CH_2 Bn), 73.8 (C-5), 73.7 (CH_2 Bn), 72.8 (C-4), 72.4 (CH_2 Bn), 71.3 (C-4), 68.8 (C-6), 57.1 (CH_3 OMe); spectra in agreement with literature.[79]

Rhamnose acceptors

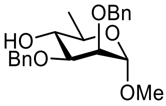
Preparation of acceptor **36**



S17 **36**

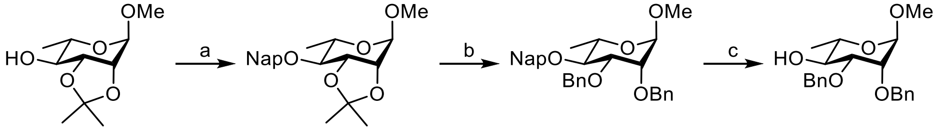
Scheme S19: *preparation of acceptor* ***36***: *reagents and conditions: a) i: TsCl, pyridine, ii: LiAlH$_4$, THF, reflux, 52% over 2 steps*

Methyl 2,3-di-*O*-benzyl-α-D-rhamnopyranoside (36)



Methyl 2,3-di-*O*-benzyl-α-D-mannopyranoside (**S17**, 1.80 g, 4.81 mmol, 1 eq) and TsCl (1.1 g, 5.77 mmol, 1.2 eq) were dissolved in 30 ml pyridine and stirred at RT overnight. The reaction mixture was diluted in EtOAc and washed three times with 1M aq. HCl. The organic layer was dried over $MgSO_4$, filtered and concentrated under reduced pressure to obtain crude intermediate. The crude intermediate was dissolved in 30 ml THF and a solution of $LiAlH_4$ (2.4 M in THF, 8.01 ml, 19.22 mmol, 4 eq) was slowly added. The reaction mixture was refluxed for 10 min, set to cool down to RT and quenched with 1M aq. HCl and extracted with EtOAc. The organic layer was washed once with 1M aq. HCl and twice aq. Bicarb solution. The organic layer was dried over $MgSO_4$, filtered and concentrated under reduced pressure. The Purification was performed on flash column chromatography (8/2 pentane/EtOAc) to provide the title compound as an oil. Yield: 0.88 g, 2.50 mmol, 52%. $[\alpha]_D^{25}$ = -10.9° (c = 0.34, $CHCl_3$); IR (thin film): 698, 738, 1027, 1059, 1268, 1367, 1454; ^1H NMR (400 MHz, $CDCl_3$) δ 7.40 – 7.23 (m, 10H, CH_{arom}), 4.74 – 4.66 (m, 2H, H-1, C*H*H Bn), 4.63 (d, *J* = 12.3 Hz, 1H, C*H*H Bn), 4.56 (d, *J* = 11.7 Hz, 1H, C*H*H Bn), 4.41 (d, *J* = 11.7 Hz, 1H, C*H*H Bn), 3.79 (dd, *J* = 3.1, 1.8 Hz, 1H, H-2), 3.77 – 3.68 (m, 1H, H-4), 3.67 – 3.56 (m, 2H, H-3, H-5), 3.32 (s, 3H, CH_3 OMe), 2.33 (s, 1H, OH), 1.33 (d, *J* = 6.1 Hz, 3H, H-6); ^{13}C NMR (101 MHz, $CDCl_3$) δ 138.2, 138.2 (C_q), 128.6, 128.5, 128.0, 127.9, 127.8, 127.8, 127.8 (CH_{arom}), 99.2 (C-1), 79.9 (C-3), 73.8 (C-2), 72.7 (CH_2 Bn), 71.7 (C-4), 71.5 (CH_2 Bn), 68.3 (C-5), 54.8 (CH_3 OMe), 17.9 (C-6); HRMS: $[M+Na]^+$ calcd for $C_{21}H_{26}O_5Na$ 381.16725, found 381.16640.

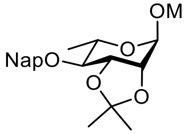
Preparation of acceptor **37**



S53 **S54** **S55** **37**

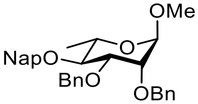
Scheme S20: *preparation of acceptor* ***37****: reagents and conditions: a) NapBr, NaH, DMF, 71%; b) i: PTSA, methanol, 60 °C, ii: BnBr, NaH, DMF, 70% over 2 steps; DDQ, DCM/H₂O (9:1), 79%*

Methyl 2,3-*O*-isopropylidene-4-*O*-(2-naphthyl)methyl-α-L-rhamnopyranoside (S54)



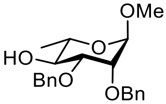
Methyl 2,3-*O*-isopropylidene-α-L-rhamnopyranoside[80] (**S53**, 4.00 g, 18.3 mmol) was dissolved in DMF and cooled to 0 °C after which NaH (60% dispersion in mineral oil, 953 mg, 23.8 mmol, 1.3 eq) was added. After stirring for 10 minutes, 2-(Bromomethyl)naphthalene (5.27 g, 23.8 mmol, 1.3 eq) was added. The reaction mixture was allowed to warm to RT and upon completion (as indicated by TLC) quenched with water. The aqueous phase was extracted twice with diethyl ether, the combined organic phases were dried with $MgSO_4$ and concentrated. The residue is purified over silica (3% EtOAc in pentane), yielding the desired product as yellow oil. Yield: 4.68 g, 13.1 mmol, 71%. ^1H NMR (400 MHz, $CDCl_3$) δ 7.85 – 7.76 (m, 4H, CH_{arom}), 7.53 – 7.35 (m, 3H, CH_{arom}), 5.05 (d, *J* = 11.8 Hz, 1H, C*H*H Nap), 4.85 (app. s, 1H, H-1), 4.79 (d, *J* = 11.8 Hz, 1H, CH*H* Nap), 4.29 (dd, *J* = 7.1, 5.8 Hz, 1H, H-3), 4.14 (d, *J* = 5.8 Hz, 1H, H-2), 3.69 (dq, *J* = 9.7, 6.2 Hz, 1H, H-5), 3.35 (s, 3H, CH_3 OMe), 3.25 (dd, *J* = 9.8, 7.1 Hz, 1H, H-4), 1.50 (s, 3H, CH_3 isopropylidene), 1.38 (s, 3H, CH_3 isopropylidene), 1.31 (d, *J* = 6.2 Hz, 3H, H-6); ^{13}C NMR (101 MHz, $CDCl_3$) δ 135.9, 133.3, 133.1 (C_q), 128.7, 128.5, 128.1, 128.0, 127.8, 127.6, 127.5, 126.9, 126.2, 126.1, 126.0, 125.9, 125.6 (CH_{arom}), 109.3 (C_q isopropylidene), 98.1 (C-1), 81.1 (C-4), 78.8 (C-3), 76.1 (C-2), 73.0 (CH_2 Nap), 64.5 (C-5), 54.9 (CH_3 OMe), 28.1, 26.4 (CH_3 isopropylidene), 18.0 (C-6); HRMS: $[M+Na]^+$ calcd for $C_{21}H_{26}O_5NH_4$ 381.16725, found 381.16670.

Methyl 2,3-di-*O*-benzyl-4-*O*-(2-naphtyl)mehtyl-α-L-rhamnopyranoside (S55)



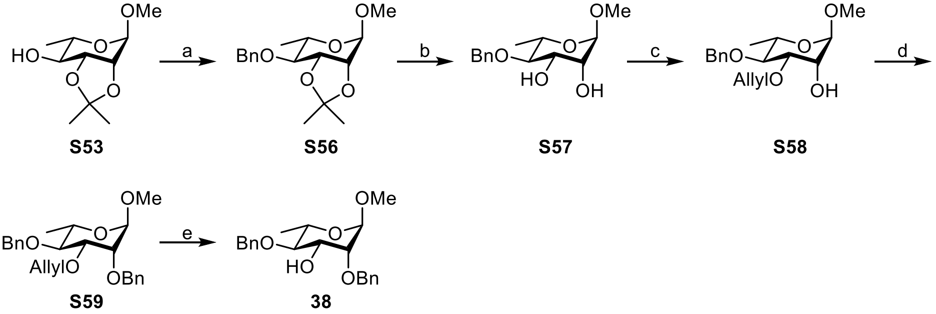
Methyl 2,3-*O*-isopropylidene-4-*O*-(2-naphthyl)methyl-α-L-rhamnopyranoside (**S54**, 1.40 g, 3.91 mmol) was dissolved in methanol with PTSA-H_2O (74 mg, 0.39 mmol, 0.1 eq) and heated to 60 °C. When TLC shows full removal of the isopropylidene, the reaction is quenched with triethylamine (0.13 mL, 0.98 mmol, 0.2 eq) and concentrated under reduced pressure. The residue is coevaporated with toluene and dissolved in DMF. The resulting solution is cooled to 0 °C, after which NaH (60% dispersion in mineral oil, 469 mg, 11.7 mmol, 3 eq) was added. After stirring for 10 minutes, benzyl bromide (1.93 mL, 11.7 mmol, 3 eq) was added. The reaction mixture was allowed to warm to RT and upon completion (as indicated by TLC) quenched with water. The aqueous phase was extracted twice with diethyl ether, the combined organic phases were dried with $MgSO_4$ and concentrated. The residue is purified over silica (5→10% EtOAc in pentane), yielding the desired product as yellowish oil. Yield: 1.365 g, 2.74 mmol, 70% over 2 steps.^{1}H NMR (400 MHz, $CDCl_3$) δ 7.85 – 7.72 (m, 4H, CH_{arom}), 7.47 – 7.41 (m, 3H, CH_{arom}), 7.40 – 7.25 (m, 10H, CH_{arom}), 5.10 (d, *J* = 11.1 Hz, 1H, C*H*H Bn/Nap), 4.81 (d, *J* = 11.2 Hz, 1H, CH*H* Bn/Nap), 4.77 – 4.70 (m, 2H, CH_2 Bn/Nap), 4.67 (d, *J* = 1.8 Hz, 1H, H-1), 4.62 (s, 2H, CH_2 Bn/Nap), 3.88 (dd, *J* = 9.0, 3.1 Hz, 1H, H-3), 3.80 (dd, *J* = 3.2, 1.9 Hz, 1H, H-2), 3.72 – 3.67 (m, 2H, H-4, H-5), 3.29 (s, 3H, CH_3 OMe), 1.37 (d, *J* = 5.7 Hz, 3H, H-6); ^{13}C NMR (101 MHz, $CDCl_3$) δ 138.7, 138.4, 136.3, 133.4, 133.0 (C_q), 128.5, 128.1, 128.1, 128.0, 127.8, 127.7, 127.6, 126.6, 126.2, 126.1, 125.9 (CH_{arom}), 99.2 (C-1), 80.6 (C-4), 80.3 (C-3), 75.5 (CH_2 Bn/Nap), 74.8 (C-2), 72.9, 72.2 (CH_2 Bn/Nap), 68.0 (C-5), 54.7 (CH_3 OMe), 18.2 (C-6); HRMS: $[M+NH_4]^+$ calcd for $C_{32}H_{34}O_5NH_4$ 516.27445, found 516.27370.

Methyl 2,3-di-*O*-benzyl-4-*O*-(2-naphtyl)mehtyl-α-L-rhamnopyranoside (37)



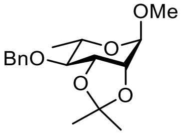
Methyl 2,3-di-*O*-benzyl-4-*O*-(2-naphtyl)mehtyl-α-L-rhamnopyranoside (**S55**, 1.30 g, 2.61 mmol) was dissolved in 20 mL 9:1 DCM/water, after which DDQ (1.184 g, 5.21 mmol, 2 eq) was added. When TLC shows full conversion, the reaction mixture is diluted with DCM and washed twice with sat. aq. $NaHCO_3$. The organic phase was dried with $MgSO_4$ and concentrated under reduced pressure. The residue is purified over silica, yielding the title compound as colourless oil. Yield: 740 mg, 2.07 mmol, 79%. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.39 – 7.24 (m, 10H, CH_{arom}), 4.74 – 4.68 (m, 2H, H-1, C*H*H Bn), 4.64 (d, *J* = 12.3 Hz, 1H, CH*H* Bn), 4.56 (d, *J* = 11.6 Hz, 1H, C*H*H Bn), 4.41 (d, *J* = 11.7 Hz, 1H, CH*H* Bn), 3.79 (dd, *J* = 3.1, 1.8 Hz, 1H, H-2), 3.72 (td, *J* = 9.3, 1.6 Hz, 1H, H-4), 3.66 – 3.59 (m, 2H, H-3, H-5), 3.33 (s, 3H, CH_3 OMe), 2.31 (d, *J* = 1.9 Hz, 1H, OH), 1.33 (d, *J* = 6.1 Hz, 3H, H-6); ^{13}C NMR (101 MHz, $CDCl_3$) δ 138.3, 138.2 (C_q), 128.7, 128.5, 128.0, 128.0, 127.9, 127.9 (CH_{arom}), 99.2 (H-1), 79.9 (H-3), 73.8 (H-2), 72.8 (CH_2 Bn), 71.8 (C-4), 71.6 (CH_2 Bn), 68.3 (C-5), 54.9 (CH_3 OMe), 17.9 (C-6). spectra in agreement with literature.[81]

Preparation of acceptor **38**



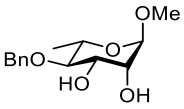
***Scheme S21**: preparation of acceptor **38**: reagents and conditions: a) BnBr, NaH, DMF 81%; b) MeOH, PTSA,* 50 °C *,93%; c) i: DBTO, toluene, reflux, ii: CsF, allyl bromide, DMF, 93% over 2 steps; d) BnBr, NaH, DMF, 80%; e) Pd(Ph$_3$P)$_4$, DMBA, MeOH,* 40 °C, *84%*

Methyl 4-*O*-benzyl-2,3-*O*-ispropylidene-α-L-rhamnopyranoside (S56)



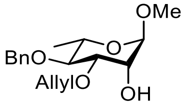
S53 (2.62 g, 12 mmol) was dissolved in DMF and cooled to 0 °C, after which NaH (60% dispersion in mineral oil, 720 mg, 18 mmol, 1.5 eq) was added. The solution was stirred for 10 minutes at 0 °C, benzyl bromide (2.14 mL, 18 mmol, 1.5 eq) was added and the reaction mixture was allowed to warm to RT. When TLC shows full conversion of the starting material, the reaction is quenched with water and extracted with diethyl ether. The organic phase was dried with MgSO$_4$ and concentrated under reduced pressure. The residue was purified over silica (10% diethyl ether in pentane), yielding the desired product as colourless oil. Yield: 2.99 g, 9.69 mmol, 81%. ^{1}H NMR (400 MHz, CDCl$_3$) δ 7.38 – 7.23 (m, 5H, CH$_{\text{arom}}$), 4.90 (d, *J* = 11.6 Hz, 1H, C*H*H Bn), 4.85 (app. s, 1H, H-1), 4.62 (d, *J* = 11.6 Hz, 1H, CH*H* Bn), 4.25 (dd, *J* = 7.1, 5.8 Hz, 1H, H-3), 4.12 (dd, *J* = 5.8, 0.7 Hz, 1H, H-2), 3.66 (dq, *J* = 9.8, 6.2 Hz, 1H, H-5), 3.35 (s, 3H, CH$_3$ OMe), 3.21 (dd, *J* = 9.8, 7.1 Hz, 1H, H-4), 1.50 (s, 3H, CH$_3$ isopropylidene), 1.37 (s, 3H, CH$_3$ isopropylidene), 1.29 (d, *J* = 6.2 Hz, 3H, H-6) ^{13}C NMR (101 MHz, CDCl$_3$) δ 138.4 (C$_q$), 128.3, 128.0, 127.6 (CH$_{\text{arom}}$), 109.2 (C$_q$ isopropylidene), 98.1 (C-1), 81.1 (C-4), 78.7 (C-3), 76.0 (C-2), 72.9 (CH$_2$ Bn), 64.4 (C-5), 54.8 (CH$_3$ OMe), 28.0 (CH$_3$ isopropylidene), 26.3 (CH$_3$ isopropylidene), 17.9 (C-6). Spectra in agreement with literature.[82]

Methyl 4-*O*-benzyl-α-L-rhamnopyranoside (S57)



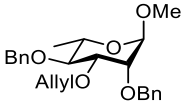
S56 (2.90 g, 9.40 mmol) was dissolved in methanol with PTSA-H$_2$O (179 mg, 0.94 mmol, 0.1 eq) and heated to 50 °C. When TLC shows full conversion, the reaction is quenched with triethylamine (0.26 mL, 1.88 mmol, 0.2 eq) and concentrated under reduced pressure. The residue is purified over silica (25% acetone in pentane) yielding the title compound as white powder. Yield: 2.437 g, 8.75 mmol, 93%. ^{1}H NMR (400 MHz, CDCl$_3$) δ 7.46 – 7.14 (m, 5H, CH$_{arom}$), 4.76 (d, *J* = 11.3 Hz, 1H, C*H*H Bn), 4.71 (d, *J* = 11.3 Hz, 1H, CH*H* Bn), 4.63 (d, *J* = 1.4 Hz, 1H, H-1), 3.93 – 3.84 (m, 2H, H-2, H-3), 3.69 (dq, *J* = 9.5, 6.3 Hz, 1H, H-5), 3.39 – 3.29 (m, 4H, CH$_3$ OMe, H-4), 2.84 (d, *J* = 3.8 Hz, 1H, OH), 2.67 (d, *J* = 5.2 Hz, 1H, OH), 1.35 (d, *J* = 6.3 Hz, 3H, H-6) ^{13}C NMR (101 MHz, CDCl$_3$) δ 138.4 (C$_q$), 128.7, 128.1, 128.0 (CH$_{arom}$), 100.5 (C-1), 81.7 (C-4), 75.1 (CH$_2$ Bn), 71.6, 71.2 (C-2 and C-3), 67.1 (C-5), 54.9 (CH$_3$ OMe), 18.1 (C-6). Spectra in agreement with literature.[82]

Methyl 3-*O*-allyl-4-*O*-benzyl-α-L-rhamnopyranoside (S58)



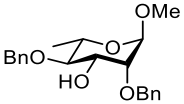
S57 (1.43 g, 5 mmol) and dibutyltin oxide (1.618 g, 6.5 mmol, 1.3 eq) were refluxed in toluene for 2 hr with a Dean-Stark setup. The reaction mixture was concentrated under reduced pressure and the residue dissolved in DMF, after which Caesium fluoride (987 mg, 6.5 mmol, 1.3 eq) and allyl bromide (0.56 mL, 6.5 mmol, 1.3 eq) were added. The reaction mixture was stirred overnight, diluted with water and extracted twice with diethyl ether. Combined organic phases were dried and concentrated under reduced pressure. The residue was purified using flash chromatography (20% EtOAc in pentane) yielding the product as colourless oil. Yield: 1.428 g, 4.63 mmol, 93%. ^{1}H NMR (400 MHz, CDCl$_3$) δ 7.37 – 7.27 (m, 5H, CH$_{arom}$), 5.95 (ddt, *J* = 17.2, 10.4, 5.6 Hz, 1H, CH$_2$-C*H*=CH$_2$), 5.32 (dq, *J* = 17.2, 1.6 Hz, 1H, CH$_2$-CH=C*H*H), 5.20 (dq, *J* = 10.4, 1.4 Hz, 1H, CH$_2$-CH=CH*H*), 4.87 (d, *J* = 10.9 Hz, 1H, C*H*H Bn), 4.70 (d, *J* = 1.6 Hz, 1H, H-1), 4.63 (d, *J* = 10.9 Hz, 1H, CH*H* Bn), 4.19 (ddt, *J* = 12.7, 5.8, 1.4 Hz, 1H, C*H*H-CH=CH$_2$), 4.13 (ddt, *J* = 12.6, 5.5, 1.5 Hz, 1H, CH*H*-CH=CH$_2$), 4.00 (dt, *J* = 3.6, 1.8 Hz, 1H, H-2), 3.74 – 3.63 (m, 2H, H-3, H-5), 3.41 (t, *J* = 9.3 Hz, 1H, H-4), 3.34 (s, 3H, CH$_3$ OMe), 2.53 (d, *J* = 2.0 Hz, 1H, OH), 1.31 (d, *J* = 6.2 Hz, 3H, H-6), ^{13}C NMR (101 MHz, CDCl$_3$) δ 138.5 (C$_q$), 134.6 (CH$_2$-*C*H=CH$_2$), 128.4, 128.0, 127.7 (CH$_{arom}$), 117.4 (CH$_2$-CH=*C*H$_2$), 100.0 (C-1), 79.9 (C-4), 79.6 (C-3), 75.3 (CH$_2$ Bn), 70.9 (*C*H$_2$-CH=CH$_2$), 68.6 (C-2), 67.1 (C-5), 54.8 (CH$_3$ OMe), 17.9 (C-6). Spectra in agreement with literature.[83]

Methyl 3-*O*-allyl-2,4-di-*O*-benzyl-α-L-rhamnopyranoside (S59)



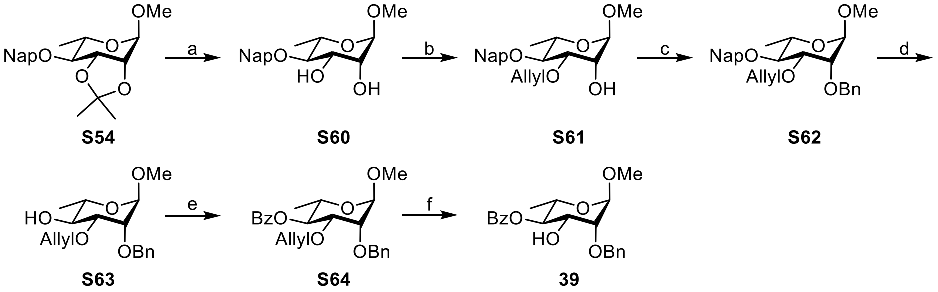
S58 (1.40 g, 4.54 mmol) was dissolved in DMF and cooled to 0 °C, after which NaH (60% dispersion in mineral oil, 272 mg, 6.81 mmol, 1.5 eq) was added. The solution was stirred for 10 minutes at 0 °C, benzyl bromide (0.81 mL, 6.81 mmol, 1.5 eq) was added and the reaction mixture was allowed to warm to RT. When TLC shows full conversion of the starting material, the reaction is quenched with water and extracted with diethyl ether. The organic phase was dried with MgSO$_4$ and concentrated under reduced pressure. The residue was purified over silica (10% diethyl ether in pentane), yielding the desired product as colourless oil. Yield: 1.454 g, 3.65 mmol, 80%. ^{1}H NMR (400 MHz, CDCl$_3$) δ 7.43 – 7.25 (m, 10H, CH$_{arom}$), 5.93 (ddt, *J* = 17.3, 10.6, 5.4 Hz, 1H, CH$_2$-C*H*=CH$_2$), 5.32 (dq, *J* = 17.2, 1.7 Hz, 1H, CH$_2$-CH=C*H*H), 5.17 (dq, *J* = 10.5, 1.5 Hz, 1H, CH$_2$-CH=CH*H*), 4.94 (d, *J* = 10.8 Hz, 1H, C*H*H Bn), 4.79 (d, *J* = 12.6 Hz, 1H, C*H*H Bn), 4.74 (d, *J* = 12.5 Hz, 1H, CH*H* Bn), 4.67 – 4.59 (m, 2H, CH*H* Bn, H-1), 4.08 (dq, *J* = 5.4, 1.4 Hz, 2H, C*H*$_2$-CH=CH$_2$), 3.77 – 3.69 (m, 2H, H-2, H-3), 3.68 – 3.60 (m, 1H, H-5), 3.59 – 3.54 (m, 1H, H-4), 3.29 (s, 3H, CH$_3$ OMe), 1.33 (d, *J* = 6.1 Hz, 3H, H-6) ^{13}C NMR (101 MHz, CDCl$_3$) δ 138.8, 138.5 (C$_q$), 135.1 (CH$_2$-*C*H=CH$_2$), 128.5, 128.5, 128.1, 128.0, 127.8, 127.7 (CH$_{arom}$), 116.7 (CH$_2$-CH=*C*H$_2$), 99.2 (C-1), 80.5 (C-4), 79.9 (C-3), 75.5 (CH$_2$ Bn), 74.8 (C-2), 72.9 (CH$_2$ Bn), 71.1 (*C*H$_2$-CH=CH$_2$), 67.9 (C-5), 54.7 (CH$_3$ OMe), 18.1 (C-6). Spectra in agreement with literature.[84]

Methyl 2,4-di-*O*-benzyl-α-L-rhamnopyranoside (38)



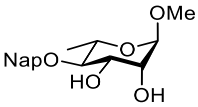
S59 (1.40 g, 3.51 mmol) and 1,3-dimethylbarbituric acid (1.097 g, 7.03 mmol, 2 eq) were dissolved in methanol, flushed with nitrogen and heated to 40 °C. Tetrakis(triphenylphosphine)palladium(0) (203 mg, 0.176 mmol, 0.05 eq) was added under a flow of nitrogen. When TLC shows full conversion, the reaction mixture was concentrated to ca. 20% of the original volume, diluted with ethyl acetate and wash twice with sat. aq. NaHCO$_3$. The organic phase was dried with MgSO$_4$ and concentrated under reduced pressure. The residue was purified over silica (15% acetone in pentane) yielding the title compound as colourless oil. Yield: 1.06 g, 2.96 mmol, 84 %. ^{1}H NMR (400 MHz, CDCl$_3$) δ 7.41 – 7.25 (m, 10H, CH$_{arom}$), 4.90 (d, *J* = 11.1 Hz, 1H, C*H*H Bn), 4.74 (d, *J* = 11.8 Hz, 1H, C*H*H Bn), 4.71 (d, *J* = 1.5 Hz, 1H, H-1), 4.65 (d, *J* = 11.1 Hz, 1H, CH*H* Bn), 4.58 (d, *J* = 11.7 Hz, 1H, CH*H* Bn), 3.92 (td, *J* = 9.2, 3.8 Hz, 1H, H-3), 3.71 (dd, *J* = 3.9, 1.6 Hz, 1H, H-2), 3.65 (dq, *J* = 9.5, 6.2 Hz, 1H, H-5), 3.37 – 3.25 (m, 4H, CH$_3$ OMe, H-4), 2.33 (d, *J* = 9.3 Hz, 1H, OH), 1.34 (d, *J* = 6.2 Hz, 3H, H-6) ^{13}C NMR (101 MHz, CDCl$_3$) δ 138.7, 137.8 (C$_q$), 128.7, 128.5, 128.2, 128.1, 128.0, 127.8 (CH$_{arom}$), 98.0 (C-1), 82.4 (C-4), 78.7 (C-2), 75.1 (CH$_2$ Bn), 73.1 (CH$_2$ Bn), 71.7 (C-3), 67.1 (C-5), 54.8 (CH$_3$ OMe), 18.1 (C-6). Spectra in agreement with literature.[84]

Preparation of acceptor **39**



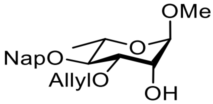
***Scheme S22**: preparation of acceptor **39**: reagents and conditions: a) PTSA, MeOH, 50 °C, 77%; b) i: DBTO, toluene, reflux, ii: allyl bromide, CsF, DMF, 100% over 2 steps; c) BnBr, NaH, DMF, 78%; d) DDQ, DCM/H$_2$O (9:1), 92%; e) BzCl, pyridine 87%; f) Pd(Ph$_3$P)$_4$, DMBA, MeOH,* 40 °C, *100%*

Methyl 4-*O*-(2-naphthyl)methyl-α-L-rhamnopyranoside (S60)



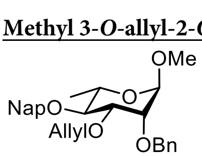
2,3-*O*-isopropylidene-4-*O*-(2-naphthyl)methyl-α-L-rhamnopyranoside (**S54**, 2.56 g, 7.14 mmol) and PTSA-H_2O (136 mg, 0.71 mmol, 0.1 eq) were dissolved in MeOH and heated to 50 °C. When TLC showed full conversion, the reaction was quenched with trimethylamine (0.2 mL, 1.43 mmol, 0.2 eq) and concentrated under reduced pressure. The residue is purified over silica (50% EA/pentane), yielding the title compound as white powder. Yield: 1.76 g, 5.53 mmol, 77%. ^1H NMR (400 MHz, DMSO) δ 7.92 – 7.78 (m, 4H, CH_{arom}), 7.50 (td, *J* = 5.9, 3.0 Hz, 3H, CH_{arom}), 5.02 (d, *J* = 11.8 Hz, 1H, C*H*H Nap), 4.99 (d, *J* = 4.4 Hz, 1H, OH), 4.88 (d, *J* = 6.9 Hz, 1H, OH), 4.75 (d, *J* = 11.8 Hz, 1H, CH*H* Nap), 4.46 (d, *J* = 1.4 Hz, 1H, H-1), 3.68 – 3.62 (m, 2H, H-2, H-3), 3.48 (dq, *J* = 9.5, 6.2 Hz, 1H, H-5), 3.31 (t, *J* = 9.2 Hz, 1H, H-4), 3.23 (s, 3H, CH_3 OMe), 1.17 (d, *J* = 6.3 Hz, 3H, H-6); ^{13}C NMR (101 MHz, DMSO) δ 136.8, 132.8, 132.4 (C_q), 127.7, 127.6, 127.6, 126.2, 126.1, 125.9, 125.8 (CH_{arom}), 101.0 (C-1), 80.8 (C-4), 73.8 (CH_2 Nap), 71.1, 70.8 (C-2, C-3), 66.9 (C-5), 54.1 (CH_3 OMe), 18.1 (C-6); HRMS: $[M+Na]^+$ calcd for $C_{18}H_{22}O_5Na$ 341.13594, found 341.13544.

Methyl 3-*O*-allyl-4-*O*-(2-naphthyl)methyl-α-L-rhamnopyranoside (S61)



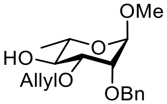
Methyl 4-*O*-(2-naphthyl)methyl-α-L-rhamnopyranoside (**S60**, 1.59 g, 5 mmol) and dibutyltin oxide (1.49 g, 6 mmol, 1.2 eq) are suspended in toluene and heated to reflux in a Dean-Stark setup for 2 hr, after which the reaction mixture was concentrated under reduced pressure. The residue is dissolved in DMF after which caesium fluoride (911 mg, 6 mmol, 1.2 eq) and allyl bromide (0.52 mL, 6 mmol, 1.2 eq) were added. After overnight stirring at room temperature, the reaction mixture was diluted with water and extracted with diethyl ether. The organic phase was dried with $MgSO_4$ and concentrated under reduced pressure. Silica chromatography (20% EtOAc in pentane) yields the title compound in quantitative yield as colourless oil. ^1H NMR (400 MHz, $CDCl_3$) δ 7.84 – 7.77 (m, 4H, CH_{arom}), 7.49 – 7.44 (m, 3H, CH_{arom}), 5.95 (ddt, *J* = 17.2, 10.3, 5.6 Hz, 1H, CH_2-C*H*=CH_2), 5.32 (dq, *J* = 17.2, 1.6 Hz, 1H, CH_2-CH=C*H*H), 5.20 (dq, *J* = 10.4, 1.4 Hz, 1H, CH_2-CH=CH*H*), 5.02 (d, *J* = 11.0 Hz, 1H, C*H*H Nap), 4.79 (d, *J* = 11.2 Hz, 1H, CH*H* Nap), 4.71 (d, *J* = 1.7 Hz, 1H, H-1), 4.21 (ddt, *J* = 12.7, 5.7, 1.4 Hz, 1H, C*H*H-CH=CH_2), 4.15 (ddt, *J* = 12.7, 5.6, 1.5 Hz, 1H, CH*H*-CH=CH_2), 4.01 (dt, *J* = 3.6, 1.9 Hz, 1H, H-2), 3.80 – 3.66 (m, 2H, H-3, H-5), 3.47 (t, *J* = 9.4 Hz, 1H, H-4), 3.35 (s, 3H, CH_3 OMe), 2.59 (d, *J* = 2.1 Hz, 1H, OH), 1.34 (d, *J* = 6.2 Hz, 3H, H-5); ^{13}C NMR (101 MHz, $CDCl_3$) δ 136.1 (C_q), 134.7 (CH_2-*C*H=CH_2), 133.4, 133.1 (C_q), 128.2, 128.0, 127.8, 126.7, 126.1, 126.1, 126.0 (CH_{arom}), 117.5 (CH_2-CH=*C*H_2), 100.2 (C-1), 80.0 (C-4), 79.7 (C-3), 75.5 (CH_2 Nap), 71.0 (*C*H_2-CH=CH_2), 68.7 (C-2), 67.2 (C-5), 54.9 (CH_3 OMe), 18.1 (C-6); HRMS: $[M+Na]^+$ calcd for $C_{21}H_{26}O_5Na$ 381.16725, found 381.166652

Methyl 3-*O*-allyl-2-*O*-benzyl-4-*O*-(2-naphthyl)methyl-α-L-rhamnopyranoside (S62)



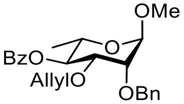
S61 (1.70 g, 4.74 mmol) was dissolved in DMF and cooled to 0 °C after which NaH (60% dispersion in mineral oil, 285 mg, 7.11 mmol, 1.5 eq) was added. After stirring for 10 minutes, benzyl bromide (0.84 mL, 7.11 mmol, 1.5 eq) was added. The reaction mixture was allowed to warm to RT and upon completion (as indicated by TLC) quenched with water. The aqueous phase was extracted twice with diethyl ether, the combined organic phases were dried with $MgSO_4$ and concentrated. The residue is purified over silica (10% diethyl ether in pentane), yielding the desired product as colourless oil. Yield: 1.67 g, 3.72 mmol, 78%. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.90 – 7.72 (m, 4H, CH_{arom}), 7.53 – 7.25 (m, 8H, CH_{arom}), 5.95 (ddt, *J* = 17.2, 10.6, 5.4 Hz, 1H, CH_2-*C*H=CH_2), 5.33 (dq, *J* = 17.2, 1.7 Hz, 1H, CH_2-CH=C*H*H), 5.18 (dq, *J* = 10.4, 1.5 Hz, 1H, CH_2-CH=CH*H*), 5.10 (d, *J* = 11.2 Hz, 1H, C*H*H Bn/Nap), 4.86 – 4.71 (m, 3H, CH*H* Bn/Nap, CH_2 Bn/Nap), 4.65 (d, *J* = 1.5 Hz, 1H, H-1), 4.10 (dq, *J* = 5.3, 1.3 Hz, 2H, C*H*$_2$-CH=CH_2), 3.82 – 3.73 (m, 2H, H-2, H-3), 3.73 – 3.59 (m, 2H, H-4, H-5), 3.29 (s, 3H, CH_3 OMe), 1.36 (d, *J* = 5.9 Hz, 3H, H-6); ^{13}C NMR (101 MHz, $CDCl_3$) δ 138.5, 136.4 (C_q), 135.1 (CH_2-*C*H=CH_2), 133.4, 133.1 (C_q), 128.5, 128.2, 128.0, 127.8, 126.6, 126.2, 126.1, 125.9 (CH_{arom}), 116.7 (CH_2-CH=*C*H_2), 99.2 (C-1), 80.6 (C-4), 80.0 (C-3), 75.5 (CH_2 Bn/Nap), 74.8 (C-2), 72.9 (CH_2 Bn/Nap), 71.1 (*C*H_2-CH=CH_2), 67.9 (C-5), 54.7 (CH_3 OMe), 18.2 (C-6); HRMS: $[M+NH_4]^+$ calcd for $C_{28}H_{32}O_5NH_4$ 466.25880, found 466.25794.

Methyl 3-*O*-allyl-2-*O*-benzyl-α-L-rhamnopyranoside (S63)



S62 (1.6 g, 3.57 mmol) was dissolved in 20 mL 9:1 DCM/H_2O, after which DDQ (1.62 g, 7.13 mmol, 2 eq) was added. When TLC shows full conversion, the reaction mixture was diluted with DCM and washed twice with sat. aq. Bicarb. The organic phase was dried and concentrated under reduced pressure. Silica chromatography (10% acetone in pentane) yield the title compound as yellowish oil. Yield: 1.01 g, 3.28 mmol, 92%. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.40 – 7.27 (m, 5H), 5.90 (ddt, *J* = 17.1, 10.3, 5.6 Hz, 1H), 5.28 (dq, *J* = 17.2, 1.6 Hz, 1H), 5.19 (dq, *J* = 10.4, 1.4 Hz, 1H), 4.76 – 4.58 (m, 3H), 4.01 (ddt, *J* = 12.5, 5.5, 1.5 Hz, 1H), 3.90 (ddt, *J* = 12.6, 5.8, 1.4 Hz, 1H), 3.75 (dd, *J* = 3.1, 1.8 Hz, 1H), 3.69 (td, *J* = 9.3, 2.0 Hz, 1H), 3.63 (dq, *J* = 9.3, 6.0 Hz, 1H), 3.53 (dd, *J* = 9.2, 3.1 Hz, 1H), 2.43 (d, *J* = 2.0 Hz, 1H), 1.34 (d, *J* = 6.0 Hz, 3H); ^{13}C NMR (101 MHz, $CDCl_3$) δ 138.1, 134.5, 128.4, 128.0, 127.8, 117.5, 99.2, 79.4, 73.4, 72.6, 71.6, 70.3, 68.2, 54.8, 17.8; HRMS: $[M+Na]^+$ calcd for $C_{17}H_{24}O_5Na$ 331.15160, found 331.15103.

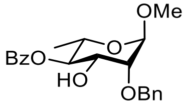
Methyl 3-*O*-allyl-4-*O*-benzoyl-2-*O*-benzyl-α-L-rhamnopyranoside (S64)



S63 (975 mg, 3.16 mmol) is dissolved in 5 mL pyridine after which benzoyl chloride (0.55 mL, 4.74 mmol, 1.5 eq) was added slowly. When TLC shows that the reaction is complete, the mixture is diluted with ethyl acetate and washed with 2 x 100 mL 1M aq. HCl and with 100 mL sat. aq. $NaHCO_3$. The organic phase was dried and concentrated under reduced pressure. The residue is purified with silica chromatography (5% → 10% ethyl acetate in pentane) to yield the desired compound as a colourless oil. Yield: 1.13 g, 2.74 mmol, 87%. ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.09 – 8.04 (m, 2H, CH_{arom}), 7.60 – 7.54 (m, 1H, CH_{arom}), 7.45 (dd, *J* = 8.4, 7.1 Hz, 2H, CH_{arom}), 7.42 – 7.38 (m, 2H, CH_{arom}), 7.36 – 7.32 (m, 2H, CH_{arom}), 7.30 – 7.26 (m, 1H, CH_{arom}), 5.72 (ddt, *J* = 17.2, 10.3, 5.5 Hz, 1H, CH_2-C*H*=CH_2), 5.44 (t, *J* = 9.7 Hz, 1H, H-4), 5.16 (dq, *J* = 17.2, 1.7 Hz, 1H, CH_2-

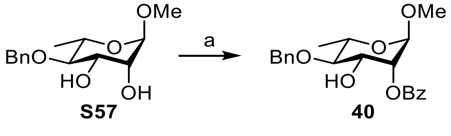
CH=C*H*H), 5.04 (dq, *J* = 10.4, 1.4 Hz, 1H, CH_2-CH=CH*H*), 4.85 (d, *J* = 12.5 Hz, 1H, C*H*H Bn), 4.75 (d, *J* = 12.5 Hz, 1H, CH*H* Bn), 4.71 (d, *J* = 1.8 Hz, 1H, H-1), 4.03 (ddt, *J* = 13.0, 5.4, 1.5 Hz, 1H, C*H*H-CH=CH_2), 3.92 (ddt, *J* = 13.1, 5.7, 1.5 Hz, 1H, CH*H*-CH=CH_2), 3.89 – 3.82 (m, 2H, H-3, H-5), 3.81 (dd, *J* = 3.2, 1.9 Hz, 1H, H-2), 3.36 (s, 3H, CH_3 OMe), 1.27 (d, *J* = 6.3 Hz, 3H, H-6); ^{13}C NMR (101 MHz, $CDCl_3$) δ 165.8 (C=O), 138.4 (C_q), 134.8 (CH_2-*C*H=CH_2), 133.1 (CH_{arom}), 130.3 (C_q), 129.8, 128.5, 128.4, 128.1, 127.7 (CH_{arom}), 117.1 (CH_2-CH=*C*H_2), 99.8 (C-1), 77.2 (C-3), 74.6 (C-2), 73.8 (C-4), 73.2 (CH_2 Bn), 71.3 (*C*H_2-CH=CH_2), 67.0 (C-5), 55.0 (CH_3 OMe), 17.8 (C-6); HRMS: $[M+NH_4]^+$ calcd for $C_{24}H_{28}O_6NH_4$ 430.22241, found 430.22153.

Methyl 4-*O*-benzoyl-2-*O*-benzyl-α-L-rhamnopyranoside (39)



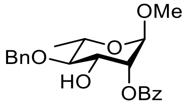
Nr. (1.10 g, 2.67 mmol) and 1,3-Dimethylbarbituric acid (833 mg, 5.33 mmol, 2 eq) were dissolved in methanol. The solution was flushed with nitrogen and heated to 40 °C, after which $Pd(PPh_3)_4$ (154 mg, 0.133 mmol, 0.05 eq) was added under a flow of nitrogen. When TLC shows full conversion, the reaction mixture is cooled to RT, diluted with ethyl acetate and washed with sat. aq. $NaHCO_3$. The aqueous phase was extracted with ethyl acetate, combined organic phases were dried with $MgSO_4$ and concentrated under reduced pressure. The residue is purified over silica (30% diethyl ether in pentane), yielding the title compound in quantitative yield as a yellowish oil that solidifies over a few days. $[\alpha]_D^{25}$ = -0.29° (c = 0.34, $CHCl_3$); IR (thin film): 711, 1069, 1269, 1316, 1452, 1724; ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.13 – 8.00 (m, 2H, CH_{arom}), 7.56 (ddt, *J* = 8.7, 7.0, 1.3 Hz, 1H, CH_{arom}), 7.47 – 7.41 (m, 2H, CH_{arom}), 7.39 – 7.29 (m, 5H, CH_{arom}), 5.14 (t, *J* = 9.8 Hz, 1H, H-4), 4.83 – 4.70 (m, 2H, H-1, C*H*H Bn), 4.62 (d, *J* = 11.7 Hz, 1H, CH*H* Bn), 3.98 (ddd, *J* = 11.0, 9.8, 3.7 Hz, 1H, H-3), 3.89 (dq, *J* = 9.7, 6.3 Hz, 1H, H-5), 3.78 (dd, *J* = 3.8, 1.6 Hz, 1H, H-2), 3.38 (s, 3H, CH_3 OMe), 2.40 (d, *J* = 11.0 Hz, 1H, OH), 1.27 (d, *J* = 6.3 Hz, 3H, H-6); ^{13}C NMR (101 MHz, $CDCl_3$) δ 166.7 (C=O), 137.6 (C_q), 133.3 (CH_{arom}), 130.0 (C_q), 129.9, 128.7, 128.5, 128.2, 128.0 (CH_{arom}), 98.3 (C-1), 78.5 (C-2), 75.6 (C-3), 73.3 (CH_2 Bn, 69.9 (C-3), 66.1 (C-5), 55.1 (CH_3 OMe), 17.7 (C-6); HRMS: $[M+Na]^+$ calcd for $C_{21}H_{24}O_6Na$ 395.14651, found 395.14590

Preparation of acceptor **40**



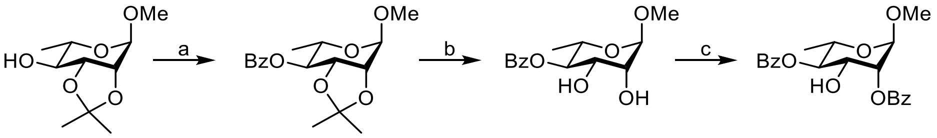
Scheme S23*: preparation of acceptor* ***40****: reagents and conditions: a) BzCN, DMAP, DCM, -78 °C, 81%*

Methyl 2-*O*-benzoyl-4-*O*-benzyl-α-L-rhamnopyranoside (40)



Nr. (805 mg, 3 mmol) and benzoyl cyanide (433 mg, 3.30 mmol, 1.1 eq) were dissolved in dichloromethane. 3A molecular sieves were added, the solution was stirred for 30 min at room temperature and subsequently cooled to -78 °C. DMAP (37 mg, 0.30 mmol, 0.1 eq) was added and the reaction mixture kept at that temperature for 2 hr after which it was slowly allowed to warm to RT. When TLC showed full conversion, the reaction was quenched with MeOH and sat aq. NH_4Cl, diluted with dichloromethane, washed with sat aq. NH_4Cl and sat aq. $NaHCO_3$. The organic phase was dried with $MgSO_4$ and concentrated under reduced pressure. The residue was purified over silica (15% EA in pentane) yielding the title compound as colourless oil. Yield: 900 mg, 2.42 mmol, 81%. ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.15 – 7.97 (m, 2H, CH_{arom}), 7.59 (ddt, *J* = 8.7, 6.9, 1.3 Hz, 1H, CH_{arom}), 7.53 – 7.43 (m, 2H, CH_{arom}), 7.40 – 7.28 (m, 5H, CH_{arom}), 5.33 (dd, *J* = 3.6, 1.7 Hz, 1H, H-2), 4.86 (d, *J* = 11.1 Hz, 1H, C*H*H Bn), 4.77 – 4.71 (m, 2H, CH*H* Bn, H-1), 4.20 (ddd, *J* = 9.0, 5.1, 3.5 Hz, 1H, H-3), 3.79 (dq, *J* = 9.5, 6.2 Hz, 1H, H-5), 3.46 (t, *J* = 9.4 Hz, 1H, H-4), 3.37 (s, 3H, CH_3 OMe), 2.28 (d, *J* = 5.1 Hz, 1H, OH), 1.40 (d, *J* = 6.3 Hz, 3H, H-6) ^{13}C NMR (101 MHz, $CDCl_3$) δ 166.4 (C=O), 138.3 (C_q), 133.5, 130.0 (CH_{arom}), 129.8 (C_q), 128.6, 128.6, 128.1, 128.0 (CH_{arom}), 98.5 (C-1), 81.8 (C-4), 75.2 (CH_2 Bn), 73.3 (C-2), 70.6 (C-3), 67.4 (C-5), 55.1 (CH_3 OMe), 18.3 (C-6). Spectra in agreement with literature.[83]

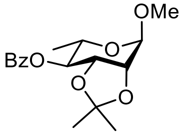
Preparation of acceptor **41**



S53 **S65** **S66** **41**

Scheme S24: *preparation of acceptor **41**: reagents and conditions: a) BzCl, pyridine, 100%; PTSA, MeOH, 50 °C, 78%; c) BzCN, DMAP, DCM, -78 °C, 44%*

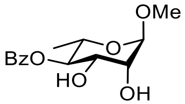
Methyl 4-*O*-benzoyl-2,3-isopropylidene-α-L-rhamnopyranoside (S65)



S53 (2.18 g, 10 mmol) was dissolved in 10 mL pyridine, after which benzoyl chloride (1.74 mL, 15 mmol, 1.5 eq) was added dropwise. When TLC shows full consumption of the starting material, the reaction mixture is diluted with ethyl acetate and washed twice with water. The organic phase is dried with $MgSO_4$ and concentrated under reduced pressure. Residual pyridine was removed by coevaporation with toluene. The residue was purified over silica (10% EtOAc in pentane) yielding the title compound in quantitative yield as colourless oil that slowly solidifies. ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.10 – 8.03 (m, 2H, CH_{arom}), 7.60 – 7.50 (m, 1H, CH_{arom}), 7.44 (dd, *J* = 8.4, 7.1 Hz, 2H, CH_{arom}), 5.13 (dd, *J* = 10.1, 7.8 Hz, 1H, H-4), 4.96 (app. s, 1H, H-1), 4.34 (dd, *J* = 7.8, 5.4 Hz, 1H, H-3), 4.20 (dd, *J* = 5.4, 0.7 Hz, 1H, H-2), 3.87 (dq, *J* = 10.1, 6.3 Hz, 1H, H-5), 3.42 (s, 3H, CH_3 OMe), 1.63 (s, 3H, CH_3 isopropylidene), 1.36 (s, 3H, s, 3H, CH_3 isopropylidene), 1.23 (d, *J* = 6.4 Hz, 3H, H-6) ^{13}C NMR (101 MHz, $CDCl_3$) δ 165.9 (C=O), 133.3, 129.9, 128.5 (CH_{arom}), 110.0 (C_q isopropylidene), 98.2 (C-1), 76.1 (C-2), 76.0 (C-3), 75.1 (C-4), 64.1 (C-5), 55.1 (CH_3

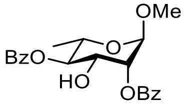
OMe), 27.9 (CH_3 isopropylidene), 26.5 (CH_3 isopropylidene), 17.2 (C-6). Spectra in agreement with literature.[85]

Methyl 4-*O*-benzoyl-α-L-rhamnopyranoside (S66)



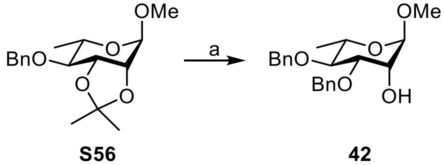
S65 (3.5 g, 10.9 mmol) was dissolved in methanol with PTSA-H_2O (207 mg, 1.09 mmol, 0.1 eq) and heated to 50 °C. When TLC shows full conversion, the reaction is quenched with triethylamine (0.31 mL, 2.17 mmol, 0.2 eq) and concentrated under reduced pressure. The residue is purified over silica (20% acetone in pentane) yielding the title compound as viscous colourless oil. Yield: 2.38 g, 8.43 mmol, 78%. ^1H NMR (400 MHz, $CDCl_3$) δ 8.16 – 7.91 (m, 2H, CH_{arom}), 7.63 – 7.53 (m, 1H, CH_{arom}), 7.44 (dd, *J* = 8.6, 7.0 Hz, 2H, CH_{arom}), 5.09 (t, *J* = 9.3 Hz, 1H, H-4) 4.76 (d, *J* = 1.2 Hz, 1H, H-1), 4.04 – 3.99 (m, 2H, H-2, H-3), 3.94 (dq, *J* = 9.8, 6.3 Hz, 1H, H-5), 3.40 (s, 3H, CH_3 OMe), 1.28 (d, *J* = 6.3 Hz, 3H, H-6); ^{13}C NMR (101 MHz, $CDCl_3$) δ 167.5 (C=O), 133.5, 130.0 (CH_{arom}), 129.6 (C_q), 128.6 (CH_{arom}), 100.7 (C-1), 76.1 (C-4), 71.0, 70.4 (C-2, C-3), 65.8 (C-5), 55.2 (CH_3 OMe), 17.7 (C-6). Spectra in agreement with literature.[86]

Methyl 2,4-di-*O*-benzoyl-α-L-rhamnopyranoside (41)



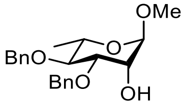
S66 (1.129g, 4 mmol) and benzoyl cyanide (557 mg, 4.40 mmol, 1.1 eq) were dissolved in dichloromethane. 3 Å molecular sieves were added, the solution was stirred for 30 min at room temperature and subsequently cooled to -78 °C. DMAP (49 mg, 0.40 mmol, 0.1 eq) was added and the reaction mixture kept at that temperature for 2 hr after which it was slowly allowed to warm to RT. When TLC showed full conversion, the reaction was quenched with MeOH and sat aq. NH_4Cl, diluted with dichloromethane, washed with sat aq. NH_4Cl and sat aq. $NaHCO_3$. The organic phase was dried with $MgSO_4$ and concentrated under reduced pressure. The residue was purified over silica (15% EA in pentane) yielding the title compound as colourless oil. Yield: 672 mg, 1.74 mmol, 44% ^1H NMR (400 MHz, $CDCl_3$) δ 8.14 – 8.05 (m, 4H, CH_{arom}), 7.64 – 7.57 (m, 2H, CH_{arom}), 7.52 – 7.44 (m, 4H, CH_{arom}), 5.38 (dd, *J* = 3.5, 1.7 Hz, 1H, H-2), 5.26 (t, *J* = 9.8 Hz, 1H, H-4), 4.87 (d, *J* = 1.6 Hz, 1H, H-1), 4.30 (ddd, *J* = 9.9, 8.1, 3.5 Hz, 1H, H-3), 4.11 – 3.99 (m, 1H, H-5), 3.45 (s, 3H, CH_3 OMe), 2.44 (d, *J* = 8.2 Hz, 1H, OH), 1.33 (d, *J* = 6.2 Hz, 3H, H-6) ^{13}C NMR (101 MHz, $CDCl_3$) δ 167.2, 166.2 (C=O), 133.7, 133.6, 130.0, 130.0 (CH_{arom}), 129.6, 129.5 (C_q), 128.7, 128.6 (CH_{arom}), 98.5 (C-1), 75.7 (C-4), 73.3 (C-2), 69.1 (C-3), 66.2 (C-5), 55.4 (CH_3 OMe), 17.8 (C-6). Spectra in agreement with literature.[87]

Preparation of acceptor **42**



***Scheme S25**: preparation of acceptor **42**: reagents and conditions: a) i: PTSA, MeOH, 50 °C, ii: DBTO, toluene, reflux, iii: CsF, BnBr, DMF, 77% over 3 steps*

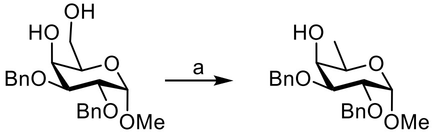
Methyl 3,4-di-*O*-benzyl-α-L-rhamnopyranoside (42)



Methyl 4-*O*-benzyl-2,3-*O*-ispropylidene-α-L-rhamnopyranoside (**S56**, 1.12 g, 3.63 mmol) and PTSA-H_2O (69 mg, 0.36 mmol, 0.1 eq) were dissolved in methanol. The reaction mixture was heated to 50 °C. When TLC shows full removal of the isopropylidene, triethylamine (0.1 mL, 0.73 mmol, 0.2 eq) was added and the mixture was concentrated under reduced pressure. The residue was dissolved in toluene with dibutyltin oxide (1.18 g, 4.72 mmol, 1.3 eq) and refluxed for 2.5 hr in a Dean-Stark setup. The reaction mixture was cooled to RT and concentrated under reduced pressure. The residue was dissolved in DMF and caesium fluoride (717 mg, 4.72 mmol, 1.3 eq) and benzyl bromide (0.56 mL, 4.72 mmol, 1.3 eq) were added. After 72 hr stirring, the reaction mixture was diluted with water and extracted twice with diethyl ether. Combined organic phases were dried with $MgSO_4$ and concentrated. The residue was purified over silica (10% Et_2O in pentane) yielding the title compound as colourless oil. Yield: 1.00 g, 2.79 mmol, 77%. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.42 – 7.26 (m, 10H, CH_{arom}), 4.88 (d, *J* = 10.9 Hz, 1H, C*H*H Bn), 4.70 (d, *J* = 1.7 Hz, 1H, H-1), 4.68 (s, 2H, CH_2 Bn), 4.64 (d, *J* = 10.9 Hz, 1H, CH*H* Bn), 4.02 (dt, *J* = 3.6, 1.8 Hz, 1H, H-2), 3.82 (dd, *J* = 9.1, 3.4 Hz, 1H, H-3), 3.70 (dq, *J* = 9.6, 6.2 Hz, 1H, H-5), 3.45 (t, *J* = 9.4 Hz, 1H, H-4), 3.34 (s, 3H, CH_3 OMe), 2.53 (d, *J* = 1.9 Hz, 1H, OH), 1.32 (d, *J* = 6.3 Hz, 3H, H-6), ^{13}C NMR (101 MHz, $CDCl_3$) δ 138.5, 138.0 (C_q), 128.7, 128.5, 128.1, 128.0, 127.8 (CH_{arom}), 100.1 (C-1), 80.2, 80.0 (C-3, C-4), 75.5, 72.1 (CH_2 Bn), 68.6 (C-2), 67.2 (C-5), 54.9 (CH_3 OMe), 18.0 (C-6). Spectra in agreement with literature.[88]

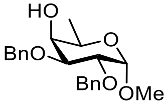
Fucose acceptors

Preparation of acceptor **43**



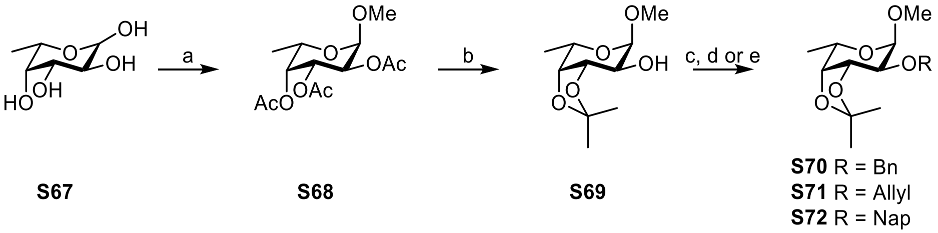
***Scheme S26**: preparation of acceptor **43**: reagents and conditions: a) i: TsCl, pyridine, ii: LiAlH₄, THF, reflux, 52% over 2 steps*

Methyl 2,3-di-*O*-benzyl-α-D-fucopyranoside (43)



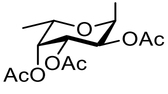
Methyl 2,3,-di-*O*-benzyl-α-D-galactopyranoside (**S38**, 0.75 g, 2 mmol) was dissolved in pyridine (3.3 mL, 40 mmol, 20 eq.) and cooled to 0 °C. Tosyl chloride (0.458 g, 2.4 mmol, 1.2 eq) was added and the reaction mixture was allowed to warm to RT overnight, diluted with ethyl acetate and washed with 1 M HCl and sat. aq. $NaHCO_3$. The organic phase was dried with $MgSO_4$ and concentrated under reduced pressure to yield the crude tosylate which was used without further purification. The tosylate was dissolved in THF, $LiAlH_4$ (2.50 mL of a 2.4M solution in 2-methyltetrahydrofuran, 6 mmol, 3 eq) was added and the reaction mixture was heated to a gentle reflux. When TLC shows full conversion, the reaction mixture was cooled to 0 °C and carefully quenched with sat. aq. $NaHCO_3$. Solids were filtered off over celite and the filtrate was extracted with ethyl acetate. The organic phase was washed with 1M HCl, sat. aq. $NaHCO_3$ and brine, dried with $MgSO_4$ and concentrated. The residue was purified over silica (30%→50% EA in pentane) to give the title compound as colourless oil. Yield: 373 mg, 1.04 mmol, 52%. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.45 – 7.21 (m, 10H, CH_{arom}), 4.80 (d, *J* = 11.9 Hz, 2H, 2x C*H*H Bn), 4.68 (dd, *J* = 13.6, 11.9 Hz, 2H, 2x CH*H* Bn), 4.62 (d, *J* = 3.4 Hz, 1H, H-1), 3.91 – 3.75 (m, 4H, H-2, H-3, H-4, H-5), 3.36 (s, 3H, CH_3 OMe), 2.49 (s, 1H, OH), 1.26 (d, *J* = 6.6 Hz, 3H, H-6); ^{13}C NMR (101 MHz, $CDCl_3$) δ 138.5, 138.3 (C_q), 128.6, 128.4, 128.1, 127.9, 127.9, 127.8 (CH_{arom}), 98.6 (C-1), 78.0 (C-3), 75.6 (C-2), 73.5, 72.8 (CH_2 Bn), 70.4 (C-4), 65.1 (C-5), 55.4 (CH_3 OMe), 16.2 (C-6). Spectra in agreement with literature.[89]

Preparation of isopropylidene intermediates of fucose acceptors



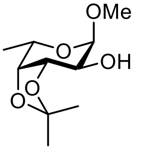
Scheme S27: *preparation of isopropylidene intermediates: reagents and conditions: a) i: MeOH, amberlite-H*$^+$*, reflux, ii:* Ac_2O*, pyridine, 52% over 2 steps; b) i: NaOMe, MeOH, ii: PTSA, 2,2-dimethoxypropane, 76% over 2 steps; c) Benzyl bromide, NaH, DMF, 82%; d) allyl bromide, NaH, DMF, 97%; e) NapBr, NaH, DMF, 77%*

Methyl 2,3,4-tri-*O*-acetyl-α-L-fucopyranoside (S68)



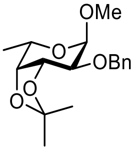
Fucose (**S67**, 5.0 g, 30.5 mmol) was dissolved in methanol, after which 8 g Amberlite IR-120 H-form was added. The mixture was refluxed for 24 hr, cooled to RT and filtered to remove the Amberlite. The filtrate was concentrated under reduced pressure, coevaporated with toluene and dissolved in 30 mL pyridine. Ac_2O (17.3 mL, 183 mmol, 6 eq) was added and the mixture was reacted overnight, after which it was diluted with ethyl acetate and washed with 1 M HCl and sat. aq. $NaHCO_3$. The organic phase was dried with $MgSO_4$ and concentrated under reduced pressure, yielding a mixture of both anomers. The desired α-anomer was isolated via silica chromatography (20% diethyl ether in pentane, first eluting product) as a colourless oil. Yield: 4.92 g, 16.2 mmol, 53%.^{1}H NMR (300 MHz, $CDCl_3$) δ 5.36 (dd, *J* = 10.8, 3.4 Hz, 1H, H-3), 5.30 (dd, *J* = 3.4, 1.3 Hz, 1H, H-4), 5.15 (dd, *J* = 10.8, 3.7 Hz, 1H, H-2), 4.94 (d, *J* = 3.7 Hz, 1H, H-1), 4.18 – 4.10 (m, 1H, H-5), 3.40 (s, 3H, CH_3 OMe), 2.18 (s, 3H, CH_3 Ac), 2.09 (s, 3H, CH_3 Ac), 1.99 (s, 3H, CH_3 Ac), 1.16 (d, *J* = 6.5 Hz, 3H, H-6). Spectra in agreement with literature.[90]

Methyl 3,4-*O*-isopropylidene-α-L-fucopyranoside (S69)



Methyl 2,3,4-tri-*O*-acetyl-α-L-fucopyranoside (**S68**, 9.95 g, 32.7 mmol) and sodium methoxide (353 mg, 6.54 mmol, 0.2 eq) were dissolved in methanol. When TLC shows full deprotection, the solution was acidified with Amberlite IR-120 H-form to a pH of 5 and filtered over a short path of celite. The filtrate was concentrated under reduced pressure and residual water and methanol were removed by azeotropic distillation with toluene. The residue was suspended in 2,2-dimehtoxypropane (40 mL, 327 mmol, 10 eq) and PTSA-H_2O (622 mg, 3.27 mmol, 0.1 eq) was added. After overnight stirring, triethylamine (0.92 mL, 6.54 mmol, 0.2 eq) was added and the mixture was concentrated under reduced pressure. Silica chromatography (10% acetone in pentane) yields the title compound as colourless oil. Yield: 5.40 g, 24.7 mmol, 76%. ^{1}H NMR (400 MHz, $CDCl_3$) δ 4.72 (d, *J* = 3.9 Hz, 1H, H-1), 4.19 (t, *J* = 6.3 Hz, 1H, H-3), 4.11 (qd, *J* = 6.7, 2.4 Hz, 1H, H-5), 4.05 (dd, *J* = 5.9, 2.4 Hz, 1H, H-4), 3.79 (td, *J* = 6.7, 3.8 Hz, 1H, H-2), 3.44 (s, 3H, CH_3 OMe), 2.43 (d, *J* = 6.7 Hz, 1H, OH), 1.52 (s, 3H, CH_3 isopropylidene), 1.36 (s, 3H, CH_3 isopropylidene), 1.33 (d, *J* = 6.7 Hz, 3H, H-6); ^{13}C NMR (101 MHz, $CDCl_3$) δ 109.3 (C_q isopropylidene), 98.8 (C-1), 76.4 (C-3), 75.8 (C-4), 69.6 (C-2), 63.8 (C-5), 55.5 (CH_3 OMe), 28.0, 26.1 (, CH_3 isopropylidene), 16.4 (C-6). Spectra in agreement with literature.[91]

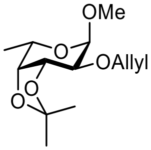
Methyl 2-*O*-benzyl-3,4-*O*-isopropylidene-α-L-fucopyranoside (S70)



Methyl 3,4-*O*-isopropylidene-α-L-fucopyranoside (**S69**, 1.5 g, 6.87 mmol), benzyl bromide (1.22 mL, 10.3 mmol, 1.5 eq) and sodium hydride (60% dispersion in mineral oil, 412 mg, 10.3 mmol, 1.5 eq) were dissolved in dimethylformamide. When TLC shows full conversion, the reaction was quenched with water and extracted with diethyl ether. The organic phase was dried with $MgSO_4$ and concentrated under reduced pressure. The residue was purified over silica (10% diethyl ether in pentane), yielding the title compound as colourless oil. Yield: 1.74 g, 5.65 mmol, 82%. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.41 – 7.24 (m, 5H, CH_{arom}), 4.82 (d, *J* = 12.6 Hz, 1H, C*H*H Bn), 4.72 (d, *J* =

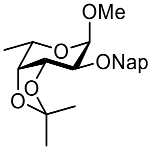
12.7 Hz, 1H, CH*H* Bn), 4.61 (d, *J* = 3.5 Hz, 1H, H-1), 4.32 (dd, *J* = 7.9, 5.4 Hz, 1H, H-3), 4.11 – 4.01 (m, 2H, H-4, H-5), 3.50 (dd, *J* = 7.9, 3.6 Hz, 1H, H-2), 3.38 (s, 3H, CH_3 OMe), 1.40 (s, 3H, CH_3 isopropylidene), 1.35 (s, 3H, CH_3 isopropylidene), 1.32 (d, *J* = 6.7 Hz, 3H, H-6), ^{13}C NMR (101 MHz, $CDCl_3$) δ 138.3 (C_q), 128.5, 128.1, 127.9 (CH_{arom}), 108.9 (C_q isopropylidene), 98.5 (C-1), 76.3, 76.2, 76.2 (C-2, C-3, C-4), 72.4 (CH_2 Bn), 62.9 (C-5), 55.6 (CH_3 OMe), 28.3, 26.6 (CH_3 isopropylidene), 16.4 (C-6). Spectra in agreement with literature.[92]

Methyl 2-*O*-allyl-3,4-*O*-isopropylidene-α-L-fucopyranoside (S71)



Methyl 3,4-*O*-isopropylidene-α-L-fucopyranoside (**S69**, 1.5 g, 6.87 mmol), allyl bromide (0.89 mL, 10.3 mmol, 1.5 eq) and sodium hydride (60% dispersion in mineral oil, 247 mg, 10.3 mmol, 1.5 eq) were dissolved in DMF. After full conversion, the reaction was quenched with water and extracted with diethyl ether. The organic phase was dried with $MgSO_4$ and concentrated under reduced pressure. Silica chromatography (10% acetone in pentane) yields the title compound as colourless oil. Yield: 1.71 g, 6.64 mmol, 97%. ^{1}H NMR (400 MHz, $CDCl_3$) δ 5.93 (dddd, *J* = 17.3, 10.3, 6.3, 5.5 Hz, 1H, CH_2-C*H*=CH_2), 5.28 (dq, *J* = 17.3, 1.6 Hz, 1H, CH_2-CH=C*H*H), 5.19 (dq, *J* = 10.3, 1.3 Hz, 1H, CH_2-CH=CH*H*), 4.73 (d, *J* = 3.5 Hz, 1H, H-1), 4.32 – 4.23 (m, 2H, H-3, C*H*H-CH=CH_2), 4.18 (ddt, *J* = 13.0, 6.3, 1.3 Hz, 1H, CH*H*-CH=CH_2), 4.12 – 4.02 (m, 2H, H-4, H-5), 3.52 (dd, *J* = 7.9, 3.6 Hz, 1H, H-2), 3.41 (s, 3H, CH_3 OMe), 1.53 (s, 3H, CH_3 isopropylidene), 1.39 – 1.30 (m, 6H, H-6, CH_3 isopropylidene), ^{13}C NMR (101 MHz, $CDCl_3$) δ 135.0 (CH_2-*C*H=CH_2), 117.8 (CH_2-CH=*C*H_2), 108.9 (C_q isopropylidene), 98.5 (C-1), 76.5, 76.3, 76.1 (C-2, C-3, C-4), 71.9 (*C*H_2-CH=CH_2), 62.9 (C-5), 55.6 (CH_3 OMe), 28.4, 26.5 (CH_3 isopropylidene), 16.4 (C-6). Spectra in agreement with literature.[93]

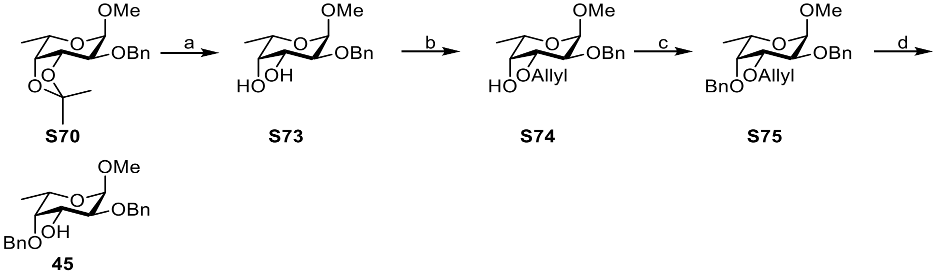
Methyl 3,4-*O*-isopropylidene-2-*O*-(2-naphthyl)methyl-α-L-fucopyranoside (S72)



Methyl 3,4-*O*-isopropylidene-α-L-fucopyranoside (1 g, 4.58 mmol), 2-(Bromomethyl)naphthalene (1.52 g, 6.87 mmol, 1.5 eq) and sodium hydride (60% dispersion in mineral oil, 275 mg, 6.87 mmol, 1.5 eq) were dissolved in DMF. When TLC shows full conversion, the reaction was quenched with water and extracted with diethyl ether. The organic phase was dried with $MgSO_4$ and concentrated under reduced pressure. The residue was purified over silica (10% diethyl ether in pentane) to yield the title compound as colourless oil. Yield: 1.27 g, 3.54 mmol, 77%. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.91 – 7.79 (m, 4H, CH_{arom}), 7.55 (dd, *J* = 8.4, 1.7 Hz, 1H, CH_{arom}), 7.52 – 7.45 (m, 2H, CH_{arom}), 5.01 (d, *J* = 12.2 Hz, 1H, C*H*H Nap), 4.91 (d, *J* = 12.7 Hz, 1H, CH*H* Nap), 4.66 (d, *J* = 3.6 Hz, 1H, H-1), 4.39 (dd, *J* = 7.9, 5.5 Hz, 1H, H-3), 4.17 – 4.05 (m, 2H, H-4, H-5), 3.58 (dd, *J* = 7.9, 3.5 Hz, 1H, H-2), 3.41 (s, 3H, CH_3 OMe), 1.41 (s, 3H, CH_3 isopropylidene), 1.38 (s, 3H, CH_3 isopropylidene), 1.34 (d, *J* = 6.7 Hz, 3H, H-6), ^{13}C NMR

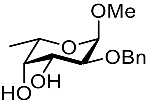
(101 MHz, $CDCl_3$) δ 135.8, 133.3, 133.2 (C_q), 128.3, 128.0, 127.8, 127.0, 126.2, 126.1, 126.0 (CH_{arom}), 108.9 (C_q isopropylidene), 98.5 (C-1), 76.3, 76.2, 76.2 (C-2, C-3, C-4), 72.6 (CH_2 Nap), 62.9 (C-5), 55.6 (CH_3 OMe, 28.3, 26.5 (CH_3 isopropylidene), 16.4 (C-6). Spectra in agreement with literature.[94]

Preparation of acceptor **45**



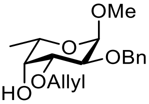
*Scheme **S28**: preparation of acceptor **45**: reagents and conditions: a) PTSA, MeOH, 91%; b) i: DBTO, toluene reflux, ii: allyl bromide, CsF, DMF, 58%; c) BnBr, NaH, DMF, %; d) DMBA, $Pd(Ph_3P)_4$, MeOH, 40 °C, 96%*

Methyl 2-*O*-benzyl-α-L-fucopyranoside (S73)



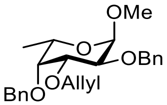
Methyl 2-*O*-benzyl-3,4-*O*-isopropylidene-α-L-fucopyranoside (**S70**, 1.40 g, 4.54 mmol) and PTSA-H_2O (86 mg, 0.45 mmol, 0.1 eq) were dissolved in methanol and stirred until TLC showed full conversion of the starting material. 0.19 mL triethylamine was added and the reaction mixture was concentrated under reduced pressure. The residue was purified over silica (30% EtOAc in pentane) to give the title compound as colourless oil. Yield: 1.11 g, 4.14 mmol, 91%. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.38 – 7.28 (m, 5H, CH_{arom}), 4.68 – 4.63 (m, 3H, H-1, CH_2 Bn), 3.97 (dt, *J* = 9.8, 3.1 Hz, 1H, H-3), 3.94 – 3.88 (m, 1H, H-5), 3.81 – 3.75 (m, 1H, H-4), 3.69 (dd, *J* = 9.9, 3.5 Hz, 1H, H-2), 3.34 (s, 3H, CH_3 OMe), 2.79 (d, *J* = 3.2 Hz, 1H, 3-OH), 2.63 (d, *J* = 2.7 Hz, 1H, 4-OH), 1.27 (d, *J* = 6.6 Hz, 3H, H-6), ^{13}C NMR (101 MHz, $CDCl_3$) δ 138.0 C_q), 128.6, 128.2, 128.1 (CH_{arom}), 97.7 (C-1), 76.5 (C-2), 72.8 (CH_2 Bn), 71.6 (C-4), 69.5 (C-3), 65.3 (C-5), 55.3 (CH_3 OMe), 16.1 (C-6). Spectra in agreement with literature.[95]

Methyl 3-*O*-allyl-2-*O*-benzyl-α-L-fucopyranoside (S74)



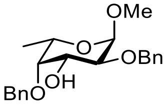
Methyl 2-O-benzyl-α-L-fucopyranoside (**S73**, 671 mg, 2.5 mmol) and dibutyltin oxide (809 mg, 3.25 mmol, 1.3 eq) were refluxed in toluene for 2 hr, while water was removed using a Dean-Stark trap. The reaction mixture was cooled to RT and concentrated under reduced pressure. The residue was dissolved in DMF, after which CsF (494 mg, 3.25 mmol, 1.3 eq) and allyl bromide (0.28 mL, 3.25 mmol, 1.3 eq) were added. The reaction mixture was stirred overnight, after which it was diluted with water and extracted with diethyl ether. The organic phase was dried with $MgSO_4$ and concentrated under reduced pressure. Silica chromatography (30% diethyl ether in pentane) yield the title compound as colourless oil. Yield: 446 mg, 1.45 mmol, 58%. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.42 – 7.19 (m, 5H, CH_{arom}), 5.95 (ddt, *J* = 17.2, 10.4, 5.6 Hz, 1H, CH_2-C*H*=CH_2), 5.32 (dq, *J* = 17.2, 1.7 Hz, 1H, CH_2-CH=C*H*H), 5.20 (dt, *J* = 10.3, 1.5 Hz, 1H, CH_2-CH=CH*H*), 4.78 (d, *J* = 12.1 Hz, 1H, C*H*H Bn), 4.64 (d, *J* = 12.1 Hz, 1H, CH*H* Bn), 4.61 (d, *J* = 2.7 Hz, 1H, H-1), 4.29 – 4.16 (m, 2H, C*H*$_2$-CH=CH_2), 3.89 (q, *J* = 6.6 Hz, 1H, H-5), 3.83 (q, *J* = 1.5 Hz, 1H, H-4), 3.79 – 3.72 (m, 2H, H-2, H-3), 3.36 (s, 3H, CH_3 OMe), 2.60 – 2.31 (m, 1H, OH), 1.28 (d, *J* = 6.6 Hz, 3H, H-6), ^{13}C NMR (101 MHz, $CDCl_3$) δ 138.5 (C_q), 134.9 (CH_2-*C*H=CH_2), 128.5, 128.1, 127.9 (CH_{arom}), 117.4 (CH_2-CH=*C*H$_2$), 98.7 (C-1), 77.5, 75.3 (C-2, C-3), 73.5 (CH_2 Bn), 71.6 (*C*H$_2$-CH=CH_2), 70.4 (C-4), 65.1 (C-5), 55.4 (CH_3 OMe), 16.2 (C-6); HRMS: $[M+H]^+$ calcd for $C_{17}H_{24}O_5H$ 309.16965, found 309.14832.

Methyl 3-*O*-allyl-2,4-di-*O*-benzyl-α-L-fucopyranoside (S75)



Methyl 3-*O*-allyl-2-*O*-benzyl-α-L-fucopyranoside (**S74**, 425 mg, 1.38 mmol), benzyl bromide (0.33 mL, 2.76 mmol, 1.5 eq) and sodium hydride (60% dispersion in mineral oil, 110 mg, 2.76 mmol, 1.5 eq) were dissolved in DMF. After full conversion of the starting material, the reaction was quenched with water and extracted with diethyl ether. The organic phase was dried with $MgSO_4$ and concentrated under reduced pressure. Silica chromatography (25% diethyl ether in pentane) yield the title compound as colourless oil. Yield: 438 mg, 1.10 mmol, 80%). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.41 – 7.25 (m, 10H, CH_{arom}), 5.98 (ddt, *J* = 17.2, 10.5, 5.2 Hz, 1H, CH_2-C*H*=CH_2), 5.36 (dq, *J* = 17.2, 1.8 Hz, 1H, CH_2-CH=C*H*H), 5.19 (dq, *J* = 10.5, 1.5 Hz, 1H, CH_2-CH=CH*H*), 4.98 (d, *J* = 11.6 Hz, 1H, C*H*H Bn), 4.82 (d, *J* = 12.1 Hz, 1H, C*H*H Bn), 4.70 – 4.62 (m, 3H, H-1, 2x CH*H* Bn), 4.31 (ddt, *J* = 13.0, 5.0, 1.6 Hz, 1H, C*H*H-CH=CH_2), 4.20 (ddt, *J* = 13.1, 5.5, 1.5 Hz, 1H, CH*H*-CH=CH_2), 3.97 (dd, *J* = 10.1, 3.7 Hz, 1H, H-2), 3.88 – 3.77 (m, 2H, H-3, H-5), 3.63 (dd, *J* = 2.9, 1.3 Hz, 1H, H-4), 3.34 (s, 3H, CH_3 OMe), 1.12 (d, *J* = 6.5 Hz, 3H, H-6), ^{13}C NMR (101 MHz, $CDCl_3$) δ 138.8 (C_q), 135.4 (CH_2-*C*H=CH_2), 128.6, 128.4, 128.3, 128.2, 127.7, 127.7 (CH_{arom}), 116.4 (CH_2-CH=*C*H$_2$), 99.0 (C-1), 79.1 (C-3), 77.6 (C-4), 76.1 (C-2), 74.8, 73.6 (CH_2 Bn), 72.0 (*C*H$_2$-CH=CH_2), 66.1 (C-5), 55.4 (CH_3 OMe), 16.7 (C-6); HRMS: $[M+Na]^+$ calcd for $C_{24}H_{30}O_5Na$ 421.19909, found 421.19662.

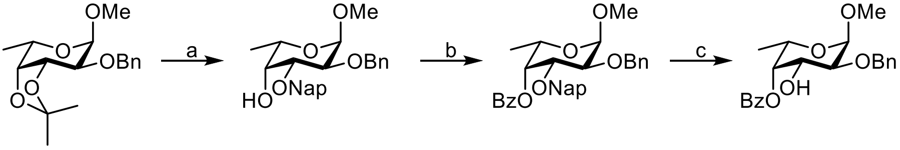
Methyl 2,4-di-*O*-benzyl-α-L-fucopyranoside (45)



Methyl 3-*O*-allyl-2,4-di-*O*-benzyl-α-L-fucopyranoside (**S75**, 418 mg, 1.05 mmol) and DMBA (328 mg, 2.10 mmol, 2 eq) were dissolved in methanol. The reaction mixture was flushed with N_2 for 30 min and heated to 40 °C, after which $Pd(Ph_3P)_4$ (61 mg, 0.05 mmol, 0.05 eq) was added under a flow of N_2. Upon completion, the reaction mixture was concentrated under reduced pressure and the residue was purified by silica chromatography (15% acetone in pentane), yielding the title compound as colourless oil. Yield: 361 mg, 1.01 mmol, 96%. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.52 –

7.14 (m, 10H, CH$_{arom}$), 4.84 (d, *J* = 11.6 Hz, 1H, C*H*H Bn), 4.73 – 4.63 (m, 4H, H-1, CH*H* Bn, CH$_2$ Bn), 4.06 (ddd, *J* = 10.0, 4.7, 3.2 Hz, 1H, H-3), 3.92 – 3.86 (m, 1H, H-5), 3.78 (dd, *J* = 10.1, 3.5 Hz, 1H, H-2), 3.64 (dd, *J* = 3.4, 1.3 Hz, 1H, H-5), 3.32 (s, 3H, CH$_3$ OMe), 2.28 (d, *J* = 4.7 Hz, 1H, OH), 1.17 (d, *J* = 6.6 Hz, 3H, H-6), ^{13}C NMR (101 MHz, CDCl$_3$) δ 138.5, 138.3 (C$_q$), 128.6, 128.5, 128.4, 128.3, 128.1, 127.9 (CH$_{arom}$), 98.1 (C-1), 79.5 (C-4), 77.2 (C-2), 75.6, 73.0 (CH$_2$ Bn), 70.6 (C-3), 66.1 (C-5), 55.4 (CH$_3$ OMe), 16.8 (C-6). Spectra in agreement with literature.[95]

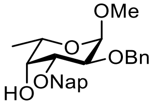
Preparation of acceptor **46**



S70 **S76** **S77** **46**

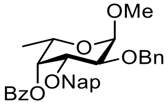
Scheme S29: *preparation of acceptor* ***46***: *reagents and conditions: a) i: PTSA, MeOH, 50 °C, ii: DBTO, toluene reflux, iii: NapBr, CsF, DMF, 76%; b) BzCl, pyridine, 98%; c) DDQ, DCM/*H_2O *(9:1), 84%*

Methyl 2-*O*-benzyl-3-*O*-(2-naphthyl)methyl-α-L-fucopyranoside (S76)



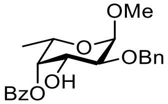
Methyl 2-*O*-benzyl-3,4-*O*-isopropylidene-α-L-fucopyranoside (**S70**, 1.72 g, 5.58 mmol) and PTSA-H$_2$O (106 mg, 0.56 mmol, 0.1 eq) were dissolved in methanol and stirred until TLC showed full conversion of the starting material. 0.16 mL triethylamine was added and the reaction mixture was concentrated under reduced pressure. The residue was dissolved in toluene with dibutyltin oxide (1.81 g, 7.25 mmol, 1.3 eq) and heated to a reflux while removing water with a Dean-Stark trap. After 2 hr, the reaction mixture was cooled to RT and concentrated under reduced pressure. The residue was dissolved in DMF and NapBr (1.60 g, 7.25 mmol, 1.3 eq) and CsF (1.10 g, 7.25 mmol, 1.3 eq) were added. After stirring overnight, the reaction mixture was diluted with water and extracted with diethyl ether. The organic phase was dried with MgSO$_4$ and concentrated under reduced pressure. Silica chromatography (10% acetone in pentane) yields the title compound as colourless oil. Yield: 1.72 g, 4.22 mmol, 76%. ^{1}H NMR (400 MHz, CDCl$_3$) δ 7.91 – 7.81 (m, 5H, CH$_{arom}$), 7.56 – 7.49 (m, 4H, CH$_{arom}$), 7.45 – 7.30 (m, 5H, CH$_{arom}$), 5.00 (d, *J* = 12.6 Hz, 1H, C*H*H Bn/Nap), 4.91 (d, *J* = 11.8 Hz, 1H, CH*H* Bn/Nap), 4.86 (d, *J* = 12.2 Hz, 1H, C*H*H Bn/Nap), 4.74 (d, *J* = 12.1 Hz, 1H, CH*H* Bn/Nap), 4.68 (d, *J* = 3.5 Hz, 1H, H-1), 3.95 (dd, *J* = 9.8, 3.2 Hz, 1H, H-3), 3.92 – 3.87 (m, 2H, H-2, H-5), 3.85 (dt, *J* = 3.1, 1.5 Hz, 1H, H-4), 3.41 (s, 3H, CH$_3$ OMe), 2.55 (t, *J* = 1.5 Hz, 1H, OH), 1.30 (d, *J* = 6.6 Hz, 3H, H-6), ^{13}C NMR (101 MHz, CDCl$_3$) δ 138.5, 135.7, 133.3, 133.2 (C$_q$), 128.5, 128.4, 128.4, 128.2, 128.0, 127.9, 127.8, 126.8, 126.3, 126.3, 126.1, 126.0, 125.9 (CH$_{arom}$), 98.6 (C-1), 77.8 (C-3), 75.7 (C-2), 73.5, 73.0 (CH$_2$ Bn, CH$_2$ Nap), 70.6 (C-4), 65.1 (C-5), 55.4 (CH$_3$ OMe), 16.2 (C-6); HRMS: [M+NH$_4$]$^+$ calcd for $C_{25}H_{28}O_5NH_4$ 426.22750, found 426.22659.

Methyl 4-*O*-benzoyl-2-*O*-benzyl-3-*O*-(2-naphthyl)methyl-α-L-fucopyranoside (S77)



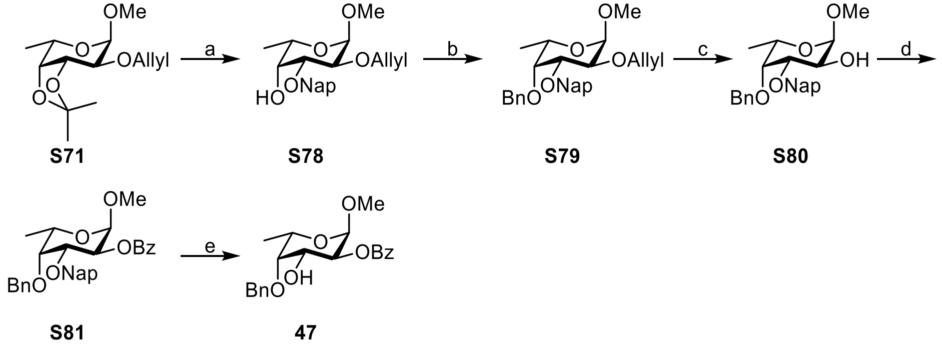
Methyl 2-*O*-benzyl-3-*O*-(2-naphthyl)methyl-α-L-fucopyranoside (**S76**, 1.67 g, 4.09 mmol) was dissolved in 5 mL pyridine, after which benzoyl chloride (0.71 mL, 6.13 mmol, 1.5 eq) was added. Upon full conversion of the starting material, the reaction mixture was diluted with ethyl acetate and washed with 1M HCl and with sat. aq. $NaHCO_3$. The organic phase was dried and concentrated under reduced pressure. Silica chromatography (25% diethyl ether in pentane) yields the title compound as colourless oil. Yield: 2.06 g, 4.09 mmol, 98%. ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.17 – 8.10 (m, 2H, CH_{arom}), 7.87 – 7.78 (m, 3H, CH_{arom}), 7.75 – 7.71 (m, 1H, CH_{arom}), 7.66 – 7.60 (m, 1H, CH_{arom}), 7.53 – 7.43 (m, 5H, CH_{arom}), 7.42 – 7.32 (m, 5H, CH_{arom}), 5.69 (dd, *J* = 3.4, 1.3 Hz, 1H, H-4), 5.00 (d, *J* = 11.7 Hz, 1H, C*H*H Bn/Nap), 4.91 (d, *J* = 12.1 Hz, 1H, C*H*H Bn/Nap), 4.83 (d, *J* = 11.7 Hz, 1H, CH*H* Bn/Nap), 4.79 – 4.73 (m, 2H, H-1, CH*H* Bn/Nap), 4.19 – 4.11 (m, 2H, H-3, H-5), 4.00 (dd, *J* = 10.1, 3.6 Hz, 1H, H-2), 3.46 (s, 3H, CH_3 OMe), 1.23 (d, *J* = 6.5 Hz, 3H, H-6), ^{13}C NMR (101 MHz, $CDCl_3$) δ 166.4 (C=O), 138.5, 135.9, 133.4 (C_q), 133.2 (CH_{arom}), 133.0, 130.2 (C_q), 130.2, 130.1, 128.5, 128.5, 128.4, 128.2, 128.1, 128.1, 127.9, 127.7, 126.7, 126.0, 126.0, 125.8 (CH_{arom}), 99.2 (C-1), 76.4 (C-3), 75.0 (C-2), 73.7, 72.1 (CH_2 Bn, CH_2 Nap), 71.8 (C-4), 64.9 (C-5), 55.6 (CH_3 OMe), 16.4 (C-6); HRMS: $[M+NH_4]^+$ calcd for $C_{32}H_{32}O_6NH_4$ 530.25371, found 530.25291.

Methyl 4-*O*-benzoyl-2-*O*-benzyl-α-L-fucopyranoside (46)



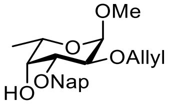
Methyl 4-*O*-benzoyl-2-*O*-benzyl-α-L-fucopyranoside (2.00 g, 3.90 mmol) and DDQ (1.77 g, 7.80 mmol, 2 eq) were dissolved in DCM/H_2O (9:1). After full conversion, the reaction mixture was diluted with DCM and washed twice with sat. aq. $NaHCO_3$. The organic phase was dried with $MgSO_4$ and concentrated under reduced pressure. The residue was purified over silica (15% acetone in pentane) to give the title compound as colourless oil. Yield: 1.22 g, 3.28 mmol, 84%. $[\alpha]_D^{25}$ = -99.0° (c = 0.60, $CHCl_3$); IR (thin film): 668, 713, 751, 1050, 1274, 1452, 1721; ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.13 – 8.05 (m, 2H, CH_{arom}), 7.65 – 7.58 (m, 1H, CH_{arom}), 7.48 (dd, *J* = 8.4, 7.1 Hz, 2H, CH_{arom}), 7.44 – 7.31 (m, 5H, CH_{arom}), 5.50 (dd, *J* = 3.6, 1.3 Hz, 1H, H-4), 4.80 (d, *J* = 3.5 Hz, 1H, H-1), 4.77 (d, *J* = 12.0 Hz, 1H, C*H*H Bn), 4.73 (d, *J* = 12.0 Hz, 1H, CH*H* Bn), 4.30 (dt, *J* = 10.0, 3.3 Hz, 1H, H-3), 4.14 (qd, *J* = 6.5, 1.3 Hz, 1H, H-5), 3.85 (dd, *J* = 10.1, 3.5 Hz, 1H, H-2), 3.42 (s, 3H, CH_3 OMe), 2.45 (d, *J* = 3.2 Hz, 1H, OH), 1.20 (d, *J* = 6.6 Hz, 3H, H-6), ^{13}C NMR (101 MHz, $CDCl_3$) δ 166.6 (C=O), 137.9 (C_q), 133.2, 129.9 (CH_{arom}), 129.8 (C_q), 128.6, 128.4, 128.2, 128.1 (CH_{arom}), 98.1 (C-1), 76.5 (C-2), 73.8 (C-4), 72.9 (CH_2 Bn), 68.3 (C-3), 64.9 (C-5), 55.5 (CH_3 OMe), 16.2 (C-6); HRMS: $[M+Na]^+$ calcd for $C_{21}H_{24}O_6Na$ 395.14651, found 395.14616.

Preparation of acceptor **47**



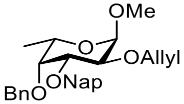
Scheme S30: *preparation of acceptor **47**: reagents and conditions: a) i: PTSA, MeOH, 50 °C, ii: DBTO, toluene reflux, iii: NapBr, CsF, DMF, 98%; b) BnBr, NaH, DMF, 65%; c) Pd(Ph_3P)$_4$, DMBA, MeOH, 40 °C, 71%; d) BzCl, pyridine, 100%; e) DDQ, DCM/H_2O (9:1), 84%*

Methyl 2-*O*-allyl-3-*O*-(2-naphthyl)methyl-α-L-fucopyranoside (S78)



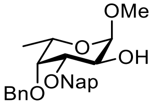
Methyl 2-*O*-allyl-3,4-*O*-isopropylidene-α-L-fucopyranoside (**S71**, 1.7 g, 6.58 mmol) and PTSA-H_2O (125 mg, 0.66 mmol, 0.1 eq) were dissolved in methanol and heated to 50 °C. After full conversion, 0.2 mL triethylamine was added and the reaction mixture was concentrated under reduced pressure. The residue was dissolved in toluene with dibutyltin oxide (2.1 g, 8.45 mmol, 1.3 eq) and heated to a reflux for 2 hr, while removing water with a Dean-Stark trap. The reaction mixture was then cooled to RT and concentrated under reduced pressure. The residue was dissolved in DMF and NapBr (1.87 g, 8.45 mmol, 1.3 eq), CsF (1.28 g, 8.45 mmol, 1.3 eq) were added. After overnight stirring, the reaction mixture was diluted with water and extracted with diethyl ether. The organic phase was dried with $MgSO_4$ and concentrated under reduced pressure. The residue was purified over silica (10% acetone in pentane) yielding the slightly impure title compound as yellowish oil. Yield: 2.27 g, 6.34 mmol, 98%. ^1H NMR (400 MHz, $CDCl_3$) δ 7.93 – 7.78 (m, 4H, CH_{arom}), 7.55 – 7.45 (m, 3H, CH_{arom}), 6.00 (dddd, *J* = 17.2, 10.3, 6.3, 5.4 Hz, 1H, CH_2-C*H*=CH_2), 5.34 (dq, *J* = 17.2, 1.6 Hz, 1H, CH_2-CH=C*H*H), 5.23 (dq, *J* = 10.3, 1.3 Hz, 1H, CH_2-CH=CH*H*), 4.98 (d, *J* = 11.8 Hz, 1H, C*H*H Nap), 4.88 (d, *J* = 11.9 Hz, 1H, CH*H* Nap), 4.83 (d, *J* = 3.4 Hz, 1H, H-1), 4.31 (ddt, *J* = 12.8, 5.4, 1.4 Hz, 1H, C*H*H-CH=CH_2), 4.23 (ddt, *J* = 12.8, 6.3, 1.3 Hz, 1H, CH*H*-CH=CH_2), 3.95 – 3.80 (m, 4H, H-2, H-3, H-4, H-5), 3.43 (s, 3H, CH_3 OMe), 2.54 (t, *J* = 1.5 Hz, 1H, OH), 1.31 (d, *J* = 6.7 Hz, 3H, H-6), ^{13}C NMR (101 MHz, $CDCl_3$) δ 135.8 (C_q), 135.0 (CH_2-CH=CH_2), 133.3, 133.2 (C_q), 128.4, 128.0, 127.8, 126.8, 126.3, 126.1, 125.9 (CH_{arom}), 117.7 (CH_2-CH=*C*H_2), 98.6 (C-1), 77.7 (C-3), 75.6 (C-2), 73.1 (CH_2 Nap), 72.7 (*C*H_2-CH=CH_2), 70.7 (C-4), 65.2 (C-5), 55.4 (CH_3 OMe), 16.2 (C-6); HRMS: $[M+Na]^+$ calcd for $C_{21}H_{26}O_5Na$ 381.16725, found 381.16656.

Methyl 2-*O*-allyl-4-*O*-benzyl-3-*O*-(2-naphthyl)methyl-α-L-fucopyranoside (S79)



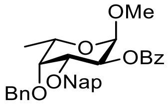
Methyl 2-*O*-allyl-3-*O*-(2-naphthyl)methyl-α-L-fucopyranoside (**S78**, 1.26 g, 3.50 mmol) was dissolved in DMF after which benzyl bromide (0.62 mL, 5.25 mmol, 1.5 eq) and sodium hydride (60% dispersion in mineral oil, 210 mg, 5.25 mmol, 1.5 eq) were added. After full conversion, the reaction was quenched with water and extracted with diethyl ether. The organic phase was dried with MgSO$_4$ and concentrated under reduced pressure. The residue was purified over silica (10% diethyl ehter in pentane) yielding the title compound as colourless oil. Yield: 1.02 g, 2.26 mmol, 65%. ^{1}H NMR (400 MHz, CDCl$_3$) δ 7.87 – 7.78 (m, 4H, CH$_{\text{arom}}$), 7.57 – 7.44 (m, 3H, CH$_{\text{arom}}$), 7.37 (ddt, *J* = 5.2, 3.8, 1.5 Hz, 2H, CH$_{\text{arom}}$), 7.35 – 7.26 (m, 3H, CH$_{\text{arom}}$), 5.97 (dddd, *J* = 17.0, 10.3, 6.3, 5.4 Hz, 1H, CH$_2$-C*H*=CH$_2$), 5.31 (dq, *J* = 17.2, 1.6 Hz, 1H, CH$_2$-CH=C*H*H), 5.18 (dq, *J* = 10.4, 1.3 Hz, 1H, CH$_2$-CH=CH*H*), 5.09 – 4.97 (m, 2H, C*H*H Bn, C*H*H Nap), 4.86 (d, *J* = 12.1 Hz, 1H, CH*H* Nap), 4.82 (d, *J* = 3.6 Hz, 1H, H-1), 4.71 (d, *J* = 11.6 Hz, 1H, CH*H* Bn), 4.31 (ddt, *J* = 12.7, 5.4, 1.5 Hz, 1H, C*H*H-CH=CH$_2$), 4.22 (ddt, *J* = 12.8, 6.3, 1.3 Hz, 1H, CH*H*-CH=CH$_2$), 4.02 (dd, *J* = 10.1, 3.6 Hz, 1H, H-2), 3.92 (dd, *J* = 10.1, 2.9 Hz, 1H, H-3), 3.82 (qd, *J* = 6.4, 1.2 Hz, 1H, H-5), 3.63 (dd, *J* = 2.9, 1.3 Hz, 1H, H-4), 3.39 (s, 3H, CH$_3$ OMe), 1.12 (d, *J* = 6.5 Hz, 3H, H-6); ^{13}C NMR (101 MHz, CDCl$_3$) δ 138.7, 136.6 (C$_q$), 135.2 (CH$_2$-*C*H=CH$_2$), 133.4, 133.0 (C$_q$), 128.6, 128.3, 128.2, 128.0, 127.8, 127.7, 126.3, 126.2, 125.9, 125.9 (CH$_{\text{arom}}$), 117.6 (CH$_2$-CH-*C*H$_2$), 98.9 (C-1), 79.3 (C-3), 78.2 (C-2), 76.5 (C-4), 75.0 (CH$_2$ Bn), 73.6 (CH$_2$ Nap), 72.8 (*C*H$_2$-CH=CH$_2$), 66.2 (C-5), 55.4 (CH$_3$ OMe), 16.7 (C-6); HRMS: [M+NH$_4$]$^+$ calcd for C$_{28}$H$_{32}$O$_5$NH$_4$ 466.25880, found 466.25832.

Methyl 4-*O*-benzyl-3-*O*-(2-naphthyl)methyl-α-L-fucopyranoside (S80)



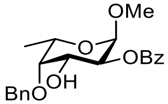
Methyl 2-*O*-allyl-4-*O*-benzyl-3-*O*-(2-naphthyl)methyl-α-L-fucopyranoside (**S79**, 1.00 g, 2.23 mmol) and DMBA (696 mg, 4.46 mmol, 2eq) were dissolved in methanol, heated to 40 °C and flushed with N$_2$ for 30 minutes after which Pd(Ph$_3$P)$_4$ was added under a flow of N$_2$. After full conversion, as indicated by TLC, the reaction mixture was concentrated under reduced pressure. The residue was dissolved in ethyl acetate and washed twice with sat aq. NaHCO$_3$. The organic phase was dried with MgSO$_4$ and concentrated under reduced pressure. The residue was purified over silica (15% acetone in pentane) yielding the title compound as off-white powder. Yield: 650 mg, 1.59 mmol, 71%. ^{1}H NMR (400 MHz, CDCl$_3$) δ 7.90 – 7.79 (m, 4H, CH$_{\text{arom}}$), 7.54 – 7.45 (m, 3H, CH$_{\text{arom}}$), 7.41 – 7.36 (m, 2H, CH$_{\text{arom}}$), 7.34 – 7.26 (m, 3H, CH$_{\text{arom}}$), 4.97 (d, *J* = 11.6 Hz, 1H, C*H*H Bn/Nap), 4.89 (s, 2H, CH$_2$ Bn/Nap), 4.82 (d, *J* = 3.9 Hz, 1H, H-1), 4.70 (d, *J* = 11.6 Hz, 1H, CH*H* Bn/Nap), 4.21 (ddd, *J* = 9.9, 7.6, 4.0 Hz, 1H, H-2), 3.84 (qd, *J* = 6.3, 1.4 Hz, 1H, H-5), 3.73 (dd, *J* = 9.9, 2.8 Hz, 1H, H-3), 3.68 (dd, *J* = 2.9, 1.2 Hz, 1H, H-4), 3.39 (s, 3H, CH$_3$ OMe), 2.19 (d, *J* = 7.7 Hz, 1H, OH), 1.19 (d, *J* = 6.5 Hz, 3H, H-6), ^{13}C NMR (101 MHz, CDCl$_3$) δ 138.6, 135.9, 133.4, 133.1 (C$_q$), 128.4, 128.4, 128.4, 128.0, 127.9, 127.8, 126.5, 126.3, 126.1, 125.8 (CH$_{\text{arom}}$), 99.9 (C-1), 80.0 (C-3), 76.9 (C-4), 74.4, 73.4 (CH$_2$ Bn, CH$_2$ Nap), 69.1 (C-2), 66.7 (C-5), 55.5 (CH$_3$ OMe), 16.9 (C-6); HRMS: [M+NH$_4$]$^+$ calcd for C$_{25}$H$_{28}$O$_5$ 426.22750, found 426.22664.

Methyl 2-*O*-benzoyl-4-*O*-benzyl-3-*O*-(2-naphthyl)methyl-α-L-fucopyranoside (S81)



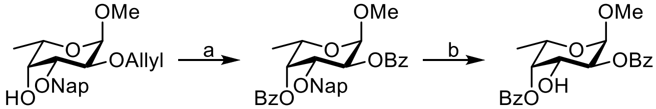
Methyl 4-*O*-benzyl-3-*O*-(2-naphthyl)methyl-α-L-fucopyranoside (**S80**, 625 mg, 1.53 mmol) was dissolved in 5 mL pyridine, after which benzoyl chloride (0.27 mL, 2.30 mol, 1.5 eq) was added. After full conversion of the starting material (TLC), the reaction mixture was diluted with ethyl acetate and washed with 1M HCl and sat. aq. $NaHCO_3$. The organic phase was dried with $MgSO_4$ and concentrated under reduced pressure. The residue was purified over silica (5%→10% acetone in pentane) yielding the title compound as oil that solidifies upon standing. Yield: 784 mg, 1.53 mmol, 100%. ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.09 – 8.04 (m, 2H, CH_{arom}), 7.82 – 7.78 (m, 1H, CH_{arom}), 7.73 (d, *J* = 8.8 Hz, 2H, CH_{arom}), 7.71 – 7.67 (m, 1H, CH_{arom}), 7.59 – 7.53 (m, 1H, CH_{arom}), 7.48 – 7.38 (m, 7H, CH_{arom}), 7.34 – 7.26 (m, 3H, CH_{arom}), 5.60 (dd, *J* = 10.5, 3.8 Hz, 1H, H-2), 5.07 (d, *J* = 3.8 Hz, 1H, H-1), 5.04 (d, *J* = 11.7 Hz, 1H, C*H*H Bn/Nap), 4.86 (s, 2H, CH_2 Bn/Nap), 4.72 (d, *J* = 11.7 Hz, 1H, CH*H* Bn/Nap), 4.14 (dd, *J* = 10.5, 2.9 Hz, 1H, H-3), 3.91 (q, *J* = 6.3 Hz, 1H, H-5), 3.75 (dd, *J* = 2.9, 1.3 Hz, 1H, H-4), 3.32 (s, 3H, CH_3 OMe), 1.20 (d, *J* = 6.5 Hz, 3H, H-6); ^{13}C NMR (101 MHz, $CDCl_3$) δ 166.3 (C=O), 138.5, 135.9, 133.3 (C_q), 133.1 (CH_{arom}), 133.1, 130.3 (C_q), 130.0, 128.6, 128.5, 128.4, 128.3, 128.0, 127.8, 126.5, 126.2, 126.0, 125.9 (CH_{arom}), 97.8 (C-1), 77.3 (C-3, C-4), 75.0, 73.0 (CH_2 Bn, CH_2 Nap), 71.8 (C-2), 66.3 (C-5), 55.5 (CH_3 OMe), 16.8 (C-6); HRMS: $[M+NH_4]^+$ calcd for $C_{32}H_{32}O_6NH_4$ 530.25371, found 530.25265.

Methyl 2-*O*-benzoyl-4-*O*-benzyl-α-L-fucopyranoside (47)



Methyl 2-*O*-benzoyl-4-*O*-benzyl-3-*O*-(2-naphthyl)methyl-α-L-fucopyranoside (**S81**, 750 mg, 1.46 mmol) and DDQ (664 mg, 2.93 mmol, 2eq) were dissolved in DCM/H_2O (9:1). After full conversion, indicated by TLC, the reaction mixture was diluted with DCM and washed twice with sat. aq. $NaHCO_3$. The organic phase was dried with $MgSO_4$ and concentrated under reduced pressure, The residue was purified over silica (5%→10% acetone in pentane) yielding the title compound as oil that solidifies upon standing. Yield: 455 mg, 1.22 mmol, 84%. $[\alpha]_D^{25}$ = -126.0° (c = 0.35, $CHCl_3$); IR (thin film): 711, 756, 1049, 1279, 1452, 1720; ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.16 – 8.02 (m, 2H, CH_{arom}), 7.65 – 7.53 (m, 1H, CH_{arom}), 7.49 – 7.28 (m, 8H, CH_{arom}), 5.25 (dd, *J* = 10.4, 3.7 Hz, 1H, H-2), 4.99 (d, *J* = 3.7 Hz, 1H, H-1), 4.83 (d, *J* = 11.6 Hz, 1H, C*H*H Bn), 4.76 (d, *J* = 11.6 Hz, 1H, CH*H* Bn), 4.19 (ddd, *J* = 10.5, 9.4, 3.5 Hz, 1H, H-3), 4.01 (qd, *J* = 6.6, 1.5 Hz, 1H, H-5), 3.73 (dd, *J* = 3.7, 1.3 Hz, 1H, H-4), 3.38 (s, 3H, CH_3 OMe), 2.23 (d, *J* = 9.4 Hz, 1H, OH), 1.30 (d, *J* = 6.6 Hz, 3H, H-6), ^{13}C NMR (101 MHz, $CDCl_3$) δ 167.0 (C=O), 138.1, 133.3 (CH_{arom}), 130.0 (C_q), 129.9, 128.7, 128.5, 128.2, 128.2 (CH_{arom}), 97.8 (C-1), 80.9 (C-4), 76.3 (CH_2 Bn), 72.7 (C-2), 69.3 (C-3), 66.2 (C-5), 55.6 (CH_3 OMe), 16.9 (C-6); HRMS: $[M+NH_4]^+$ calcd for $C_{21}H_{24}O_6NH_4$ 390.19111, found 390.19054.

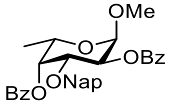
Preparation of acceptor **48**



S78 **S82** **48**

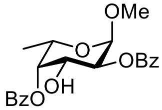
*Scheme **S31**: preparation of acceptor **48**: reagents and conditions: a) i: DMBA, Pd(Ph_3P)$_4$, methanol, 40 °C, ii: BzCl, pyridine, 73%; b) DDQ, DCM/H_2O (9:1), 58%*

Methyl 2,4-di-*O*-benzoyl-3-*O*-(2-naphthyl)methyl-α-L-fucopyranoside (S82)



Methyl 2-*O*-allyl-3-*O*-(2-naphthyl)methyl-α-L-fucopyranoside (**S78**, 896 mg, 2.50 mmol) and DMBA (781 mg, 5.00 mmol, 2 eq) were dissolved in methanol, heated to 40 °C and flushed with N_2 for 30 minutes after which Pd(Ph_3P)$_4$ (144 mg, 0.125 mmol, 0.05 eq) was added under a flow of N_2. After full conversion, as indicated by TLC, the reaction mixture was concentrated under reduced pressure. The residue was dissolved in 7.5 mL pyridine and benzoyl chloride (0.87 mL, 7.50 mmol, 3 eq) was added. After overnight reaction, the reaction mixture was diluted with ethyl acetate and washed with 1M HCl and sat. aq. $NaHCO_3$. The organic phase was dried with $MgSO_4$ and concentrated under reduced pressure. The residue was purified over silica to give the title compound. Yield: 632 mg, 1.20 mmol, 48%. Further elution gave methyl 2-*O*-benzoyl-3-*O*-(2-naphthyl)methyl-α-L-fucopyranoside. Yield: 323 mg, 0.77 mmol, 31%. The latter was converted to the title compound with BzCl/pyridine in 89%, to give a total yield of 73%. ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.29 – 8.19 (m, 2H, CH_{arom}), 8.08 – 8.02 (m, 2H, CH_{arom}), 7.85 – 7.79 (m, 1H, CH_{arom}), 7.74 – 7.68 (m, 2H, CH_{arom}), 7.67 – 7.58 (m, 3H, CH_{arom}), 7.56 – 7.36 (m, 7H, CH_{arom}), 5.79 (dd, *J* = 3.5, 1.3 Hz, 1H, H-4), 5.52 (dd, *J* = 10.4, 3.8 Hz, 1H, H-2), 5.17 (d, *J* = 3.7 Hz, 1H, H-1), 4.92 (d, *J* = 12.6 Hz, 1H, C*H*H Nap), 4.77 (d, *J* = 12.6 Hz, 1H, CH*H* Nap), 4.26 (dd, *J* = 10.4, 3.5 Hz, 1H, H-3), 4.21 (qd, *J* = 6.6, 1.2 Hz, 1H, H-5), 3.40 (s, 3H, CH_3 OMe), 1.30 (d, *J* = 6.6 Hz, 3H, H-6); ^{13}C NMR (101 MHz, $CDCl_3$) δ 166.6, 166.3 (C=O), 135.5 (C_q), 133.4, 133.3 (CH_{arom}), 133.1 (C_q), 130.2, 130.0 (CH_{arom}), 130.0, 129.9 (C_q), 128.6, 128.6, 128.5, 128.2, 128.0, 127.7, 126.7, 126.1, 125.9 (CH_{arom}), 97.8 (C-1), 73.2 (C-3), 71.4 (CH_2 Nap), 71.0, 71.0 (C-2, C-4), 64.9 (C-5), 55.6 (CH_3 OMe), 16.5 (C-6); HRMS: $[M+NH_4]^+$ calcd for $C_{32}H_{30}O_7NH_4$ 544.23298, found 544.23201.

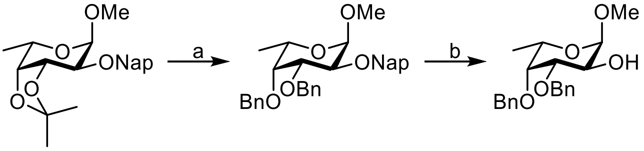
Methyl 2,4-di-*O*-benzoyl-α-L-fucopyranoside (48)



Methyl 2,4-di-*O*-benzoyl-3-*O*-(2-naphthyl)methyl-α-L-fucopyranoside (**S82**, 950 mg, 1.80 mmol) and DDQ (819 mg, 3.61 mmol, 2 eq) were dissolved in 9:1 DCM/H_2O. After full conversion, the reaction mixture was diluted with DCM and washed twice with sat. aq. $NaHCO_3$. The organic phase was dried with $MgSO_4$ and concentrated under reduced pressure. The residue was purified over silica (10% acetone in pentane) to give the title compound as white solid. Yield: 403 mg, 1.04

mmol, 58%. ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.19 – 8.12 (m, 2H, CH_{arom}), 8.11 – 8.04 (m, 2H, CH_{arom}), 7.64 – 7.53 (m, 2H, CH_{arom}), 7.52 – 7.39 (m, 4H, CH_{arom}), 5.56 (dd, *J* = 3.6, 1.3 Hz, 1H, H-4), 5.35 (dd, *J* = 10.5, 3.6 Hz, 1H, H-2), 5.11 (d, *J* = 3.7 Hz, 1H, H-1), 4.48 (dd, *J* = 10.4, 3.5 Hz, 1H, H-3), 4.22 (qd, *J* = 6.5, 1.4 Hz, 1H, H-5), 3.43 (s, 3H, CH_3 OMe), 2.39 (s, 1H, OH), 1.25 (d, *J* = 6.6 Hz, 3H, H-6), ^{13}C NMR (101 MHz, $CDCl_3$) δ 167.0, 166.9 (C=O), 133.6, 133.5, 130.1, 130.0 (CH_{arom}), 129.7, 129.5 (C_q), 128.7, 128.6 (CH_{arom}), 97.8 (C-1), 74.5 (C-4), 72.4 (C-2), 67.6 (C-3), 65.1 (C-5), 55.7 (CH_3 OMe), 16.4 (C-6). Spectra in agreement with literature.[96]

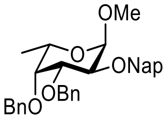
Preparation of acceptor **49**



S72 **S83** **49**

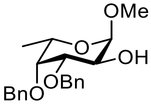
Scheme S32: *preparation of acceptor* ***49***: *reagents and conditions: a) i: PTSA, MeOH, 50 °C, ii: BnBr, NaH, DMF, 72%; b) DDQ, DCM/H_2O (9:1), 82%*

Methyl 3,4-di-*O*-benzyl-2-*O*-(2-naphthyl)methyl-α-L-fucopyranoside (S83)



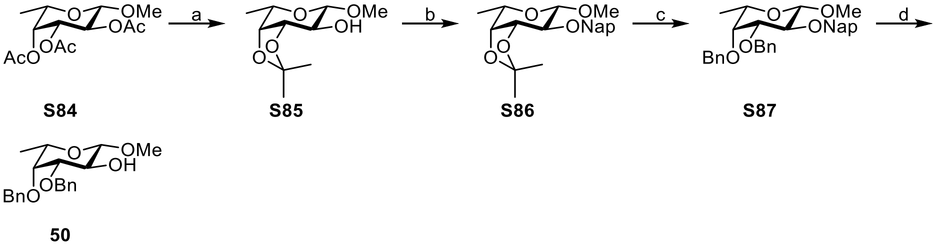
Methyl 3,4-*O*-isopropylidene-2-*O*-(2-naphthyl)methyl-α-L-fucopyranoside (**S72**, 1.25 g, 3.49 mmol) and PTSA-H_2O (66 mg, 0.35 mmol, 0.1 eq) were dissolved in methanol and heated to 50 °C. After full conversion, 0.1 mL of triethylamine was added and the mixture was concentrated under reduced pressure. The residue was dissolved in DMF and benzyl bromide (1.24 mL, 10.5 mmol, 3 eq) and sodium hydride (60% dispersion in mineral oil, 418 mg, 10.5 mmol, 3 eq) were added. After stirring for 2.5 hr, the reaction was quenched with water and extracted with diethyl ether. The organic phase was dried with $MgSO_4$ and concentrated under reduced pressure. The residue was purified over silica (5% acetone in pentane) to give the title compound as colourless oil. Yield: 1.25 g, 2.51 mmol, 72%. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.84 – 7.73 (m, 4H, CH_{arom}), 7.50 (dd, *J* = 8.4, 1.7 Hz, 1H, CH_{arom}), 7.48 – 7.39 (m, 4H, CH_{arom}), 7.38 – 7.25 (m, 7H, CH_{arom}), 5.01 – 4.96 (m, 2H, 2x C*H*H Bn/Nap), 4.91 (d, *J* = 11.8 Hz, 1H, C*H*H Bn/Nap), 4.86 (d, *J* = 12.3 Hz, 1H, CH*H* Bn/Nap), 4.77 (d, *J* = 11.8 Hz, 1H, CH*H* Bn/Nap), 4.68 – 4.62 (m, 2H, H-1, CH*H* Bn/Nap), 4.09 (dd, *J* = 10.1, 3.6 Hz, 1H, H-2), 3.96 (dd, *J* = 10.1, 2.9 Hz, 1H, H-3), 3.88 – 3.79 (m, 1H, H-5), 3.65 (dd, *J* = 2.9, 1.2 Hz, 1H, H-4), 3.36 (s, 3H, CH_3 OMe), 1.10 (d, *J* = 6.5 Hz, 3H, H-6), ^{13}C NMR (101 MHz, $CDCl_3$) δ 139.1, 138.7, 136.1, 133.4, 133.2 (C_q), 128.6, 128.5, 128.3, 128.2, 128.1, 127.8, 127.7, 127.6, 127.0, 126.2, 126.1, 125.9 (CH_{arom}), 98.9 (C-1), 79.5 (C-3), 78.0 (C-4), 75.8 (C-2), 75.0, 73.7, 73.5 (CH_2 Bn, CH_2 Nap), 66.2 (C-5), 55.5 (CH_3 OMe), 16.7 (C-6); HRMS: $[M+NH_4]^+$ calcd for $C_{32}H_{34}O_5NH_4$ 516.27445, found 516.27365.

Methyl 2,3-di-*O*-benzyl-α-L-fucopyranoside (49)



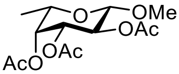
Methyl 3,4-di-*O*-benzyl-2-*O*-(2-naphthyl)methyl-α-L-fucopyranoside (**S83**, 1.12 g, 2.25 mmol) and DDQ (1.02 g, 4.50 mmol, 2 eq) were dissolved in DCM/H_2O 9:1. After full conversion of the starting material, the reaction mixture was diluted with dichloromethane and washed twice with sat. aq. $NaHCO_3$. The organic phase was dried with $MgSO_4$ and concentrated under reduced pressure. The residue was purified over silica (10%→15% acetone in pentane) to give the title compound as white solid. Yield: 665 mg, 1.86 mmol, 82%. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.42 – 7.23 (m, 10H, CH_{arom}), 4.94 (d, *J* = 11.5 Hz, 1H, C*H*H Bn), 4.81 (d, *J* = 3.9 Hz, 1H, H-1), 4.75 (d, *J* = 11.9 Hz, 1H, C*H*H Bn), 4.72 (d, *J* = 11.8 Hz, 1H, CH*H* Bn), 4.65 (d, *J* = 11.6 Hz, 1H, CH*H* Bn), 4.17 (ddd, *J* = 9.8, 7.3, 3.9 Hz, 1H, H-2), 3.88 – 3.81 (m, 1H, H-5), 3.70 (dd, *J* = 9.9, 2.8 Hz, 1H, H-3), 3.67 (dd, *J* = 2.9, 1.1 Hz, 1H, H-4), 3.40 (s, 3H, CH_3 OMe), 2.17 (d, *J* = 7.3 Hz, 1H, OH), 1.19 (d, *J* = 6.5 Hz, 3H, H-6), ^{13}C NMR (101 MHz, $CDCl_3$) δ 138.5, 138.3 (C_q), 128.5, 128.3, 128.3, 127.8, 127.7 (CH_{arom}), 99.7 (C-1), 80.0 (C-3), 76.7 (C-4), 74.0, 72.1 (CH_2 Bn), 68.9 (C-2), 66.1 (C-5), 54.9 (CH_3 OMe), 15.7 (C-6). Spectra in agreement with literature.[97]

Preparation of acceptor **50**



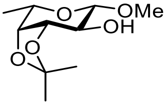
Scheme S33: *preparation of acceptor* ***50***: *reagents and conditions: a) i: NaOMe, MeOH, ii: 2,2-dimethoxypropane, PTSA, 76%; b) NapBr, NaH, DMF, 92%; c) i: PTSA, MeOH, 50 °C, ii: BnBr, NaH, DMF, 79%; d) DDQ, DCM/H₂O (9:1), 77%*

Methyl 2,3,4-tri-*O*-acetyl-β-L-fucopyranoside (S84)



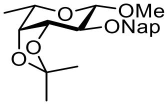
Title compound was isolated as a side product during multiple preparations of the α-anomer (**S68**). ^{1}H NMR (400 MHz, $CDCl_3$) δ 5.24 (dd, *J* = 3.5, 1.2 Hz, 1H, H-4), 5.18 (dd, *J* = 10.4, 7.9 Hz, 1H, H-2), 5.02 (dd, *J* = 10.4, 3.4 Hz, 1H, H-3), 4.38 (d, *J* = 7.9 Hz, 1H, H-1), 3.82 (qd, *J* = 6.4, 1.1 Hz, 1H, H-5), 3.52 (s, 3H, CH_3 OMe), 2.18 (s, 3H, CH_3 Ac), 2.06 (s, 3H, CH_3 Ac), 1.99 (s, 3H, CH_3 Ac), 1.24 (d, *J* = 6.5 Hz, 3H, H-6); Spectra in agreement with literature.[90]

Methyl 3,4-*O*-isopropylidene-β-L-fucopyranoside (S85)



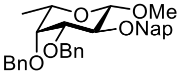
Methyl 2,3,4-tri-*O*-acetyl-β-L-fucopyranoside (**S84**, 3.00 g, 9.86 mmol) and NaOMe (53 mg, 0.99 mmol, 0.1 eq) were dissolved in methanol. After full deprotection, the pH of the reaction mixture was adjusted to 5 with amberlite. The solution was filtered over a short path of celite and concentrated under reduced pressure. Residual methanol and water were removed by coevaporation with toluene. The residue was suspended in 2,2-dimethoxypropane (30.2 mL, 246 mmol, 25 eq), after which PTSA-H_2O (188 mg, 0.99 mmol, 0.1 eq) was added. After 16 hr, triethylamine (0.28 mL, 1.97 mmol, 0.2 eq) was added and the reaction mixture was concentrated under reduced pressure. The residue was purified over silica (35% ethyl acetate in pentane) yields the title compound as colourless oil that slowly solidifies. Yield: 1.63 g, 7.47 mmol, 76%. ^{1}H NMR (400 MHz, $CDCl_3$) δ 4.10 – 4.01 (m, 2H, H-1, H-2), 4.01 (dd, *J* = 5.5, 2.2 Hz, 1H, H-4), 3.87 (qd, *J* = 6.6, 2.1 Hz, 1H, H-5), 3.56 – 3.47 (m, 4H, H-3, CH_3 OMe), 2.79 (d, *J* = 2.5 Hz, 1H, OH), 1.53 (s, 3H, CH_3 isopropylidene), 1.43 (d, *J* = 6.6 Hz, 3H, H-6), 1.36 (s, 3H, CH_3 isopropylidene), ^{13}C NMR (101 MHz, $CDCl_3$) δ 109.9 (C_q isopropylidene), 103.2 (C-1), 78.9 (C-2), 76.4 (C-4), 73.7 (C-3), 69.2 (C-5), 56.9 (CH_3 OMe), 28.3, 26.4, (CH_3 isopropylidene) 16.6 (C-6). Spectra in agreement with literature.[91]

Methyl 3,4-*O*-isopropylidene-2-*O*-(2-naphthyl)methyl-β-L-fucopyranoside (S86)



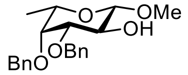
Methyl 3,4-*O*-isopropylidene-β-L-fucopyranoside (**S85**, 1.25 g, 5.73 mmol) was dissolved in DMF, after which NapBr (1.90 g, 8.59 mmol, 1.5 eq) and NaH (60% dispersion in mineral oil, 344 mg, 8.59 mmol, 1.5 eq) were added. Upon full conversion, the reaction was quenched with water and extracted with diethyl ether. The organic phase was dried with $MgSO_4$ and concentrated under reduced pressure. The residue was purified over silica (15% diethyl ether in pentane) to give the title compound as yellowish oil. Yield: 1.89 g, 5.27 mmol, 92%. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.86 – 7.77 (m, 4H, CH_{arom}), 7.52 (dd, *J* = 8.6, 1.7 Hz, 1H, CH_{arom}), 7.48 – 7.41 (m, 2H, CH_{arom}), 4.99 (d, *J* = 12.0 Hz, 1H, C*H*H Nap), 4.95 (d, *J* = 12.0 Hz, 1H, CH*H* Nap), 4.22 (d, *J* = 8.0 Hz, 1H, H-1), 4.16 (dd, *J* = 7.0, 5.5 Hz, 1H, H-3), 3.98 (dd, *J* = 5.5, 2.1 Hz, 1H, H-4), 3.82 (qd, *J* = 6.6, 2.1 Hz, 1H, H-5), 3.56 (s, 3H, CH_3 OMe), 3.42 (dd, *J* = 8.1, 7.1 Hz, 1H, H-2), 1.40 (d, *J* = 6.6 Hz, 3H, H-6), 1.33 (s, 3H, CH_3 isopropylidene), 1.29 (s, 3H, CH_3 isopropylidene); HRMS: $[M+NH_4]^+$ calcd for $C_{21}H_{26}O_5NH_4$ 376.21185, found 376.21136.

Methyl 3,4-di-*O*-benzyl-2-*O*-(2-naphthyl)methyl-β-L-fucopyranoside (S87)



Methyl 3,4-*O*-isopropylidene-2-*O*-(2-naphthyl)methyl-β-L-fucopyranoside (**S86**, 1.85 g, 5.16 mmol) and PTSA-H_2O (98 mg, 0.52 mmol, 0.1 eq) were dissolved in methanol and heated to 50 °C. After full conversion, triethylamine (0.15 mL, 1.03 mmol, 0.2 eq) was added and the mixture was concentrated under reduced pressure. Residual methanol and water were removed by coevaporation with toluene. The residue was dissolved in DMF, after which benzyl bromide (1.84 mL, 15.5 mmol, 3 eq) and sodium hydride (60% dispersion in mineral oil, 619 mg, 15.5 mmol, 3 eq) were added. After full conversion, the reaction was quenched with water and extracted with diethyl ether. The organic phase was dried with $MgSO_4$ and concentrated under reduced pressure. The residue was purified over silica (25% diethyl ether in pentane) to give the title compound as white solid. Yield: 2.03 g, 4.07 mmol, 79%. ^{1}H NMR (400 MHz, CDCl$_3$) δ 7.83 – 7.73 (m, 4H, CH$_{arom}$), 7.50 (dd, *J* = 8.4, 1.6 Hz, 1H, CH$_{arom}$), 7.48 – 7.43 (m, 2H, CH$_{arom}$), 7.39 – 7.25 (m, 10H, CH$_{arom}$), 5.07 (d, *J* = 11.2 Hz, 1H, C*H*H Bn/Nap), 4.98 (d, *J* = 11.7 Hz, 1H, C*H*H Bn/Nap), 4.92 (d, *J* = 11.2 Hz, 1H, CH*H* Bn/Nap), 4.81 (d, *J* = 11.9 Hz, 1H, C*H*H Bn/Nap), 4.74 (d, *J* = 12.0 Hz, 1H, CH*H* Bn/Nap), 4.69 (d, *J* = 11.7 Hz, 1H, CH*H* Bn/Nap), 4.28 (d, *J* = 7.6 Hz, 1H, H-1), 3.86 (dd, *J* = 9.7, 7.7 Hz, 1H, H-2), 3.58 – 3.52 (m, 5H, H-3, H-4, CH$_3$ OMe), 3.47 (qd, *J* = 6.3, 1.1 Hz, 1H, H-5), 1.20 (d, *J* = 6.4 Hz, 3H, H-6), ^{13}C NMR (101 MHz, CDCl$_3$) δ 138.8, 138.7, 136.6, 133.5, 133.1 (C$_q$), 128.6, 128.5, 128.2, 128.1, 128.0, 127.8, 127.7, 127.7, 127.6, 126.8, 126.5, 126.0, 125.8 (CH$_{arom}$), 105.0 (C-1), 82.2 (C-3), 79.7 (C-2), 76.4 (C-4), 75.2, 74.7, 73.3 (CH$_2$ Bn, CH$_2$ Nap), 69.8 (C-5), 55.6 (CH$_3$ OMe), 15.1 (C-6); HRMS: $[M+NH_4]^+$ calcd for $C_{32}H_{34}O_5NH_4$ 516.27445, found 516.27379.

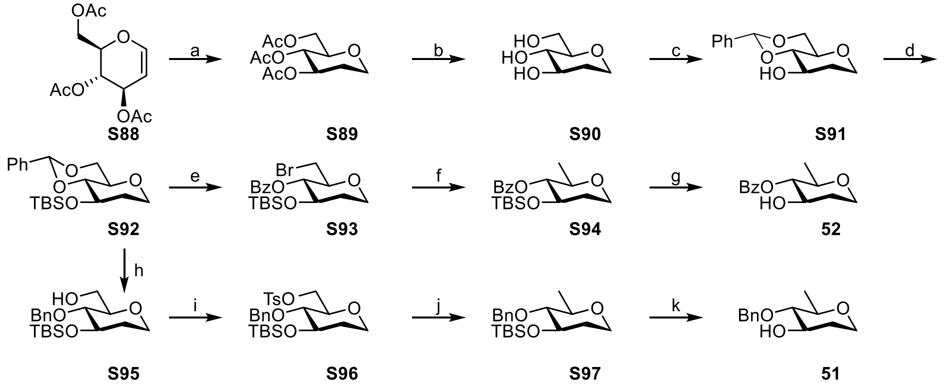
Methyl 3,4-di-*O*-benzyl-β-L-fucopyranoside (50)



Methyl 3,4-di-*O*-benzyl-2-*O*-(2-naphthyl)methyl-β-L-fucopyranoside (**S87**, 1.10 g, 2.21 mmol) and DDQ (1.00 g, 4.41 mmol, 2 eq) were dissolved in DCM/H$_2$O 9:1. After full conversion of the starting material, the reaction mixture was diluted with dichloromethane and washed twice with sat. aq. NaHCO$_3$. The organic phase was dried with MgSO$_4$ and concentrated under reduced pressure. The residue was purified over silica (15% acetone in pentane) to give the title compound as white solid. Yield: 607 mg, 1.69 mmol, 77%. $[\alpha]_D^{25}$ = 2.76° (c = 0.25, CHCl$_3$); IR (thin film): ^{1}H NMR (400 MHz, CDCl$_3$) δ 7.43 – 7.24 (m, 10H, CH$_{arom}$), 4.93 (d, *J* = 11.7 Hz, 1H, C*H*H Bn), 4.75 (d, *J* = 11.9 Hz, 1H, C*H*H Bn), 4.72 – 4.66 (m, 2H, 2x CH*H* Bn), 4.14 (d, *J* = 7.6 Hz, 1H, H-1), 3.93 (ddd, *J* = 9.7, 7.6, 1.9 Hz, 1H, H-2), 3.61 (dd, *J* = 2.9, 1.1 Hz, 1H, H-4), 3.55 – 3.48 (m, 4H, H-5, CH$_3$ OMe), 3.44 (dd, *J* = 9.8, 2.9 Hz, 1H, H-3), 2.41 (d, *J* = 2.0 Hz, 1H, OH), 1.24 (d, *J* = 6.4 Hz, 3H, H-6), ^{13}C NMR (101 MHz, CDCl$_3$) δ 138.6, 138.2 (C$_q$), 128.7, 128.5, 128.3, 128.0, 127.8, 127.7 (CH$_{arom}$), 104.1 (C-1), 82.5 (C-3), 75.7 (C-4), 74.8, 73.1 (CH$_2$ Bn), 71.3 (C-2), 70.8 (C-5), 58.0 (CH$_3$ OMe), 10.8 (C-6); HRMS: $[M+NH_4]^+$ calcd for $C_{21}H_{26}O_5NH_4$ 376.21185, found 376.21140.

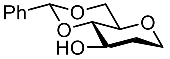
Model acceptors

Preparation of acceptors **51** and **52**



Scheme S34: *preparation of acceptors* ***51*** *and* ***52****: reagents and conditions: a) Pd/C,* H_2*, EtOAc; b) NaOMe/MeOH; c)* $PhCH(OMe)_2$*, PTSA, 85% over 3 steps; d) TBSCl, imidazole, DMF, 98%; e) NBS,* $BaCO_3$*, cyclohexane, reflux, 75%; f)* Bu_3SnH*, cat AIBN, toluene, reflux 94%; g) PTSA, MeOH, 95%; h)* BH_3*-*$NH(CH_3)_2$*,* BF_3*-*Et_2O*, 89%; i) TsCl, pyridine; j) LAH, THF, reflux, 79% over 2 steps; k) PTSA, MeOH, 91%*

1,2-di-deoxy-4,6-*O*-benzylidene-D-glucopyranose (S91)

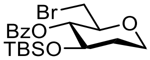


commercially available tri-*O*-acetly-D-glucal (**S88**, 20 g, 73.5 mmol) and Pd/C (10%, 500 mg) were dissolved in ethyl acetate and flushed with nitrogen gas, flushed with hydrogen gas and kept under hydrogen atmosphere overnight. The reaction mixture was flushed with nitrogen, filtered over celite and concentrated, yielding **S89**. The residue was dissolved in methanol and NaOMe (794 mg, 14.7 mmol, 0.2 eq) was added. When TLC shows full conversion, the reaction was quenched with amberlite, concentrated under reduced pressure and residual methanol and water were removed by azeotroping with toluene. The crude triol (**S90**) was then dissolved in acetonitrile with PTSA-H_2O (1.40 g, 7.35 mmol, 0.1 eq) and benzaldehyde dimethyl acetal (15.5 mL, 103 mmol, 1.4 eq). The reaction was heated to 60 °C at 275 mbar. After 45 min, the reaction was concentrated under reduced pressure. The residue was dissolved in ethyl acetate and washed with sat aq. $NaHCO_3$. The organic phase was dried with $MgSO_4$ and concentrated. The residue was purified by precipitation form EA/pentane yielding the title compound white solid. Yield: 14.7 g, 62.2 mmol, 85% over 3 steps. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.49 (dq, *J* = 4.9, 2.7 Hz, 2H, CH_{arom}), 7.38 (qd, *J* = 4.7, 1.7 Hz, 3H, CH_{arom}), 5.55 (s, 1H, C*H*Ph), 4.28 (dd, *J* = 10.4, 4.9 Hz, 1H, H-6), 3.98 (ddd, *J* = 11.8, 5.3, 1.6 Hz, 1H, H-1_{eq}), 3.86 (tdt, *J* = 11.4, 5.9, 2.9 Hz, 1H, H-3), 3.69 (td, *J* = 10.3, 3.9 Hz, 1H, H-6), 3.55 (tt, *J* = 11.9, 2.9 Hz, 1H, H-1_{ax}), 3.43 (t, *J* = 9.0 Hz, 1H, H-4), 3.33 (td, *J* = 9.6, 4.9 Hz, 1H, H-5), 2.65 (t, *J* = 2.8 Hz, 1H, OH), 2.09 – 1.92 (m, 1H, H-2_{eq}), 1.80 (tdd, *J* = 13.1, 11.0, 5.2 Hz, 1H, H-2_{ax}). Spectra in agreement with literature.[98]

1,2-di-deoxy-4,6-*O*-benzylidene-3-*O*-dimethyltertbutylsilyl-D-glucopyranose (S92)

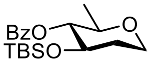
S91 (2 g, 8.46 mmol) was dissolved in DMF and imidazole (1.15 g, 16.9 mmol, 2 eq) and TBSCl (1.91 g, 12.7 mmol, 1.5 eq) were added. When TLC shows full conversion, the reaction is quenched with 5 mL methanol, diluted with water and extracted with diethyl ether. The organic phase was dried with $MgSO_4$, concentrated and the residue was purified over silica (10% diethyl ether in pentane) yielding the product as colourless oil. Yield: 2.90 g, 8.27 mmol, 98%. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.54 – 7.46 (m, 2H, CH_{arom}), 7.41 – 7.30 (m, 3H, CH_{arom}), 5.56 (s, 1H, C*H*Ph), 4.27 (dd, *J* = 10.3, 4.9 Hz, 1H, H-6), 3.95 (ddd, *J* = 11.8, 5.1, 1.6 Hz, 1H, H-1_{eq}), 3.87 (ddd, *J* = 10.6, 8.6, 5.4 Hz, 1H, H-3), 3.70 (t, *J* = 10.2 Hz, 1H, H-6), 3.55 (td, *J* = 12.2, 2.6 Hz, 1H, H-1_{ax}), 3.44 (t, *J* = 8.9 Hz, 1H, H-4), 3.31 (td, *J* = 9.6, 4.9 Hz, 1H, H-5), 1.97 – 1.76 (m, 2H, H-2_{ax}, H-2_{eq}), 0.87 (s, 9H, $C(CH_3)$ TBS), 0.08 (s, 3H, CH_3 TBS), 0.04 (s, 3H, CH_3 TBS) ^{13}C NMR (101 MHz, $CDCl_3$) δ 137.8 (C_q), 128.9, 128.2, 126.2 (CH_{arom}), 101.6 (CHPh), 84.0 (C-4), 71.9 (C-5), 70.4 (C-3), 69.1 (C-6), 66.6 (C-1), 35.6 (C-2), 25.9 (C(*C*$H_3)_3$ TBS), 18.4 (*C*$(CH_3)_3$ TBS), -4.3 (CH_3 TBS), -4.7 (CH_3 TBS). spectra in agreement with literature.[99]

1,2,6-tri-deoxy-6-bromo-4-*O*-benzoyl-3-*O*-dimethyltertbutylsilyl-D-glucopyranose (S93)



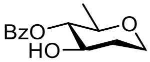
S92 (1.4 g, 3.99 mmol), N-bromosuccinimide (782 mg, 4.39 mmol, 1.1 eq) and barium carbonate (1.58 g, 7.99 mmol, 2 eq) were suspended in cyclohexane and heated to a reflux, after which the reaction mixture turns red. After the red colour fades, the progress was checked with TLC. Since some starting material was still present, another 0.2 eq of NBS was added and the reaction progress was checked again after the red colour faded again. TLC showed full consumption of the starting material, so the solids in the reaction mixture were removed by filtration and washed with ethyl acetate. The filtrate was washed with sat. aq. $Na_2S_2O_3$, dried with $MgSO_4$ and concentrated under reduced pressure. The residue was purified over silica (3% EA in pentane) yielding the title compound as colourless oil. Yield: 1.29 g, 3 mmol, 75%. ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.13 – 7.96 (m, 2H, CH_{arom}), 7.66 – 7.54 (m, 1H, CH_{arom}), 7.52 – 7.40 (m, 2H, CH_{arom}), 5.01 (dd, *J* = 9.3, 8.5 Hz, 1H, H-4), 4.07 (ddd, *J* = 11.9, 4.7, 2.2 Hz, 1H, H-1_{eq}), 3.91 (ddd, *J* = 10.7, 8.5, 5.2 Hz, 1H, H-3), 3.62 (ddd, *J* = 9.4, 7.5, 2.7 Hz, 1H, H-5), 3.54 (td, *J* = 11.6, 11.1, 2.1 Hz, 1H, H-1_{ax}), 3.51 – 3.47 (m, 1H, H-6), 3.41 (dd, *J* = 11.1, 7.5 Hz, 1H, H-6), 2.01 – 1.80 (m, 2H, H-2_{ax}, H-2_{eq}), 0.74 (s, 9H $C(CH_3)_3$ TBS), 0.01 (s, 3H, CH_3 TBS), -0.14 (s, 3H, CH_3 TBS) ^{13}C NMR (101 MHz, $CDCl_3$) δ 165.5 (C=O), 133.4, 129.9 (CH_{arom}), 129.8 (C_q), 128.5 (CH_{arom}), 78.2 (C-5), 75.3 (C-4), 71.5 (C-3), 65.4 (C-1), 34.9 (C-2), 32.4 (C-6), 25.6 (C(*C*$H_3)_3$ TBS), 17.8 (*C*$(CH_3)_3$ TBS), -4.3 (CH_3 TBS), -4.8 (CH_3 TBS). spectra in agreement with literature.[99]

1,2,6-tri-deoxy-4-*O*-benzoyl-3-*O*-dimethyltertbutylsilyl-D-glucopyranose (S94)



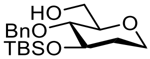
S93 (1.25 g, 2.91 mmol), AIBN (0.2 M solution in toluene, 1.46 mL, 0.29 mmol, 0.1 eq) and tri-n-butyltin hydride (1,10 mL, 4.08 mmol, 1.4 eq) were dissolved in toluene and heated to a reflux. When TLC shows full conversion, the reaction mixture was concentrated and the residue was purified over silica (3→6% diethyl ether in pentane) yielding the slightly impure title compound as colourless oil. Yield: 974 mg, 2.75 mmol, 94%. ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.05 (dt, *J* = 7.1, 1.4 Hz, 2H, CH_{arom}), 7.61 – 7.52 (m, 1H, CH_{arom}), 7.51 – 7.38 (m, 2H, CH_{arom}), 4.88 (t, *J* = 9.1 Hz, 1H, H-4), 3.96 (ddd, *J* = 11.8, 4.8, 1.9 Hz, 1H, H-1_{eq}), 3.85 (ddd, *J* = 10.7, 8.7, 5.5 Hz, 1H, H-3), 3.55 – 3.33 (m, 2H, H-1_{ax}, H-5), 1.98 – 1.77 (m, 2H, H-2), 1.21 (d, *J* = 6.2 Hz, 3H, H-6), 0.74 (s, 9H, $C(CH_3)_3$ TBS), 0.01 (s, 3H, CH_3 TBS), -0.14 (s, 3H, CH_3 TBS) ^{13}C NMR (101 MHz, $CDCl_3$) δ 165.8 (C=O), 133.1 (CH_{arom}), 130.4 (C_q), 129.8, 128.4 (CH_{arom}), 78.3 (C-4), 75.0 (C-5), 71.8 (C-3), 65.6 (C-1), 35.5 (C-2), 25.6 ($C(CH_3)_3$ TBS), 18.2 (C-6), 17.9 (*C*$(CH_3)_3$ TBS), -4.3 (CH_3 TBS), -4.8 (CH_3 TBS); HRMS: $[M+H]^+$ calcd for $C_{19}H_{30}O_4SiH$ 351.19861, found 351.19794.

1,2,6-tri-deoxy-4-*O*-benzoyl-D-glucopyranose (52)



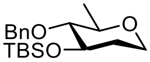
S94 (925 mg, 2.64 mmol) and PTSA-H_2O (50 mg, 0.26 mmol, 0.1 eq) were dissolved in methanol. When TLC indicates full conversion, the reaction was quenched with triethylamine (0.08 mL, 0.53 mmol, 0.2 eq) and concentrated. The residue was purified over silica (25% EtOAc in pentane) to give the title compound as a colourless oil that slowly solidifies. Yield: 595 mg, 2.52 mmol, 95%. $[\alpha]_D^{25}$ = 33.4° (c = 0.39, $CHCl_3$); IR (thin film): 711, 1069, 1118, 1271, 1721; ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.14 – 7.97 (m, 2H, CH_{arom}), 7.59 (ddt, *J* = 8.7, 6.9, 1.3 Hz, 1H, CH_{arom}), 7.52 – 7.42 (m, 2H, CH_{arom}), 4.71 (t, *J* = 9.2 Hz, 1H, H-4), 3.98 (ddd, *J* = 11.8, 5.0, 1.7 Hz, 1H, H-1_{eq}), 3.84 (ddt, *J* = 11.3, 8.9, 5.1 Hz, 1H, H-3), 3.57 – 3.41 (m, 2H, H-1_{ax}, H-5), 2.71 (d, *J* = 5.0 Hz, 1H, OH), 2.10 (ddt, *J* = 13.2, 5.3, 1.9 Hz, 1H, H-2_{eq}), 1.83 (tdd, *J* = 12.9, 11.3, 5.0 Hz, 1H, H-2_{ax}), 1.26 (d, *J* = 6.2 Hz, 3H, H-6) ^{13}C NMR (101 MHz, $CDCl_3$) δ 167.4 (C=O), 133.6, 129.9 (CH_{arom}), 129.7 (C_q), 128.6 (CH_{arom}), 79.9 (C-4), 74.6 (C-5), 71.8 (C-3), 65.7 (C-1), 34.6 (C-2), 18.3 (C-6); HRMS: $[M+Na]^+$ calcd for $C_{13}H_{16}O_4Na$ 259.09408, found 259.09365.

1,2-di-deoxy-4-*O*-benzyl-3-*O*-dimethyltertbutylsilyl-D-glucopyranose (S95)



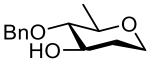
S92 (1.4 g, 3.99 mmol) was dissolved in dichloromethane and cooled to 0 °C, after which borane dimethylamine complex (1.18 g, 20.0 mmol, 5 eq) and BF_3-etherate (2.47 mL, 20.0 mmol, 5 eq) were added. When TLC shows full conversion of the starting material, the reaction was quenched with sat. aq. $NaHCO_3$, diluted and extracted twice with DCM. Combined organic phases were washed with sat. aq. $NaHCO_3$, dried with $MgSO_4$ and concentrated. The residue was purified over silica (20% EA in pentane) to yield the title compound as colourless oil. Yield: 1.25 g, 3.55 mmol, 89% ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.37 – 7.26 (m, 5H, CH_{arom}), 4.91 (d, *J* = 11.1 Hz, 1H, C*H*H Bn), 4.61 (d, *J* = 11.2 Hz, 1H, CH*H* Bn), 3.91 (ddd, *J* = 11.7, 4.9, 1.8 Hz, 1H, H-1_{eq}), 3.84 – 3.75 (m, 2H, H-3, H-6), 3.63 (ddd, *J* = 11.6, 6.8, 4.7 Hz, 1H, H-6), 3.41 (ddd, *J* = 12.7, 11.7, 2.2 Hz, 1H, H-1_{ax}), 3.28 (dd, *J* = 9.6, 8.1 Hz, 1H, H-4), 3.21 (ddd, *J* = 9.5, 4.8, 2.7 Hz, 1H, H-5), 1.92 (dd, *J* = 6.9, 6.0 Hz, 1H, OH), 1.86 (ddt, *J* = 13.3, 5.2, 2.0 Hz, 1H, H-2_{eq}), 1.77 – 1.64 (m, 1H, H-2_{ax}), 0.93 (s, 9H, $C(CH_3)_3$ TBS) 0.11 (s, 3H, CH_3 TBS), 0.10 (s, 3H, CH_3 TBS) ^{13}C NMR (101 MHz, $CDCl_3$) δ 138.5 (C_q), 128.5, 128.1, 127.8 (CH_{arom}), 79.9, 79.8 (C-4/C-5), 75.2 (CH_2 Bn), 74.6 (C-3), 65.5 (C-1), 62.8 (C-6), 35.6 (C-2), 26.0 ($C(CH_3)_3$ TBS), 18.1 (*C*$(CH_3)_3$ TBS), -4.2 (CH_3 TBS), -4.4 (CH_3 TBS). spectra in agreement with literature.[99]

1,2,6-tri-deoxy-4-*O*-benzyl-3-*O*-dimethyltertbutylsilyl-D-glucopyranose (S97)



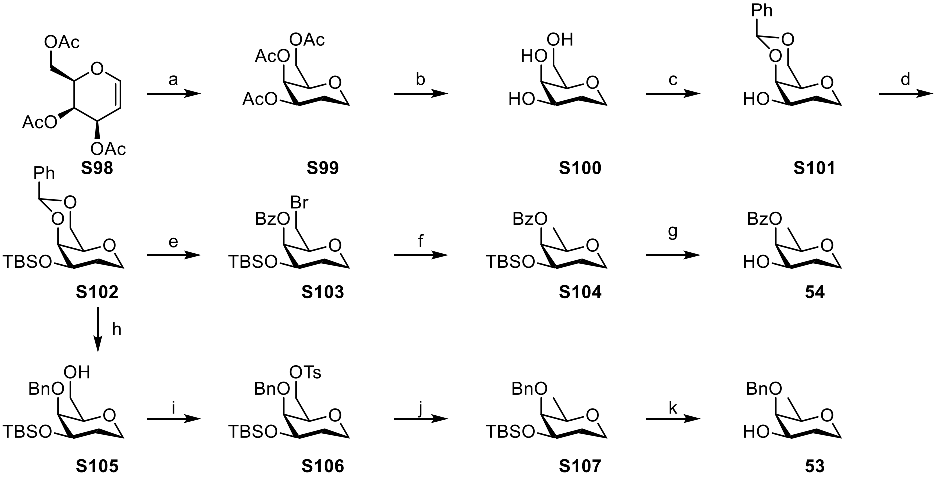
S95 (1.20 g, 3.40 mmol) was dissolved in 5.5 mL pyridine, after which *p*-toluenesulfonyl chloride (1.30 g, 6.81 mmol, 2 eq) was added. When TLC shows full conversion, the reaction mixture is diluted with ethyl acetate and washed with 2x 100 mL 1M HCl and with sat. aq. $NaHCO_3$. The organic phase was dried with $MgSO_4$ and concentrated under reduced pressure, yielding the crude tosylate (**S96)** which was used without further purification. The tosylate was dissolved in THF, lithium aluminium hydride (2.4 M in 2-methyltetrahydrofuran, 5.67 mL, 13.6 mmol, 4 eq) was added and the mixture was heated to reflux. When TLC shows full conversion, the reaction mixture was cooled to 0 °C and excess reagent was very carefully quenched with 1M aq HCl and extracted twice with ethyl acetate. Combined organic phases were washed with sat. aq. $NaHCO_3$, dried with $MgSO_4$ and concentrated under reduced pressure. The residue was purified over silica (3→6% diethyl ether in pentane), yielding the title compound as colourless oil. Yield: 906 mg, 2.69 mmol, 79% over 2 steps. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.40 – 7.24 (m, 5H, CH$_{arom}$), 4.93 (d, *J* = 11.0 Hz, 1H, C*H*H Bn), 4.61 (d, *J* = 11.1 Hz, 1H, CH*H* Bn), 3.85 (ddd, *J* = 11.7, 4.8, 1.8 Hz, 1H, H-1$_{eq}$), 3.74 (ddd, *J* = 11.0, 8.3, 5.2 Hz, 1H, H-3), 3.37 (td, *J* = 12.2, 2.2 Hz, 1H, H-1$_{ax}$), 3.24 (dq, *J* = 9.2, 6.2 Hz, 1H, H-5), 2.95 (t, *J* = 8.8 Hz, 1H, H-4), 1.85 (ddt, *J* = 13.2, 5.2, 2.0 Hz, 1H, H-2$_{eq}$), 1.72 (tdd, *J* = 12.9, 11.0, 4.9 Hz, 1H, H-2$_{eq}$), 1.25 (d, *J* = 6.2 Hz, 3H, H-6), 0.92 (s, 9H, $C(CH_3)_3$ TBS), 0.16 – 0.06 (m, 6H, 2x CH_3 TBS) ^{13}C NMR (101 MHz, $CDCl_3$) δ 138.7 (C$_q$), 128.4, 128.0, 127.7 (CH$_{arom}$), 85.7 (C-4), 76.1 (C-5), 75.5 (CH_2 Bn), 74.6 (C-3), 65.4 (C-1), 35.9 (C-2), 26.0 ($C(CH_3)_3$ TBS), 18.7 (C-6), 18.1 (*C*($CH_3)_3$ TBS), -4.2 (CH_3 TBS), -4.3 (CH_3 TBS); HRMS: $[M+Na]^+$ calcd for $C_{19}H_{32}O_3SiNa$ 359.20129, found 359.20078.

1,2,6-tri-deoxy-4-*O*-benzyl-D-glucopyranose (51)



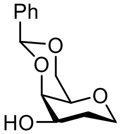
S97 (875 mg, 2.60 mmol) and PTSA-H_2O (50 mg, 0.26 mmol, 0.1 eq) were dissolved in methanol. When TLC shows full conversion, the reaction was quenched with triethylamine (0.07 mL, 0.52 mmol, 0.2 eq) and concentrated under reduced pressure. The residue was purified over silica (25% EtOAc in pentane) to give the desired compound as white solid. Yield: 528 mg, 2.38 mmol, 91%. $[\alpha]_D^{25}$ = -13.0° (c = 0.35, $CHCl_3$); IR (thin film): 689, 839, 1070, 1090, 1105, 1454; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.43 – 7.29 (m, 5H, CH$_{arom}$), 4.79 (d, *J* = 11.2 Hz, 1H, CH*H* Bn), 4.70 (d, *J* = 11.3 Hz, 1H, CH*H* Bn), 3.90 (ddd, *J* = 11.7, 5.0, 1.6 Hz, 1H, H-1$_{eq}$), 3.67 (tdt, *J* = 8.4, 5.1, 2.9 Hz, 1H, H-3), 3.41 (ddd, *J* = 12.6, 11.7, 2.2 Hz, 1H, H-1$_{ax}$), 3.27 (dq, *J* = 9.2, 6.2 Hz, 1H, H-5), 2.95 (t, *J* = 8.9 Hz, 1H, H-4), 2.19 (d, *J* = 2.9 Hz, 1H, OH), 1.94 (ddt, *J* = 13.0, 5.2, 1.9 Hz, 1H, H-2$_{eq}$), 1.69 (tdd, *J* = 12.9, 11.4, 5.0 Hz, 1H, H-2$_{ax}$), 1.35 (d, *J* = 6.2 Hz, 3H, H-6) ^{13}C NMR (101 MHz, $CDCl_3$) δ 138.4 (C$_q$), 128.8, 128.2, 128.0 (CH$_{arom}$), 86.7 (C-4), 76.0 (C-5), 75.4 (CH_2 Bn), 72.9 (C-3), 65.7 (C-1), 33.8 (C-2), 18.8 (C-6). HRMS: $[M+Na]^+$ calcd for $C_{13}H_{18}O_3Na$ 245.11482, found 245.11489.

Preparation of acceptors **53** and **54**



***Scheme S35**: preparation of acceptors **53** and **54**: reagents and conditions: a) Pd/C, H_2, EtOAc; b) NaOMe/MeOH; c) $PhCH(OMe)_2$, PTSA, 55% over 3 steps; d) TBSCl, imidazole, DMF, 73%; e) NBS, $BaCO_3$, cyclohexane, reflux, 70%; f) Bu_3SnH, cat AIBN, toluene, reflux 89%; g) PTSA, MeOH, 91%; h) BH_3-$NH(CH_3)_2$, BF_3-Et_2O, 62%; i) TsCl, pyridine; j) LAH, THF, reflux, 39% over 2 steps; k) PTSA, MeOH, 67%*

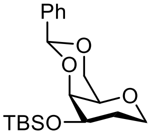
1,2-di-deoxy-4,6-*O*-benzylidene-D-galactopyranose (S101)



commercially available tri-*O*-acetly-D-galactal (**S98**, 10 g, 36.5 mmol) and Pd/C (5%, 500 mg) were dissolved in ethyl acetate and flushed with nitrogen gas, flushed with hydrogen gas and kept under hydrogen atmosphere overnight. The reaction mixture was flushed with nitrogen, filtered over celite, concentrated, yielding **S99**. The residue was dissolved in methanol and NaOMe (394 mg, 7.29 mmol, 0.2 eq) was added. When TLC shlows full conversion, the reaction was quenched with Amberilte IR-120 H-form to a pH of ~5, concentrated under reduced pressure and residual methanol and water were removed by azeotroping with toluene. The crude triol (**S100**) was then dissolved in acetonitrile with PTSA-H_2O (694 mg, 3.65 mmol, 0.1 eq) and benzaldehyde dimethyl acetal (7.7 mL, 51 mmol, 1.4 eq). The reaction was heated to 60 ^oC at 275 mbar. After 60 min, the reaction was concentrated under reduced pressure. The residue was dissolved in ethyl acetate and washed with sat. aq. $NaHCO_3$. The organic phase was dried with $MgSO_4$ and concentrated. The residue was recrystallized from EA/pentane to yield the title compound as fluffy white solid. Yield: 4.72 g, 20 mmol, 55% over 3 steps. ^1H NMR (400 MHz, $CDCl_3$) δ 7.58 – 7.52 (m, 2H, CH_{arom}), 7.44 – 7.37 (m, 3H, CH_{arom}), 5.62 (s, 1H, C*H*Ph), 4.30 (dd, *J* = 12.4, 1.6 Hz, 1H, H-6), 4.16 – 4.10 (m, 2H, H-1_{eq}, H-4), 4.04 (dd, *J* = 12.5, 1.8 Hz, 1H, H-6), 3.78 (dddd, *J* = 11.8, 10.8, 5.1, 3.5 Hz, 1H, H-3), 3.48 (td, *J* = 12.2, 2.0 Hz, 1H, H-1_{ax}), 3.33 (q, *J* = 1.6 Hz, 1H, H-5), 2.52 (d, *J* = 10.8 Hz, 1H, OH), 2.02 (qd, *J* = 12.4, 4.6 Hz, 1H, H-2_{ax}), 1.81 – 1.74 (m, 1H, H-2_{eq}); ^{13}C NMR

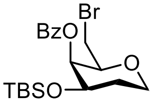
(101 MHz, $CDCl_3$) δ 137.8 (C_q), 129.1, 128.2, 126.4 (CH_{arom}), 101.2 (CHPh), 75.3 (C-4), 70.3 (C-5), 70.1 (C-6), 68.8 (C-3), 65.8 (C-1), 30.2 (C-2). Spectra in agreement with literature.[100]

1,2-di-deoxy-4,6-*O*-benzylidene-3-*O*-dimethyltertbutylsilyl-D-galactopyranose (S102)



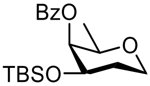
1,2-di-deoxy-4,6-*O*-benzylidene-D-galactopyranose (**S101**, 4.70 g, 19.9 mmol) was dissolved in DMF with imidazole (3.39 g, 49.8 mmol, 2.5 eq). TBSCl (3.90 g, 25.9 mmol, 1.3 eq) was added and the mixture was stirred at room temperature. When TLC shows full conversion, the reaction mixture was diluted with water and extracted twice with diethyl ether. Combined organic phases were dried with $MgSO_4$ and concentrated under reduced pressure. The residue was purified over silica (10% acetone in pentane) yielding the title compound as white powder. Yield: 5.12 g, 14.6 mmol, 73% ^1H NMR (400 MHz, $CDCl_3$) δ 7.57 – 7.52 (m, 2H, CH_{arom}), 7.37 – 7.28 (m, 3H, CH_{arom}), 5.57 (s, 1H, C*H*Ph), 4.27 (dd, *J* = 12.4, 1.6 Hz, 1H, H-6), 4.10 (ddd, *J* = 11.7, 4.6, 1.8 Hz, 1H, H-1_{eq}), 4.01 (dd, *J* = 12.3, 1.8 Hz, 1H, H-6), 3.96 (d, *J* = 3.2 Hz, 1H, H-4), 3.84 (ddd, *J* = 11.7, 4.8, 3.4 Hz, 1H, H-3), 3.49 (ddd, *J* = 12.6, 11.6, 2.0 Hz, 1H, H-1_{ax}), 3.26 (q, *J* = 1.5 Hz, 1H, H-5), 2.21 (tdd, *J* = 12.8, 11.6, 4.6 Hz, 1H, H-2_{ax}), 1.55 (ddq, *J* = 12.8, 4.7, 1.7 Hz, 1H, H-1_{eq}), 0.91 (s, 9H, $C(CH_3)_3$ TBS), 0.20 – 0.00 (m, 6H, 2x CH_3 TBS), ^{13}C NMR (101 MHz, $CDCl_3$) δ 138.3 (C_q), 128.6, 128.0, 126.3 (CH_{arom}), 100.7 (CHPh), 76.5 (C-4), 70.7 (C-3), 70.6 (C-6), 70.4 (C-5), 66.2 (C-1), 30.0 (C-2), 25.9 ($C(CH_3)_3$ TBS), 18.3 ($C(CH_3)_3$ TBS), -4.2, -4.3 (CH_3 TBS); HRMS: $[M+Na]^+$ calcd for $C_{19}H_{30}O_4SiNa$ 373.18056, found 373.17989.

1,2,6-tri-deoxy-6-bromo-4-*O*-benzoyl-3-*O*-dimethyltertbutylsilyl-D-galactopyranose (S103)



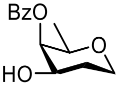
1,2-di-deoxy-4,6-*O*-benzylidene-3-*O*-dimethyltertbutylsilyl-D-galactopyranose (**S102**, 2.28 g, 6.50 mmol), barium carbonate (2.57 g, 13.0 mmol, 2 eq) and N-bromosuccinimide (1.27g, 7.15 mmol, 1.1 eq) were suspended in cyclohexane and heated to a reflux. Upon heating, the solution becomes red and then colourless after a few minutes. After the fading of the red colour, TLC showed full conversion. Solids were filtered off and washed with ethyl acetate. The organic phase was washed with sat. aq. $Na_2S_2O_3$, dried with $MgSO_4$ and concentrated under reduced pressure. The residue was purified over silica (5% diethyl ether in pentane) to obtain the title compound as colourless oil. ^1H NMR (400 MHz, $CDCl_3$) δ 8.14 – 8.04 (m, 2H, CH_{arom}), 7.61 – 7.54 (m, 1H, CH_{arom}), 7.48 – 7.41 (m, 2H, CH_{arom}), 5.51 – 5.46 (m, 1H, H-4), 4.14 (ddd, *J* = 11.9, 4.7, 2.2 Hz, 1H, H-1_{eq}), 3.95 (ddd, *J* = 10.9, 4.8, 3.2 Hz, 1H, H-3), 3.77 (ddd, *J* = 7.3, 5.7, 1.5 Hz, 1H, H-5), 3.57 (td, *J* = 12.1, 2.3 Hz, 1H, H-1_{ax}), 3.47 – 3.36 (m, 2H, 2x H-6), 2.10 (qd, *J* = 12.4, 4.7 Hz, 1H, H-2_{ax}), 1.69 (dddt, *J* = 13.0, 4.8, 2.5, 1.2 Hz, 1H, H-2_{eq}), 0.77 (s, 9H, $C(CH_3)_3$ TBS), 0.06 (s, 3H, CH_3 TBS), 0.05 (s, 3H, CH_3 TBS), ^{13}C NMR (101 MHz, $CDCl_3$) δ 166.1 (C=O), 133.2 (CH_{arom}), 130.2 (C_q), 130.0, 128.5 (CH_{arom}), 79.7 (C-5), 72.9 (C-4), 68.6 (C-3), 65.3 (C-1), 30.8, 30.7 (C-2, C-6), 25.7 ($C(CH_3)_3$ TBS), 18.0 ($C(CH_3)_3$ TBS), -4.7, -4.8 (CH_3 TBS); HRMS: $[M+H]^+$ calcd for $C_{19}H_{29}BrO_4SiH$ 429.10913; 431.10708, found 429.10855; 431.10647.

1,2-di-deoxy-4-*O*-benzoyl-3-*O*-dimethyltertbutylsilyl-D-fucopyranose (S104)



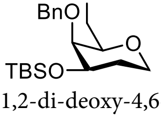
1,2,6-tri-deoxy-6-bromo-4-*O*-benzoyl-3-*O*-dimethyltertbutylsilyl-D-galactopyranose (**S103**, 1.90 g, 4.42 mmol), tributyltin hydride (1.67 mL, 6.19 mmol, 1.4 eq) and AIBN (0.2 M in toluene, 2.21 mL, 0.44 mmol, 0.1 eq) were dissolved in toluene and heated to a reflux. After 4 hr, the reaction was incomplete and showed no further conversion, so an extra 0.5 eq tributyltin hydride and 0.05 eq AIBN were added. After completion, the reaction mixture was concentrated under reduced pressure. The residue was purified over silica (5% diethyl ether in pentane) to give the title compound as colourless oil. Yield: 1.38 g, 3.93 mmol, 89%. ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.18 – 8.11 (m, 2H, CH_{arom}), 7.63 – 7.55 (m, 1H, CH_{arom}), 7.51 – 7.42 (m, 2H, CH_{arom}), 5.27 (dd, *J* = 3.1, 1.4 Hz, 1H, H-4), 4.10 (ddd, *J* = 11.8, 4.8, 1.8 Hz, 1H, H-1$_{eq}$), 3.94 (ddd, *J* = 11.5, 5.0, 3.3 Hz, 1H, H-3), 3.68 (qd, *J* = 6.4, 1.2 Hz, 1H, H-5), 3.56 (ddd, *J* = 12.8, 11.8, 2.1 Hz, 1H, H-1$_{ax}$), 2.12 (tdd, *J* = 12.8, 11.4, 4.8 Hz, 1H, H-2$_{ax}$), 1.72 – 1.64 (m, 1H, H-2$_{eq}$), 1.23 (d, *J* = 6.4 Hz, 3H, H-6), 0.79 (s, 9H, $C(CH_3)_3$ TBS), 0.08 (s, 3H, CH_3 TBS), 0.07 (s, 3H, CH_3 TBS), ^{13}C NMR (101 MHz, $CDCl_3$) δ 166.6 (C=O), 132.9 (CH_{arom}), 130.7 (C_q), 129.9, 128.4 (CH_{arom}), 73.8 (C-5), 73.4 (C-4), 69.7 (C-3), 66.0 (C-1), 30.8 (C-2), 25.7 ($C(CH_3)_3$ TBS) , 18.1 (*C*(CH_3)$_3$ TBS), 17.5 (C-6), -4.6, -4.8 (CH_3 TBS); HRMS [M+H]$^+$ calcd for $C_{19}H_{30}O_4SiH$ 351.19861, found 351.19802.

1,2-di-deoxy-4-*O*-benzoyl-D-fucopyranose (54)



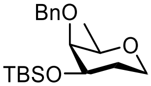
1,2-di-deoxy-4-*O*-benzoyl-3-*O*-dimethyltertbutylsilyl-D-fucopyranose (**S104**, 1.30 g, 3.71 mmol) and PTSA-H_2O (71 mg, 0.37 mmol, 0.1 eq) were dissolved in methanol. After full conversion, triethylamine (0.10 mL, 0.74 mmol, 0.2 eq) was added and the reaction mixture was concentrated under reduced pressure. Silica chromatography (25% EtOAc in pentane) yields the title compound as colourless oil. Yield: 800 mg, 3.39 mmol, 91%. $[\alpha]_D^{25}$ = 30.8° (c = 1.12, $CHCl_3$); IR (thin film): 713, 1086, 1115, 1274, 1717; ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.20 – 8.08 (m, 2H, CH_{arom}), 7.65 – 7.55 (m, 1H, CH_{arom}), 7.53 – 7.41 (m, 2H, CH_{arom}), 5.37 – 5.18 (m, 1H, H-4), 4.09 (ddd, *J* = 11.8, 4.8, 1.8 Hz, 1H, H-1$_{eq}$), 3.99 (dtd, *J* = 11.7, 4.9, 3.2 Hz, 1H, H-3), 3.64 (qd, *J* = 6.5, 1.2 Hz, 1H, H-5), 3.53 (ddd, *J* = 12.6, 11.8, 2.3 Hz, 1H, H-1$_{ax}$), 2.42 (d, *J* = 4.9 Hz, 1H, OH), 2.08 – 1.91 (m, 1H, H-2$_{ax}$), 1.83 – 1.72 (m, 1H, H-2$_{eq}$), 1.22 (d, *J* = 6.4 Hz, 3H, H-6), ^{13}C NMR (101 MHz, $CDCl_3$) δ 167.6 (C=O), 133.5, 130.0 (CH_{arom}), 129.8 (C_q), 128.6 (CH_{arom}), 73.8 (C-4), 73.5 (C-5), 69.6 (C-3), 66.1 (C-1), 29.6 (C-2), 17.6 (C-6); HRMS [M+H]$^+$ calcd for $C_{13}H_{16}O_4H$ 237.11214, found 237.11150.

1,2-di-deoxy-4-*O*-benzyl-3-*O*-dimethyltertbutylsilyl-D-galactopyranose (S105)



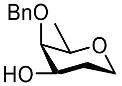
1,2-di-deoxy-4,6-*O*-benzylidene-3-*O*-dimethyltertbutylsilyl-D-galactopyranose (**S102**, 2.28 g, 6.50 mmol) and BH_3-$NH(CH_3)_2$ (1.92 g, 32.5 mmol, 5 eq) were dissolved in DCM and cooled to 0 °C after which BF_3-Et_2O (4.0 mL, 32.5 mol, 5 eq) was added dropwise. After full conversion, the reaction was quenched with sat. aq. $NaHCO_3$. The aquatic phase was extracted twice with dichloromethane. Organic phases were combined, washed with sat. aq. $NaHCO_3$, dried with $MgSO_4$ and concentrated under reduced pressure. Silica chromatography (15% acetone in pentane) yields the title compound as colourless oil. Yield: 1.41 g, 4.00 mmol, 62%.^{1}H NMR (400 MHz, $CDCl_3$) δ 7.40 – 7.27 (m, 5H, CH$_{\text{arom}}$), 4.99 (d, *J* = 11.7 Hz, 1H, C*H*H Bn), 4.64 (d, *J* = 11.7 Hz, 1H, CH*H* Bn), 4.03 (ddd, *J* = 11.6, 4.8, 2.1 Hz, 1H, H-1$_{\text{eq}}$), 3.84 (ddd, *J* = 11.3, 4.6, 2.7 Hz, 1H, H-3), 3.78 (ddd, *J* = 11.2, 7.0, 3.0 Hz, 1H, H-6), 3.59 (dt, *J* = 2.6, 1.3 Hz, 1H, H-4), 3.49 – 3.40 (m, 2H, H-1$_{\text{ax}}$, H-6), 3.34 (ddd, *J* = 7.1, 4.7, 1.4 Hz, 1H, H-5), 2.19 (tdd, *J* = 14.1, 11.8, 4.8 Hz, 1H, H-2$_{\text{ax}}$), 1.82 (dd, *J* = 8.8, 3.5 Hz, 1H, OH), 1.58 (ddtd, *J* = 12.9, 4.6, 2.3, 1.4 Hz, 1H, H-2$_{\text{eq}}$), 0.94 (s, 9H, $C(CH_3)_3$ TBS), 0.14 (s, 3H, CH_3 TBS), 0.12 (s, 3H, CH_3 TBS), ^{13}C NMR (101 MHz, $CDCl_3$) δ 138.8 (C$_q$), 128.6, 128.5, 127.9 (CH$_{\text{arom}}$), 79.1 (C-5), 76.1 (C-4), 74.5 (CH_2 Bn), 72.8 (C-3), 66.0 (C-1), 63.2 (C-6), 30.8 (C-2), 26.0 (C(*C*H$_3$)$_3$ TBS), 18.2 (*C*(CH$_3$)$_3$ TBS), -4.3, -4.5 (CH_3 TBS); HRMS: $[M+Na]^+$ calcd for $C_{19}H_{32}O_4SiNa$ 375.19621, found 375.19571

1,2-di-deoxy-4-*O*-benzyl-3-*O*-dimethyltertbutylsilyl-D-fucopyranose (S107)



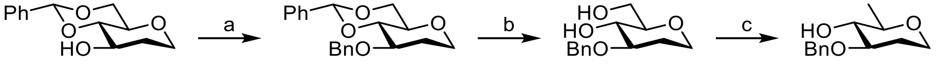
1,2-di-deoxy-4-*O*-benzyl-3-*O*-dimethyltertbutylsilyl-D-galactopyranose (1.35 g, 3.83 mmol) and tosyl chloride (1.46 g, 7.66 mmol, 2 eq) were dissolved in pyridine and reacted for 4 hr, after which the reaction mixture was diluted with ethyl acetate and washed with 1M HCl and sat. aq. $NaHCO_3$. The organic phase was dried with $MgSO_4$ and concentrated under reduced pressure, yielding **S106**. The residue was dissolved in THF and lithium aluminiumhydride (4 M in Et_2O, 3.83 mL, 15.3 mmol, 4 eq) was added dropwise. The reaction mixture was refluxed overnight, before being cooled to 0 °C. Excess reagent was carefully quenched with 1M HCl. The aquatic phase was extracted twice with ethyl acetate. Combined organic phases were washed with sat. aq. $NaHCO_3$, dried with $MgSO_4$ and concentrated under reduced pressure. Silica chromatography (10% diethyl ether in pentane) gives the title compound as colourless oil. Yield: 506 mg, 1.50 mmol, 39%. Further elution also gave 29% of recovered starting material. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.42 – 7.38 (m, 2H, CH$_{\text{arom}}$), 7.34 – 7.30 (m, 2H, CH$_{\text{arom}}$), 7.28 – 7.24 (m, 1H, CH$_{\text{arom}}$), 5.01 (d, *J* = 11.6 Hz, 1H, C*H*H Bn), 4.64 (d, *J* = 11.6 Hz, 1H, CH*H* Bn), 3.97 (ddd, *J* = 11.6, 4.9, 1.8 Hz, 1H, H-1$_{\text{eq}}$), 3.82 (ddd, *J* = 11.5, 4.7, 2.6 Hz, 1H, H-3), 3.49 – 3.32 (m, 3H, H-1$_{\text{ax}}$, H-4, H-5), 2.16 (tdd, *J* = 12.7, 11.5, 4.9 Hz, 1H, H-2$_{\text{ax}}$), 1.58 – 1.48 (m, 1H, H-2$_{\text{eq}}$), 1.16 (d, *J* = 6.3 Hz, 3H, H-6), 0.94 (s, 9H, $C(CH_3)_3$ TBS), 0.12 (s, 3H, CH_3 TBS), 0.11 (s, 3H, CH_3 TBS), ^{13}C NMR (101 MHz, $CDCl_3$) δ 139.3 (C$_q$), 128.5, 128.2, 127.5 (CH$_{\text{arom}}$), 79.2 (C-4), 75.0 (CH_2 Bn), 75.0 (C-5), 73.4 (C-3), 66.0 (C-1), 30.4 (C-2), 26.0 (C(*C*H$_3$)$_3$ TBS), 18.2 (*C*(CH$_3$)$_3$ TBS), 17.9 (C-6), -4.3, -4.5 (C-6); HRMS: $[M+NH_4]^+$ calcd for $C_{19}H_{32}O_3SiNH_4$ 354.24590, found 354.24526

1,2-di-deoxy-4-*O*-benzyl-D-fucopyranose (53)



1,2-di-deoxy-4-*O*-benzyl-3-*O*-dimethyltertbutylsilyl-D-fucopyranose (**S107**, 450 mg, 1.34 mmol) and PTSA-H_2O (25 mg, 0.13 mmol, 0.1 eq) were dissolved in methanol. After full conversion, triethylamine (38 μL, 0.27 mmol, 0.2 eq) was added and the reaction mixture was concentrated under reduced pressure. Silica chromatography (25% ethyl acetate in pentane) yield the title compound as colourless oil. Yield: 200 mg, 0.90 mmol, 67%. $[\alpha]_D^{25}$ = 54.4° (c = 0.33, $CHCl_3$); IR (thin film): 714, 1027, 1086, 1275, 1454; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.41 – 7.29 (m, 5H, CH_{arom}), 4.85 (d, *J* = 11.6 Hz, 1H, C*H*H Bn), 4.64 (d, *J* = 11.7 Hz, 1H, CH*H* Bn), 3.98 (ddd, *J* = 11.7, 4.8, 2.0 Hz, 1H, H-1_{eq}), 3.68 (dddd, *J* = 11.5, 10.1, 5.1, 3.4 Hz, 1H, H-3), 3.51 – 3.49 (m, 1H, H-4), 3.48 – 3.35 (m, 2H, H-1_{ax}, H-5), 1.91 – 1.78 (m, 2H, H-2_{ax}, OH), 1.69 (ddtd, *J* = 12.7, 5.3, 2.2, 1.0 Hz, 1H, H-2_{eq}), 1.30 (d, *J* = 6.5 Hz, 3H, H-6), ^{13}C NMR (101 MHz, $CDCl_3$) δ 138.4 (C_q), 128.8, 128.2, 128.2 (CH_{arom}), 80.1 (C-4), 76.1 (CH_2 Bn), 75.0 (C-5), 70.1 (C-3), 65.8 (C-1), 30.7 (C-2), 17.9 (C-6); HRMS: $[M+Na]^+$ calcd for $C_{13}H_{18}O_3Na$ 245.11482, found 245.11441.

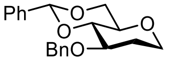
Preparation of acceptor **55**



S91 **S108** **S109** **55**

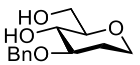
*Scheme **S36**: preparation of acceptor **55**: reagents and conditions: a) BnBr, NaH, DMF, 86%; b) MeOH, 60 °C, 100%; c) i: TsCl, pyridine, ii: LiAlH$_4$, THF, reflux, 68% over 2 steps*

1,2-di-deoxy-3-*O*-benzyl-4,6-*O*-benzylidene-D-glucopyranose (S108)



1,2-di-deoxy-4,6-*O*-benzylidene-D-glucopyranose (**S91**, 1.18 g, 5 mmol), benzyl bromide (0.89 mL, 7.50 mmol, 1.5 eq) and sodium hydride (60% dispersion in mineral oil, 300 mg, 7.50 mmol, 1.5 eq) were dissolved in DMF. When TLC shows full conversion, the reaction is quenched with water and extracted with diethyl ether. The organic phase was dried with $MgSO_4$ and concentrated under reduced pressure. The residue was purified over silica (15% diethyl ether in pentane), yielding the title compound as white solid. Yield: 1.41 g, 4.30 mmol, 86%. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.54 – 7.49 (m, 2H, CH_{arom}), 7.43 – 7.25 (m, 8H, CH_{arom}), 5.62 (s, 1H, C*H*Ph), 4.84 (d, *J* = 12.1 Hz, 1H, C*H*H Bn), 4.72 (d, *J* = 12.1 Hz, 1H, CH*H* Bn), 4.29 (dd, *J* = 10.4, 4.9 Hz, 1H, H-6), 3.98 (ddd, *J* = 11.8, 5.3, 1.5 Hz, 1H, H-1_{eq}), 3.77 – 3.64 (m, 3H, H-3, H-4, H-6), 3.52 (ddd, *J* = 12.8, 11.8, 2.4 Hz, 1H, H-1_{ax}), 3.34 (ddd, *J* = 10.1, 8.7, 4.9 Hz, 1H, H-5), 2.06 (dddd, *J* = 13.5, 5.0, 2.3, 1.5 Hz, 1H, H-2_{eq}), 1.82 (tdd, *J* = 13.1, 10.6, 5.3 Hz, 1H, H-2_{ax}), ^{13}C NMR (101 MHz, $CDCl_3$) δ 138.8, 137.8 (C_q), 129.0, 128.5, 128.3, 127.8, 127.7, 126.2 (CH_{arom}), 101.4 (CHPh), 84.0 (C-4), 76.0 (C-3), 72.7 (CH_2 Bn), 71.8 (C-5), 69.1 (C-6), 66.6 (C-1), 32.5 (C-2); HRMS: $[M+Na]^+$ calcd for $C_{20}H_{22}O_4Na$ 349.14103, found 349.14054.

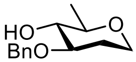
1,2-di-deoxy-3-*O*-benzyl-D-glucopyranose (S109)



1,2-di-deoxy-3-*O*-benzyl-4,6-*O*-benzylidene-D-glucopyranose (**S108**, 1.40 g, 4.3 mmol) and PTSA-H_2O (82 mg, 0.43 mmol, 0.1 eq) were dissolved in methanol and heated to 60 °C. When TLC shows full conversion, triethylamine (0.12 mL, 0.86 mmol, 0.2 eq) was added and the reaction mixture was concentrated under reduced pressure. The residue was purified over silica (15% acetone in DCM) yielding the title compound as colourless oil in quantitative yield. ^{1}H

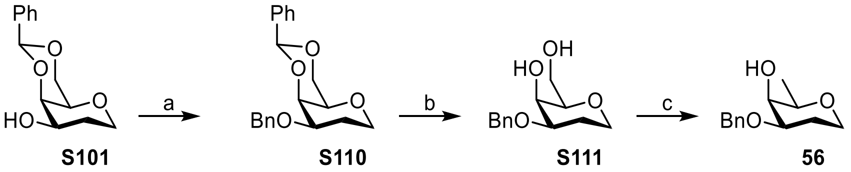
NMR (400 MHz, CDCl$_3$) δ 7.40 – 7.28 (m, 5H, CH$_{arom}$), 4.71 (d, *J* = 11.6 Hz, 1H, C*H*H Bn), 4.52 (d, *J* = 11.6 Hz, 1H, CH*H* Bn), 4.00 (ddd, *J* = 11.8, 4.9, 1.7 Hz, 1H, H-1$_{eq}$), 3.87 (ddd, *J* = 11.7, 6.0, 3.5 Hz, 1H, H-6), 3.74 (ddd, *J* = 11.7, 6.6, 5.2 Hz, 1H, H-6), 3.56 – 3.37 (m, 3H, H-1$_{ax}$, H-3, H-4), 3.24 (ddd, *J* = 8.9, 5.2, 3.4 Hz, 1H, H-5), 2.79 (d, *J* = 2.2 Hz, 1H, 4-OH), 2.27 (t, *J* = 6.3 Hz, 1H, 6-OH), 2.07 (ddt, *J* = 12.8, 4.0, 1.9 Hz, 1H, H-2$_{eq}$), 1.62 (tdd, *J* = 12.7, 10.7, 4.9 Hz, 1H, H-2$_{ax}$), ^{13}C NMR (101 MHz, CDCl$_3$) δ 138.2 (C$_q$), 128.6, 127.9, 127.8 (CH$_{arom}$), 80.5 (C-3), 79.7 (C-5), 71.6 (C-4), 70.9 (CH$_2$ Bn), 65.7 (C-1), 63.1 (C-6), 30.5 (C-2). Spectra in agreement with literature.[101]

1,2,6-tri-deoxy-3-*O*-benzyl-D-glucopyranose (55)



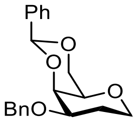
1,2-di-deoxy-3-*O*-benzyl-D-glucopyranose (**S109**, 1.03 g, 4.30 mmol) was dissolved in 25 mL pyridine, after which para-toluenesulfonyl chloride (1.23 g, 6.45 mmol, 1.5 eq) was added. The reaction mixture was stirred overnight, diluted with ethyl acetate and washed with 1M HCl and sat. aq. NaHCO$_3$. The organic phase was dried with MgSO$_4$ and concentrated under reduced pressure. The crude tosylate was dissolved in THF and lithium aluminiumhydride (2.4 M in THF, 7.2 mL, 17.2 mmol, 4 eq) was added. The reaction mixture was heated to a reflux. When complete, the reaction mixture was cooled to 0 °C, carefully quenched with 1M HCl and extracted twice with ethyl acetate. The combined organic phases were washed with sat. aq. NaHCO$_3$, dried with MgSO$_4$ and concentrated under reduced pressure. The residue was purified by silica chromatography (10% acetone in pentane) to give the title compound as colourless oil. Yield: 645 mg, 2.90 mmol, 68% over 2 steps. $[\alpha]_D^{25}$ = -65.0° (c = 0.10, CHCl$_3$); IR (thin film): 668, 699, 1093, 1276, 1455; ^{1}H NMR (400 MHz, CDCl$_3$) δ 7.41 – 7.27 (m, 5H, CH$_{arom}$), 4.71 (d, *J* = 11.6 Hz, 1H, C*H*H Bn), 4.50 (d, *J* = 11.6 Hz, 1H, CH*H* Bn), 3.95 (ddd, *J* = 11.9, 4.9, 1.7 Hz, 1H, H-1$_{eq}$), 3.47 – 3.35 (m, 2H, H-1$_{ax}$, H-3), 3.28 – 3.15 (m, 2H, H-4, H-5), 2.53 (d, *J* = 1.7 Hz, 1H, OH), 2.07 (ddt, *J* = 12.8, 4.4, 2.0 Hz, 1H, H-2$_{eq}$), 1.64 (tdd, *J* = 12.7, 11.1, 4.9 Hz, 1H, H-2$_{ax}$), 1.30 (d, *J* = 5.5 Hz, 3H, H-6), ^{13}C NMR (101 MHz, CDCl$_3$) δ 138.2 (C$_q$), 128.6, 127.9, 127.8 (CH$_{arom}$), 80.6 (C-3), 76.2, 76.2 (C-4, C-5), 70.7 (CH$_2$ Bn), 65.5 (C-1), 30.7 (C-2), 18.3 (C-6); HRMS: [M+Na]$^+$ calcd for C$_{13}$H$_{18}$O$_3$Na 245.11482, found 245.11450.

Preparation of acceptor **56**



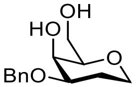
*Scheme **S37**: preparation of acceptor **56**: reagents and conditions: a) BnBr, NaH, DMF, 89%; b) MeOH, 60 °C, 97%; c) i: TsCl, pyridine, ii: LiAlH$_4$, THF, reflux, 70% over 2 steps*

1,2-di-deoxy-3-*O*-benzyl-4,6-*O*-benzylidene-D-galactopyranose (S110)



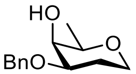
1,2-di-deoxy-4,6-*O*-benzylidene-D-galactopyranose (**S101**, 1.18 g, 5 mmol), benzyl bromide (0.89 mL, 7.50 mmol, 1.5 eq) and sodium hydride (60% dispersion in mineral oil, 300 mg, 7.50 mmol, 1.5 eq) were dissolved in DMF. When TLC shows full conversion, the reaction is quenched with water and extracted with diethyl ether. The organic phase was dried with $MgSO_4$ and concentrated under reduced pressure. The residue was purified over silica (10%→15% acetone in pentane), yielding the title compound as white powder. Yield: 1.45 g, 4.43 mmol, 89%. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.60 – 7.53 (m, 2H, CH_{arom}), 7.41 – 7.26 (m, 8H, CH_{arom}), 5.58 (s, 1H, C*H*Ph), 4.67 (s, 2H, CH_2 Bn), 4.26 (dd, *J* = 12.3, 1.6 Hz, 1H, H-2), 4.20 – 4.12 (m, 2H, H-1_{eq}, H-4), 4.01 (dd, *J* = 12.4, 1.8 Hz, 1H, H-6), 3.57 (ddd, *J* = 11.9, 4.7, 3.1 Hz, 1H, H-3), 3.47 (ddd, *J* = 12.6, 11.7, 2.0 Hz, 1H, H-1_{ax}), 3.23 (q, *J* = 1.6 Hz, 1H, H-5), 2.25 (qd, *J* = 12.5, 4.6 Hz, 1H, H-2_{ax}), 1.74 (dddd, *J* = 12.4, 4.6, 2.8, 1.3 Hz, 1H, H-2_{eq}), ^{13}C NMR (101 MHz, $CDCl_3$) δ 138.4, 138.1 (C_q), 128.9, 128.6, 128.2, 127.8, 127.8, 126.5 (CH_{arom}), 101.1 (*C*HPh), 75.5 (C-3), 73.4 (C-4), 70.6 (C-6), 70.2 (C-5), 69.6 (C-1), 66.2 (CH_2 Bn), 26.9 (C-2); HRMS: $[M+Na]^+$ calcd for $C_{20}H_{22}O_4Na$ 349.14103, found 349.14066.

1,2-di-deoxy-3-*O*-benzyl-D-galactopyranose (S111)



1,2-di-deoxy-3-*O*-benzyl-4,6-*O*-benzylidene-D-galactopyranose (**S110)** 1.63 g, 5 mmol) and PTSA-H_2O (95 mg, 0.5 mmol, 0.1 eq) were dissolved in methanol and heated to 60 °C. When TLC shows full conversion, triethylamine (0.14 mL, 1 mmol, 0.2 eq) was added and the reaction mixture was concentrated under reduced pressure. The residue was purified over silica (25% acetone in DCM) yielding the title compound as white powder. Yield: 1.16 g, 4.85 mmol, 97%. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.41 – 7.28 (m, 5H, CH_{arom}), 4.61 (d, *J* = 1.7 Hz, 2H, CH_2 Bn), 4.07 (ddd, *J* = 11.7, 5.1, 1.7 Hz, 1H, H-1_{eq}), 4.03 – 3.98 (m, 1H, H-4), 3.92 (ddd, *J* = 11.7, 6.7, 3.7 Hz, 1H, H-6), 3.75 (ddd, *J* = 11.7, 8.5, 4.3 Hz, 1H, H-6), 3.53 (ddd, *J* = 11.6, 5.0, 3.0 Hz, 1H, H-3), 3.41 (ddd, *J* = 12.7, 11.7, 2.3 Hz, 1H, H-1_{ax}), 3.33 (ddt, *J* = 6.6, 4.2, 1.2 Hz, 1H, H-5), 2.61 (dd, *J* = 2.5, 1.2 Hz, 1H, 4-OH), 2.54 (dd, *J* = 8.5, 3.8 Hz, 1H, 6-OH), 2.01 (tdd, *J* = 12.8, 11.5, 5.0 Hz, 1H, H-2_{ax}), 1.75 (ddq, *J* = 13.0, 5.0, 1.9 Hz, 1H, H-2_{eq}), ^{13}C NMR (101 MHz, $CDCl_3$) δ 137.9 (C_q), 128.7, 128.1, 127.8 (CH_{arom}), 78.5 (C-5), 75.9 (C-3), 69.8 (CH_2 Bn), 67.0 (C-4), 66.0 (C-6), 63.6 (C-1), 26.5 (C-2). HRMS $[M+Na]^+$ calcd for $C_{13}H_{18}O_4Na$ 261.10973, found 261.10949.

1,2-di-deoxy-3-*O*-benzyl-D-fucopyranose (56)

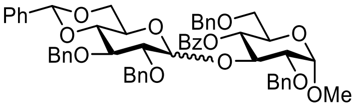


1,2-di-deoxy-3-*O*-benzyl-D-galactopyranose (**S111**, 1.13 g, 4.74 mmol) was dissolved in 25 mL pyridine, after which para-toluenesulfonyl chloride (1.36 g, 7.11 mmol, 1.5 eq) was added. The reaction mixture was stirred overnight, diluted with ethyl acetate and washed with 1M HCl and sat. aq. $NaHCO_3$. The organic phase was dried with $MgSO_4$ and concentrated under reduced pressure. The crude tosylate was dissolved in THF and lithium aluminiumhydride (2.4 M in THF, 7.9 mL, 19 mmol, 4 eq) was added. The reaction mixture was heated to a reflux. When complete, the reaction mixture was cooled to 0 °C, carefully quenched with 1M HCl and extracted twice with ethyl acetate. The combined organic phases were washed with sat. aq.

$NaHCO_3$, dried with $MgSO_4$ and concentrated under reduced pressure. The residue was purified by silica chromatography (10% acetone in pentane) to give the title compound as colourless oil. Yield: 740 mg, 3.33 mmol, 70% over 2 steps. $[\alpha]_D^{25}$ = 33.9° (c = 0.43, $CHCl_3$); IR (thin film): 668, 700, 980, 1027, 1086, 1183; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.39 – 7.28 (m, 5H, CH_{arom}), 4.64 (d, *J* = 12.0 Hz, 1H, C*H*H Bn), 4.60 (d, *J* = 11.9 Hz, 1H, CH*H* Bn), 4.00 (ddd, *J* = 11.7, 5.1, 1.7 Hz, 1H, H-1_{eq}), 3.82 – 3.74 (m, 1H, H-4), 3.52 (ddd, *J* = 11.6, 5.1, 3.0 Hz, 1H, H-3), 3.43 – 3.34 (m, 2H, H-1_{ax}, H-5), 2.22 (dd, *J* = 3.3, 1.0 Hz, 1H, OH), 1.94 (tdd, *J* = 12.9, 11.6, 5.1 Hz, 1H, H-2_{ax}), 1.73 (dddd, *J* = 11.8, 6.3, 2.4, 1.3 Hz, 1H, H-2_{eq}), 1.31 (d, *J* = 6.5 Hz, 3H, H-6), ^{13}C NMR (101 MHz, $CDCl_3$) δ 138.1 (C_q), 128.7, 128.0, 127.8 (CH_{arom}), 76.5 (C-3), 74.6 (C-5), 69.7 (CH_2 Bn), 68.8 (C-4), 65.9 (C-1), 26.3 (C-2), 17.5 (C-6); HRMS $[M+Na]^+$ calcd for $C_{13}H_{18}O_3Na$ 245.11482, found 245.11451.

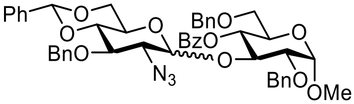
Characterisation of glycosylation products

Disaccharide 6A



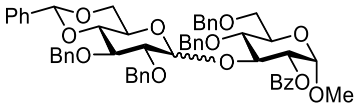
Title compound was obtained as colourless oil via the general procedure for Ph_2SO/Tf_2O mediated glycosylations with donor **A** and acceptor **6**. Yield: 93 mg, 98 μmol, 98%, α:β = 2.6:1. Data reported for a 1:0.4 mixture of anomers: ^{1}H NMR (500 MHz, $CDCl_3$) δ 8.06 – 8.00 (m, 1H), 7.98 – 7.93 (m, 2H), 7.60 – 7.00 (m, 38H), 5.49 – 5.41 (m, 2H, H-4α, C*H*Phα), 5.30 (dd, *J* = 10.3, 9.1 Hz, 0.4H, H-4β), 5.24 (s, 0.4H, C*H*Phβ), 5.19 (d, *J* = 3.5 Hz, 1H, H-1'α), 4.97 (d, *J* = 11.5 Hz, 0.4H), 4.89 – 4.85 (m, 0.8H, H-1'β, C*H*H Bnβ), 4.82 (d, *J* = 10.9 Hz, 1H), 4.79 – 4.73 (m, 2H), 4.66 (d, *J* = 12.0 Hz, 0.4 H), 4.59 – 4.50 (m, 5H), 4.48 – 4.41 (m, 2H), 4.40 – 4.26 (m, 4H), 4.18 (d, *J* = 12.1 Hz, 1H), 4.04 – 3.93 (m, 3H), 3.68 – 3.47 (m, 7H), 3.37 (d, *J* = 2.9 Hz, 4H, CH_3 Meαβ), 3.35 – 3.30 (m, 1H), 3.28 (t, *J* = 9.3 Hz, 0.4H, H-3'β), 3.20 (td, *J* = 9.7, 5.0 Hz, 0.4H, H-5'β), 2.90 (t, *J* = 10.1 Hz, 0.4H, H-6'β); ^{13}C NMR (126 MHz, $CDCl_3$) δ 165.3, 165.2, 138.8, 138.7, 138.2, 138.0, 137.9, 137.8, 137.8, 137.7, 137.4, 133.2, 133.1, 130.6, 129.9, 129.9, 129.9, 129.0, 128.8, 128.8, 128.6, 128.6, 128.4, 128.4, 128.3, 128.3, 128.3, 128.2, 128.2, 128.2, 128.0, 128.0, 127.9, 127.9, 127.8, 127.8, 127.8, 127.6, 127.6, 127.5, 127.5, 127.5, 126.2, 126.0, 102.9 (C-1'β), 101.3 (CHPhα), 100.9 (CHPhβ), 98.6 (C-1'α), 98.1 (C-1β), 97.7 (C-1α), 82.7, 82.3, 81.5, 81.0, 80.3, 78.8, 78.6, 78.6, 77.4, 77.2, 76.9, 76.2, 75.5, 75.3, 75.0, 73.9, 73.7, 73.7, 73.6, 72.9, 72.2, 69.6, 69.4, 69.1, 68.8, 68.6, 68.5, 65.5, 63.0, 55.5, 55.4, HRMS: $[M+NH_4]^+$ calcd for $C_{55}H_{56}O_{12}NH_4$ 926.41100, found 926.40958.

Disaccharide 6B



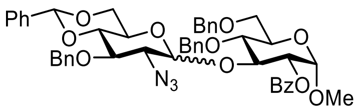
Title compound was obtained as colourless oil via the general procedure for Ph_2SO/Tf_2O mediated glycosylations with donor **B** and acceptor **6**. Yield: 86 mg, 99 μmol, 99%, α:β = 1:5. IR (thin film): 696, 711, 749, 998, 1027, 1043, 1070, 1091, 1174, 1269, 1452, 1727, 2109; Data for β-anomer: ^{1}H NMR (500 MHz, $CDCl_3$) δ 8.04 – 7.14 (m, 25H, CH_{arom}), 5.27 (dd, *J* = 10.3, 9.1 Hz, 1H, H-4), 5.23 (s, 1H, CH Ph), 4.89 (d, *J* = 11.9 Hz, 1H, C*H*H Bn), 4.83 (d, *J* = 11.4 Hz, 1H, C*H*H Bn), 4.73 (d, *J* = 11.4 Hz, 1H, CH*H* Bn), 4.67 (d, *J* = 8.0 Hz, 1H, H-1'), 4.60 (d, *J* = 11.8 Hz, 1H, CH*H* Bn), 4.56 (d, *J* = 3.6 Hz, 1H, H-1), 4.53 – 4.47 (m, 2H, C*H*H Bn, CH*H* Bn), 4.26 (t, *J* = 9.3 Hz, 1H, H-3), 4.02 – 3.92 (m, 1H, H-5), 3.85 (dd, *J* = 10.5, 5.0 Hz, 1H, H-6'), 3.72 (dd, *J* = 9.7, 3.6 Hz, 1H, H-2), 3.63 – 3.51 (m, 2H, H-6 x2), 3.47 – 3.42 (m, 1H, H-3'), 3.37 (d, *J* = 4.2 Hz, 4H, CH_3 OMe, H-2'), 3.34 – 3.28 (m, 1H, H-4'), 3.17 – 3.11 (m, 1H, H-5'), 2.76 (t, *J* = 10.3 Hz, 1H, H-6'). ^{13}C NMR (126 MHz, $CDCl_3$) δ 165.1 (C=O), 138.1, 138.0, 137.8, 137.2, 133.1, 130.5, 129.9, 129.7, 129.1, 128.9, 128.7, 128.7, 128.6, 128.6, 128.4, 128.4, 128.3, 128.3, 128.3, 128.3, 128.3, 128.2, 128.1, 127.8, 127.8, 127.8, 127.6, 127.6, 126.1, 126.0 (CH_{arom}), 102.2 (C-1'), 101.1 (CH Ph), 97.8 (C-1), 81.4 (C-4'), 79.8 (C-2), 79.2 (C-3'), 77.7 (C-3), 74.9 (CH_2 Bn), 73.8 (CH_2 Bn), 73.7 (CH_2 Bn), 69.5 (C-4), 68.9 (C-6), 68.7 (C-5), 68.1 (C-6'), 66.2 (C-2'), 65.6 (C-5'), 55.5 (CH_3 OMe). Diagnostic peaks for α-anomer: ^{1}H NMR (500 MHz, $CDCl_3$) δ 5.50 (s, 1H, CH Ph), 5.36 (dd, *J* = 10.3, 9.2 Hz, 1H, H-4), 5.04 (d, *J* = 3.8 Hz, 1H, H-1'), 4.65 – 4.63 (m, 1H, H-1), 4.15 (dd, *J* = 10.2, 4.9 Hz, 1H, H-5), 3.37 (s, 3H, CH_3 OMe). ^{13}C NMR (126 MHz, $CDCl_3$) δ 165.3 (C=O), 137.5, 137.5, 133.3, 131.8, 131.2, 129.7, 124.8, 124.5 (CH_{arom}), 101.3 (CHPh), 99.5 (C-1'), 97.5 (C-1), 82.7 (C-4'), 78.0, 77.6, 76.7, 75.1 (CH_2 Bn), 73.3 (CH_2 Bn), 72.1 (C-4), 69.3 (C-6'), 68.8 (C-6), 63.3, 63.0, 55.4 (CH_3 OMe); HRMS: $[M+NH_4]^+$ calcd for $C_{48}H_{49}N_3O_{11}NH_4$ 861.37053, found 861.36976.

Disaccharide 7A



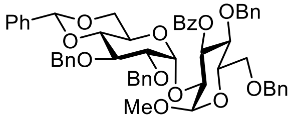
Title compound was obtained as colourless oil via the general procedure for Ph_2SO/Tf_2O mediated glycosylations with donor **A** and acceptor **7**. Yield: 94 mg, 99 µmol, 99%, α:β = 1.8:1. Data reported for a 2:1 mixture of anomers: ^{1}H NMR (500 MHz, $CDCl_3$) δ 8.04 – 7.99 (m, 4H), 7.95 (dd, *J* = 8.3, 1.4 Hz, 2H), 7.53 (t, *J* = 7.4 Hz, 1H), 7.50 – 7.45 (m, 4H), 7.41 – 7.15 (m, 66H), 7.10 (ddt, *J* = 7.8, 4.8, 2.2 Hz, 6H), 5.50 (s, 1H, C*H*Phβ), 5.39 (s, 2H, C*H*Phα), 5.21 (dd, *J* = 9.7, 3.8 Hz, 2H, H-2α), 5.14 (dd, *J* = 9.9, 3.6 Hz, 3H, H-1'α, H-2β), 5.10 – 5.06 (m, 3H, H-1β, C*H*H Bnα)), 4.95 (d, *J* = 10.5 Hz, 1H), 4.92 (d, *J* = 3.8 Hz, 2H, H-1α), 4.90 (d, *J* = 7.7 Hz, 1H, H-1'β), 4.82 (d, *J* = 11.4 Hz, 2H), 4.77 – 4.70 (m, 6H), 4.67 (d, *J* = 12.1 Hz, 1H), 4.65 – 4.57 (m, 5H), 4.57 – 4.50 (m, 4H), 4.48 – 4.40 (m, 3H), 4.39 – 4.31 (m, 3H), 4.14 (dd, *J* = 10.2, 4.9 Hz, 2H), 3.99 (t, *J* = 9.4 Hz, 2H), 3.94 (td, *J* = 10.0, 4.9 Hz, 2H), 3.89 – 3.79 (m, 6H), 3.78 – 3.73 (m, 2H), 3.70 (td, *J* = 10.6, 1.8 Hz, 3H), 3.63 – 3.55 (m, 2H), 3.53 (t, *J* = 8.9 Hz, 1H), 3.48 – 3.42 (m, 4H), 3.40 – 3.33 (m, 12H); ^{13}C NMR (126 MHz, $CDCl_3$) δ 166.0 (C=Oα), 165.9 (C=Oβ), 138.7, 138.6, 138.5, 138.5, 138.3, 138.3, 138.1, 138.1, 137.6, 137.4, 133.2, 133.1, 130.1, 129.9, 129.8, 129.7, 129.0, 128.8, 128.5, 128.5, 128.4, 128.4, 128.3, 128.3, 128.3, 128.2, 128.1, 128.1, 128.0, 128.0, 128.0, 127.9, 127.8, 127.8, 127.6, 127.5, 127.4, 126.2, 126.1, 103.9 (C-1'β), 101.2 (CHPhα), 101.1 (CHPhβ), 98.9 (C-1'α), 97.2 (C-1α), 97.0 (C-1β), 82.3, 82.3, 81.7, 81.2, 79.6, 79.5, 78.1, 77.8, 77.7, 77.4, 77.2, 76.9, 76.0, 75.2, 75.1, 75.1, 75.0, 74.9, 74.7, 73.7, 73.7, 73.7, 73.0, 70.1, 69.8, 68.9, 68.7, 68.6, 68.6, 66.1, 63.2, 55.3, 55.3; HRMS: $[M+NH_4]^+$ calcd for $C_{55}H_{56}O_{12}NH_4$ 926.41100, found 926.40981

Disaccharide 7B



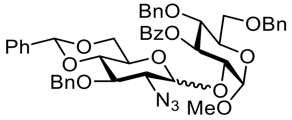
Title compound was obtained as colourless oil via the general procedure for Ph_2SO/Tf_2O mediated glycosylations with donor **B** and acceptor **7.** Yield: 81 mg, 93 µmol, 93%, α:β = 1:4. Data for the β-anomer: ^{1}H NMR (500 MHz, $CDCl_3$) δ 8.08 (dd, *J* = 8.4, 1.3 Hz, 2H, CH_{arom}), 7.62 – 7.56 (m, 1H, CH_{arom}), 7.49 – 7.43 (m, 4H, CH_{arom}), 7.41 – 7.20 (m, 18H, CH_{arom}), 5.51 (s, 1H, C*H*Ph), 5.23 (dd, *J* = 10.0, 3.7 Hz, 1H, H-2), 5.05 (d, *J* = 3.6 Hz, 1H, H-1), 4.94 (d, *J* = 10.6 Hz, 1H, C*H*H Bn), 4.75 (d, *J* = 11.3 Hz, 1H, C*H*H Bn), 4.71 (d, *J* = 8.0 Hz, 1H, H-1'), 4.66 (d, *J* = 12.0 Hz, 1H, , C*H*H Bn), 4.60 (d, *J* = 11.2 Hz, 1H, CH*H* Bn), 4.54 (d, *J* = 12.2 Hz, 1H, CH*H* Bn), 4.49 – 4.43 (m, 2H, H-3, CH*H* Bn), 4.26 (dd, *J* = 10.5, 5.0 Hz, 1H, H-6'), 3.84 (ddd, *J* = 10.0, 3.7, 1.9 Hz, 1H, H-5), 3.80 – 3.73 (m, 2H, H-4, H-6), 3.70 (dd, *J* = 10.7, 1.9 Hz, 1H, H-6), 3.61 (t, *J* = 9.2 Hz, 1H, H-4'), 3.55 (t, *J* = 10.2 Hz, 1H, H-6'), 3.38 – 3.32 (m, 5H, H-2', H-5', CH_3 OMe), 3.29 (t, *J* = 9.2 Hz, 1H, H-3'); ^{13}C NMR (126 MHz, $CDCl_3$) δ 165.8 (C=O), 138.5, 138.1, 137.8, 137.1 (C_q), 133.3 (CH_{arom}), 129.9 (C_q), 129.8, 129.8, 129.2, 128.6, 128.6, 128.5, 128.4, 128.4, 128.4, 128.3, 128.3, 128.1, 128.1, 128.0, 127.9, 127.9, 127.9, 127.8, 127.8, 127.8, 127.7, 126.2, 126.0 (CH_{arom}), 102.9 (C-1'), 101.3 (CHPh), 97.1 (C-1), 81.6 (C-4'), 79.4 (C-3), 79.2 (C-3'), 76.0 (C-4), 75.0, 74.9 (CH_2 Bn), 74.2 (C-2), 73.7 (CH_2 Bn), 70.2 (C-5), 68.6, 68.5 (C-6, C-6'), 66.5, 66.3 (C-2', C-5'), 55.3 (CH_3 OMe); diagnostic peaks for the α-anomer: ^{1}H NMR (500 MHz, $CDCl_3$) δ 5.41 (d, *J* = 3.8 Hz, 1H, H-1'), 5.35 (s, 1H, C*H*Ph), 4.82 (d, *J* = 11.0 Hz, 1H, C*H*H Bn), 4.38 (dd, *J* = 10.0, 8.4 Hz, 1H, H-3), 4.08 (dd, *J* = 10.2, 4.8 Hz, 1H, H-6'), 3.94 (dd, *J* = 10.0, 9.1 Hz, 1H), 3.46 (t, *J* = 10.3 Hz, 1H); ^{13}C NMR (126 MHz, $CDCl_3$) δ 166.1 (C=O), 98.4 (C-1'), 97.2 (C-1), 82.8, 78.8, 76.6, 76.2, 75.0, 74.5, 73.8, 72.3, 70.1, 68.3, 63.4, 63.0, 55.3 (CH_3 OMe); HRMS: $[M+NH_4]^+$ calcd for $C_{48}H_{49}N_3O_{11}NH_4$ 861.37053, found 861.36933.

Disaccharide 10A



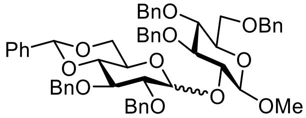
Title compound was obtained as colourless oil via the general procedure for Ph_2SO/Tf_2O mediated glycosylations with donor **A** and acceptor **10**. Yield: 75 mg, 78 µmol, 78%, α:β > 20:1. ^{1}H NMR (500 MHz, $CDCl_3$) δ 8.07 – 7.98 (m, 2H, CH_{arom}), 7.41 – 7.17 (m, 23H, CH_{arom}), 7.13 – 7.08 (m, 3H, CH_{arom}), 7.01 – 6.97 (m, 2H, CH_{arom}), 5.88 (dd, *J* = 10.1, 8.9 Hz, 1H, H-3), 5.30 (s, 1H, C*H*Ph), 4.92 (d, *J* = 3.4 Hz, 1H, H-1), 4.84 (d, *J* = 12.0 Hz, 1H, C*H*H Bn), 4.80 – 4.76 (m, 2H, H-1', C*H*H Bn), 4.71 (d, *J* = 11.2 Hz, 1H, CH*H* Bn), 4.67 (d, *J* = 8.7 Hz, 1H, C*H*H Bn), 4.64 (d, *J* = 8.6 Hz, 1H, CH*H* Bn), 4.52 (d, *J* = 9.0 Hz, 1H, CH*H* Bn), 4.50 (d, *J* = 7.8 Hz, 1H, C*H*H Bn), 4.40 (d, *J* = 10.8 Hz, 1H, C*H*H Bn), 3.95 – 3.86 (m, 4H, H-2, H-3', H-4, H-5), 3.84 – 3.78 (m, 2H, H-6, H-6'), 3.72 – 3.66 (m, 2H, H-5', H-6), 3.44 (dd, *J* = 9.3, 3.5 Hz, 1H, H-2'), 3.41 – 3.38 (m, 4H, H-4', CH_3 OMe), 3.37 – 3.33 (m, 1H, H-6'); ^{13}C NMR (126 MHz, $CDCl_3$) δ 165.5 (C=O), 138.8, 138.6, 137.8, 137.6, 137.5, 133.0 (C_q), 130.1, 129.7, 128.8, 128.6, 128.5, 128.5, 128.3, 128.3, 128.3, 128.3, 128.3, 128.2, 128.1, 128.0, 128.0, 127.9, 127.8, 127.6, 126.3 (CH_{arom}), 101.2 (CHPh), 98.0 (C-1'), 97.3 (C-1), 82.1 (C-4'), 78.7 (C-3'), 78.2 (C-2'), 76.5 (C-4), 76.2 (C-2), 75.2 (CH_2 Bn), 74.5 (CH_2 Bn), 73.8 (CH_2 Bn), 73.7 (C-3), 73.5 (CH_2 Bn), 69.9 (C-5), 68.6 (C-6'), 68.3 (C-6), 63.0 (C-5'), 55.4 (CH_3 OMe); HRMS: $[M+NH_4]^+$ calcd for $C_{55}H_{56}O_{12}NH_4$ 926.41100, found 926.40995.

Disaccharide 10B



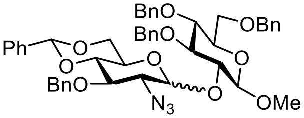
Title compound was obtained as colourless oil via the general procedure for Ph_2SO/Tf_2O mediated glycosylations with donor **B** and acceptor **10.** Yield: 69 mg, 82 µmol, 82%, α:β = 6:1. Data for α-anomer: ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.06 – 8.01 (m, 2H, CH_{arom}), 7.47 – 7.19 (m, 18H, CH_{arom}), 7.15 – 7.08 (m, 3H, CH_{arom}), 7.01 (dt, *J* = 4.6, 3.4 Hz, 2H, CH_{arom}), 5.86 (dd, *J* = 10.0, 8.9 Hz, 1H, H-3), 5.33 (s, 1H, C*H*Ph), 4.98 (d, *J* = 3.5 Hz, 1H, H-1), 4.88 (d, *J* = 3.6 Hz, 1H, H-1'), 4.80 (d, *J* = 10.9 Hz, 1H, C*H*H Bn), 4.68 (d, *J* = 5.9 Hz, 1H, C*H*H Bn), 4.65 (d, *J* = 4.7 Hz, 1H, CH*H* Bn), 4.53 (d, *J* = 8.9 Hz, 1H, CH*H* Bn), 4.50 (d, *J* = 7.7 Hz, 1H, C*H*H Bn), 4.42 (d, *J* = 10.8 Hz, 1H, CH*H* Bn), 3.97 – 3.87 (m, 4H, H-2, H-3', H-4, H-5), 3.84 – 3.77 (m, 2H, H-6, H-6'), 3.75 – 3.65 (m, 2H, H-5', H-6), 3.52 – 3.46 (m, 4H, H-4', CH_3 OMe), 3.39 (t, *J* = 10.2 Hz, 1H, H-6'), 3.27 (dd, *J* = 10.0, 3.6 Hz, 1H, H-2'); ^{13}C NMR (101 MHz, $CDCl_3$) δ 165.5 (C=O), 138.0, 137.9, 137.6, 137.3, 133.15 (C_q), 130.0, 129.7, 129.7, 129.0, 128.6, 128.6, 128.5, 128.4, 128.4, 128.3, 128.2, 128.2, 128.1, 128.1, 128.0, 127.9, 127.9, 127.8, 127.8, 126.3, 126.0 (CH_{arom}), 101.3 (CHPh), 98.1 (C-1'), 97.3 (C-1), 82.6 (C-4'), 76.9 (C-2), 76.1 (C-4), 75.7 (C-3'), 75.1 (CH_2 Bn), 74.6 (CH_2 Bn), 73.8 (CH_2 Bn), 73.6 (C-3), 70.0 (C-5), 68.5 (C-6'), 68.3 (C-6), 63.4 (C-5'), 63.0 (C-2'), 55.6 (CH_3 OMe); Diagnostic peaks for β-anomer: ^{1}H NMR (400 MHz, $CDCl_3$) δ 5.52 (s, 1H, C*H*Ph), 4.95 (d, *J* = 3.5 Hz, 1H, H-1), 4.28 – 4.21 (m, 2H, H-1', H-6); ^{13}C NMR (101 MHz, $CDCl_3$) δ 103.9 (C-1'), 101.3 (CHPh), 99.5 (C-1), 81.2, 80.1, 79.7, 76.2, 74.9, 73.3, 68.5, 66.2 (C-6), 65.7, 55.5 (CH_3 OMe); HRMS: $[M+NH_4]^+$ calcd for $C_{48}H_{49}N_3O_{11}NH_4$ 861.37053, found 861.36950.

Disaccharide 12A



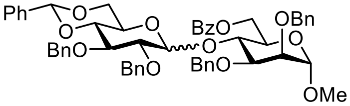
Title compound was obtained as colourless oil via the general procedure for Ph_2SO/Tf_2O mediated glycosylations with donor **A** and acceptor **12**. Yield: 86 mg, 96 µmol, 96%, α:β = 1:1.9. Data reported for a 1:2 mixture: ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.56 – 7.08 (m, 90H, CH_{arom}), 5.68 (d, *J* = 3.8 Hz, 1H, H-1'α), 5.61 (s, 2H, C*H*Phβ), 5.53 (s, 1H, C*H*Phα), 5.11 (d, *J* = 7.6 Hz, 2H, H-1'β), 5.01 (d, *J* = 11.0 Hz, 1H, C*H*H Bnα), 4.97 – 4.86 (m, 9H), 4.86 – 4.82 (m, 8H), 4.77 (d, *J* = 11.2 Hz, 2H), 4.68 (dd, *J* = 12.2, 3.9 Hz, 3H), 4.64 – 4.56 (m, 6H), 4.49 (dd, *J* = 5.4, 2.2 Hz, 1H, H-1α), 4.41 (d, *J* = 7.5 Hz, 2H, H-1β), 4.37 (dd, *J* = 10.4, 5.0 Hz, 2H, H-6'β), 4.26 – 4.19 (m, 2H), 4.08 (t, *J* = 9.4 Hz, 1H), 3.90 – 3.85 (m, 3H), 3.84 – 3.71 (m, 14H), 3.66 – 3.61 (m, 3H), 3.60 (s, 6H, CH_3 OMeβ), 3.59 (s, 3H, CH_3 OMeα), 3.56 (t, *J* = 7.9 Hz, 3H), 3.41 (td, *J* = 9.8, 5.0 Hz, 2H, H-5'β); ^{13}C NMR (126 MHz, $CDCl_3$) δ 138.8, 138.6, 138.5, 138.3, 138.2, 138.2, 138.1, 138.0, 137.9, 137.8, 137.8, 137.4, 135.4, 131.7, 131.4, 130.4, 129.0, 128.7, 128.5, 128.5, 128.5, 128.4, 128.4, 128.3, 128.3, 128.2, 128.1, 128.1, 128.1, 128.0, 128.0, 127.9, 127.9, 127.9, 127.8, 127.8, 127.7, 127.7, 127.7, 127.6, 127.6, 127.5, 126.4, 126.1, 104.6 (C-1α), 102.7 (C-1β), 102.5 (C-1'β), 101.2 (CHPhα), 101.1 (CHPhβ), 96.2 (C-1'α), 85.3, 83.0, 82.5, 82.4, 81.5, 81.1, 78.9, 78.7, 78.6, 78.3, 78.2, 76.2, 75.5, 75.4, 75.3, 75.2, 75.1, 75.0, 75.0, 75.0, 74.9, 73.6, 73.0, 69.0, 68.9, 68.8, 68.7, 66.0 (C-5'β), 62.5 (C-5'α), 56.8 (CH_3 OMeα), 56.5 (CH_3 OMeβ); HRMS: $[M+NH_4]^+$ calcd for $C_{55}H_{58}O_{11}NH_4$ 912.43174, found 912.43016.

Disaccharide 12B



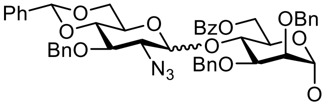
Title compound was obtained as colourless oil via the general procedure for Ph_2SO/Tf_2O mediated glycosylations with donor **B** and acceptor **12**. Yield: 65 mg, 78 µmol, 78%, α:β = 1:6. Data for the β-anomer: ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.41 – 7.24 (m, 25H, CH_{arom}), 5.56 (s, 1H. C*H*Ph), 4.95 (d, *J* = 10.6 Hz, 1H, C*H*H Bn), 4.92 (d, *J* = 11.2 Hz, 1H, C*H*H Bn), 4.88 (d, *J* = 10.6 Hz, 1H, CH*H* Bn), 4.82 – 4.77 (m, 3H, H-1', C*H*H Bn, CH*H* Bn), 4.62 (d, *J* = 12.2 Hz, 1H, C*H*H Bn), 4.58 – 4.51 (m, 2H, CH*H* Bn), 4.32 (d, *J* = 7.2 Hz, 1H, H-1), 4.29 (dd, *J* = 10.5, 5.1 Hz, 1H, H-6'), 3.81 (t, *J* = 10.3 Hz, 1H, H-6'), 3.77 – 3.69 (m, 5H, H-2, H-4, H-4', 2x H-6), 3.68 – 3.64 (m, 1H, H-3), 3.56 (t, *J* = 9.2 Hz, 1H, H-3'), 3.53 (s, 3H, CH_3 OMe), 3.51 – 3.46 (m, 2H, H-2', H-5), 3.30 (td, *J* = 9.7, 5.0 Hz, 1H, H-5'); ^{13}C NMR (126 MHz, $CDCl_3$) δ 138.3, 138.2, 138.0, 137.8, 137.2 (C_q), 129.2, 128.6, 128.5, 128.5, 128.5, 128.5, 128.4, 128.3, 128.2, 128.1, 128.0, 128.0, 127.9, 127.9, 127.9, 127.9, 127.9, 127.9, 127.8, 127.7, 126.3, 126.1 (CH_{arom}), 102.6 (C-1), 101.5 (C-1'), 101.3 (CHPh), 84.9 (C-4), 81.6 (C-4'), 79.7, 79.6 (C-2, C-3'), 78.3 (C-3), 75.6, 75.0 (CH_2 Bn), 74.9 (C-2'), 74.9, 73.6 (CH_2 Bn), 68.8, 68.7 (C-6, C-6'), 66.3, 66.3 (C-5, C-5'), 56.7 (CH_3 OMe); diagnostic peaks for the α-anomer: ^{1}H NMR (500 MHz, $CDCl_3$) δ 5.59 (d, *J* = 3.8 Hz, 1H, H-1'), 5.52 (s, 1H, C*H*Ph), 4.37 (d, *J* = 7.1 Hz, 1H, H-1), 3.98 (dd, *J* = 10.0, 9.1 Hz, 1H); ^{13}C NMR (126 MHz, $CDCl_3$) δ 104.6 (C-1), 101.4 (CHPh), 97.1 (C-1'), 83.0, 78.6, 76.2, 76.1, 75.6, 63.0, 62.8, 57.2 (CH_3 OMe); HRMS: $[M+NH_4]^+$ calcd for $C_{48}H_{51}N_3O_{10}NH_4$ 847.39127, found 847.38954.

Disaccharide 14A



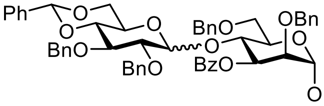
Title compound was obtained as colourless oil via the general procedure for Ph_2SO/Tf_2O mediated glycosylations with donor **A** and acceptor **14**. Yield: 75 mg, 79 µmol, 79%, α:β = 1.3:1. Data reported for a 1:1 mixture of anomers: ^{1}H NMR (500 MHz, $CDCl_3$) δ 8.10 – 8.06 (m, 2H), 8.02 – 7.94 (m, 2H), 7.54 – 7.10 (m, 56H), 5.73 (d, *J* = 4.0 Hz, 1H, H-1'α), 5.48 (s, 1H, C*H*Phβ), 5.47 (s, 1H, C*H*Phα), 4.90 – 4.83 (m, 4H), 4.82 – 4.71 (m, 9H), 4.70 – 4.62 (m, 4H), 4.62 – 4.56 (m, 8H), 4.55 – 4.46 (m, 4H), 4.30 (t, *J* = 9.2 Hz, 1H, H-4β), 4.17 (dd, *J* = 10.5, 5.0 Hz, 1H, H-6'β), 4.11 – 3.97 (m, 6H), 3.86 (ddd, *J* = 14.7, 9.2, 4.1 Hz, 3H), 3.82 – 3.77 (m, 2H, H-2αβ), 3.74 (t, *J* = 9.0 Hz, 1H), 3.62 (t, *J* = 9.3 Hz, 1H), 3.58 – 3.53 (m, 2H), 3.51 (dd, *J* = 9.5, 4.0 Hz, 1H, H-2'α), 3.45 (t, *J* = 8.2 Hz, 1H, H-2'β), 3.37 (s, 3H, CH_3 OMeα), 3.36 (s, 3H, CH_3 OMeβ), 3.24 (td, *J* = 9.7, 5.0 Hz, 1H, H-5'β); ^{13}C NMR (126 MHz, $CDCl_3$) δ 166.3, 166.2, 139.1, 138.8, 138.5, 138.5, 138.3, 138.3, 138.1, 137.5, 137.4, 133.0, 133.0, 130.2, 130.1, 129.9, 129.9, 129.8, 129.7, 129.0, 128.9, 128.9, 128.5, 128.5, 128.5, 128.5, 128.4, 128.4, 128.4, 128.4, 128.4, 128.3, 128.3, 128.3, 128.2, 128.1, 128.1, 128.0, 127.9, 127.8, 127.7, 127.7, 127.7, 127.6, 127.6, 127.6, 127.5, 127.5, 127.2, 126.9, 126.3, 126.1, 103.5 (C-1'β), 101.3 (CHPhα), 101.2 (CHPhβ), 99.1 (C-1β), 98.6 (C-1α), 98.4 (C-1'α), 82.7, 82.3, 81.7, 81.5, 80.3, 78.8, 78.6, 77.9, 75.9, 75.7, 75.6, 75.4, 75.2, 74.2, 73.3, 73.0, 72.7, 72.6, 71.7, 71.0, 70.2, 69.4, 68.9, 66.0, 64.2, 63.6, 63.6, 55.1;); HRMS: $[M+NH_4]^+$ calcd for $C_{55}H_{56}O_{12}NH_4$ 926.41100, found 926.40949

Disaccharide 14B



Title compound was obtained as colourless oil via the general procedure for Ph_2SO/Tf_2O mediated glycosylations with donor **B** and acceptor **14**. Yield: 78 mg, 92 µmol, 92%, α:β = 1:8. Data for β-anomer: ^1H NMR (500 MHz, $CDCl_3$) δ 8.07 (dd, *J* = 8.3, 1.4 Hz, 2H, CH_{arom}), 7.54 (ddt, *J* = 8.7, 7.3, 1.3 Hz, 1H, CH_{arom}), 7.44 – 7.22 (m, 22H, CH_{arom}), 5.47 (s, 1H, C*H*Ph), 4.89 (d, *J* = 11.0 Hz, 1H, C*H*H Bn), 4.79 – 4.76 (m, 2H, H-1, H-6), 4.75 – 4.70 (m, 3H, 2x C*H*H Bn, CH*H* Bn), 4.66 – 4.60 (m, 3H, H-6, 2x CH*H* Bn), 4.52 (d, *J* = 8.1 Hz, 1H, H-1'), 4.35 (t, *J* = 9.4 Hz, 1H, H-4), 4.01 – 3.94 (m, 2H, H-5, H-6'), 3.91 (dd, *J* = 9.1, 3.2 Hz, 1H, H-3), 3.78 (dd, *J* = 3.2, 2.0 Hz, 1H, H-2), 3.64 – 3.57 (m, 2H, H-3', H-4'), 3.52 (t, *J* = 10.3 Hz, 1H, H-6'), 3.41 (dd, *J* = 9.3, 8.1 Hz, 1H, H-2'), 3.36 (s, 3H, CH_3 OMe), 3.18 – 3.11 (m, 1H, H-5'); ^{13}C NMR (126 MHz, $CDCl_3$) δ 166.4 (C=O), 138.8, 138.4, 137.7, 137.2 (C_q), 133.1 (CH_{arom}), 129.8 (C_q), 129.1, 128.5, 128.4, 128.4, 128.4, 128.3, 128.0, 127.7, 127.6, 127.0, 126.1 (CH_{arom}), 102.2 (C-1'), 101.3 (CHPh), 98.9 (C-1), 81.7 (C-4'), 79.7 (C-3'), 78.4 (C-3), 76.0 (C-4), 75.2 (C-2), 75.0, 72.9, 72.4 (CH_2 Bn), 69.7 (C-5), 68.6 (C-6'), 67.0 (C-2'), 66.2 (C-5'), 63.6 (C-6), 55.1 (CH_3 OMe); diagnostic peaks for the α-anomer: ^1H NMR (500 MHz, $CDCl_3$) δ 5.67 (d, *J* = 4.1 Hz, 1H, H-1'), 5.51 (s, 1H, C*H*Ph), 3.83 (dd, *J* = 3.1, 2.0 Hz, 1H, H-2); ^{13}C NMR (126 MHz, $CDCl_3$) δ 101.4 (CHPh), 99.2 (C-1), 98.7 (C-1'), 82.7, 80.6, 77.4, 76.3, 63.0, 56.1 (CH_3 OMe); HRMS: $[M+NH_4]^+$ calcd for $C_{48}H_{49}N_3O_{11}NH_4$ 861.37053, found 861.36936.

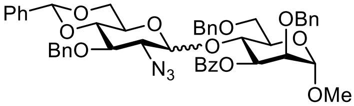
Disaccharide 15A



Title compound was obtained as colourless oil via the general procedure for Ph_2SO/Tf_2O mediated glycosylations with donor **A** and acceptor **15**. Yield: 59 mg, 62 µmol, 62%, α:β = 9:1. Data for α-anomer: ^1H NMR (500 MHz, $CDCl_3$) δ 8.03 (dd, *J* = 8.3, 1.4 Hz, 2H, CH_{arom}), 7.57 – 7.52 (m, 1H, CH_{arom}), 7.49 – 7.45 (m, 2H, CH_{arom}), 7.41 – 7.33 (m, 7H, CH_{arom}), 7.31 – 7.22 (m, 10H, CH_{arom}), 7.19 – 7.05 (m, 8H, CH_{arom}), 5.65 (dd, *J* = 8.7, 3.3 Hz, 1H, H-3), 5.49 (s, 1H, C*H*Ph), 5.35 (d, *J* = 3.8 Hz, 1H, H-1'), 4.85 (d, *J* = 2.3 Hz, 1H, H-1), 4.78 (d, *J* = 11.1 Hz, 1H, C*H*H Bn), 4.68 (d, *J* = 12.0 Hz, 1H, C*H*H Bn), 4.64 – 4.57 (m, 4H, H-4, C*H*H Bn, 2x CH*H* Bn), 4.55 (d, *J* = 11.9 Hz, 1H, CH*H* Bn), 4.38 (d, *J* = 11.9 Hz, 1H, C*H*H Bn), 4.30 (d, *J* = 11.9 Hz, 1H, CH*H* Bn), 4.07 (dd, *J* = 10.2, 4.9 Hz, 1H, H-6'), 4.00 (dd, *J* = 3.3, 2.3 Hz, 1H, H-2), 3.98 – 3.92 (m, 2H, H-5, H-6), 3.90 (t, *J* = 9.4 Hz, 1H, H-3'), 3.84 (dt, *J* = 10.0, 5.1 Hz, 1H, H-5'), 3.80 – 3.76 (m, 1H, H-6), 3.57 (t, *J* = 10.2 Hz, 1H, H-6'), 3.52 (t, *J* = 9.5 Hz, 1H, H-4'), 3.41 (s, 3H, CH_3 OMe), 3.40 – 3.36 (m, 1H, H-2'); ^{13}C NMR (126 MHz, $CDCl_3$) δ 165.6 (C=O), 138.8, 138.5, 138.0, 137.8, 137.6 (C_q), 133.2 (CH_{arom}), 130.2 (C_q), 129.9, 128.9, 128.6, 128.4, 128.4, 128.3, 128.3, 128.1, 127.9, 127.8, 127.7, 127.7, 127.6, 127.5, 126.2 (CH_{arom}), 101.2 (CHPh), 99.0 (C-1), 97.8 (C-1'), 82.1 (C-4'), 79.0

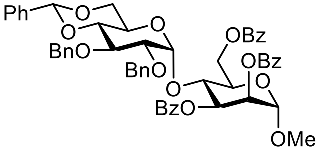
(C-2’), 78.5 (C-3’), 76.0 (C-2), 75.4 (CH_2 Bn), 74.5 (C-3), 73.6, 73.3, 72.9 (CH_2 Bn), 71.1 (C-4), 70.9 (C-5), 69.4 (C-6), 69.0 (C-6’), 63.6 (C-5’), 55.1 (CH_3 OMe); ^{1}H NMR (500 MHz, $CDCl_3$) δ 5.31 (s, 1H, C*H*Ph), 3.25 (dd, *J* = 8.9, 7.8 Hz, 1H, H-2’), 3.12 – 3.02 (m, 2H); ^{13}C NMR (126 MHz, $CDCl_3$) δ 165.6 (C=O), 103.3 (C-1’), 101.0 (CHPh), 99.1 (C-1), 82.5, 81.5, 81.0, 76.2, 75.6, 74.9, 73.4, 73.2, 72.0, 71.5, 68.6, 68.2, 65.7, 55.1 (CH_3 OMe); HRMS: $[M+NH_4]^+$ calcd for $C_{55}H_{56}O_{12}NH_4$ 926.41100, found 926.40924.

Disaccharide 15B



Title compound was obtained as colourless oil via the general procedure for Ph_2SO/Tf_2O mediated glycosylations with donor **B** and acceptor **15**. Yield: 83 mg, 87 µmol, 87%, α:β = 1.5:1. Data reported for a 1:1 mixture of anomers: ^{1}H NMR (500 MHz, $CDCl_3$) δ 8.11 – 8.01 (m, 4H), 7.60 – 7.54 (m, 2H), 7.47 – 7.13 (m, 34H), 5.60 (dd, *J* = 9.0, 3.3 Hz, 1H, H-3α), 5.53 – 5.47 (m, 2H, H-3β, C*H*Phα), 5.31 – 5.27 (m, 2H, H-1’α, C*H*Phβ), 4.88 – 4.76 (m, 4H, H-1αβ, 2x C*H*H Bn), 4.73 – 4.61 (m, 8H), 4.58 (d, *J* = 12.2 Hz, 1H, CH*H* Bn), 4.51 (d, *J* = 12.0 Hz, 1H, CH*H* Bn), 4.45 – 4.36 (m, 2H, H-4αβ), 4.17 (d, *J* = 8.1 Hz, 1H, H-1’β), 4.09 (dd, *J* = 10.3, 4.9 Hz, 1H, H-6’α), 4.03 (dd, *J* = 11.0, 3.7 Hz, 1H, H-6’β), 3.95 (dd, *J* = 3.3, 2.1 Hz, 1H), 3.96 – 3.82 (m, 6H), 3.80 (ddd, *J* = 11.0, 6.6, 1.8 Hz, 2H), 3.66 – 3.57 (m, 2H), 3.42 (s, 3H, CH_3 OMeα), 3.39 (s, 3H, CH_3 OMeβ), 3.39 – 3.29 (m, 2H), 3.27 – 3.19 (m, 2H), 3.03 – 2.93 (m, 2H); ^{13}C NMR (126 MHz, $CDCl_3$) δ 165.6, 165.5 (C=O), 138.4, 138.3, 138.1, 138.0, 137.9, 137.9, 137.3, 137.3, 133.2, 133.1, 131.3, 130.7, 130.1, 130.0, 129.7, 129.2, 129.1, 128.6, 128.6, 128.6, 128.5, 128.5, 128.4, 128.4, 128.4, 128.3, 128.3, 128.3, 128.2, 127.9, 127.9, 127.8, 127.8, 127.7, 127.6, 127.6, 126.2, 126.1, 126.1, 125.4, 121.9, 121.9, 101.7 (C-1’β), 101.4 (CHPhα), 101.2 (CHPhβ), 99.1, 99.1, 99.0 (C-1αβ, C-1’α), 82.6, 81.4, 79.2, 76.6, 76.3, 76.1, 75.2, 74.7, 74.2, 73.9, 73.8, 73.7, 73.4, 73.2, 73.1, 71.9, 71.2, 70.9, 69.8, 68.7, 68.4, 68.3, 66.3, 65.8, 63.6, 63.3, 55.2, 55.1; HRMS: $[M+NH_4]^+$ calcd for $C_{48}H_{49}N_3O_{11}NH_4$ 861.37053, found 861.36906.

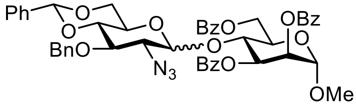
Disaccharide 16A



Title compound was obtained as colourless oil via the general procedure for Ph_2SO/Tf_2O mediated glycosylations with donor **A** and acceptor **16.** Yield: 62 mg, 66 µmol, 66%, α:β > 20: 1. Data for the α-anomer: ^{1}H NMR (500 MHz, $CDCl_3$) δ 8.13 (dd, *J* = 8.3, 1.4 Hz, 2H, CH_{arom}), 8.00 (dd, *J* = 8.3, 1.4 Hz, 2H, CH_{arom}), 7.89 (dd, *J* = 8.3, 1.3 Hz, 2H, CH_{arom}), 7.63 – 7.56 (m, 2H, CH_{arom}), 7.49 – 7.40 (m, 5H, CH_{arom}), 7.37 – 7.21 (m, 13H, CH_{arom}), 7.15 – 7.05 (m, 3H, CH_{arom}), 7.02 – 6.96 (m, 2H, CH_{arom}), 5.94 (dd, *J* = 9.5, 3.3 Hz, 1H, H-3), 5.69 (dd, *J* = 3.3, 1.9 Hz, 1H, H-2), 5.46 (s, 1H, C*H*Ph), 5.25 (d, *J* = 3.9 Hz, 1H, H-1’), 4.94 – 4.88 (m, 2H, H-1, H-6), 4.82 (d, *J* = 11.1 Hz, 1H, C*H*H Bn), 4.71 – 4.63 (m, 3H, H-4, H-6, CH*H* Bn), 4.30 – 4.24 (m, 2H, H-5, C*H*H Bn), 4.18 (d, *J* = 12.0 Hz, 1H, CH*H* Bn), 4.10 (dd, *J* = 10.2, 4.8 Hz, 1H, H-6’), 3.99 (t, *J* = 9.4 Hz, 1H, H-3’), 3.91 (dt, *J* = 9.9, 5.0 Hz, 1H, H-5’), 3.57 (t, *J* = 10.3 Hz, 1H, H-6’), 3.52 (t, *J* = 9.5 Hz, 1H, H-

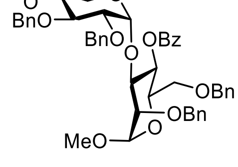
4'), 3.49 (s, 3H CH$_3$ OMe), 3.37 (dd, *J* = 9.5, 3.9 Hz, 1H, H-2'); ^{13}C NMR (126 MHz, CDCl$_3$) δ 166.1, 165.3, 165.2 (C=O), 138.7, 137.8, 137.4 (C$_q$), 133.5, 133.2, 133.2 (CH$_{\text{arom}}$), 130.1, 129.9, 129.9 (C$_q$), 129.9, 129.8, 129.8, 129.7, 129.0, 128.7, 128.7, 128.7, 128.6, 128.6, 128.6, 128.6, 128.5, 128.4, 128.4, 128.3, 128.3, 128.1, 127.7, 127.7, 127.6, 126.2 (CH$_{\text{arom}}$), 101.4 (CHPh), 99.1 (C-1'), 98.6 (C-1), 82.1 (C-4'), 78.7 (C-3'), 78.4 (C-2'), 75.4, 73.5 (CH$_2$ Bn), 72.4 (C-3), 72.1 (C-4), 70.6 (C-2), 69.5 (C-5'), 68.8 (C-6), 64.0 (C-5'), 63.4 (C-6), 55.5 (CH$_3$ OMe); diagnostic peaks for the β-anomer: ^{1}H NMR (500 MHz, CDCl$_3$) δ 5.84 (dd, *J* = 9.8, 3.2 Hz, 1H, H-3), 5.59 (dd, *J* = 3.5, 1.8 Hz, 1H, H-2), 5.28 (s, 1H, C*H*Ph), 5.15 (t, *J* = 9.8 Hz, 1H), 4.57 (d, *J* = 7.6 Hz, 1H), 4.40 (t, *J* = 9.7 Hz, 1H), 3.75 (dd, *J* = 10.5, 4.9 Hz, 1H), 3.70 – 3.63 (m, 1H); ^{13}C NMR (126 MHz, CDCl$_3$) δ 103.6 (C-1'), 101.0 (CHPh), 98.7 (C-1), 82.5, 81.3, 76.0, 75.1, 72.7, 71.1, 69.1, 68.3, 67.0, 65.9, 62.5.HRMS: [M+NH$_4$]$^+$ calcd for $C_{55}H_{52}O_{14}NH_4$ 954.36953, found 954.36920.

Disaccharide 16B



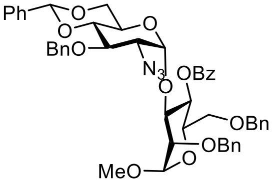
Title compound was obtained as colourless oil via the general procedure for Ph$_2$SO/Tf$_2$O mediated glycosylations with donor **B** and acceptor **16**. Yield: 86 mg, 98 μmol, 98%, α:β = 10:1. Data for α-anomer: ^{1}H NMR (500 MHz, CDCl$_3$) δ 8.13 (dd, *J* = 8.3, 1.4 Hz, 2H, CH$_{\text{arom}}$), 8.01 – 7.96 (m, 2H, CH$_{\text{arom}}$), 7.97 – 7.91 (m, 2H, CH$_{\text{arom}}$), 7.59 (dtt, *J* = 11.7, 7.4, 1.3 Hz, 2H, CH$_{\text{arom}}$), 7.54 – 7.47 (m, 1H, CH$_{\text{arom}}$), 7.49 – 7.40 (m, 5H, CH$_{\text{arom}}$), 7.41 – 7.31 (m, 9H, CH$_{\text{arom}}$), 7.31 – 7.22 (m, 6H, CH$_{\text{arom}}$), 5.87 (dd, *J* = 9.6, 3.4 Hz, 1H, H-3), 5.63 (dd, *J* = 3.4, 1.9 Hz, 1H, H-2), 5.52 (s, 1H, C*H*Ph), 5.25 (d, *J* = 4.1 Hz, 1H, H-1'), 4.92 (d, *J* = 1.9 Hz, 1H, H-1), 4.88 (d, *J* = 10.8 Hz, 1H, C*H*H Bn), 4.80 (dd, *J* = 12.1, 2.0 Hz, 1H, H-6), 4.70 (d, *J* = 10.8 Hz, 1H, CH*H* Bn), 4.65 (dd, *J* = 12.1, 3.7 Hz, 1H, H-6), 4.51 (t, *J* = 9.7 Hz, 1H, H-4), 4.27 (dd, *J* = 10.3, 4.9 Hz, 1H, H-6'), 4.22 (ddd, *J* = 9.8, 3.7, 2.0 Hz, 1H, H-5), 4.00 – 3.92 (m, 2H, H-3', H-5'), 3.65 – 3.59 (m, 2H, H-4', H-6'), 3.51 (s, 3H, CH$_3$ OMe), 3.25 (dd, *J* = 10.0, 4.1 Hz, 1H, H-2'); ^{13}C NMR (126 MHz, CDCl$_3$) δ 166.2, 165.3 (C=O), 137.7, 137.2 (C$_q$), 135.4, 133.7, 133.5, 133.3, 133.2, 131.7, 131.6, 131.1 (CH$_{\text{arom}}$), 130.4, 130.0, 130.0 (C$_q$), 129.9, 129.9, 129.8, 129.8, 129.7, 129.6, 129.6, 129.1, 128.8, 128.7, 128.7, 128.7, 128.6, 128.6, 128.5, 128.5, 128.4, 128.4, 128.4, 128.3, 128.3, 128.0, 126.1, 124.6 (CH$_{\text{arom}}$), 101.4 (CHPh), 100.2 (C-1'), 98.6 (C-1), 82.5 (C-4'), 76.6 (C-3'), 75.2 (CH$_2$ Bn), 74.1 (C-4), 72.2 (C-3), 70.6 (C-2), 69.2 (C-5), 68.5 (C-6'), 64.0 (C-5'), 63.5 (C-6), 63.1 (C-2'), 55.6 (CH$_3$ OMe); diagnostic peaks for the β-anomer: ^{1}H NMR (500 MHz, CDCl$_3$) δ 5.68 (dd, *J* = 3.4, 1.8 Hz, 1H, H-2), 5.28 (s, 1H, C*H*Ph), 4.42 (t, *J* = 9.7 Hz, 1H, H-4), 4.37 (d, *J* = 8.1 Hz, 1H, H-1'); ^{13}C NMR (126 MHz, CDCl$_3$) δ 102.3 (C-1'), 101.2 (CHPh), 98.7 (C-1), 81.2, 79.6, 74.9, 74.8, 72.7, 71.1, 61.7. HRMS: [M+NH$_4$]$^+$ calcd for $C_{46}H_{46}O_{13}N_3NH_4$: 866.33689, found 866.33809.

Disaccharide 18A



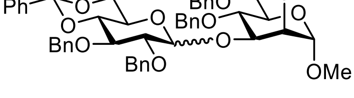
Title compound was obtained as colourless oil via the general procedure for Ph_2SO/Tf_2O mediated glycosylations with donor **A** and acceptor **18**. Yield: 83 mg, 87 µmol, 87% α:β > 20:1; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.99 – 7.92 (m, 2H, CH_{arom}), 7.50 (t, *J* = 7.5 Hz, 1H, CH_{arom}), 7.42 (td, *J* = 7.6, 2.8 Hz, 5H, CH_{arom}), 7.38 – 7.31 (m, 6H, CH_{arom}), 7.27 – 7.14 (m, 19H, CH_{arom}), 7.06 – 6.99 (m, 2H, CH_{arom}), 5.70 (t, *J* = 9.5 Hz, 1H, H-4), 5.48 (s, 1H, C*H*Ph), 5.06 (d, *J* = 3.6 Hz, 1H, H-1'), 4.84 – 4.70 (m, 4H, H-1, 2x C*H*H Bn, CH*H* Bn), 4.60 (d, *J* = 11.2 Hz, 1H, CH*H* Bn), 4.52 (d, *J* = 11.9 Hz, 1H, C*H*H Bn), 4.47 (d, *J* = 11.9 Hz, 1H, CH*H* Bn), 4.38 – 4.26 (m, 2H, H-3, C*H*H Bn), 4.24 – 4.13 (m, 2H, H-6', CH*H* Bn), 4.06 – 3.95 (m, 3H, H-6, H-3',H-5'), 3.82 (t, *J* = 2.7 Hz, 1H, H-2), 3.75 – 3.59 (m, 3H, H-5, H-6, H-6'), 3.50 (t, *J* = 9.4 Hz, 1H, H-4'), 3.42 (s, 1H, CH_3 OMe), 3.37 (dd, *J* = 9.3, 3.6 Hz, 1H, H-2'). ^{13}C NMR (101 MHz, $CDCl_3$) δ 165.4 (C=O), 138.8, 138.2, 138.1, 138.0, 137.6 (C_q), 133.1, 131.6, 131.1, 130.1, 130.0, 129.0, 128.6, 128.5, 128.4, 128.3, 128.2, 128.2, 127.9, 127.8, 127.7, 127.7, 127.6, 127.5, 126.2 (CH_{arom}), 101.4 (CHPh), 99.2 (C-1'), 99.0 (C-1), 82.1 (C-4'), 78.6 (C-2'), 78.2 (C-3'), 77.1 (C-2), 76.2 (C-3), 75.2 (CH_2 Bn), 73.6 (CH_2 Bn), 73.1 (CH_2 Bn), 72.5 (CH_2 Bn), 70.7 (C-5), 70.2 (C-6), 70.0 (C-4), 69.1 (C-6'), 63.5 (C-5'), 55.2 (CH_3 OMe); HRMS: $[M+NH_4]^+$ calcd for $C_{55}H_{56}O_{12}NH_4$ 926.41100, found 926.40970.

Disaccharide 18B



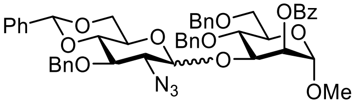
Title compound was obtained as colourless oil via the general procedure for Ph_2SO/Tf_2O mediated glycosylations with donor **B** and acceptor **18.** Yield: 74 mg, 87 µmol, 87%, α:β > 20: 1. ^{1}H NMR (500 MHz, $CDCl_3$) δ 8.04 – 7.99 (m, 2H, CH_{arom}), 7.58 – 7.53 (m, 1H, CH_{arom}), 7.47 – 7.37 (m, 10H, CH_{arom}), 7.32 – 7.16 (m, 13H, CH_{arom}), 5.70 (t, *J* = 9.8 Hz, 1H, H-4), 5.52 (s, 1H, C*H*Ph), 5.03 (d, *J* = 3.8 Hz, 1H, H-1'), 4.85 (dd, *J* = 6.4, 4.4 Hz, 2H, H-1, C*H*H Bn), 4.76 (d, *J* = 12.1 Hz, 1H, C*H*H Bn), 4.71 (d, *J* = 12.0 Hz, 1H, CH*H* Bn), 4.66 (d, *J* = 10.8 Hz, 1H, CH*H* Bn), 4.55 (d, *J* = 11.8 Hz, 1H, C*H*H Bn), 4.50 (d, *J* = 11.8 Hz, 1H, CH*H* Bn), 4.22 (dd, *J* = 9.5, 3.1 Hz, 1H, H-3), 4.17 (dd, *J* = 10.3, 4.8 Hz, 1H, H-6'), 4.04 – 3.90 (m, 3H, H-5, H-3', H-5'), 3.80 (dd, *J* = 3.2, 2.0 Hz, 1H, H-2), 3.74 – 3.63 (m, 3H, H-6 2x, H-6'), 3.60 (t, *J* = 9.4 Hz, 1H, H-4'), 3.43 (s, 3H, CH_3 OMe), 3.20 (dd, *J* = 9.9, 3.8 Hz, 1H, H-2'); ^{13}C NMR (126 MHz, $CDCl_3$) δ 165.6 (C=O), 138.1, 137.9, 137.7, 137.4 (C_q), 133.1, 131.5, 130.1, 129.7, 129.1, 128.7, 128.6, 128.6, 128.5, 128.5, 128.4, 128.4, 128.3, 128.0, 127.9, 127.9, 127.7, 127.7, 127.5, 126.2 (CH_{arom}), 101.5 (CHPh), 100.3 (C-1'), 98.7 (C-1), 82.8 (C-4'), 77.4 (C-2), 77.4 (C-3), 76.3 (C-3'), 75.1 (CH_2 Bn), 73.7 (CH_2 Bn), 72.9 (CH_2 Bn), 70.7 (C-5), 70.2 (C-6), 69.7 (C-4), 68.9 (C-6'), 63.4 (C-5'), 63.1 (C-2'), 55.2 (CH_3 OMe); HRMS: $[M+NH_4]^+$ calcd for $C_{48}H_{49}N_3O_{11}NH_4$ 861.37053, found 861.36924.

Disaccharide 19A



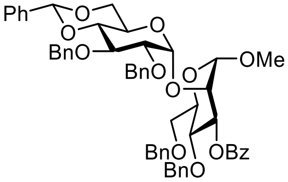
Title compound was obtained as colourless oil via the general procedure for Ph_2SO/Tf_2O mediated glycosylations with donor **A** and acceptor **19**. Yield: 79 mg, 82 µmol, 82%, α:β = 10:1. Data for α-anomer: ^{1}H NMR (500 MHz, $CDCl_3$) δ 8.12 – 7.14 (m, 30H, CH$_{arom}$), 5.42 (dd, *J* = 3.2, 2.0 Hz, 1H, H-2), 5.36 (s, 1H, C*H*Ph), 5.17 (d, *J* = 11.0 Hz, 1H, C*H*H Bn), 5.03 (d, *J* = 3.7 Hz, 1H, H-1'), 4.90 (d, *J* = 2.0 Hz, 1H, H-1), 4.80 (d, *J* = 11.6 Hz, 1H, C*H*H Bn), 4.73 (d, *J* = 11.5 Hz, 1H, CH*H* Bn), 4.71 – 4.61 (m, 3H, 2x C*H*H Bn, CH*H* Bn), 4.57 (d, *J* = 11.1 Hz, 1H, CH*H* Bn), 4.52 (d, *J* = 12.0 Hz, 1H, CH*H* Bn), 4.24 (dd, *J* = 9.3, 3.1 Hz, 1H, H-3), 4.18 (t, *J* = 9.4 Hz, 1H, H-4), 4.03 – 3.95 (m, 2H, H-3', H-6'), 3.90 – 3.84 (m, 2H, H-5, H-6), 3.81 – 3.74 (m, 2H, H-6, H-5'), 3.53 – 3.46 (m, 3H, H-2', H-4', H-6'), 3.41 (s, 3H, CH_3 OMe); ^{13}C NMR (126 MHz, $CDCl_3$) δ 166.3 (C=O), 138.8, 138.8, 138.5, 138.2, 137.6, 135.4, 134.2, 133.3, 131.9, 131.4, 131.3, 130.3, 130.0, 129.9, 128.9, 128.7, 128.5, 128.5, 128.5, 128.4, 128.3, 128.3, 128.2, 128.1, 128.0, 128.0, 128.0, 127.9, 127.8, 127.7, 127.6, 127.6, 127.6, 127.6, 127.5, 127.5, 126.3, 126.1 (CH$_{arom}$), 101.3 (CHPh), 100.5 (C-1'), 98.1 (C-1), 82.1 (C-4'), 80.7 (C-3), 79.1 (C-2'), 78.2 (C-3'), 75.1 (CH_2 Bn), 73.8 (CH_2 Bn), 73.6 (C-4), 73.4 (CH_2 Bn), 72.4 (CH_2 Bn), 71.5 (C-2), 69.2 (C-5), 69.0 (C-6), 63.7 (C-6'), 55.3 (CH_3 OMe); Diagnostic peaks for β-anomer: ^{1}H NMR (500 MHz, $CDCl_3$) δ 5.50 (dd, *J* = 3.1, 2.1 Hz, 1H, H-2'), 5.49 (s, 1H, C*H*Ph), 4.94 (d, *J* = 10.6 Hz, 1H, C*H*H Bn), 4.29 (dd, *J* = 10.5, 5.0 Hz, 1H, H-6'), 3.69 – 3.65 (m, 1H), 3.65 – 3.61 (m, 1H, H-6'), 3.40 (s, 3H, CH_3 OMe); ^{13}C NMR (126 MHz, $CDCl_3$) δ 165.7 (C=O), 101.2 (CHPh), 100.6 (C-1'), 98.4 (C-1), 82.0 (C-4'), 81.7, 81.0, 75.5, 75.2 (CH_2 Bn), 74.6, 73.7 (CH_2 Bn), 72.1, 70.8, 69.5, 69.4 (CH_2 Bn), 69.1 (CH_2 Bn), 66.0, 55.2 (CH_3 OMe); HRMS: $[M+NH_4]^+$ calcd for $C_{55}H_{56}O_{12}NH_4$ 926.41100, found 926.40968.

Disaccharide 19B



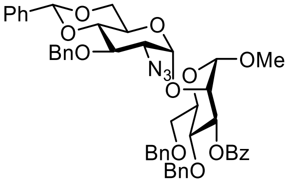
Title compound was obtained as colourless oil via the general procedure for Ph_2SO/Tf_2O mediated glycosylations with donor **B** and acceptor **19**. Yield: 78 mg, 93 µmol, 93%, α:β = 1:1. Data reported for a 1:1 mixture of anomers: ^{1}H NMR (500 MHz, $CDCl_3$) δ 8.10 (ddd, *J* = 8.4, 6.8, 1.4 Hz, 4H), 7.60 – 7.53 (m, 2H), 7.50 – 7.45 (m, 2H), 7.42 – 7.20 (m, 42H), 5.55 (s, 1H, C*H*Phβ), 5.54 (dd, *J* = 3.4, 2.0 Hz, 1H, H-2β), 5.46 (s, 1H, C*H*Phα), 5.40 (dd, *J* = 3.2, 1.9 Hz, 1H, H-2α), 5.22 (d, *J* = 3.8 Hz, 1H, H-1'α), 5.03 (d, *J* = 10.4 Hz, 1H), 4.91 (d, *J* = 10.6 Hz, 1H), 4.89 – 4.85 (m, 3H), 4.83 (d, *J* = 11.0 Hz, 1H), 4.73 (dd, *J* = 11.5, 7.5 Hz, 3H), 4.65 (s, 1H), 4.59 – 4.51 (m, 6H), 4.47 (dd, *J* = 9.3, 3.3 Hz, 1H), 4.33 – 4.27 (m, 2H), 4.24 – 4.11 (m, 3H), 3.98 – 3.87 (m, 4H), 3.84 (ddt, *J* = 9.8, 3.9, 2.0 Hz, 2H), 3.78 (dt, *J* = 10.7, 1.9 Hz, 2H), 3.73 – 3.55 (m, 5H), 3.44 – 3.38 (m, 8H), 3.32 (dd, *J* = 9.4, 8.0 Hz, 1H, H-2'β); ^{13}C NMR (126 MHz, $CDCl_3$) δ 166.1, 138.5, 138.5, 138.4, 138.3, 137.9, 137.9, 137.5, 137.2, 133.4, 133.3, 131.6, 131.1, 130.1, 130.0, 130.0, 129.9, 129.7, 129.2, 129.0, 128.6, 128.5, 128.5, 128.5, 128.5, 128.4, 128.4, 128.4, 128.3, 128.2, 128.2, 128.2, 128.1, 128.0, 128.0, 127.9, 127.8, 127.7, 127.7, 127.7, 126.3, 126.1, 101.5, 101.4 (CHPhαβ), 100.2 (C-1'α), 99.3 (C-1'β), 98.6, 98.3 (C-1αβ), 82.7, 81.8, 79.4, 77.9, 77.4, 77.2, 76.9, 76.6, 76.3, 75.1, 75.1, 75.0, 74.7, 73.6, 73.6, 73.5, 72.4, 71.7, 71.4, 69.0, 68.9, 68.8, 68.8, 68.7, 66.9, 66.3, 63.5, 63.4, 55.2, 55.2; HRMS: $[M+NH_4]^+$ calcd for $C_{48}H_{49}N_3O_{11}NH_4$ 861.37053, found 861.36959.

Disaccharide 22A



Title compound was obtained as colourless oil via the general procedure for Ph_2SO/Tf_2O mediated glycosylations with donor **A** and acceptor **22**. Yield: 77 mg, 76 µmol, 76%, α:β = 17:1. Data for α-anomer: ^{1}H NMR (500 MHz, $CDCl_3$) δ 8.07 – 8.01 (m, 2H, CH_{arom}), 7.52 – 7.46 (m, 3H, CH_{arom}), 7.41 – 7.34 (m, 5H, CH_{arom}), 7.33 – 7.15 (m, 18H, CH_{arom}), 7.09 – 7.04 (m, 2H, CH_{arom}), 5.59 – 5.52 (m, 2H, H-3, C*H*Ph), 4.91 (d, *J* = 3.7 Hz, 1H, H-1'), 4.86 – 4.82 (m, 2H, H-1, C*H*H Bn), 4.79 (d, *J* = 12.2 Hz, 1H, C*H*H Bn), 4.69 (d, *J* = 11.2 Hz, 1H, CH*H* Bn), 4.64 (d, *J* = 10.9 Hz, 1H, C*H*H Bn), 4.61 (s, 2H, CH_2 Bn), 4.58 (d, *J* = 12.2 Hz, 1H, C*H*H Bn), 4.52 (d, *J* = 10.9 Hz, 1H, CH*H* Bn), 4.31 (t, *J* = 9.5 Hz, 1H, H-4), 4.27 (dd, *J* = 10.2, 4.9 Hz, 1H, H-6'), 4.25 (dd, *J* = 3.1, 2.1 Hz, 1H, H-2), 4.12 (t, *J* = 9.3 Hz, 1H, H-3'), 4.06 (td, *J* = 10.0, 4.9 Hz, 1H, H-5'), 3.93 – 3.85 (m, 2H, H-5, H-6), 3.79 – 3.72 (m, 1H, H-6), 3.67 (t, *J* = 10.3 Hz, 1H, H-6'), 3.59 (t, *J* = 9.5 Hz, 1H, H-4'), 3.49 (dd, *J* = 9.3, 3.7 Hz, 1H, H-2'), 3.41 (s, 3H, CH_3 OMe); ^{13}C NMR (126 MHz, $CDCl_3$) δ 166.0 (C=O), 138.8, 138.6, 138.5, 138.1, 137.5 (C_q), 133.2 (CH_{arom}), 130.1 (C_q) , 129.9, 129.0, 128.5, 128.4, 128.4, 128.4, 128.3, 128.0, 127.8, 127.7, 127.6, 127.6, 127.5, 127.4, 126.2 (CH_{arom}), 101.4 (CHPh), 99.8 (C-1), 99.5 (C-1'), 82.3 (C-4'), 78.9 (C-2'), 78.6 (C-3'), 76.1 (C-2), 75.3, 75.1 (CH_2 Bn), 74.5 (C-3), 73.7 (CH_2 Bn), 73.6 (C-4), 72.9 (CH_2 Bn), 72.0 (C-5), 69.2 (C-6), 69.0 (C-6'), 63.2 (C-5'), 55.1 (CH_3 OMe); Diagnostic peaks for β-anomer: ^{1}H NMR (500 MHz, $CDCl_3$) δ 5.39 (dd, *J* = 9.7, 3.5 Hz, 1H, H-3), 5.28 (s, 1H, C*H*Ph), 5.04 (d, *J* = 10.4 Hz, 1H, C*H*H Bn), 4.41 (d, *J* = 7.7 Hz, 1H, H-1'); ^{13}C NMR (126 MHz, $CDCl_3$) δ 104.2 (C-1'), 101.0 (CHPh), 99.4 (C-1), 81.5, 81.3, 80.8, 76.5, 74.1, 72.9, 72.4, 65.5, 55.0 (CH_3 OMe); HRMS: $[M+NH_4]^+$ calcd for $C_{55}H_{56}O_{12}NH_4$ 926.41100, found 926.40906.

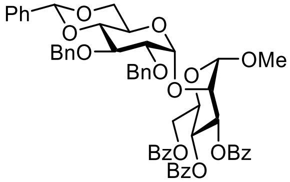
Disaccharide 22B



Title compound was obtained as colourless oil via the general procedure for Ph_2SO/Tf_2O mediated glycosylations with donor **B** and acceptor **22**. Yield: 44 mg, 51 µmol, 51%, α:β = 7:1. Data for α-anomer: ^{1}H NMR (500 MHz, $CDCl_3$) δ 8.14 (dd, *J* = 8.2, 1.4 Hz, 2H, CH_{arom}), 7.62 – 7.54 (m, 1H, CH_{arom}), 7.53 – 7.43 (m, 5H, CH_{arom}), 7.40 – 7.25 (m, 15H, CH_{arom}), 7.22 – 7.14 (m, 3H), 7.13 – 7.07 (m, 2H, CH_{arom}), 5.62 – 5.53 (m, 2H, H-3, C*H*Ph), 4.94 (d, *J* = 3.7 Hz, 1H, H-1'), 4.88 (d, *J* = 10.9 Hz, 1H, C*H*H Bn), 4.79 – 4.76 (m, 2H, H-1, C*H*H Bn), 4.71 (d, *J* = 10.8 Hz, 1H, C*H*H Bn), 4.63 (d, *J* = 11.0 Hz, 1H, CH*H* Bn), 4.58 (dd, *J* = 11.6, 2.8 Hz, 2H, 2x CH*H* Bn), 4.34 (t, *J* = 9.4 Hz, 1H, H-4), 4.27 (dd, *J* = 10.4, 4.9 Hz, 1H, H-6'), 4.20 (dd, *J* = 3.2, 2.0 Hz, 1H, H-2), 4.14 – 4.04 (m, 2H, H-3', H-5'), 3.92 – 3.86 (m, 2H, H-5, H-6), 3.79 – 3.67 (m, 3H, H-4', H-6, H-6'), 3.42 (s, 3H, CH_3 OMe), 3.26 (dd, *J* = 10.1, 3.7 Hz, 1H, H-2'); ^{13}C NMR (126 MHz, $CDCl_3$) δ 166.0

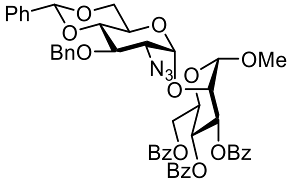
(C=O), 138.6, 138.0, 138.0, 137.3 (C_q), 133.4 (CH_{arom}), 131.7 (C_q), 131.4, 129.9, 129.9, 129.2, 128.7, 128.6, 128.5, 128.5, 128.5, 128.4, 128.4, 128.4, 128.4, 128.3, 128.2, 128.1, 128.1, 128.0, 128.0, 128.0, 127.8, 127.8, 127.6, 127.6, 127.6, 126.2, 126.1 (CH_{arom}), 101.6 (CHPh), 100.7 (C-1'), 99.9 (C-1), 82.9 (C-4'), 77.5 (C-2), 75.6 (C-3'), 75.2 (CH_2 Bn x2), 74.2 (C-3), 73.6 (CH_2 Bn), 73.4 (C-4), 71.9 (C-5), 69.1 (C-6), 68.7 (C-6'), 63.3 (C-5'), 62.9 (C-2'), 55.2 (CH_3 OMe); Diagnostic peaks for the β-anomer: ^{1}H NMR (500 MHz, $CDCl_3$) δ 5.36 (dd, *J* = 9.5, 3.5 Hz, 1H, H-3), 5.30 (s, 1H, C*H*Ph), 3.17 – 3.09 (m, 1H), 2.79 (t, *J* = 10.4 Hz, 1H); ^{13}C NMR (126 MHz, $CDCl_3$) δ 102.4 (C-1'), 101.5 (CHPh), 99.2 (C-1); HRMS: $[M+NH_4]^+$ calcd for $C_{48}H_{49}N_3O_{11}NH_4$ 861.37053, found 861.36930.

Disaccharide 23A



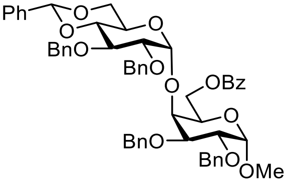
Title compound was obtained as colourless oil via the general procedure for Ph_2SO/Tf_2O mediated glycosylations with donor **A** and acceptor **23**. Yield: 73 mg, 77 µmol, 77%, α:β >20:1. ^{1}H NMR (500 MHz, $CDCl_3$) δ 8.10 – 8.05 (m, 2H, CH_{arom}), 8.02 – 7.94 (m, 4H, CH_{arom}), 7.51 – 7.44 (m, 3H, CH_{arom}), 7.42 – 7.16 (m, 21H, CH_{arom}), 6.18 (t, *J* = 10.1 Hz, 1H, H-4), 5.73 (dd, *J* = 10.1, 3.1 Hz, 1H, H-3), 5.51 (s, 1H, C*H*Ph), 4.96 (d, *J* = 3.7 Hz, 1H, H-1'), 4.93 (d, *J* = 1.9 Hz, 1H, H-1), 4.82 (d, *J* = 11.1 Hz, 1H, C*H*H Bn), 4.72 – 4.63 (m, 3H, H-6, C*H*H Bn, CH*H* Bn), 4.56 – 4.48 (m, 2H, H-6, C*H*H Bn), 4.39 (dd, *J* = 3.2, 1.9 Hz, 1H, H-2), 4.33 (ddd, *J* = 10.1, 4.7, 2.7 Hz, 1H, H-5), 4.25 (dd, *J* = 10.3, 4.9 Hz, 1H, H-6'), 4.10 (t, *J* = 9.3 Hz, 1H, H-3'), 3.99 (td, *J* = 10.0, 4.9 Hz, 1H, H-5'), 3.66 (t, *J* = 10.4 Hz, 1H, H-6'), 3.57 (t, *J* = 9.5 Hz, 1H, H-4'), 3.51 (s, 3H, CH_3 OMe), 3.48 (dd, *J* = 9.4, 3.8 Hz, 1H, H-2'); ^{13}C NMR (126 MHz, $CDCl_3$) δ 166.4, 166.1, 165.4 (C=O), 138.9, 138.3, 137.4 (C_q), 133.4, 133.3, 133.0, 130.0, 129.9, 129.8 (CH_{arom}), 129.4, 129.4 (C_q), 129.0, 128.5, 128.5, 128.5, 128.4, 128.4, 128.3, 128.3, 128.0, 128.0, 128.0, 127.8, 127.6, 127.6, 126.2 (CH_{arom}), 101.4 (CHPh), 100.1 (C-1), 99.7 (C-1'), 82.1 (C-4'), 78.5, 78.5 (C-2', C-3'), 75.5 (C-2), 75.4, 72.7 (CH_2 Bn), 72.3 (C-3), 69.0 (C-5), 68.9 (C-6'), 67.1 (C-4), 63.4 (C-5'), 63.3 (C-6), 55.5 (CH_3 OMe); HRMS: $[M+NH_4]^+$ calcd for $C_{55}H_{52}O_{14}NH_4$ 954.36953, found 954.36815.

Disaccharide 23B



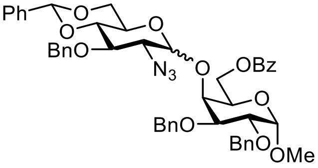
Title compound was obtained as colourless oil via the general procedure for Ph_2SO/Tf_2O mediated glycosylations with donor **B** and acceptor **23**. Yield: 42 mg, 51 µmol, 51%, α:β > 20:1. ^{1}H NMR (500 MHz, $CDCl_3$) δ 8.05 (dq, *J* = 7.0, 1.6 Hz, 4H, CH_{arom}), 8.00 – 7.93 (m, 2H, CH_{arom}), 7.54 – 7.45 (m, 4H, CH_{arom}), 7.40 – 7.27 (m, 15H, CH_{arom}), 6.04 (t, *J* = 10.1 Hz, 1H, H-4), 5.72 (dd, *J* = 10.1, 3.2 Hz, 1H, H-3), 5.56 (s, 1H, C*H*Ph), 4.99 (d, *J* = 3.8 Hz, 1H, H-1'), 4.92 (d, *J* = 10.8 Hz, 1H, C*H*H Bn), 4.88 (d, *J* = 1.8 Hz, 1H, H-1), 4.71 (d, *J* = 10.8 Hz, 1H, CH*H* Bn), 4.65 (dd, *J* = 12.1, 2.9 Hz, 1H, H-6), 4.50 (dd, *J* = 12.1, 5.5 Hz, 1H, H-6), 4.37 – 4.30 (m, 2H, H-2, H-5), 4.27 (dd, *J* = 10.4, 4.9 Hz, 1H, H-6'), 4.13 (dd, *J* = 10.1, 9.1 Hz, 1H, H-3'), 4.02 (td, *J* = 10.0, 4.9 Hz, 1H, H-5'), 3.71 (dt, *J* = 11.5, 9.9 Hz, 2H, H-4', H-6'), 3.51 (s, 3H, CH_3 OMe), 3.34 (dd, *J* = 10.1, 3.8 Hz, 1H, H-2'); ^{13}C NMR (126 MHz, $CDCl_3$) δ 166.3, 166.0, 165.4 (C=O), 138.0, 137.1, 133.5 (C_q), 133.4, 133.1, 131.7, 131.3, 130.0, 129.9, 129.9, 129.8, 129.3, 129.3, 129.2, 128.6, 128.6, 128.5, 128.4, 128.4, 128.4, 128.4, 128.2, 128.0, 126.2, 126.1 (CH_{arom}), 101.6 (CHPh), 100.7 (C-1'), 100.0 (C-1), 82.7 (C-4'), 76.7 (C-2), 76.2 (C-3'), 75.3 (CH_2 Bn), 71.7 (C-3), 68.8 (C-5), 68.7 (C-6'), 67.3 (C-4), 63.6 (C-6), 63.4 (C-5'), 63.1 (C-2'), 55.5 (CH_3 OMe); HRMS: $[M+NH_4]^+$ calcd for $C_{48}H_{45}N_3O_{13}NH_4$ 889.32906, found 889.32759

Disaccharide 25A



Title compound was obtained as colourless oil via the general procedure for Ph_2SO/Tf_2O mediated glycosylations with donor **A** and acceptor **25**. 79 mg, 85 μmol, 85%, α:β > 20:1. ^1H NMR (400 MHz, $CDCl_3$) δ 7.99 – 7.14 (m, 30H, CH_{arom}), 5.53 (s, 1H, C*H*Ph), 4.97 (d, *J* = 11.0 Hz, 1H, C*H*H Bn), 4.93 – 4.84 (m, 3H, H-1', 2x C*H*H Bn), 4.82 – 4.74 (m, 5H, C*H*H Bn, 4x CH*H* Bn), 4.66 (q, *J* = 3.9 Hz, 2H, H-1, H-6'), 4.59 (dd, *J* = 11.1, 6.4 Hz, 1H, H-6'), 4.27 (td, *J* = 10.0, 4.9 Hz, 1H, H-5), 4.05 – 3.94 (m, 4H, H-3, H-4, H-6, H-3'), 3.91 (dd, *J* = 10.3, 2.5 Hz, 1H, H-2), 3.82 (dd, *J* = 10.1, 4.9 Hz, 1H, H-5'), 3.66 – 3.54 (m, 2H, H-2', H-4'), 3.50 (t, *J* = 10.2 Hz, 1H, H-6), 3.36 (s, 3H, CH_3 OMe). ^{13}C NMR (101 MHz, $CDCl_3$) δ 166.1 (C=O), 138.9, 138.4, 138.1, 137.9, 137.8, 133.2 (C_q), 129.9, 129.6, 128.8, 128.6, 128.6, 128.5, 128.5, 128.4, 128.4, 128.2, 128.0, 127.9, 127.9, 127.8, 127.7, 127.6, 126.1 (CH_{arom}), 101.2 (CHPh), 101.0 (C-1'), 99.1 (C-1), 82.7 (C-4'), 79.3 (C-3'), 78.8 (C-2'), 78.0 (C-4), 77.5 (C-2), 75.3 (CH_2 Bn), 74.5 (CH_2 Bn), 74.1 (C-3), 73.6 (CH_2 Bn), 73.2 (CH_2 Bn), 69.0 (C-6), 68.5 (C-5'), 63.2 (C-5), 62.8 (C-6'), 55.4 (CH_3 OMe); HRMS: $[M+NH_4]^+$ calcd for $C_{55}H_{56}O_{12}NH_4$ 926.41100, found 926.40964.

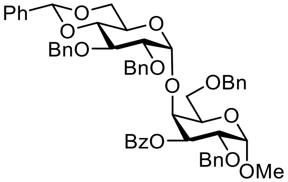
Disaccharide 25B



Title compound was obtained as colourless oil via the general procedure for Ph_2SO/Tf_2O mediated glycosylations with donor **B** and acceptor **25**. Yield: 84 mg, 100 μmol, 100%, α:β = 3:1. Data for the α-anomer: ^1H NMR (400 MHz, $CDCl_3$) δ 8.01 (dd, *J* = 8.3, 1.5 Hz, 2H, CH_{arom}), 7.48 – 7.22 (m, 23H, CH_{arom}), 5.55 (s, 1H, C*H*Ph), 4.97 (d, *J* = 10.7 Hz, 1H, C*H*H Bn), 4.93 (d, *J* = 3.7 Hz, 1H, H-1'), 4.90 – 4.75 (m, 4H, 2x C*H*H Bn, 2x CH*H* Bn), 4.72 (d, *J* = 2.8 Hz, 1H, H-1), 4.69 – 4.57 (m, 3H, 2x H-6, CH*H* Bn), 4.35 – 4.27 (m, 1H, H-5'), 4.07 (d, *J* = 2.2 Hz, 1H, H-4), 4.03 (t, *J* = 6.9 Hz, 1H, H-5), 4.01 – 3.92 (m, 3H, H-2, H-3, H-3'), 3.83 (dd, *J* = 10.2, 4.9 Hz, 1H, H-6'), 3.69 (t, *J* = 9.5 Hz, 1H, H-4'), 3.58 – 3.50 (m, 2H, H-2', H-6'), 3.38 (s, 3H, CH_3 OMe); ^{13}C NMR (101

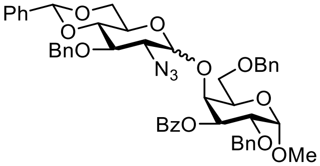
MHz, $CDCl_3$) δ 166.1 (C=O), 138.3, 138.1, 138.0, 137.6 (C_q), 133.4, 129.7, 129.6, 129.0, 128.6, 128.6, 128.6, 128.6, 128.6, 128.5, 128.5, 128.4, 128.4, 128.3, 128.2, 128.0, 128.0, 127.9, 127.9, 127.8, 127.7, 127.4, 126.1, 126.1 (CH_{arom}), 101.3 (CHPh), 99.7 (C-1'), 98.9 (C-1), 82.9 (C-4'), 77.2, 77.2, 77.2 (C-3, C-3', C-4), 75.3 (CH_2 Bn), 74.5 (C-2), 73.5, 73.5 (CH_2 Bn), 68.8 (C-6'), 68.5 (C-5), 64.1 (C-2'), 63.3 (C-5'), 62.8 (C-6), 55.5 (CH_3 OMe); diagnostic peaks for the β-anomer: ^{1}H NMR (400 MHz, $CDCl_3$) δ 5.49 (s, 1H, C*H*Ph), 4.47 (dd, *J* = 11.4, 5.7 Hz, 1H, H-6), 3.35 (s, 3H, CH_3 OMe); 3.17 (td, *J* = 9.7, 5.0 Hz, 1H, H-5'); ^{13}C NMR (101 MHz, $CDCl_3$) δ 166.2 (C=O), 102.1 (C-1'), 99.0 (C-1), 81.4, 78.9, 78.1, 74.9, 74.4, 74.0, 68.5, 67.6, 66.5, 66.0, 63.8; HRMS: $[M+NH_4]^+$ calcd for $C_{48}H_{49}N_3O_{11}NH_4$ 861.37053, found 861.36949.

Disaccharide 26A



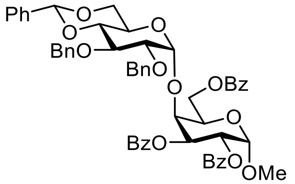
Title compound was obtained as colourless oil via the general procedure for Ph_2SO/Tf_2O mediated glycosylations with donor **A** and acceptor **26**. Yield: 66 mg, 78 μmol, 78%, α:β = 11:1. Data for the α-anomer: ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.07 – 8.02 (m, 2H, CH_{arom}), 7.59 – 7.53 (m, 1H, CH_{arom}), 7.51 – 7.47 (m, 2H, CH_{arom}), 7.44 – 7.16 (m, 25H, CH_{arom}), 5.51 – 5.42 (m, 2H, H-3, C*H*Ph), 4.94 (d, *J* = 11.2 Hz, 1H, C*H*H Bn), 4.86 – 4.76 (m, 4H, H-1, H-1', C*H*H Bn, C*H*H Bn), 4.73 (d, *J* = 10.6 Hz, 1H, C*H*H Bn), 4.68 (d, *J* = 12.3 Hz, 1H, CH*H* Bn), 4.62 (d, *J* = 11.8 Hz, 1H, C*H*H Bn), 4.38 – 4.31 (m, 2H, H-4, C*H*H Bn), 4.25 (d, *J* = 12.1 Hz, 1H, CH*H* Bn), 4.16 – 4.09 (m, 2H, H-2, H-5), 4.07 – 3.99 (m, 2H, H-3', H-5'), 3.86 (dd, *J* = 10.2, 6.5 Hz, 1H, H-6), 3.59 (dd, *J* = 10.3, 6.7 Hz, 1H, H-6'), 3.53 (t, *J* = 9.5 Hz, 1H, H-4'), 3.49 – 3.43 (m, 2H, H-2', H-6'), 3.42 (s, 3H, CH_3 OMe), 3.34 (t, *J* = 10.3 Hz, 1H, H-6'); 13C NMR (101 MHz, $CDCl_3$) δ 166.4 (C=O), 138.7, 138.2, 138.1, 137.8, 137.6, 133.2 (Cq), 129.9, 129.9, 128.9, 128.6, 128.5, 128.5, 128.4, 128.4, 128.4, 128.3, 128.3, 128.3, 128.2, 128.2, 128.1, 128.1, 128.1, 128.0, 128.0, 128.0, 127.9, 127.9, 127.8, 127.6, 127.6, 127.6, 127.5, 127.5, 127.4, 127.4, 126.0, 126.0 (CH_{arom}), 101.0 (CHPh), 100.2 (C-1'), 98.3 (C-1), 82.8 (C-4'), 79.5 (C-2'), 78.5 (C-3'), 77.2 (C-4), 75.1 (CH_2 Bn), 74.4 (CH_2 Bn), 73.5 (C-2), 73.1 (CH_2 Bn), 73.2 (CH_2 Bn), 72.6 (C-3), 69.2 (C-5), 68.7 (C-6'), 68.5 (C-6), 63.4 (C-5'), 55.4 (CH_3 OMe). Diagnostic peaks for the β-anomer: ^{1}H NMR (400 MHz, $CDCl_3$) δ 5.64 (dd, *J* = 10.4, 3.1 Hz, 1H, H-3), 5.10 (dd, *J* = 10.5, 2.9 Hz, 1H), 5.05 (d, *J* = 11.6 Hz, 1H, C*H*H Bn), 4.52 (d, *J* = 12.0 Hz, 1H), 4.47 – 4.43 (m, 2H, H-1'), 3.44 (s, 3H, CH_3 OMe). ^{13}C NMR (101 MHz, $CDCl_3$) δ 165.8 (C=O), 103.4 (C-1'), 101.1 (CHPh), 98.4 (C-1), 82.7, 82.2, 81.5, 80.7, 76.3, 75.2 (CH_2 Bn), 75.0 (CH_2 Bn), 74.6 (CH_2 Bn), 74.1, 73.8, 73.3 (CH_2 Bn), 69.8, 68.9, 65.8, 63.3, 55.5 (CH_3 OMe); HRMS: $[M+Na]^+$ calcd for $C_{55}H_{56}O_{12}Na$ 931.36640, found 931.36295.

Disaccharide 26B



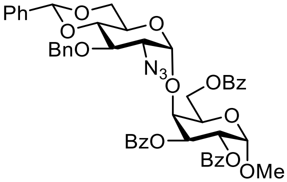
Title compound was obtained as colourless oil via the general procedure for Ph_2SO/Tf_2O mediated glycosylations with donor **B** and acceptor **26**. Yield: 56 mg, 67 μmol, 67%, α:β = 3:1. Data for the α-anomer: ^1H NMR (400 MHz, $CDCl_3$) δ 8.09 – 8.03 (m, 2H, CH_{arom}), 7.62 – 7.51 (m, 1H, CH_{arom}), 7.49 – 7.15 (m, 22H, CH_{arom}), 5.52 (dd, *J* = 10.9, 2.9 Hz, 1H, H-3), 5.43 (s, 1H, C*H*Ph), 4.97 (d, *J* = 10.8 Hz, 1H, C*H*H Bn), 4.86 – 4.82 (m, 2H, H-1, H-1'), 4.78 (d, *J* = 10.7 Hz, 1H, CH*H* Bn), 4.72 (d, *J* = 8.9 Hz, 1H, C*H*H Bn), 4.68 (d, *J* = 12.2 Hz, 1H, CH*H* Bn), 4.61 (d, *J* = 11.9 Hz, 1H, C*H*H Bn), 4.47 (d, *J* = 11.9 Hz, 1H, CH*H* Bn), 4.43 (d, *J* = 2.9 Hz, 1H, H-4), 4.17 – 4.09 (m, 2H, H-2, H-5), 4.07 – 4.00 (m, 1H, H-5'), 3.97 (dd, *J* = 9.9, 9.1 Hz, 1H, H-3'), 3.92 (t, *J* = 9.0 Hz, 1H, H-6), 3.61 – 3.54 (m, 2H, H-4', H-6), 3.42 (s, 3H, CH_3 OMe), 3.30 (t, *J* = 10.3 Hz, 1H, H-6'), 3.24 – 3.17 (m, 2H, H-2', H-6'); ^{13}C NMR (101 MHz, $CDCl_3$) δ 166.2 (C=O), 138.0, 137.8, 137.6 (C_q), 137.5, 133.4, 130.0, 129.9, 129.0 (CH_{arom}), 128.8 (C_q), 128.7, 128.6, 128.6, 128.5, 128.5, 128.5, 128.4, 128.4, 128.3, 128.3, 128.2, 128.2, 128.1, 128.0, 127.4, 126.1, 126.0 (CH_{arom}), 101.1 (CHPh), 98.6, 98.4 (C-1, C-1'), 82.9 (C-4'), 76.3 (C-3'), 75.2 (CH_2 Bn), 75.0 (C-4), 73.6 (CH_2 Bn), 73.3 (C-2), 73.1 (CH_2 Bn), 72.1 (C-2), 68.5 (C-5), 68.4 (C-6'), 67.0 (C-6), 63.4 (C-2'), 63.2 (C-5'), 55.6 (CH_3 OMe); diagnostic peaks for the β-anomer: ^1H NMR (400 MHz, $CDCl_3$) δ 5.60 (dd, *J* = 10.5, 3.0 Hz, 1H, H-3), 5.49 (s, 1H, C*H*Ph), 4.36 (d, *J* = 8.0 Hz, 1H, H-1'), 4.34 (dd, *J* = 3.1, 1.2 Hz, 1H, H-4), 4.24 (dd, *J* = 10.5, 3.6 Hz, 1H, H-2), 3.43 (s, 3H, CH_3 OMe), 3.09 (td, *J* = 9.8, 5.0 Hz, 1H, H-5'); ^{13}C NMR (101 MHz, $CDCl_3$) δ 165.9 (C=O), 102.4 (C-1'), 101.4 (CHPh), 98.6 (C-1), 81.5, 78.9, 75.4, 74.9, 74.2, 73.4, 72.4, 69.5, 68.7, 68.3, 66.4, 66.0, 55.6; HRMS: $[M+Na]^+$ calcd for $C_{48}H_{49}N_3O_{11}Na$ 866.32593, found 866.32307.

Disaccharide 27A



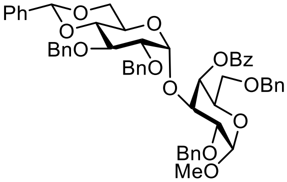
Title compound was obtained as colourless oil via the general procedure for Ph_2SO/Tf_2O mediated glycosylations with donor **A** and acceptor **27**. Yield: 70 mg, 70 μmol, 70%, α:β > 20:1. ^1H NMR (400 MHz, $CDCl_3$) δ 8.08 – 7.93 (m, 6H, CH_{arom}), 7.65 – 7.54 (m, 1H, CH_{arom}), 7.52 – 7.12 (m, 23H, CH_{arom}), 5.73 – 5.64 (m, 2H, H-2, H-3), 5.43 (s, 1H, C*H*Ph), 5.25 (d, *J* = 2.9 Hz, 1H, H-1), 5.00 (d, *J* = 11.1 Hz, 1H, C*H*H Bn), 4.90 (d, *J* = 4.7 Hz, 1H, C*H*H Bn), 4.87 (d, *J* = 4.1 Hz, 1H, CH*H* Bn), 4.82 (d, *J* = 3.7 Hz, 1H, H-1'), 4.77 – 4.70 (m, 3H, CH*H* Bn, 2x H-6), 4.48 – 4.45 (m, 1H, H-4), 4.35 (t, *J* = 6.5 Hz, 1H, H-5), 4.22 (t, *J* = 9.4 Hz, 1H, H-3'), 4.15 (dt, *J* = 10.0, 5.0 Hz, 1H, H-5'), 3.60 (dd, *J* = 10.2, 4.7 Hz, 1H, H-6'), 3.58 – 3.52 (m, 2H, H-2', H-4'), 3.42 (s, 3H, CH_3 OMe), 3.36 (t, *J* = 10.2 Hz, 1H, H-6'). ^{13}C NMR (101 MHz, $CDCl_3$) δ 166.4, 166.1, 166.0 (C=O), 138.8, 137.9, 137.6, 133.5, 133.3 (C_q), 129.9, 129.7, 129.5, 129.3, 128.9, 128.7, 128.6, 128.6, 128.5, 128.4, 128.2, 128.2, 127.9, 127.7, 126.2 (CH_{arom}), 101.3 (CHPh), 100.9 (C-1'), 97.5 (C-1), 82.7 (C-4'), 78.9 (C-2'), 78.7 (C- 3'), 77.2 (C-4), 75.4 (CH_2 Bn), 74.6 (CH_2 Bn), 70.7 (C-2), 69.2 (C-3), 68.8 (C-6'), 68.4 (C-5), 63.7 (C-5'), 63.1 (C-6), 55.5 (CH_3 OMe); HRMS: $[M+NH_4]^+$ calcd for $C_{55}H_{52}O_{14}NH_4$ 954.36953, found 954.36827.

Disaccharide 27B



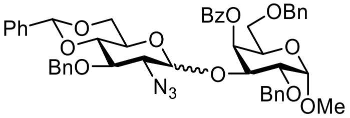
Title compound was obtained as colourless oil via the general procedure for Ph_2SO/Tf_2O mediated glycosylations with donor **B** and acceptor **27**. Yield: 87 mg, 100 µmol, 100%, α:β > 20:1. ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.09 – 8.05 (m, 2H, CH$_{arom}$), 8.04 – 8.00 (m, 2H, CH$_{arom}$), 7.97 (dd, *J* = 7.1, 1.4 Hz, 2H, CH$_{arom}$), 7.61 – 7.27 (m, 19H, CH$_{arom}$), 5.76 (dd, *J* = 11.0, 2.8 Hz, 1H, H-2), 5.69 (dd, *J* = 11.0, 3.5 Hz, 1H, H-3), 5.43 (s, 1H, C*H*Ph), 5.28 (d, *J* = 3.5 Hz, 1H, H-1), 5.01 (d, *J* = 10.7 Hz, 1H, C*H*H Bn), 4.98 (d, *J* = 3.8 Hz, 1H, H-1'), 4.87 (d, *J* = 10.8 Hz, 1H, CH*H* Bn), 4.82 – 4.70 (m, 2H, 2x H-6), 4.54 (d, *J* = 2.8 Hz, 1H, H-4), 4.42 (t, *J* = 7.0 Hz, 1H, H-6), 4.21 (t, *J* = 9.6 Hz, 1H, H-3'), 4.15 (dt, *J* = 10.0, 5.0 Hz, 1H, H-5'), 3.63 (t, *J* = 9.4 Hz, 1H, H-4'), 3.55 – 3.46 (m, 2H, H-2', H-6'), 3.45 (s, 3H, CH_3 OMe), 3.37 (t, *J* = 10.2 Hz, 1H, H-6'); ^{13}C NMR (101 MHz, $CDCl_3$) δ 166.3, 166.1, 166.0 (C=O), 137.9, 137.3, 133.6, 133.4, 133.3 (C$_q$), 129.9, 129.8, 129.8, 129.8, 129.7, 129.6, 129.4, 129.0, 129.0, 128.8, 128.7, 128.6, 128.5, 128.5, 128.4, 128.4, 128.3, 128.3, 128.2, 128.1, 127.9, 126.2 (CH$_{arom}$), 101.3 (CHPh), 99.5 (C-1'), 97.6 (C-1), 82.7 (C-4'), 76.6 (C-3'), 76.1 (C-4), 75.3 (CH_2 Bn), 70.4 (C-2), 68.9 (C-3), 68.4 (C-6'), 68.1 (C-5), 63.8 (C-5'), 63.6 (C-2'), 62.5 (C-6), 55.6 (CH_3 OMe); HRMS: $[M+NH_4]^+$ calcd for $C_{48}H_{45}N_3O_{13}NH_4$ 889.32906, found 889.32801.

Disaccharide 29A



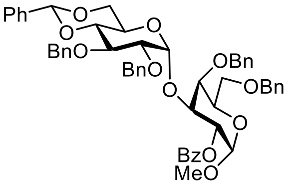
Title compound was obtained as colourless oil via the general procedure for Ph_2SO/Tf_2O mediated glycosylations with donor **A** and acceptor **29**. Yield: 72 mg, 76 µmol, 76%, α:β = 16:1. Data for α-anomer: ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.97 – 7.90 (m, 2H, CH$_{arom}$), 7.54 – 7.49 (m, 1H, CH$_{arom}$), 7.42 – 7.31 (m, 10H, CH$_{arom}$), 7.28 – 7.12 (m, 17H, CH$_{arom}$), 5.83 (dd, *J* = 3.3, 1.2 Hz, 1H, H-4), 5.49 (s, 1H, C*H*Ph), 5.27 (d, *J* = 3.6 Hz, 1H, H-1'), 4.84 – 4.80 (m, 2H, H-1, C*H*H Bn), 4.76 (d, *J* = 11.3 Hz, 1H, C*H*H Bn), 4.68 (d, *J* = 11.9 Hz, 1H, CH*H* Bn), 4.63 (d, *J* = 11.3 Hz, 1H, CH*H* Bn), 4.58 (d, *J* = 12.1 Hz, 1H, C*H*H Bn), 4.49 – 4.39 (m, 3H, C*H*H Bn, 2x CH*H* Bn), 4.34 (dd, *J* = 10.2, 3.2 Hz, 1H, H-3), 4.28 (dd, *J* = 10.1, 4.9 Hz, 1H, H-6'), 4.16 – 4.07 (m, 2H, H-5, H-5'), 4.03 (dd, *J* = 10.2, 3.6 Hz, 1H, H-2), 3.98 (t, *J* = 9.3 Hz, 1H, H-3'), 3.64 (t, *J* = 10.2 Hz, 1H, H-6'), 3.56 (t, *J* = 9.5 Hz, 1H, H-4'), 3.54 – 3.51 (m, 3H, H-2', 2x H-6), 3.43 (s, 3H, CH_3 OMe); ^{13}C NMR (126 MHz, $CDCl_3$) δ 166.1 (C=O), 138.7, 138.3, 138.0, 137.9, 137.8 (C$_q$), 133.2, 130.0 (CH$_{arom}$), 129.9 (C$_q$), 128.9, 128.6, 128.5, 128.5, 128.5, 128.4, 128.4, 128.2, 128.2, 128.2, 128.1, 127.9, 127.8, 127.8, 127.7, 127.5, 127.4, 126.3 (CH$_{arom}$), 101.4 (CHPh), 98.7 (C-1), 94.1 (C-1'), 82.2 (C-4'), 78.6 (C-3'), 78.3 (C-2'), 75.0 (CH_2 Bn), 74.3 (C-2), 73.7, 73.5, 72.7 (CH_2 Bn), 71.3 (C-3), 69.1, 69.0 (C-6, C-6'), 68.2 (C-5), 67.9 (C-4), 62.8 (C-5'), 55.5 (CH_3 OMe); diagnostic peaks for the β-anomer: ^{1}H NMR (500 MHz, $CDCl_3$) δ 5.73 (dd, *J* = 3.6, 1.2 Hz, 1H, H-4), 5.53 (s, 1H, C*H*Ph), 4.98 (d, *J* = 7.6 Hz, 1H, H-1'), 4.86 (d, *J* = 11.4 Hz, 1H, C*H*H Bn), 3.75 (t, *J* = 10.3 Hz, 1H), 3.41 (s, 3H), 3.30 (t, *J* = 7.9 Hz, 1H); ^{13}C NMR (126 MHz, $CDCl_3$) δ 165.6, 103.1 (C-1'), 101.1 (CHPh), 98.6 (C-1), 82.5, 81.5, 80.8, 77.3, 75.4, 74.9, 74.9, 74.8, 73.8, 73.2, 72.4, 71.9, 68.3, 65.9, 55.7; HRMS: $[M+NH_4]^+$ calcd for $C_{55}H_{56}O_{12}NH_4$ 926.41100, found 926.40952.

Disaccharide 29B



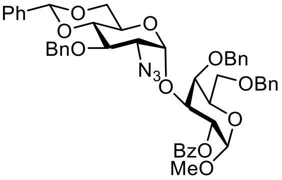
Title compound was obtained as colourless oil via the general procedure for Ph_2SO/Tf_2O mediated glycosylations with donor **B** and acceptor **29**. Yield: 52 mg, 60 µmol, 60%, α:β = 1.3:1. Data reported for a 1:1 mixture of anomers: ^{1}H NMR (500 MHz, $CDCl_3$) δ 8.11 – 8.06 (m, 2H), 8.05 – 8.02 (m, 2H), 7.61 – 7.55 (m, 2H), 7.49 – 7.40 (m, 8H), 7.39 – 7.31 (m, 12H), 7.29 – 7.19 (m, 20H), 5.84 (dd, *J* = 3.4, 1.3 Hz, 1H, H-4α), 5.67 (dd, *J* = 3.6, 1.2 Hz, 1H, H-4β), 5.54 (s, 1H, C*H*Phα), 5.53 (s, 1H, C*H*Phβ), 5.30 (d, *J* = 3.7 Hz, 1H, H-1'α), 4.90 – 4.82 (m, 4H), 4.81 – 4.77 (m, 2H, H-1'β, C*H*H Bn), 4.75 – 4.70 (m, 2H, H-1α, CH*H* Bn), 4.67 – 4.62 (m, 2H, H-1β, CH*H* Bn), 4.58 (d, *J* = 11.8 Hz, 1H), 4.52 – 4.46 (m, 2H), 4.44 – 4.38 (m, 2H), 4.38 – 4.27 (m, 3H), 4.19 – 4.10 (m, 3H), 4.08 (dd, *J* = 10.1, 3.6 Hz, 1H), 3.96 (dd, *J* = 9.5, 3.0 Hz, 1H), 3.95 – 3.91 (m, 1H), 3.76 (t, *J* = 10.3 Hz, 1H), 3.71 – 3.62 (m, 3H), 3.59 – 3.49 (m, 4H), 3.43 (s, 4H), 3.40 (s, 3H), 3.34 – 3.26 (m, 3H); ^{13}C NMR (126 MHz, $CDCl_3$) δ 166.0, 165.9, 138.1, 138.0, 137.9, 137.8, 137.7, 137.6, 137.3, 133.3, 133.2, 130.0, 130.0, 129.9, 129.9, 129.8, 129.1, 129.0, 129.0, 128.7, 128.7, 128.6, 128.5, 128.5, 128.5, 128.5, 128.5, 128.4, 128.4, 128.4, 128.3, 128.3, 128.3, 128.2, 128.1, 128.1, 128.1, 127.9, 127.9, 127.8, 127.8, 127.8, 127.7, 126.3, 126.1, 125.1, 102.4 (C-1β), 101.5 (CHPhα), 101.3 (CHPhβ), 98.7 (C-1α), 98.2 (C-1β), 94.0 (C-1'α), 82.8, 81.5, 78.9, 77.4, 77.2, 77.0, 76.9, 75.5, 75.0, 74.8, 74.6, 73.9, 73.7, 73.6, 73.5, 71.8, 70.9, 69.2, 68.8, 68.7, 68.6, 68.4, 67.8, 66.7, 66.5, 66.0, 62.8, 62.7, 55.6, 55.6; HRMS: $[M+NH_4]^+$ calcd for $C_{48}H_{49}N_3O_{11}NH_4$ 861.37053, found 861.36925.

Disaccharide 30A



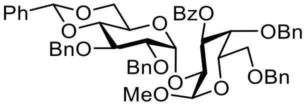
Title compound was obtained as colourless oil via the general procedure for Ph_2SO/Tf_2O mediated glycosylations with donor **A** and acceptor **30.** Yield: 81 mg, 84 µmol, 84%, α:β >20:1. ^{1}H NMR (500 MHz, $CDCl_3$) δ 8.10 – 7.16 (m, 30H, CH_{arom}), 5.59 (dd, *J* = 10.5, 3.7, 0.8 Hz, 1H, H-2), 5.41 (s, 1H, C*H*Ph), 5.05 (dd, *J* = 5.9, 3.7 Hz, 2H, H-1, H-1'), 4.99 (d, *J* = 11.6 Hz, 1H, C*H*H Bn), 4.86 (d, *J* = 11.5 Hz, 1H, C*H*H Bn), 4.77 (d, *J* = 11.4 Hz, 1H, C*H*H Bn), 4.66 (t, *J* = 11.2 Hz, 2H, C*H*H Bn, CH*H* Bn), 4.47 (dd, *J* = 11.7, 2.8 Hz, 2H, 2x CH*H* Bn), 4.37 (d, *J* = 11.8 Hz, 1H, CH*H* Bn), 4.22 (dd, *J* = 10.4, 2.8 Hz, 1H, H-3), 4.07 – 4.03 (m, 1H, H-4), 3.99 – 3.90 (m, 3H, H-5, H-3', H-5'), 3.82 (dd, *J* = 10.2, 4.9 Hz, 1H, H-6'), 3.60 – 3.45 (m, 4H, 2x H-6, H-2', H-4'), 3.42 – 3.36 (m, 1H, H-6'), 3.35 (s, 3H, CH_3 OMe); ^{13}C NMR (126 MHz, $CDCl_3$) δ 166.19 (C=O), 138.8, 138.6, 138.2, 138.1, 137.6, 133.1, 130.0, 130.0, 128.9, 128.6, 128.5, 128.5, 128.4, 128.3, 128.3, 128.3, 128.2, 128.1, 128.0, 127.9, 127.8, 127.7, 127.5, 126.3 (CH_{arom}), 101.3 (CHPh), 99.4 (C-1'), 97.7 (C-1), 82.5 (C-4'), 79.6 (C-2'), 78.5 (C-3'), 77.8 (C-3), 75.2 (C-4), 75.2 (CH_2 Bn), 75.0 (CH_2 Bn), 74.6 (CH_2 Bn), 73.6 (CH_2 Bn), 71.0 (C-2), 69.5 (C-5), 69.1 (C-6), 68.8 (C-6'), 63.3 (C-5'), 55.5 (CH_3 OMe); HRMS: $[M+NH_4]^+$ calcd for $C_{55}H_{56}O_{12}NH_4$ 926.41100, found 926.40731.

Disaccharide 30B



Title compound was obtained as colourless oil via the general procedure for Ph_2SO/Tf_2O mediated glycosylations with donor **B** and acceptor **30.** Yield: 69 mg, 82 μmol, 82%, α:β = 13:1. Data for α-anomer: ^1H NMR (500 MHz, $CDCl_3$) δ 8.09 – 7.18 (m, 25H, CH_{arom}), 5.62 (dd, *J* = 10.5, 3.7 Hz, 1H, H-2), 5.45 (s, 1H, C*H*Ph), 5.10 (d, *J* = 3.6 Hz, 1H, H-1'), 5.04 (d, *J* = 3.8 Hz, 1H, H-1), 4.99 (d, *J* = 11.4 Hz, 1H, C*H*H Bn), 4.76 (d, *J* = 11.0 Hz, 1H, C*H*H Bn), 4.59 (dd, *J* = 11.2, 3.7 Hz, 2H, 2x CH*H* Bn), 4.51 (d, *J* = 11.8 Hz, 1H, C*H*H Bn), 4.44 (d, *J* = 11.7 Hz, 1H, CH*H* Bn), 4.31 (dd, *J* = 10.5, 2.9 Hz, 1H, H-3), 4.15 (dd, *J* = 2.9, 1.2 Hz, 1H, H-4), 4.09 – 3.95 (m, 3H, H-5, H-5', H-6'), 3.89 (dd, *J* = 9.9, 9.1 Hz, 1H, H-3'), 3.66 – 3.56 (m, 3H, 2x H-6, H-4'), 3.53 – 3.45 (m, 2H, H-2', H-6'), 3.35 (s, 3H, CH_3 OMe); ^{13}C NMR (126 MHz, $CDCl_3$) δ 166.1 (C=O), 138.6, 138.0, 137.7, 137.4 (C_q), 133.1, 129.9, 129.9, 129.1, 129.0, 128.7, 128.6, 128.6, 128.5, 128.5, 128.5, 128.4, 128.4, 128.4, 128.4, 128.3, 128.2, 128.1, 128.0, 127.9, 127.9, 127.9, 127.8, 127.8, 127.8, 126.2, 126.1 (CH_{arom}), 101.4 (CHPh), 97.7 (C-1), 97.3 (C-1'), 82.8 (C-4'), 76.2 (C-3'), 75.7 (C-3), 75.2 (CH_2 Bn), 75.0 (CH_2 Bn), 74.6 (C-4), 73.7 (2x CH_2 Bn), 70.7 (C-2), 69.3 (C-5), 68.8 (C-6'), 68.6 (C-6), 63.6 (C-2'), 63.3 (C-5), 55.6 (CH_3 OMe); Diagnostic peaks for β-anomer: ^1H NMR (500 MHz, $CDCl_3$) 5.57 (s, 1H, CHPh), 5.13 (d, *J* = 3.8 Hz, 1H, H-1), 4.65 (d, *J* = 8.0 Hz, 1H, H-1'); ^{13}C NMR (126 MHz, $CDCl_3$) δ 104.3 (C-1'), 101.4 (CH Ph), 98.0 (C-1); HRMS: $[M+NH_4]^+$ calcd for $C_{48}H_{40}N_3O_{11}NH_4$ 861.37053, found 861.36922.

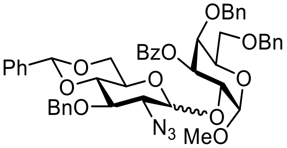
Disaccharide 33A



Title compound was obtained as colourless oil via the general procedure for Ph_2SO/Tf_2O mediated glycosylations with donor **A** and acceptor **33**. Yield: 85 mg, 89 μmol, 89%, α:β > 20:1. ^1H NMR (500 MHz, $CDCl_3$) δ 8.06 – 7.99 (m, 2H, CH_{arom}), 7.41 – 7.14 (m, 28H, CH_{arom}), 5.63 (dd, *J* = 10.7, 3.1 Hz, 1H, H-3), 5.44 (s, 1H, C*H*Ph), 4.98 (d, *J* = 3.5 Hz, 1H, H-1), 4.90 (d, *J* = 3.6 Hz, 1H, H-1'), 4.82 (d, *J* = 12.1 Hz, 1H, C*H*H Ph), 4.77 (d, *J* = 11.2 Hz, 1H, C*H*H Bn), 4.70 (d, *J* = 11.2 Hz, 1H, CH*H* Bn), 4.67 (d, *J* = 12.1 Hz, 1H, CH*H* Bn), 4.63 (d, *J* = 11.3 Hz, 1H, C*H*H Bn), 4.54 (d, *J* = 11.9 Hz, 1H, C*H*H Bn), 4.47 – 4.42 (m, 3H, H-2, 2x CH*H* Bn), 4.24 (d, *J* = 2.4 Hz, 1H, H-4), 4.15 (t, *J* = 6.5 Hz, 1H, H-5), 4.06 – 3.94 (m, 3H, H-3', H-5', H-6'), 3.63 – 3.48 (m, 6H, H-2', H-4', H-5, 2x H-6, H-6'), 3.43 (s, 3H, CH_3 OMe); ^{13}C NMR (126 MHz, $CDCl_3$) δ 165.9 (C=O), 138.7, 138.4, 137.9, 137.9, 137.5, 133.1 (C_q), 129.7, 129.6, 128.8, 128.6, 128.5, 128.4, 128.3, 128.3, 128.1, 128.0, 128.0, 127.8, 127.8, 127.5, 126.2 (CH_{arom}), 101.2 (CHPh), 97.2 (C-1), 96.6 (C-1'), 82.1 (C-

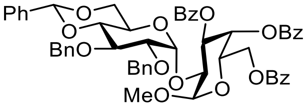
4'), 78.8 (C-2'), 78.3 (C-3'), 75.4 (C-4), 75.3, 75.2, 73.5, 73.4 (CH_2 Bn), 72.3 (C-3), 71.6 (C-2), 68.9 (C-5), 68.8(C-6), 68.7 (C-6'), 62.8 (C-5'), 55.4 (CH_3 OMe); HRMS: $[M+NH_4]^+$ calcd for $C_{55}H_{56}O_{12}NH_4$ 926.41100, found 926.40964.

Disaccharide 33B



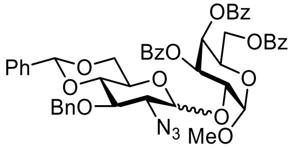
Title compound was obtained as colourless oil via the general procedure for Ph_2SO/Tf_2O mediated glycosylations with donor **B** and acceptor **33**. 44 mg, 51 μmol, 51%, α:β = 3:1. Data for the α-anomer: ^{1}H NMR (500 MHz, $CDCl_3$) δ 8.06 – 8.01 (m, 2H, CH$_{arom}$), 7.49 – 7.17 (m, 23H, CH$_{arom}$), 5.63 (dd, *J* = 10.6, 3.1 Hz, 1H, H-3), 5.44 (s, 1H, C*H*Ph), 5.01 (d, *J* = 3.5 Hz, 1H, H-1), 4.97 (d, *J* = 3.8 Hz, 1H, H-1'), 4.78 (d, *J* = 10.9 Hz, 1H, C*H*H Bn), 4.72 – 4.60 (m, 2H, C*H*H Bn, CH*H* Bn), 4.54 (d, *J* = 11.9 Hz, 1H, C*H*H Bn), 4.50 – 4.39 (m, 3H, H-2, 2x CH*H* Bn), 4.19 (d, *J* = 2.6 Hz, 1H, H-4), 4.16 (t, *J* = 6.5 Hz, 1H, H-5), 4.01 (dd, *J* = 10.1, 4.9 Hz, 1H, H-6'), 3.99 – 3.89 (m, 2H, H-3', H-5'), 3.61 – 3.52 (m, 5H, H-4', H-5, 2x H-6, H-6'), 3.48 (s, 3H, CH_3 OMe), 3.34 (dd, *J* = 10.1, 3.4 Hz, 1H, H-2'); ^{13}C NMR (126 MHz, $CDCl_3$) δ 165.8 (C=O), 138.0, 137.9, 137.8, 137.3 (C$_q$), 133.3, 129.8, 129.7 (CH$_{arom}$), 129.6 (C$_q$), 129.0, 128.7, 128.5, 128.5, 128.4, 128.4, 128.3, 128.3, 128.2, 128.1, 128.1, 127.9, 127.9, 127.9, 127.9, 127.8, 127.8, 126.2, 126.0 (CH$_{arom}$), 101.4 (CHPh), 97.4 (C-1), 97.2 (C-1'), 82.7 (C-4'), 75.8 (C-3'), 75.6 (C-4), 75.4, 75.1, 73.6 (CH_2 Bn), 72.8 (C-2), 72.0 (C-3), 68.9 (C-5), 68.7, 68.6 (C-6, C-6'), 63.2 (C-5'), 63.0 (C-2'), 55.7 (CH_3 OMe); diagnostic peaks for the β-anomer: ^{1}H NMR (500 MHz, $CDCl_3$) δ 5.59 (dd, *J* = 10.7, 3.2 Hz, 1H, H-3), 5.54 (s, 1H, C*H*Ph), 4.29 (td, *J* = 10.5, 4.3 Hz, 2H, H-5'), 4.23 (d, *J* = 3.2 Hz, 1H, H-4), 3.75 (t, *J* = 10.3 Hz, 1H), 3.69 – 3.64 (m, 1H), 3.44 (s, 3H, CH_3 OMe); ^{13}C NMR (126 MHz, $CDCl_3$) δ 165.9 (C=O), 104.4 (C-1'), 101.3 (CHPh), 99.8 (C-1), 81.3, 79.2, 75.5, 74.8, 68.7, 68.6, 68.5, 66.2, 65.7, 55.6; HRMS: $[M+NH_4]^+$ calcd for $C_{48}H_{40}N_3O_{11}NH_4$ 861.37053, found 861.36914.

Disaccharide 34A



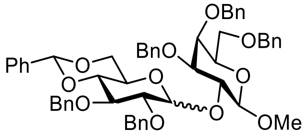
Title compound was obtained as colourless oil via the general procedure for Ph_2SO/Tf_2O mediated glycosylations with donor **A** and acceptor **34.** Yield: 89 mg, 88 μmol, 88%, α:β > 20:1. ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.02 (ddd, *J* = 8.5, 2.6, 1.3 Hz, 4H, CH$_{arom}$), 7.83 – 7.73 (m, 2H, CH$_{arom}$), 7.66 – 7.59 (m, 1H, CH$_{arom}$), 7.57 – 7.52 (m, 1H, CH$_{arom}$), 7.50 – 7.12 (m, 22H, CH$_{arom}$) , 5.99 (dd, *J* = 3.5, 1.3 Hz, 1H, H-4), 5.84 (dd, *J* = 10.6, 3.4 Hz, 1H, H-3), 5.36 (s, 1H, C*H*Ph), 5.10 (d, *J* = 3.4 Hz, 1H, H-1), 4.92 – 4.85 (m, 2H, H-1', C*H*H Bn), 4.78 (d, *J* = 11.2 Hz, 1H, C*H*H Bn), 4.71 (d, *J* = 11.3 Hz, 1H, CH*H* Bn), 4.67 (d, *J* = 12.0 Hz, 1H, CH*H* Bn), 4.64 – 4.52 (m, 2H, H-5, H-6), 4.41 (dd, *J* = 10.6, 3.4 Hz, 1H, H-2), 4.34 (dd, *J* = 10.8, 5.2 Hz, 1H, H-6), 3.96 (t, *J* = 9.3 Hz, 1H, H-3'), 3.90 – 3.78 (m, 2H, H-5', H-6'), 3.54 – 3.42 (m, 6H, CH_3 OMe, H-2', H-4', H-6'). ^{13}C NMR (101 MHz, $CDCl_3$) δ 166.1, 165.5, 165.5 (C=O), 138.7, 138.5, 137.4, 133.6, 133.3, 133.0 (C$_q$), 129.9, 129.8, 129.7, 129.6, 129.5, 129.4, 128.9, 128.7, 128.7, 128.5, 128.4, 128.4, 128.3, 128.1, 128.0, 128.0, 128.0, 127.6, 126.2 (CH$_{arom}$), 101.2 (CHPh), 97.6 (C-1), 97.3 (C-1'), 82.1 (C-4'), 78.9 (C-2'), 78.3 (C-3'), 75.2 (CH$_2$ Bn), 73.8 (CH$_2$ Bn), 72.1 (C-2), 69.5 (C-4), 69.3 (C-3), 68.7 (C-6'), 66.9 (C-5), 62.8 (C-5'), 62.7 (C-6), 55.7 (CH$_3$ OMe); HRMS: [M+NH$_4$]$^+$ calcd for C$_{55}$H$_{52}$O$_{14}$NH$_4$ 954.36953, found 954.36787.

Disaccharide 34B



Title compound was obtained as colourless oil via the general procedure for Ph$_2$SO/Tf$_2$O mediated glycosylations with donor **B** and acceptor **34**. Yield: 76 mg, 87 µmol, 87%, α:β = 6:1. Data for α-anomer: ^{1}H NMR (400 MHz, CDCl$_3$) δ 8.07 – 7.98 (m, 4H, CH$_{\text{arom}}$), 7.87 – 7.78 (m, 2H, CH$_{\text{arom}}$), 7.63 (ddt, *J* = 8.1, 7.0, 1.4 Hz, 1H, CH$_{\text{arom}}$), 7.55 (ddt, *J* = 8.1, 7.0, 1.3 Hz, 1H, CH$_{\text{arom}}$), 7.51 – 7.19 (m, 17H, CH$_{\text{arom}}$), 5.96 (dd, *J* = 3.6, 1.2 Hz, 1H, H-4), 5.83 (dd, *J* = 10.5, 3.5 Hz, 1H, H-3), 5.37 (s, 1H, C*H*Ph), 5.15 (d, *J* = 3.5 Hz, 1H, H-1), 4.98 (d, *J* = 3.6 Hz, 1H, H-1'), 4.82 (d, *J* = 10.9 Hz, 1H, C*H*H Bn), 4.67 (d, *J* = 10.9 Hz, 1H, CH*H* Bn), 4.64 – 4.54 (m, 2H, H-5, H-6), 4.36 (m, 2H, H-2, H-6), 4.02 – 3.96 (t, *J* = 9.1 Hz, 1H, H-3'), 3.87 - 3.77 (m, 2H, H-5', H-6'), 3.56 (m, 4H, H-4', CH$_3$ OMe), 3.48 – 3.41 (m, 1H, H-6'), 3.33 (dd, *J* = 10.0, 3.6 Hz, 1H, H-2'). ^{13}C NMR (101 MHz, CDCl$_3$) δ 166.1, 165.5, 165.4 (C=O), 137.8, 137.1, 133.6, 133.3, 133.2 (C$_q$), 129.9, 129.8, 129.6, 129.4, 129.3, 129.0, 128.7, 128.7, 128.5, 128.5, 128.5, 128.4, 128.4, 128.3, 128.3, 128.3, 128.1, 128.1, 127.9, 126.1, 126.0 (CH$_{\text{arom}}$), 101.3 (CHPh), 98.0 (C-1'), 97.8 (C-1), 82.6 (C-4'), 75.6 (C-3'), 75.1 (CH$_2$ Bn), 73.6 (C-2), 69.4 (C-4), 69.2 (C-3), 68.4 (C-6'), 66.8 (C-5), 63.3 (C-5'), 62.9 (C-2'), 62.6 (C-6), 55.9 (CH$_3$ OMe). Diagnostic peaks for β-anomer: ^{1}H NMR (400 MHz, CDCl$_3$) δ 5.99 (dd, *J* = 3.6, 1.2 Hz, 1H, H-4), 5.55 (s, 1H, C*H*Ph), 5.12 (d, *J* = 3.6 Hz, 1H, H-1), 4.45 (d, *J* = 7.7 Hz, 1H, H-1'), 4.26 (dd, *J* = 10.5, 3.4 Hz, 1H, H-2), 3.52 (s, 3H, CH$_3$ OMe). ^{13}C NMR (101 MHz, CDCl$_3$) δ 104.3 (C-1'), 101.5 (CHPh), 99.8 (C-1), 76.7 (C-2), 55.8 (CH$_3$ OMe); HRMS: [M+NH$_4$]$^+$ calcd for C$_{48}$H$_{45}$N$_3$O$_{13}$NH$_4$ 889.32906, found 889.32747.

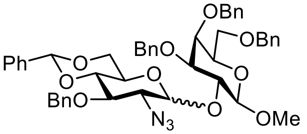
Disaccharide 35A



Title compound was obtained as colourless oil via the general procedure for Ph$_2$SO/Tf$_2$O mediated glycosylations with donor **A** and acceptor **35**. Yield: 75 mg, 83 mmol, 83%, α:β = 1.5:1. Data reported for a 1:1 mixture: ^{1}H NMR (400 MHz, CDCl$_3$) δ 7.60 – 6.94 (m, 60H), 5.56 (s, 1H, C*H*Phβ), 5.53 – 5.49 (m, 2H, H-1'α, C*H*Phα), 5.08 (d, *J* = 7.5 Hz, 1H, H-1'β), 4.94 – 4.71 (m, 9H), 4.67 (d, *J* = 2.4 Hz, 2H), 4.63 (d, *J* = 10.6 Hz, 1H), 4.60 – 4.52 (m, 3H), 4.50 – 4.38 (m, 6H), 4.35 – 4.30 (m, 1H), 4.21 – 4.07 (m, 3H), 3.99 (t, *J* = 9.3 Hz, 1H), 3.93 (d, *J* = 2.8 Hz, 1H, H-4α), 3.90 (d, *J* = 2.8 Hz, 1H, H-4β), 3.85 – 3.80 (m, 1H), 3.80 – 3.75 (m, 1H), 3.72 (dd, *J* = 9.2, 7.9 Hz, 1H), 3.66 – 3.53 (m, 10H), 3.50 (d, *J* = 8.5 Hz, 7H), 3.42 (ddd, *J* = 10.0, 8.9, 5.0 Hz, 1H); ^{13}C NMR (101 MHz, CDCl$_3$) δ 139.0, 138.7, 138.7, 138.2, 137.9, 137.9, 137.9, 137.5, 137.5, 129.0, 128.8, 128.6, 128.6, 128.6, 128.5, 128.5, 128.4, 128.4, 128.4, 128.3, 128.3, 128.2, 128.2, 128.1, 128.1, 128.1, 128.1, 128.0, 128.0, 127.9, 127.9, 127.8, 127.8, 127.7, 127.6, 127.5, 126.3, 126.1, 104.8 (C-1α), 103.5 (C-

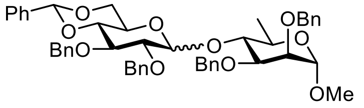
1β), 103.2 (C-1’β), 101.3 (CHPhα), 101.2 (CHPhβ), 96.8 (C-1’α), 82.8, 82.7, 82.3, 81.5, 81.3, 80.4, 79.1, 78.6, 77.2, 75.3, 75.0, 75.0, 74.7, 74.5, 73.7, 73.7, 73.5, 73.4, 73.3, 73.0, 73.0, 72.9, 72.8, 72.5, 69.1, 69.0, 68.8, 68.7, 66.0, 62.1, 56.7 (CH_3 OMeα), 56.6 (CH_3 OMeβ); HRMS: $[M+NH_4]^+$ calcd for $C_{55}H_{58}O_{11}NH_4$ 912.43174, found 912.42989.

Disaccharide 35B



Title compound was obtained as colourless oil via the general procedure for Ph_2SO/Tf_2O mediated glycosylations with donor **B** and acceptor **35**. Yield: 80 mg, 96 µmol, 96%, α:β = 1:10. Data for the β-anomer: ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.49 – 7.20 (m, 25H), 5.54 (s, 1H, C*H*Ph), 4.93 – 4.84 (m, 3H, H-1’, 2x C*H*H Bn), 4.77 (d, *J* = 11.4 Hz, 1H, CH*H* Bn), 4.74 – 4.68 (m, 2H, CH_2 Bn), 4.55 (d, *J* = 11.7 Hz, 1H, CH*H* Bn), 4.45 (d, *J* = 11.9 Hz, 1H, C*H*H Bn), 4.40 (d, *J* = 11.7 Hz, 1H, CH*H* Bn), 4.33 – 4.27 (m, 2H, H-1, H-6’), 4.08 (dd, *J* = 9.6, 7.6 Hz, 1H, H-2), 3.93 (d, *J* = 2.8 Hz, 1H, H-4), 3.79 (t, *J* = 10.3 Hz, 1H, H-6’), 3.76 – 3.70 (m, 1H, H-4’), 3.63 (dd, *J* = 9.6, 2.8 Hz, 1H, H-3), 3.60 – 3.57 (m, 3H, H-3’, 2x H-6), 3.55 – 3.46 (m, 5H, H-2’, H-5, CH_3 OMe), 3.34 (td, *J* = 9.9, 4.9 Hz, 1H, H-5’); ^{13}C NMR (101 MHz, $CDCl_3$) δ 138.6, 138.0, 137.9, 137.3 (C_q), 131.5, 129.1, 128.6, 128.6, 128.5, 128.5, 128.5, 128.4, 128.4, 128.3, 128.1, 128.1, 128.1, 128.0, 128.0, 127.9, 127.9, 127.6, 126.1 (CH_{arom}), 102.6 (C-1), 102.2 (C-1’), 101.3 (CHPh), 83.0 (C-3), 81.6 (C-4’), 79.4 (C-2’), 77.2 (C-2), 74.9, 74.6, 73.6 (CH_2 Bn), 73.3 (C-3’), 72.8 (C-4), 72.7 (CH_2 Bn), 68.7, 68.7 (C-6, C-6’), 66.5, 66.2 (C-5, C-5’), 56.3 (CH_3 OMe); Diagnostic peaks for the α-anomer: ^{1}H NMR (400 MHz, $CDCl_3$) δ 5.53 (s, 1H, C*H*Ph), 5.46 (d, *J* = 3.8 Hz, 1H, H-1’), 4.14 (dd, *J* = 10.2, 5.0 Hz, 1H), 4.01 (dd, *J* = 10.0, 7.7 Hz, 1H); ^{13}C NMR (101 MHz, $CDCl_3$) δ 104.9 (C-1), 101.4 (CHPh), 97.6 (C-1’), 82.9, 80.3, 76.0, 74.3, 73.4, 69.3, 63.2, 62.4, 58.0 (CH_3 OMe); HRMS: $[M+NH_4]^+$ calcd for $C_{48}H_{51}N_3O_{10}NH_4$ 847.39127, found 847.38959.

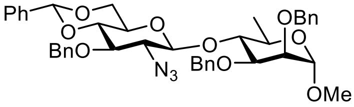
Disaccharide 36A



Title compound was obtained as colourless oil via the general procedure for Ph_2SO/Tf_2O mediated glycosylations with donor **A** and acceptor **36**. Yield: 70 mg, 80 µmol, 89%, α:β = 1:2.4. Data reported for a 1:2 mixture of anomers: ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.68 – 7.01 (m, 75H), 5.77 (d, *J* = 4.1 Hz, 1H, H-1’α), 5.55 (s, 1H, C*H*Phα), 5.48 (s, 2H, C*H*Phβ), 4.91 (d, *J* = 11.3 Hz, 3H), 4.84 (d, *J* = 2.8 Hz, 4H), 4.81 – 4.74 (m, 8H), 4.72 – 4.67 (m, 6H), 4.65 – 4.58 (m, 7H), 4.57 – 4.49 (m, 3H), 4.44 (d, *J* = 12.1 Hz, 1H), 4.29 (dd, *J* = 10.4, 4.9 Hz, 1H, H-6’α), 4.15 (dd, *J* = 10.5, 5.0 Hz, 2H, H-6’β), 4.04 – 3.94 (m, 3H), 3.90 (td, *J* = 9.7, 1.4 Hz, 2H, H-4β), 3.80 – 3.72 (m, 8H), 3.71 – 3.65 (m, 2H), 3.61 (td, *J* = 9.4, 4.6 Hz, 3H), 3.56 – 3.49 (m, 3H), 3.43 (dd, *J* = 8.8, 7.7 Hz, 2H, H-4’β), 3.33 (s, 9H, CH_3 OMeαβ), 3.27 (td, *J* = 9.9, 5.0 Hz, 2H, H-5’β), 1.42 (d, *J* = 6.2 Hz, 3H, H-6α), 1.36 (d, *J* = 6.3 Hz, 6H, H-6β); ^{13}C NMR (126 MHz, $CDCl_3$) δ 139.4, 138.8, 138.6, 138.5, 138.4, 138.2, 138.0, 137.5, 137.5, 129.9, 129.6, 129.0, 129.0, 128.5, 128.4, 128.4, 128.4, 128.3, 128.3, 128.2, 128.1, 128.1, 128.1, 128.0, 128.0, 127.9, 127.9, 127.8, 127.7, 127.7, 127.7, 127.6, 127.6, 127.4, 127.3, 127.0, 126.7, 126.1, 126.1, 103.9 (C-1’β), 101.2 (CHPhαβ), 99.5 (C-1β), 98.8 (C-1α), 98.0

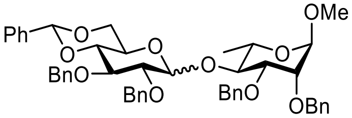
(C-1’α), 83.0 (C-4’β), 82.2 (C-4’α), 81.8, 81.5, 81.4, 80.7, 78.8, 78.7, 78.2, 77.4, 77.2, 76.9, 76.1, 75.7, 75.7, 75.4, 75.2, 73.9, 73.2, 73.0, 72.8, 72.6, 70.5, 69.0, 68.9, 67.9, 66.9, 65.9, 63.3, 54.9 (CH_3 OMeβ), 54.8 (CH_3 OMeα), 19.3 (C-6α), 18.2 (C-6β); HRMS: $[M+NH_4]^+$ calcd for $C_{48}H_{52}O_{10}NH_4$ 806.38987, found 806.38846.

Disaccharide 36B



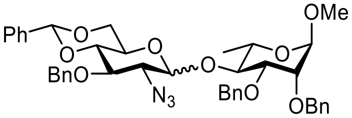
Title compound was obtained as colourless oil via the general procedure for Ph_2SO/Tf_2O mediated glycosylations with donor **B** and acceptor **36**. Yield: 54 mg, 75 µmol, 75%, α:β < 1:20. ^1H NMR (400 MHz, $CDCl_3$) δ 7.48 – 7.22 (m, 20H, CH_{arom}), 5.48 (s, 1H, C*H*Ph), 4.91 (d, *J* = 11.1 Hz, 1H, C*H*H Bn), 4.77 (d, *J* = 11.2 Hz, 1H, CH*H* Bn), 4.72 (d, *J* = 12.4 Hz, 1H, C*H*H Bn), 4.69 – 4.63 (m, 3H, H-1, C*H*H Bn, CH*H* Bn), 4.60 – 4.54 (m, 2H, H-1’, CH*H* Bn), 4.00 (dd, *J* = 10.5, 5.0 Hz, 1H, H-6’), 3.89 (t, *J* = 9.1 Hz, 1H, H-4), 3.80 – 3.69 (m, 3H, H-2, H-3, H-5), 3.66 – 3.55 (m, 2H, H-3’, H-4’), 3.52 (t, *J* = 10.3 Hz, 1H, H-6’), 3.38 (dd, *J* = 9.0, 7.9 Hz, 1H, H-2’), 3.31 (s, 3H, CH_3 OMe), 3.19 (td, *J* = 9.4, 5.0 Hz, 1H, H-5’), 1.43 (d, *J* = 6.2 Hz, 3H, H-6); ^{13}C NMR (101 MHz, $CDCl_3$) δ 139.1, 138.4, 137.9, 137.3 (C_q), 131.5, 131.2, 129.1, 128.5, 128.5, 128.4, 128.4, 128.3, 128.3, 128.0, 128.0, 127.7, 127.4, 126.8, 126.1 (CH_{arom}), 102.4 (C-1’), 101.3 (CHPh), 99.2 (C-1), 81.7 (C-4’), 81.4 (C-4), 79.5 (C-3’), 78.6 (C-3), 75.2 (C-2), 75.0, 73.1, 72.2 (CH_2 Bn), 68.6 (C-6’), 67.5 , 67.4 (C-2’, C-5), 66.1 (C-5’), 54.9 (CH_3 OMe), 18.1 (C-6); HRMS: $[M+NH_4]^+$ calcd for $C_{41}H_{45}N_3O_9NH_4$ 741.34941, found 741.34849.

Disaccharide 37A



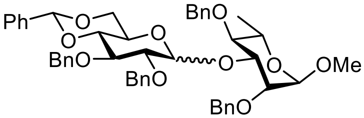
Title compound was obtained as colourless oil via the general procedure for Ph_2SO/Tf_2O mediated glycosylations with donor **A** and acceptor **37**. Yield: 91 mg, 90 µmol, 90%, α:β = 1.7:1. Data reported for a 2:1 mixture: ^1H NMR (400 MHz, $CDCl_3$) δ 7.76 – 7.06 (m, 75H), 5.61 (s, 1H, C*H*Phβ), 5.57 (s, 2H, C*h*Phα), 5.14 – 5.06 (m, 3H, H-1’αβ), 5.02 – 4.97 (m, 3H), 4.93 (d, *J* = 11.6 Hz, 1H), 4.90 – 4.84 (m, 5H), 4.79 (d, *J* = 11.6 Hz, 2H), 4.76 – 4.64 (m, 8H), 4.60 (s, 4H), 4.51 (d, *J* = 10.9 Hz, 1H), 4.40 (d, *J* = 11.1 Hz, 1H), 4.38 – 4.31 (m, 2H), 4.12 (dd, *J* = 10.2, 4.9 Hz, 2H, H-6’α), 4.07 (t, *J* = 9.3 Hz, 2H, H-4α), 3.95 (t, *J* = 9.3 Hz, 1H, H-4β), 3.86 – 3.81 (m, 6H), 3.81 – 3.73 (m, 3H), 3.73 – 3.60 (m, 6H), 3.45 (dd, *J* = 9.2, 6.9 Hz, 1H, H-2’β), 3.43 – 3.37 (m, 4H), 3.35 (s, 6H, CH_3 OMeα), 1.42 (d, *J* = 5.9 Hz, 6H, H-6α), 1.39 (d, *J* = 6.2 Hz, 3H, H-6β); ^{13}C NMR (101 MHz, $CDCl_3$) δ 138.9, 138.4, 138.0, 138.0, 137.8, 131.7, 129.0, 128.9, 128.5, 128.5, 128.4, 128.4, 128.4, 128.3, 128.2, 128.2, 128.1, 128.1, 128.1, 128.0, 128.0, 127.9, 127.9, 127.9, 127.8, 127.8, 127.7, 127.6, 127.6, 127.5, 126.2, 126.1, 103.1 (C-1’β), 101.2 (CHPhα), 101.2 (CHPhβ), 99.0 (C-1β, 99.0, 98.9 (C-1α, C-1’α), 82.8, 82.6, 81.9, 81.1, 80.5, 79.6, 79.1, 79.0, 77.9, 76.6, 75.3, 75.2, 75.1, 74.6, 74.4, 74.3, 72.9, 72.8, 72.2, 71.5, 69.1, 68.9, 68.0, 67.3, 65.7, 62.8, 54.9 (CH_3 OMeβ), 54.7 (CH_3 OMeα), 18.3 (C-6α), 18.0 (C-6β); HRMS: $[M+NH_4]^+$ calcd for $C_{48}H_{52}O_{10}NH_4$ 806.38987, found 806.38859.

Disaccharide 37B



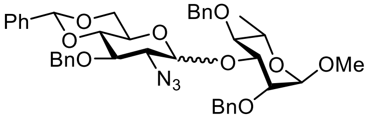
Title compound was obtained as colourless oil via the general procedure for Ph_2SO/Tf_2O mediated glycosylations with donor **B** and acceptor **37**. Yield: 72 mg, 99 μmol, 99%, α:β = 1:10. Data for β-anomer: ^1H NMR (400 MHz, $CDCl_3$) δ 7.76 – 7.64 (m, 2H, CH_{arom}), 7.47 (dd, *J* = 7.6, 2.2 Hz, 2H, CH_{arom}), 7.43 – 7.25 (m, 16H, CH_{arom}), 5.55 (s, 1H, C*H*Ph), 4.94 – 4.86 (m, 2H, H-1', C*H*H Bn), 4.78 (d, *J* = 11.4 Hz, 1H, CH*H* Bn), 4.68 – 4.60 (m, 4H, H-1, C*H*H Bn, CH_2 Bn), 4.51 (d, *J* = 10.9 Hz, 1H, CH*H* Bn), 4.30 (dd, *J* = 10.5, 5.0 Hz, 1H, H-6'), 3.92 – 3.82 (m, 2H, H-3, H-4), 3.77 (dd, *J* = 3.0, 1.8 Hz, 1H, H-2), 3.72 (t, *J* = 10.3 Hz, 1H, H-6'), 3.68 – 3.62 (m, 2H, H-4', H-5), 3.47 (t, *J* = 9.2 Hz, 1H, H-3'), 3.39 (dd, *J* = 9.6, 7.9 Hz, 1H, H-2'), 3.36 – 3.29 (m, 4H, H-5', CH_3 OMe), 1.31 (d, *J* = 6.2 Hz, 3H, H-6); ^{13}C NMR (101 MHz, $CDCl_3$) δ 138.3, 138.2, 138.1, 137.3 (C_q), 131.6, 129.1, 128.5, 128.5, 128.5, 128.4, 128.4, 128.4, 128.3, 128.2, 128.0, 127.9, 127.9, 127.8, 126.1 (CH_{arom}), 102.1 (C-1'), 101.3 (CHPh), 98.9 (C-1), 81.9 (C-4'), 80.1 (C-3), 79.1 (C-3'), 77.4 (C-4), 74.9 (CH_2 Bn), 74.1 (C-2), 72.8, 72.0 (CH_2 Bn), 68.7 (C-6), 67.0 (C-5), 66.5 (C-2'), 65.8 (C-5'), 54.9 (CH_3 OMe), 17.9 (C-6); diagnostic peaks for the α-anomer: ^1H NMR (400 MHz, $CDCl_3$) δ 5.52 (s, 1H, C*H*Ph), 5.06 (d, *J* = 3.8 Hz, 1H, H-1'), 4.03 (dd, *J* = 10.2, 4.9 Hz, 1H), 3.98 (t, *J* = 9.5 Hz, 1H), 1.41 (d, *J* = 6.1 Hz, 3H); ^{13}C NMR (101 MHz, $CDCl_3$) δ 101.3 (CHPh), 98.7 (C-1'), 82.9, 81.3, 80.8, 75.1, 74.3, 71.3, 68.0, 63.7, 62.8, 21.9 (C-6); HRMS: $[M+NH_4]^+$ calcd for $C_{41}H_{45}N_3O_9NH_4$ 741.34941, found 741.34836.

Disaccharide 38A



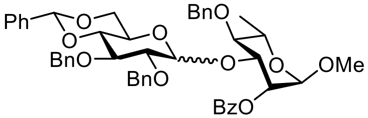
Title compound was obtained as colourless oil via the general procedure for Ph_2SO/Tf_2O mediated glycosylations with donor **A** and acceptor **38**. Yield: 79 mg, 100 μmol, 100%, α:β = 7:1. Data for α-anomer: ^1H NMR (400 MHz, $CDCl_3$) δ 7.45 – 7.12 (m, 25H, CH_{arom}), 5.53 (s, 1H, C*H*Ph), 5.11 (d, *J* = 3.5 Hz, 1H, H-1'), 4.96 – 4.89 (m, 2H, 2x C*H*H Bn), 4.83 – 4.77 (m, 3H, 2x C*H*H Bn, CH*H* Bn), 4.74 (d, *J* = 11.8 Hz, 1H, CH*H* Bn), 4.61 – 4.54 (m, 3H, H-1, 2x CH*H* Bn), 4.19 – 4.10 (m, 3H, H-4, H-5', H-6'), 4.09 – 4.05 (m, 1H, H-3), 3.86 (dd, *J* = 2.9, 2.1 Hz, 1H, H-2), 3.70 – 3.58 (m, 5H, H-2', H-3', H-4', H-5, H-6'), 3.28 (s, 3H, CH_3 OMe), 1.33 (d, *J* = 5.4 Hz, 3H, H-6); ^{13}C NMR (101 MHz, $CDCl_3$) δ 138.7, 138.6, 138.2, 138.1, 137.7 (C_q), 131.6, 131.1, 128.9, 128.5, 128.5, 128.4, 128.4, 128.4, 128.4, 128.3, 128.2, 128.2, 128.2, 127.9, 127.9, 127.8, 127.8, 127.8, 127.7, 127.7, 127.6, 126.3 (CH_{arom}), 101.3 (CHPh), 99.2 (C-1), 96.5 (C-1'), 82.6 (C-4'), 80.2, 79.2 (C-2', C-3'), 78.6 (C-4), 76.9 (C-3), 75.7 (CH_2 Bn), 75.3 (C-2), 75.2, 73.9, 73.3 (CH_2 Bn), 69.1 (C-6'), 68.2 (C-5), 63.0 (C-5'), 54.8 (CH_3 OMe), 18.1 (C-6); diagnostic peaks for the β-anomer: ^1H NMR (400 MHz, $CDCl_3$) δ 5.55 (s, 1H, C*H*Ph), 5.00 (d, *J* = 11.3 Hz, 1H), 4.40 (d, *J* = 10.6 Hz, 1H), 4.31 (dd, *J* = 10.4, 5.0 Hz, 1H), 3.79 (dd, *J* = 3.3, 1.8 Hz, 1H, H-2); ^{13}C NMR (101 MHz, $CDCl_3$) δ 103.9 (C-1'), 99.5 (C-1), 81.9, 81.4, 81.0, 79.6, 74.8, 73.6, 73.2, 67.8, 66.0; HRMS: $[M+NH_4]^+$ calcd for 806.38987, found 806.38793.

Disaccharide 38B



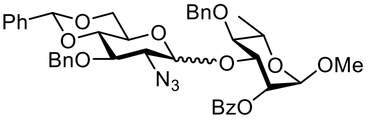
Title compound was obtained as colourless oil via the general procedure for Ph_2SO/Tf_2O mediated glycosylations with donor **B** and acceptor **38**. Yield: 49 mg, 68 μmol, 68%, α:β = 1.4:1. Data reported for a 1:1 mixture of anomers: ^1H NMR (500 MHz, $CDCl_3$) δ 7.81 – 7.59 (m, 4H), 7.51 – 7.23 (m, 32H), 7.20 – 7.09 (m, 4H), 5.59 – 5.46 (m, 2H, C*H*Phαβ), 5.02 (d, *J* = 10.6 Hz, 1H), 4.96 – 4.91 (m, 3H), 4.85 (d, *J* = 10.6 Hz, 1H), 4.82 – 4.76 (m, 3H), 4.72 (d, *J* = 11.0 Hz, 4H), 4.65 (d, *J* = 8.1 Hz, 1H, H-1'β), 4.62 (d, *J* = 10.7 Hz, 1H), 4.57 (d, *J* = 1.8 Hz, 1H, H-1β), 4.54 (d, *J* = 10.6 Hz, 1H), 4.29 (dd, *J* = 10.5, 5.0 Hz, 1H, H-6'β), 4.22 (dd, *J* = 10.2, 4.9 Hz, 1H, H-6'α), 4.15 – 4.09 (m, 2H), 4.07 – 4.01 (m, 2H), 3.82 (dd, *J* = 3.2, 2.0 Hz, 1H, H-2α), 3.77 (dd, *J* = 3.3, 1.7 Hz, 1H, H-2β), 3.74 – 3.62 (m, 6H), 3.59 (t, *J* = 8.4 Hz, 1H), 3.46 (dd, *J* = 9.4, 8.1 Hz, 1H, H-2'β), 3.38 (dd, *J* = 10.0, 3.6 Hz, 1H, H-2'α), 3.33 (dt, *J* = 9.6, 4.9 Hz, 1H), 3.30 (s, 3H, CH_3 OMeα), 3.29 (s, 3H, CH_3 OMeβ), 1.37 – 1.31 (m, 6H, H-6αβ); ^{13}C NMR (126 MHz, $CDCl_3$) δ 138.7, 138.5, 137.9, 137.9, 137.8, 137.7, 137.5, 137.2, 135.4, 134.4, 131.8, 131.7, 131.5, 131.3, 131.2, 130.4, 130.3, 129.2, 129.0, 128.6, 128.6, 128.5, 128.5, 128.5, 128.5, 128.4, 128.4, 128.4, 128.3, 128.3, 128.2, 128.1, 128.0, 128.0, 127.9, 127.8, 127.7, 126.3, 126.1, 103.0 (C-1'β), 101.4, 101.4 (CHPhαβ), 99.5 (C-1β), 98.3 (C-1α), 94.2 (C-1'α), 83.0, 81.8, 80.6, 79.9, 79.7, 79.5, 78.3, 76.1, 75.7, 75.2, 75.1, 75.0, 74.7, 73.6, 73.0, 72.6, 68.9, 68.0, 67.9, 66.9, 66.1, 62.9, 62.8, 54.8, 54.6, 18.1, 18.0; HRMS: $[M+NH_4]^+$ calcd for $C_{41}H_{45}N_3O_9NH_4$ 741.34941, found 741.34778.

Disaccharide 39A



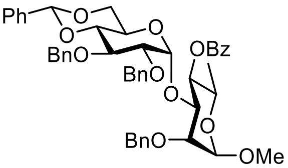
Title compound was obtained as colourless oil via the general procedure for Ph_2SO/Tf_2O mediated glycosylations with donor **A** and acceptor **39**. Yield: 53 mg, 66 μmol, 66%, α:β = 6:1. ^1H NMR (500 MHz, $CDCl_3$) δ 8.08 – 8.04 (m, 2H, CH_{arom}), 7.57 – 7.52 (m, 1H, CH_{arom}), 7.43 – 7.34 (m, 9H, CH_{arom}), 7.27 – 7.22 (m, 3H, CH_{arom}), 7.20 – 7.15 (m, 4H, CH_{arom}), 7.14 – 7.06 (m, 6H, CH_{arom}), 5.58 (dd, *J* = 3.2, 1.9 Hz, 1H, H-2), 5.51 (s, 1H, C*H*Ph), 5.18 (d, *J* = 3.6 Hz, 1H, H-1'), 4.98 (d, *J* = 10.4 Hz, 1H, C*H*H Bn), 4.81 (d, *J* = 11.4 Hz, 1H, C*H*H Bn), 4.77 (d, *J* = 1.9 Hz, 1H, H-1), 4.68 (d, *J* = 11.4 Hz, 1H, CH*H* Bn), 4.64 (d, *J* = 10.4 Hz, 1H, CH*H* Bn), 4.53 (d, *J* = 12.1 Hz, 1H C*H*H Bn), 4.44 (d, *J* = 12.1 Hz, 1H, CH*H* Bn), 4.29 (dd, *J* = 9.5, 3.3 Hz, 1H, H-3), 4.23 (dd, *J* = 10.1, 4.9 Hz, 1H, H-6'), 4.10 – 4.01 (m, 2H, H-3', H-5'), 3.82 (dq, *J* = 9.4, 6.2 Hz, 1H, H-5), 3.71 – 3.67 (m, 1H, H-4), 3.67 – 3.63 (m, 1H, H-6'), 3.60 (t, *J* = 9.5 Hz, 1H, H-4'), 3.54 (dd, *J* = 9.3, 3.6 Hz, 1H, H-2'), 3.37 (s, 3H, CH_3 OMe), 1.40 (d, *J* = 6.2 Hz, 3H, H-6); ^{13}C NMR (126 MHz, $CDCl_3$) δ 166.2 (C=O), 138.7, 138.1, 137.8, 137.7 (C_q), 133.4, 130.1 (CH_{arom}), 129.9 (C_q), 129.9, 128.9, 128.8, 128.6, 128.5, 128.5, 128.4, 128.3, 128.3, 128.2, 128.2, 128.1, 128.1, 128.0, 127.9, 127.8, 127.8, 127.6, 127.5, 126.4, 126.1 (CH_{arom}), 101.3 (CHPh), 98.6 (C-1), 93.6 (C-1'), 82.3 (C-4'), 79.7 (C-4), 78.4, 78.3 (C-2', C-3'), 76.3, 75.1 (CH_2 Bn), 72.8 (C-3), 72.7 (CH_2 Bn), 69.1 (C-6'), 68.4 (C-2), 67.9 (C-5), 62.9 (C-5'), 55.1 (CH_3 OMe), 18.2 (C-6); diagnostic peaks for the β-anomer: ^1H NMR (500 MHz, $CDCl_3$) δ 5.47 (s, 1H, C*H*Ph), 5.41 (dd, *J* = 3.5, 1.8 Hz, 1H, H-2), 4.36 (dd, *J* = 9.4, 3.5 Hz, 1H, H-3), 1.37 (d, *J* = 6.2 Hz, 3H, H-6); ^{13}C NMR (126 MHz, $CDCl_3$) δ 165.9 (C=O), 103.7 (C-1'), 101.1 (CHPh), 98.5 (C-1), 81.6, 81.3, 80.8, 76.0, 74.9, 72.9, 68.8, 67.2, 66.0, 18.1 (C-6); HRMS: $[M+NH_4]^+$ calcd for $C_{48}H_{50}O_{11}NH_4$ 820.36914, found 820.36629.

Disaccharide 39B



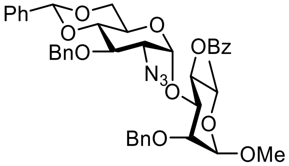
Title compound was obtained as colourless oil via the general procedure for Ph_2SO/Tf_2O mediated glycosylations with donor **B** and acceptor **39**. Yield: 41 mg, 55 µmol, 55%, α:β = 1:1. Data reported for a 1:1 mixture of anomers: ^{1}H NMR (500 MHz, $CDCl_3$) δ 8.15 – 8.12 (m, 2H), 8.09 – 8.05 (m, 2H), 7.51 – 7.26 (m, 36H), 5.61 (dd, *J* = 3.3, 1.9 Hz, 1H, H-2α/β), 5.57 (s, 1H, C*H*Ph α/β), 5.50 (s, 1H, C*H*Ph α/β), 5.34 (dd, *J* = 3.5, 1.8 Hz, 1H, H-2α/β), 5.23 (d, *J* = 3.7 Hz, 1H, H-1'α), 5.04 (d, *J* = 10.5 Hz, 1H), 4.90 (d, *J* = 11.3 Hz, 1H), 4.87 – 4.83 (m, 2H), 4.77 – 4.70 (m, 5H), 4.69 (d, *J* = 11.1 Hz, 1H), 4.65 (d, *J* = 8.1 Hz, 1H, H-1'β), 4.59 (d, *J* = 10.4 Hz, 1H), 4.35 – 4.25 (m, 4H), 4.09 (td, *J* = 9.9, 4.8 Hz, 1H), 4.01 (dd, *J* = 10.0, 9.1 Hz, 1H), 3.86 – 3.75 (m, 3H), 3.74 – 3.59 (m, 6H), 3.54 (t, *J* = 9.3 Hz, 1H), 3.42 – 3.36 (m, 7H), 3.34 – 3.30 (m, 1H), 3.27 (dd, *J* = 10.0, 3.7 Hz, 1H), 1.42 – 1.37 (m, 6H); ^{13}C NMR (126 MHz, $CDCl_3$) δ 166.0, 149.8, 137.2, 135.4, 134.5, 133.5, 133.3, 131.9, 131.7, 131.2, 130.4, 130.3, 130.0, 130.0, 129.1, 129.0, 128.7, 128.6, 128.6, 128.5, 128.5, 128.4, 128.4, 128.4, 128.4, 128.2, 128.2, 128.1, 128.0, 127.9, 126.3, 126.1, 125.1, 119.3, 102.4 (C-1'β), 101.4, 101.3 (CHPhαβ), 98.7, 98.3 (C-1αβ), 93.9 (C-1'α), 82.8, 81.5, 80.7, 79.9, 79.2, 76.4, 75.3, 75.2, 74.9, 74.8, 72.9, 72.7, 68.8, 68.5, 67.7, 67.5, 67.3, 66.5, 66.1, 62.9, 62.5, 55.0, 55.0, 18.2, 18.1; HRMS: $[M+NH_4]^+$ calcd for $C_{41}H_{43}N_3O_{10}NH_4$ 755.32867, found 755.32641

Disaccharide 40A



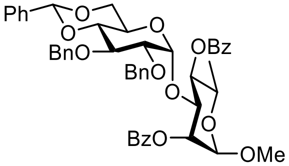
Title compound was obtained as colourless oil via the general procedure for Ph_2SO/Tf_2O mediated glycosylations with donor **A** and acceptor **40**. Yield: 55 mg, 69 µmol, 69%, α:β >20:1. ^{1}H NMR (500 MHz, $CDCl_3$) δ 8.05 – 7.98 (m, 2H, CH_{arom}), 7.50 – 7.45 (m, 1H, CH_{arom}), 7.40 – 7.35 (m, 2H, CH_{arom}), 7.34 (d, *J* = 0.9 Hz, 4H, CH_{arom}), 7.31 – 7.25 (m, 10H, CH_{arom}), 7.25 – 7.19 (m, 5H, CH_{arom}), 5.50 (t, *J* = 9.6 Hz, 1H, H-4), 5.36 (s, 1H, C*H*Ph), 4.87 – 4.84 (m, 2H, H-1', C*H*H Bn), 4.83 – 4.78 (m, 2H, 2x C*H*H Bn), 4.69 (d, *J* = 11.4 Hz, 1H, CH*H* Bn), 4.66 – 4.62 (m, 2H, 2x CH*H* Bn), 4.61 (d, *J* = 2.0 Hz, 1H, H-1), 4.09 (dd, *J* = 9.6, 3.0 Hz, 1H, H-3), 3.96 – 3.90 (m, 2H, H-2, H-3'), 3.87 – 3.76 (m, 3H, H-5, H-5', H-6'), 3.48 (dd, *J* = 9.4, 3.7 Hz, 1H, H-2'), 3.43 (t, *J* = 9.3 Hz, 1H, H-4'), 3.36 (s, 3H, CH_3 OMe), 3.30 – 3.21 (m, 1H, H-6'), 1.25 (d, *J* = 6.3 Hz, 3H, H-6); ^{13}C NMR (126 MHz, $CDCl_3$) δ 165.7 (C=O), 138.7, 138.7, 138.3, 137.6 (C_q), 133.1 (CH_{arom}), 130.2 (C_q), 129.8, 128.9, 128.5, 128.4, 128.2, 128.1, 128.1, 128.1, 127.9, 127.6, 127.5, 126.3 (CH_{arom}), 101.2 (CHPh), 100.3 (C-1), 100.2 (C-1'), 82.3 (C-4'), 79.7 (C-3), 79.5 (C-2'), 78.3 (C-3'), 76.2 (C-2), 75.1, 74.0, 73.8 (CH_2 Bn), 73.8 (C-4), 68.7 (C-6'), 66.9 (C-5), 63.4 (C-5'), 55.0 (CH_3 OMe), 17.8 (C-6); HRMS: $[M+NH_4]^+$ calcd for $C_{48}H_{50}O_{11}NH_4$ 820.36914, found 820.36724.

Disaccharide 40B



Title compound was obtained as colourless oil via the general procedure for Ph_2SO/Tf_2O mediated glycosylations with donor **B** and acceptor **40**. Yield: 37 mg, 50 µmol, 50%, α:β = 12:1. Data for the α-anomer: ^1H NMR (500 MHz, $CDCl_3$) δ 8.07 – 8.02 (m, 2H, CH_{arom}), 7.43 (dt, *J* = 7.4, 1.4 Hz, 3H, CH_{arom}), 7.35 (qt, *J* = 5.2, 2.7 Hz, 8H, CH_{arom}), 7.31 – 7.23 (m, 9H, CH_{arom}), 5.51 (t, *J* = 9.7 Hz, 1H, H-4), 5.38 (s, 1H, C*H*Ph), 4.91 (d, *J* = 3.6 Hz, 1H, H-1'), 4.83 (d, *J* = 12.2 Hz, 1H, C*H*H Bn), 4.78 (d, *J* = 11.0 Hz, 1H, C*H*H Bn), 4.73 (d, *J* = 12.2 Hz, 1H, CH*H* Bn), 4.71 (d, *J* = 1.9 Hz, 1H, H-1), 4.62 (d, *J* = 11.0 Hz, 1H, CH*H* Bn), 4.15 (dd, *J* = 9.7, 3.1 Hz, 1H, H-3), 4.00 (dd, *J* = 10.2, 4.9 Hz, 1H, H-6'), 3.92 (dd, *J* = 3.2, 2.0 Hz, 1H, H-2), 3.90 – 3.78 (m, 3H, H-3', H-5, H-5'), 3.50 (t, *J* = 9.4 Hz, 1H, H-4'), 3.40 (t, *J* = 10.3 Hz, 1H, H-6'), 3.37 (s, 3H, CH_3 OMe), 3.32 (dd, *J* = 10.0, 3.6 Hz, 1H, H-2'), 1.27 (d, *J* = 6.3 Hz, 3H, CH_3 OMe); ^{13}C NMR (126 MHz, $CDCl_3$) δ 165.6 (C=O), 138.2, 137.8, 137.4 (C_q), 133.2 (CH_{arom}), 130.0 (C_q), 129.7, 129.7, 129.0, 128.6, 128.6, 128.5, 128.5, 128.5, 128.4, 128.2, 128.1, 128.1, 128.0, 127.9, 126.3 (CH_{arom}), 101.3 (CHPh), 99.3 (C-1), 97.8 (C-1'), 82.7 (C-4'), 77.0 (C-3), 75.9 (C-3'), 75.2 (C-2), 75.0, 73.4 (CH_2 Bn), 73.3 (C-4), 68.5 (C-6), 66.8 (C-5), 63.4, 63.3 (C-2', C-5'), 55.1 (CH_3 OMe), 17.7 (C-6); diagnostic peaks for the β-anomer: ^1H NMR (500 MHz, $CDCl_3$) δ 4.95 (d, *J* = 11.0 Hz, 1H, C*H*H Bn), 4.39 (d, *J* = 7.9 Hz, 1H, H-1'), 4.30 (dd, *J* = 10.4, 5.0 Hz, 1H, H-6'), 3.73 (t, *J* = 8.9 Hz, 1H), 3.68 (t, *J* = 10.3 Hz, 1H), 3.62 (t, *J* = 9.2 Hz, 1H); ^{13}C NMR (126 MHz, $CDCl_3$) δ 104.0 (C-1'), 99.9 (C-1), 81.5, 81.1, 80.9, 79.6, 79.5, 75.2, 74.9, 73.6, 66.4, 66.1, 64.8, 55.0(CH_3 OMe); HRMS: $[M+NH_4]^+$ calcd for $C_{41}H_{43}N_3O_{10}NH_4$ 755.32867, found 755.32744.

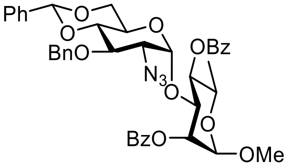
Disaccharide 41A



Title compound was obtained as colourless oil via the general procedure for Ph_2SO/Tf_2O mediated glycosylations with donor **A** and acceptor **42.** Yield: 68 mg, 83 µmol, 83%, α:β >20:1. ^1H NMR (500 MHz, $CDCl_3$) δ 8.14 – 8.10 (m, 2H, CH_{arom}), 8.07 – 8.04 (m, 2H, CH_{arom}), 7.57 – 7.51 (m, 1H, CH_{arom}), 7.43 (t, *J* = 7.7 Hz, 2H, CH_{arom}), 7.40 – 7.36 (m, 1H, CH_{arom}), 7.34 – 7.28 (m, 5H, CH_{arom}), 7.21 – 7.09 (m, 13H, CH_{arom}), 5.59 (t, *J* = 9.8 Hz, 1H, H-4), 5.55 (dd, *J* = 3.5, 1.9 Hz, 1H, H-2), 5.29 (s, 1H, C*H*Ph), 4.91 (d, *J* = 1.8 Hz, 1H, H-1), 4.88 (d, *J* = 3.6 Hz, 1H, H-1'), 4.55 (d, *J* = 11.3 Hz, 1H, C*H*H Bn), 4.49 – 4.40 (m, 3H, CH*H* Bn, CH_2 Bn), 4.33 (dd, *J* = 9.9, 3.4 Hz, 1H, H-3), 4.03 (dq, *J* = 9.7, 6.2 Hz, 1H, H-5), 3.82 (dd, *J* = 10.1, 4.8 Hz, 1H, H-6'), 3.72 (t, *J* = 9.4 Hz, 1H, H-3'), 3.67 (dt, *J* = 9.9, 5.0 Hz, 1H, H-5'), 3.46 (s, 3H, CH_3 OMe), 3.40 (t, *J* = 10.2 Hz, 1H, H-6'), 3.37 – 3.32 (m, 2H, H-2', H-4'), 1.33 (d, *J* = 6.2 Hz, 3H, H-6); ^{13}C NMR (126 MHz, $CDCl_3$) δ 166.4, 165.8 (C=O), 138.7, 138.2, 137.6 (C_q), 133.4, 133.3, 130.2 (CH_{arom}), 129.8 (C_q), 129.8 (CH_{arom}), 129.6 (C_q), 128.8, 128.7, 128.6, 128.6, 128.3, 128.2, 128.1, 128.0, 128.0, 128.0, 127.5, 127.5, 126.3

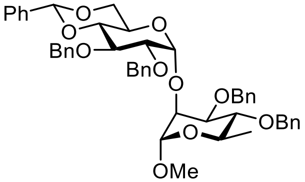
(CH$_{\mathrm{arom}}$), 101.1 (CHPh), 98.7 (C-1), 96.4 (C-1'), 81.9 (C-4'), 78.4 (C-3'), 78.0 (C-2'), 75.1 (CH$_2$ Bn), 73.0 (C-3), 72.9 (CH$_2$ Bn, 72.8 (C-4), 69.5 (C-2), 68.7 (C-6'), 66.7 (C-5), 63.2 (C-5'), 55.4 (CH$_3$ OMe), 17.8 (C-6); HRMS: $[M+NH_4]^+$ calcd for $C_{48}H_{48}O_{12}NH_4$ 834.34840, found 834.34724.

Disaccharide 41B



Title compound was obtained as colourless oil via the general procedure for Ph$_2$SO/Tf$_2$O mediated glycosylations with donor **B** and acceptor **42.** Yield: 79 mg, 100 µmol, 100%, α:β = 12:1. Data for the α-anomer: ^{1}H NMR (500 MHz, CDCl$_3$) δ 8.21 – 8.15 (m, 2H, CH$_{\mathrm{arom}}$), 8.10 – 8.02 (m, 2H, CH$_{\mathrm{arom}}$), 7.74 – 7.63 (m, 3H, CH$_{\mathrm{arom}}$), 7.61 – 7.52 (m, 2H, CH$_{\mathrm{arom}}$), 7.52 – 7.44 (m, 3H, CH$_{\mathrm{arom}}$), 7.39 – 7.27 (m, 6H, CH$_{\mathrm{arom}}$), 7.21 (pd, *J* = 4.2, 2.0 Hz, 3H, CH$_{\mathrm{arom}}$), 7.18 – 7.15 (m, 1H, CH$_{\mathrm{arom}}$), 7.14 – 7.08 (m, 2H, CH$_{\mathrm{arom}}$), 5.62 (dd, *J* = 3.5, 1.9 Hz, 1H, H-2), 5.56 (t, *J* = 9.9 Hz, 1H, H-4), 5.32 (s, 1H, C*H*Ph), 5.05 (d, *J* = 3.7 Hz, 1H, H-1'), 4.87 (d, *J* = 1.9 Hz, 1H, H-1), 4.64 (d, *J* = 10.9 Hz, 1H, C*H*H Bn), 4.46 (d, *J* = 10.9 Hz, 1H, CH*H* Bn), 4.38 (dd, *J* = 9.9, 3.4 Hz, 1H, H-3), 4.06 (dq, *J* = 9.7, 6.2 Hz, 1H, H-5), 3.98 (dd, *J* = 10.1, 4.8 Hz, 1H, H-6'), 3.71 (dd, *J* = 10.0, 9.1 Hz, 1H, H-3'), 3.66 (dt, *J* = 9.9, 5.0 Hz, 1H, H-5'), 3.51 (t, *J* = 10.2 Hz, 1H, H-6'), 3.48 – 3.43 (m, 4H, H-4', CH$_3$ OMe), 3.21 (dd, *J* = 10.0, 3.7 Hz, 1H, H-2'), 1.35 (d, *J* = 6.3 Hz, 3H, CH$_3$ OMe); ^{13}C NMR (126 MHz, CDCl$_3$) δ 166.2, 165.6 (C=O), 137.8, 137.3 (C$_q$), 135.3, 134.5, 133.5, 133.4, 131.8, 131.6, 131.1, 130.3, 130.3, 130.1, 130.0, 129.7 (CH$_{\mathrm{arom}}$), 129.5, 129.4 (C$_q$), 128.9, 128.9, 128.7, 128.6, 128.6, 128.4, 128.3, 128.2, 128.0, 127.8, 126.2 (CH$_{\mathrm{arom}}$), 101.2 (CHPh), 98.8 (C-1), 95.4 (C-1'), 82.3 (C-4'), 75.8 (C-3'), 74.9 (CH$_2$ Bn), 72.5 (C-4), 72.2 (C-3), 68.5 (C-6'), 68.2 (C-2), 66.5 (C-5), 63.2 (C-5'), 62.7 (C-2'), 55.4 (CH$_3$ OMe), 17.8 (C-6); diagnostic peaks for the α-anomer: ^{1}H NMR (500 MHz, CDCl$_3$) δ 5.70 (dd, *J* = 3.5, 1.8 Hz, 1H, H-2), 4.96 (dd, *J* = 9.8, 3.5 Hz, 1H, H-3), 4.33 – 4.27 (m, 1H); ^{13}C NMR (126 MHz, CDCl$_3$) δ 165.7 (C=O), 103.1 (C-1'), 98.6 (CHPh), 98.3 (C-1), 81.2 (, 79.2, 71.8, 70.7, 66.8, 66.7, 17.8 (C-6); HRMS: $[M+NH_4]^+$ calcd for $C_{41}H_{41}N_3O_{11}NH_4$ 769.30793, found 769.30679.

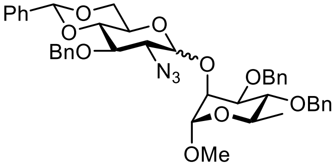
Disaccharide 42A



Title compound was obtained as colourless oil via the general procedure for Ph$_2$SO/Tf$_2$O mediated glycosylations with donor **A** and acceptor **42**. Yield: 47 mg, 59 µmol, 59%, α:β >20:1. ^{1}H NMR (400 MHz, CDCl$_3$) δ 7.52 – 7.21 (m, 25H, CH$_{\mathrm{arom}}$), 5.54 (s, 1H C*H*Ph), 4.97 – 4.88 (m, 3H, H-1', 2x C*H*H Bn), 4.86 – 4.80 (m, 2H, C*H*H Bn, CH*H* Bn), 4.74 (d, *J* = 11.9 Hz, 1H, C*H*H Bn), 4.70 – 4.66 (m, 2H, 2x CH*H* Bn), 4.65 – 4.60 (m, 2H, H-1, CH*H* Bn), 4.21 (td, *J* = 10.0, 4.9 Hz, 1H, H-5'), 4.12 (t, *J* = 9.3 Hz, 1H, H-3'), 4.02 – 3.95 (m, 2H, H-2, H-6'), 3.85 (dd, *J* = 9.2, 3.2 Hz, 1H, H-3), 3.70 – 3.57 (m, 4H, H-2', H-4', H-5, H-6'), 3.55 (t, *J* = 8.4 Hz, 1H, H-4), 3.31 (s, 3H,

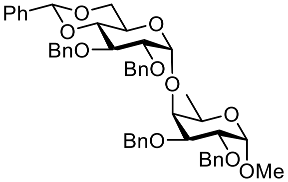
CH_3 OMe), 1.33 (d, *J* = 6.2 Hz, 3H, H-6); ^{13}C NMR (101 MHz, $CDCl_3$) δ 139.0, 138.6, 138.6, 138.5, 137.7 (C_q), 135.4, 134.3, 131.9, 131.5, 131.2, 130.4, 129.0, 128.5, 128.5, 128.5, 128.4, 128.4, 128.4, 128.3, 128.2, 128.0, 128.0, 127.8, 127.7, 127.7, 127.6, 127.6, 126.2, 126.1 (CH_{arom}), 101.3 (CHPh), 98.5 (C-1), 97.9 (C-1'), 82.5 (C-4'), 80.1 (C-4), 79.5 (C-2'), 79.0 (C-3), 78.4 (C-3'), 75.3, 75.2 (CH_2 Bn), 75.0 (C-2), 73.0, 72.2 (CH_2 Bn), 69.1 (C-6'), 68.2 (C-5), 62.8 (C-5'), 54.8 (CH_3 OMe), 18.2 (C-6); HRMS: $[M+NH_4]^+$ calcd for $C_{48}H_{52}O_{10}NH_4$ 806.38987, found 806.38837.

Disaccharide 42B



Title compound was obtained as colourless oil via the general procedure for Ph_2SO/Tf_2O mediated glycosylations with donor **B** and acceptor **42**. Yield: 56 mg, 77 µmol, 77%, α:β = 3:1. Data for the α-anomer: ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.52 – 7.23 (m, 20H, CH_{arom}), 5.56 (s, 1H, C*H*Ph), 5.02 (d, *J* = 10.9 Hz, 1H, C*H*H Bn), 4.97 – 4.89 (m, 2H, H-1', C*H*H Bn), 4.83 (d, *J* = 10.9 Hz, 1H, CH*H* Bn), 4.76 (d, *J* = 11.9 Hz, 1H, C*H*H Bn), 4.73 (d, *J* = 1.8 Hz, 1H, H-1), 4.68 – 4.62 (m, 2H, 2x CH*H* Bn), 4.31 (tt, *J* = 10.5, 5.1 Hz, 1H, H-5'), 4.19 (dd, *J* = 10.2, 9.0 Hz, 1H, H-3'), 4.07 (dd, *J* = 3.3, 1.8 Hz, 1H, H-2'), 3.97 (dd, *J* = 10.3, 4.9 Hz, 1H, H-6'), 3.87 (dd, *J* = 9.4, 3.1 Hz, 1H, H-3), 3.75 – 3.70 (m, 1H, H-4'), 3.68 – 3.60 (m, 2H, H-5, H-6'), 3.54 (t, *J* = 9.5 Hz, 1H, H-4), 3.35 (s, 3H, CH_3 OMe), 3.25 (dd, *J* = 10.1, 3.7 Hz, 1H, H-2'), 1.34 (d, *J* = 6.2 Hz, 3H, H-6); ^{13}C NMR (101 MHz, $CDCl_3$) δ 138.4, 138.2, 138.0, 137.4 (C_q), 135.3, 134.4, 131.7, 131.5, 131.1, 130.3, 130.2, 129.0, 128.5, 128.5, 128.4, 128.4, 128.3, 128.3, 128.3, 128.2, 128.1, 128.1, 127.9, 127.7, 127.6, 127.5, 127.4, 126.1, 126.0 (CH_{arom}), 101.3 (CHPh), 98.1, 98.0 (C-1, C-1'), 83.0 (C-4'), 80.0(C-4), 78.5 (C-3), 75.3 (CH_2 Bn), 75.2 (C-3'), 75.0 (CH_2 Bn), 74.6 (C-2), 72.3 (CH_2 Bn), 68.8 (C-6'), 68.1 (C-5), 62.9, 62.7 (C-2', C-5'), 54.8 (CH_3 OMe), 17.8 (C-6); diagnostic peaks for the β-anomer: ^{1}H NMR (400 MHz, $CDCl_3$) δ 5.55 (s, 1H, C*H*Ph), 4.59 (d, *J* = 7.8 Hz, 1H, H-1'), 3.32 (s, 3H, CH_3 OMe), 3.10 (qd, *J* = 7.4, 4.8 Hz, 1H), 1.31 (d, *J* = 5.8 Hz, 3H, H-6); ^{13}C NMR (101 MHz, $CDCl_3$) δ 81.4, 80.2, 74.9, 66.2; HRMS: $[M+NH_4]^+$ calcd for $C_{41}H_{45}N_3O_9NH_4$ 741.34941, found 741.34786.

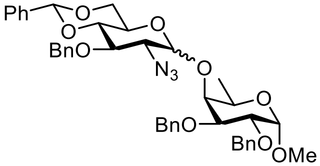
Disaccharide 43A



Title compound was obtained as colourless oil via the general procedure for Ph_2SO/Tf_2O mediated glycosylations with donor **A** and acceptor **43**. Yield: 76 mg, 98 µmol, 98%, α:β > 20:1. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.55 – 7.10 (m, 25H, CH_{arom}), 5.52 (s, 1H, C*H*Ph), 4.94 (d, *J* = 11.1 Hz, 1H, C*H*H Bn), 4.89 – 4.75 (m, 7H, H-1', 3x C*H*H Bn, 3x CH*H* Bn), 4.72 (d, *J* = 11.9 Hz, 1H, CH*H* Bn), 4.61 (d, *J* = 3.4 Hz, 1H, H-1), 4.30 (td, *J* = 10.0, 4.8 Hz, 1H, H-5'), 4.03 (t, *J* = 9.3 Hz, 1H, H-3'), 3.95 – 3.77 (m, 4H, H-2, H-3, H-5, H-6'), 3.74 (d, *J* = 2.4 Hz, 1H, H-4), 3.63 – 3.54 (m, 2H, H-2', H-4'), 3.50 (t, *J* = 10.2 Hz, 1H, H-6'), 3.36 (s, 3H, CH_3 OMe), 1.28 (d, *J* = 6.6 Hz, 3H, H-

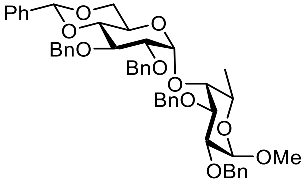
6); ^{13}C NMR (101 MHz, $CDCl_3$) δ 139.1, 138.8, 138.4, 138.3, 137.9 (C_q), 128.9, 128.7, 128.6, 128.6, 128.5, 128.5, 128.4, 128.3, 128.3, 128.2, 128.1, 128.0, 127.9, 127.9, 127.7, 127.7, 126.2 (CH_{arom}), 101.2 (CHPh), 101.0 (C-1’), 99.1 (C-1), 82.9 C-4’), 80.7 (C-4), 79.6 (C-2’), 79.1 (C-3’), 78.0 (C-2), 75.3 (CH_2 Bn), 74.4 (CH_2 Bn), 74.3 (C-3), 73.5 (CH_2 Bn), 73.1 (CH_2 Bn), 69.1 (C-6’), 66.6 (C-5), 63.2 (C-5’), 55.4 (CH_3 OMe), 16.4 (C-6); HRMS: $[M+NH_4]^+$ calcd for $C_{48}H_{52}O_{10}NH_4$ 806.38987, found 806.38813.

Disaccharide 43B



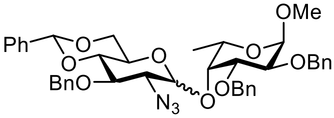
Title compound was obtained as colourless oil via the general procedure for Ph_2SO/Tf_2O mediated glycosylations with donor **B** and acceptor **43**. Yield: 73 mg, 100 µmol, 100%, α:β = 1.3:1. Data reported for a 1:1 mixture of anomers: ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.57 – 7.19 (m, 40H), 5.60 – 5.48 (m, 2H, C*H*Phαβ), 5.01 – 4.88 (m, 4H), 4.88 – 4.74 (m, 8H), 4.72 – 4.62 (m, 3H), 4.57 (d, *J* = 3.7 Hz, 1H, H-1β), 4.38 (td, *J* = 10.0, 4.9 Hz, 1H, H-5’α), 4.25 (dd, *J* = 10.5, 4.9 Hz, 1H, H-6’β), 4.09 (dd, *J* = 9.3, 3.6 Hz, 1H, H-2β), 3.99 (t, *J* = 9.5 Hz, 1H), 3.94 – 3.80 (m, 8H), 3.76 – 3.62 (m, 3H), 3.54 (t, *J* = 10.3 Hz, 1H), 3.50 – 3.42 (m, 3H, CH_3 OMeα), 3.36 (s, 3H, CH_3 OMeβ), 3.35 (s, 3H), 3.23 (td, *J* = 9.7, 5.0 Hz, 1H,), 3.09 (t, *J* = 6.3 Hz, 1H), 1.33 (d, *J* = 6.6 Hz, 3H, H-6α), 1.16 (d, *J* = 6.4 Hz, 3H, H-6β); ^{13}C NMR (101 MHz, $CDCl_3$) δ 139.0, 138.6, 138.6, 138.2, 138.0, 137.6, 137.2, 135.3, 134.4, 132.0, 131.5, 131.3, 130.3, 130.2, 129.1, 128.9, 128.5, 128.5, 128.5, 128.4, 128.4, 128.4, 128.3, 128.3, 128.3, 128.2, 128.2, 128.2, 128.1, 127.9, 127.8, 127.7, 127.6, 127.5, 127.5, 127.2, 126.1, 126.0, 125.3, 102.0 (C-1’β), 101.3 (CHPhβ), 101.2 (CHPhα), 99.7 (C-1’α), 99.0 (C-1β), 98.7 (C-1α), 82.9, 81.6, 79.4, 79.0, 78.5, 77.3, 76.9, 76.7, 76.3, 75.2, 74.9, 74.6, 73.7, 73.6, 73.3, 73.2, 68.8, 68.6, 66.4, 66.3, 65.9, 65.4, 63.8, 62.9, 55.4, 55.3, 16.6; HRMS: $[M+NH_4]^+$ calcd for $C_{41}H_{45}N_3O_9NH_4$ 741.34941, found 741.34811.

Disaccharide 44A



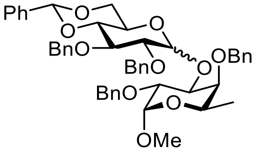
Title compound was obtained as colourless oil via the general procedure for Ph_2SO/Tf_2O mediated glycosylations with donor **A** and acceptor **44.** Yield: 67 mg, 85 µmol, 85%, α:β = 14:1. Data for α-anomer: ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.63 – 7.14 (m, 25H, CH_{arom}), 5.82 (d, *J* = 4.1 Hz, 1H, H-1’), 5.54 (s, 1H, C*H*Ph), 4.96 – 4.64 (m, 8H, H-1, 3x C*H*H Bn, 2x CH*H* Bn), 4.56 (d, *J* = 12.0 Hz, 1H, C*H*H Bn), 4.48 (d, *J* = 12.3 Hz, 1H, CH*H* Bn), 4.36 (d, *J* = 12.0 Hz, 1H, CH*H* Bn), 4.24 (dd, *J* = 10.3, 5.0 Hz, 1H, H-6’), 4.14 – 3.93 (m, 6H, H-2, H-3, H-4, H-5, H-3’, H-5’), 3.72 (t, *J* = 10.3 Hz, 1H, H-6’), 3.64 – 3.56 (t, *J* = 9.8 Hz, 1H, H-4’), 3.51 (dd, *J* = 9.5, 4.1 Hz, 1H, H-2’), 3.36 (s, 3H, CH_3 OMe), 1.31 (d, *J* = 6.6 Hz, 3H, H-6). ^{13}C NMR (101 MHz, $CDCl_3$) δ 139.1, 138.8, 138.6, 138.5, 137.6 (C_q), 129.0, 128.6, 128.6, 128.4, 128.4, 128.3, 128.3, 128.2, 128.2, 128.2, 128.1, 128.0, 128.0, 128.0, 127.9, 127.9, 127.7, 127.5, 127.4, 127.4, 126.1 (CH_{arom}), 101.2 (CHPh), 98.8 (C-1), 97.3 (C-1'), 82.1 (C-4'), 79.8 (C-2), 79.2 (C-2'), 78.2 (C-3'), 76.8 (C-3), 75.4 (CH_2 Bn), 74.7 (C-4), 74.2 (CH_2 Bn), 73.4 (CH_2 Bn), 72.2 (CH_2 Bn), 69.0 (C-6'), 66.2 (C-5), 63.0 (C-5'), 55.4 (CH_3 OMe), 17.8 (C-6). Diagnostic peaks for β-anomer: ^{1}H NMR (400 MHz, $CDCl_3$) δ 5.76 (s, 1H, C*H*Ph), 3.40 (s, 1H, CH_3 OMe), 1.40 (d, *J* = 6.4 Hz, 3H, H-6). ^{13}C NMR (101 MHz, $CDCl_3$) δ 105.38 (C-1'), 101.29 (CHPh), 97.54 (C-1), 82.94, 81.98, 81.38, 79.41, 79.06, 78.10, 75.43 (CH_2 Bn), 74.85 (CH_2 Bn), 74.09, 73.95 (CH_2 Bn), 72.09 (CH_2 Bn), 70.38, 68.94 (C-6'), 66.42, 55.37 (CH_3 OMe), 17.86 (C-6); HRMS: $[M+NH_4]^+$ calcd for $C_{48}H_{52}O_{10}NH_4$ 806.38987, found 806.38843.

Disaccharide 44B



Title compound was obtained as colourless oil via the general procedure for Ph_2SO/Tf_2O mediated glycosylations with donor **B** and acceptor **44**. Yield: 73 mg, 100 μmol, 100%, α:β = 3:1. Data for the α-anomer: ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.50 – 7.26 (m, 20H, CH_{arom}), 5.70 (d, *J* = 4.0 Hz, 1H, H-1'), 5.57 (s, 1H, C*H*Ph), 4.96 (d, *J* = 10.9 Hz, 1H, C*H*H Bn), 4.90 – 4.84 (m, 2H, C*H*H Bn, CH*H* Bn), 4.80 (d, *J* = 10.9 Hz, 1H, CH*H* Bn), 4.74 (d, *J* = 9.8 Hz, 1H, C*H*H Bn), 4.68 (d, *J* = 11.3 Hz, 1H, CH*H* Bn), 4.64 (d, *J* = 3.7 Hz, 1H, H-1), 4.27 – 4.14 (m, 2H, H-3, H-6'), 4.07 (t, *J* = 9.6 Hz, 1H, H-3'), 4.04 – 3.98 (m, 1H, H-5'), 3.97 – 3.91 (m, 3H, H-2, H-4, H-5), 3.77 – 3.65 (m, 2H, H-4', H-6'), 3.44 (dd, *J* = 10.1, 4.1 Hz, 1H, H-2'), 3.38 (s, 3H, CH_3 OMe), 1.26 (d, *J* = 6.3 Hz, 3H, CH_3 OMe); ^{13}C NMR (101 MHz, $CDCl_3$) δ 138.7, 138.6, 138.1, 137.3 (C_q), 129.1, 128.5, 128.5, 128.5, 128.4, 128.4, 128.4, 128.4, 128.2, 128.2, 128.2, 128.1, 127.9, 127.9, 127.6, 127.4, 126.1, 126.1 (CH_{arom}), 101.4 (CHPh), 99.1 (C-1), 98.0 (C-1'), 82.7 (C-4'), 79.3 (C-2), 76.4 (C-3'), 75.8, 75.7 (C-3, C-4), 75.2, 73.8, 73.6 (CH_2 Bn), 68.8 (C-6'), 65.9 (C-5), 63.7 (C-2'), 63.1 (C-5'), 55.5 (CH_3 OMe), 17.5 (C-6); diagnostic peaks for the β-anomer: ^{1}H NMR (400 MHz, $CDCl_3$) δ 5.52 (s, 1H,C*H*Ph), 4.49 (d, *J* = 7.5 Hz, 1H, H-1'), 1.35 (d, *J* = 6.7 Hz, 3H, H-6); ^{13}C NMR (101 MHz, $CDCl_3$) δ 102.8 (C-1'), 101.4 (CHPh), 98.8 (C-1), 81.4, 79.5, 78.0, 75.9, 74.9, 72.7, 68.6, 67.0, 66.5, 65.7, 16.8 (C-6); HRMS: $[M+NH_4]^+$ calcd for $C_{41}H_{45}N_3O_9NH_4$ 741.34941, found 741.34831.

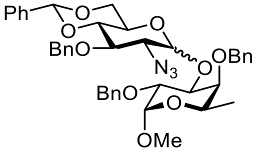
Disaccharide 45A



Title compound was obtained as colourless oil via the general procedure for Ph_2SO/Tf_2O mediated glycosylations with donor **A** and acceptor **45**. Yield: 79 mg, 100 μmol, 100%, α:β = 3.2:1. Data for the α-anomer: ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.51 – 7.14 (m, 25H, CH_{arom}), 5.61 (d, *J* = 3.7 Hz, 1H, H-1'), 5.56 (s, 1H, C*H*Ph), 5.02 (d, *J* = 11.2 Hz, 1H, C*H*H Bn), 4.85 (d, *J* = 11.4 Hz, 1H, C*H*H Bn), 4.80 – 4.73 (m, 2H, C*H*H Bn, CH*H* Bn), 4.70 (dd, *J* = 11.6, 4.4 Hz, 2H, 2x CH*H* Bn), 4.61 (d, *J* = 12.2 Hz, 1H, C*H*H Bn), 4.57 – 4.52 (m, 2H, H-1, CH*H* Bn), 4.31 – 4.23 (m, 2H, H-3, H-6'), 4.11 (dd, *J* = 10.1, 3.6 Hz, 1H, H-2), 4.07 (t, *J* = 9.3 Hz, 1H, H-3'), 3.96 (td, *J* =

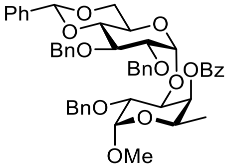
10.4, 5.2 Hz, 1H, H-5’), 3.90 (qd, *J* = 6.3, 1.2 Hz, 1H, H-5), 3.75 (t, *J* = 10.4 Hz, 1H, H-6’), 3.65 (t, *J* = 9.4 Hz, 1H, H-4’), 3.63 – 3.60 (m, 2H, H-2’, H-4), 3.30 (s, 3H, CH$_3$ OMe), 1.17 (d, *J* = 6.5 Hz, 3H, H-6); ^{13}C NMR (126 MHz, CDCl$_3$) δ 138.6, 138.5, 138.5, 138.4, 137.5 (C$_q$), 128.7, 128.4, 128.4, 128.4, 128.3, 128.3, 128.2, 128.2, 127.8, 127.8, 127.8, 127.6, 127.5, 127.5, 126.1 (CH$_{arom}$), 101.3 (CHPh), 98.4, 98.3 (C-1, C-1’), 82.2 (C-4’), 80.0 (C-4), 79.1 (C-2’), 77.9 (C-3’), 77.4 (C-2), 75.5, 75.1 (CH$_2$ Bn), 74.3 (C-3), 72.7, 72.5 (CH$_2$ Bn), 69.2 (C-6’), 66.3 (C-5), 63.6 (C-5’), 55.4 (CH$_3$ OMe), 16.7 (C-6); diagnostic peaks for the β-anomer: ^{1}H NMR (500 MHz, CDCl$_3$) δ 4.98 – 4.94 (m, 2H, 2x C*H*H Bn), 4.90 (d, *J* = 11.9 Hz, 1H, C*H* Bn), 3.56 – 3.51 (m, 2H), 3.47 – 3.40 (m, 1H, H-5’), 1.02 (d, *J* = 6.5 Hz, 3H, H-6); ^{13}C NMR (126 MHz, CDCl$_3$) δ 101.8 (C-1’), 101.2 (CHPh), 98.8 (C-1), 83.0, 81.6, 78.0, 77.1, 75.0, 74.7, 73.7, 69.1, 66.0, 16.6 (C-6); HRMS: [M+NH$_4$]$^+$ calcd for $C_{48}H_{52}O_{10}NH_4$ 806.38987, found 806.38824.

Disaccharide 45B



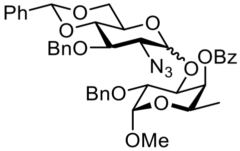
Title compound was obtained as colourless oil via the general procedure for Ph$_2$SO/Tf$_2$O mediated glycosylations with donor **B** and acceptor **45.** Yield: 64 mg, 88 μmol, 88%, α:β = 1:2. Data reported for a 1:2 mixture of anomers: ^{1}H NMR (500 MHz, CDCl$_3$) δ 7.52 – 7.23 (m, 60H, CH$_{arom}$), 5.60 (s, 1H, C*H*Phα), 5.58 (s, 2H, C*H*Phβ), 5.51 (d, *J* = 3.7 Hz, 1H, H-1’α), 5.04 (d, *J* = 11.5 Hz, 2H), 4.97 (d, *J* = 11.1 Hz, 2H), 4.95 – 4.90 (m, 2H), 4.86 – 4.77 (m, 6H), 4.68 – 4.61 (m, 6H), 4.58 – 4.53 (m, 5H, H-1α, H-1β, H-1’β), 4.30 – 4.20 (m, 3H), 4.18 (dd, *J* = 10.8, 2.8 Hz, 2H), 4.13 (dd, *J* = 10.2, 3.5 Hz, 1H), 4.05 (dd, *J* = 10.1, 9.0 Hz, 1H), 3.97 (dd, *J* = 10.1, 3.9 Hz, 3H), 3.90 – 3.83 (m, 3H), 3.80 – 3.72 (m, 8H), 3.68 (t, *J* = 9.2 Hz, 2H), 3.58 (dd, *J* = 2.8, 1.2 Hz, 1H), 3.50 (dd, *J* = 9.3, 8.1 Hz, 2H, H-2’β), 3.39 – 3.33 (m, 2H), 3.31 (d, *J* = 10.4 Hz, 10H, H-2’α, CH$_3$ OMeαβ), 1.14 – 1.10 (m, 9H, H-6αβ); ^{13}C NMR (126 MHz, CDCl$_3$) δ 138.8, 138.6, 138.3, 138.2, 137.8, 137.7, 137.3, 137.2, 135.3, 134.2, 132.0, 131.4, 131.3, 130.3, 129.2, 128.7, 128.5, 128.5, 128.4, 128.4, 128.4, 128.3, 128.3, 128.2, 128.0, 128.0, 128.0, 128.0, 127.9, 127.8, 127.7, 126.1, 126.0, 101.8 (C-1’β), 101.5 (CHPhα), 101.3 (CHPhβ), 99.5 (C-1’α), 98.8 (C-1β), 98.2 (C-1α), 83.0, 81.8, 79.8, 79.8, 79.8, 78.2, 77.6, 75.5, 75.4, 75.2, 75.1, 75.0, 74.9, 73.7, 73.3, 69.0, 68.8, 67.1, 66.4, 66.2, 66.0, 63.6, 62.8, 55.4 (CH$_3$ OMeα), 55.4 (CH$_3$ OMeβ), 16.7 (C-6α), 16.6 (C-6β); HRMS: [M+NH$_4$]$^+$ calcd for 741.34941, found 741.34841.

Disaccharide 46A



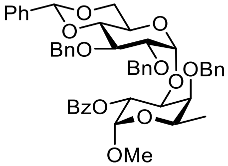
Title compound was obtained as colourless oil via the general procedure for Ph$_2$SO/Tf$_2$O mediated glycosylations with donor **A** and acceptor **46**. Yield: 80 mg, 100 μmol, 100%, α:β >20:1. ^{1}H NMR (500 MHz, CDCl$_3$) δ 8.11 – 8.03 (m, 2H, CH$_{arom}$), 7.61 – 7.56 (m, 1H, CH$_{arom}$), 7.46 – 7.40 (m, 4H, CH$_{arom}$), 7.38 – 7.33 (m, 3H, CH$_{arom}$), 7.32 – 7.28 (m, 5H, CH$_{arom}$), 7.25 – 7.16 (m, 13H, CH_{arom}), 5.50 (dd, *J* = 3.4, 1.2 Hz, 1H, H-4), 5.46 (s, 1H, C*H*Ph), 5.28 (d, *J* = 3.8 Hz, 1H, H-1'), 4.74 – 4.70 (m, 2H, 2x C*H*H Bn), 4.69 – 4.63 (m, 3H, C*H*H Bn, 2x CH*H* Bn), 4.62 – 4.59 (m, 2H, H-1, CH*H* Bn), 4.33 – 4.26 (m, 2H, H-3, H-6'), 4.17 – 4.09 (m, 1H, H-5), 3.99 (dd, *J* = 10.1, 3.6 Hz, 1H, H-2), 3.91 (td, *J* = 9.9, 4.8 Hz, 1H, H-5'), 3.85 (t, *J* = 9.4 Hz, 1H, H-3'), 3.62 (t, *J* = 10.2 Hz, 1H, H-6'), 3.56 – 3.46 (m, 2H, H-2', H-4'), 3.40 (s, 3H, CH_3 OMe), 1.16 (d, *J* = 6.6 Hz, 3H, H-6); ^{13}C NMR (126 MHz, $CDCl_3$) δ 166.4 (C=O), 138.8, 138.5, 138.4, 137.9 (C_q), 133.2 (CH_{arom}), 130.2 (C_q), 130.1, 128.9, 128.5, 128.5, 128.5, 128.3, 128.3, 128.2, 128.2, 128.0, 127.9, 127.6, 127.5, 126.5 (CH_{arom}), 101.4 (CHPh), 99.9 (C-1'), 98.9 (C-1), 82.1 (C-4'), 78.9 (C-2'), 78.1 (C-3'), 75.4 (C-3), 75.2 (C-2), 75.1 (CH_2 Bn), 74.4 (C-4), 73.3, 72.6 (CH_2 Bn), 69.1 (C-6'), 65.1 (C-5), 63.4 (C-5'), 55.6 (CH_3 OMe), 16.4 (C-6); HRMS: $[M+NH_4]^+$ calcd for $C_{48}H_{50}O_{11}NH_4$ 820.36914, found 820.36771.

Disaccharide 46B



Title compound was obtained as colourless oil via the general procedure for Ph_2SO/Tf_2O mediated glycosylations with donor **A** and acceptor **46**. Yield: 74 mg, 100 µmol, 100%, α:β = 2:1. Data reported for a 2:1 mixture of anomers: ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.13 – 8.09 (m, 4H), 8.08 – 8.04 (m, 2H), 7.65 – 7.19 (m, 54H), 5.62 (dd, *J* = 3.4, 1.3 Hz, 1H, H-4β), 5.55 (s, 1H, C*H*Phβ), 5.53 (s, 2H, C*H*Phα), 5.51 (dd, *J* = 3.6, 1.3 Hz, 2H, H-4α), 5.36 (d, *J* = 3.6 Hz, 2H, H-1'α), 4.90 – 4.82 (m, 4H), 4.78 (d, *J* = 11.2 Hz, 2H), 4.75 – 4.67 (m, 6H), 4.63 (d, *J* = 11.8 Hz, 2H), 4.57 (d, *J* = 7.9 Hz, 1H, H-1'β), 4.50 (d, *J* = 11.0 Hz, 2H), 4.38 – 4.26 (m, 5H), 4.18 – 4.07 (m, 5H), 4.05 (dd, *J* = 10.1, 3.5 Hz, 2H), 3.96 (dd, *J* = 10.2, 3.6 Hz, 1H), 3.84 (dd, *J* = 10.2, 9.0 Hz, 2H), 3.76 (t, *J* = 10.3 Hz, 1H), 3.69 (td, *J* = 9.8, 4.2 Hz, 3H), 3.61 (td, *J* = 9.2, 3.6 Hz, 3H), 3.44 – 3.35 (m, 10H), 3.32 (dd, *J* = 9.3, 8.0 Hz, 1H, H-2'β), 3.19 (dd, *J* = 10.2, 3.6 Hz, 2H, H-2'α), 1.21 – 1.16 (m, 9H, H-6αβ); ^{13}C NMR (101 MHz, $CDCl_3$) δ 166.4, 166.3 (C=O), 138.4, 138.1, 138.0, 137.9, 137.7, 137.2, 135.4, 134.4, 133.3, 131.8, 131.7, 131.5, 131.3, 131.1, 130.3, 130.3, 130.1, 130.0, 129.9, 129.7, 129.1, 129.0, 128.6, 128.6, 128.5, 128.5, 128.4, 128.4, 128.4, 128.3, 128.3, 128.3, 128.2, 128.1, 128.1, 127.9, 127.8, 126.4, 126.1, 126.1, 101.6 (CHPhα), 101.3 (CHPhβ), 99.9 (C-1'α), 99.2 (C-1β), 98.5 (C-1'β), 98.4 (C-1α), 82.9, 76.9, 75.5, 75.0, 73.7, 73.3, 73.3, 68.9, 64.9, 64.8, 63.4, 62.9, 55.6, 16.3, 16.2; HRMS: $[M+NH_4]^+$ calcd for $C_{41}H_{43}N_3O_{10}$ 755.32867, found 755.32722.

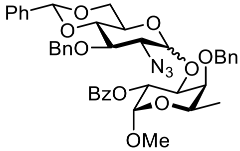
Disaccharide 47A



Title compound was obtained as colourless oil via the general procedure for Ph_2SO/Tf_2O mediated glycosylations with donor **A** and acceptor **47.** Yield: 80 mg, 100 µmol, 100%, α:β >20:1. ^{1}H NMR (500 MHz, $CDCl_3$) δ 8.00 – 7.96 (m, 2H, CH_{arom}), 7.73 – 7.63 (m, 3H, CH_{arom}), 7.59 – 7.51 (m, 2H, CH_{arom}), 7.46 (ddt, *J* = 7.0, 4.8, 2.2 Hz, 5H, CH_{arom}), 7.41 – 7.34 (m, 5H, CH_{arom}), 7.29

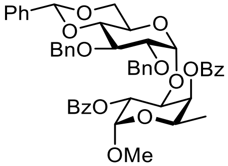
– 7.19 (m, 9H, CH$_{arom}$), 7.18 – 7.13 (m, 6H, CH$_{arom}$), 7.02 – 6.95 (m, 2H, CH$_{arom}$), 5.65 (dd, *J* = 10.4, 3.7 Hz, 1H, H-2), 5.55 (s, 1H, C*H*Ph), 5.46 (d, *J* = 3.7 Hz, 1H, H-1'), 5.08 (d, *J* = 3.7 Hz, 1H, H-1), 5.03 (d, *J* = 11.3 Hz, 1H, C*H*H Bn 4.74 – 4.69 (m, 2H, C*H*H Bn, CH*H* Bn), 4.64 (d, *J* = 11.4 Hz, 1H, CH*H* Bn), 4.53 (dd, *J* = 10.4, 2.9 Hz, 1H, H-3), 4.35 – 4.26 (m, 3H, H-6', CH$_2$ Bn), 4.05 – 3.91 (m, 3H, H-3', H-5, H-5'), 3.76 (t, *J* = 10.4 Hz, 1H, H-6'), 3.72 (dd, *J* = 3.0, 1.2 Hz, 1H, H-4), 3.62 (t, *J* = 9.5 Hz, 1H, H-4'), 3.53 (dd, *J* = 9.3, 3.7 Hz, 1H, H-2'), 3.33 (s, 3H, CH$_3$ OMe), 1.25 (d, *J* = 6.5 Hz, 3H, H-6); ^{13}C NMR (126 MHz, CDCl$_3$) δ 165.7 (C=O), 138.5, 138.3, 137.9, 137.4 (C$_q$), 135.3, 134.6, 133.2, 131.7, 131.7, 131.6, 131.0, 130.4, 130.3 (CH$_{arom}$), 130.0 (C$_q$), 129.8, 129.0, 128.6, 128.6, 128.4, 128.4, 128.3, 128.3, 128.2, 128.2, 128.2, 127.8, 127.6, 127.4, 127.3, 126.1, 124.9 (CH$_{arom}$), 101.4 (CHPh), 98.0 (C-1'), 97.4 (C-1), 81.9 (C-4'), 79.5 (C-4), 79.1 (C-2'), 77.6 (C-3'), 75.6, 75.1 (CH$_2$ Bn), 73.2 (C-3), 72.9 (C-2), 72.1 (CH$_2$ Bn), 69.1 (C-6'), 66.5 (C-5), 63.8 (C-5'), 55.5 (CH$_3$ OMe), 16.7 (C-6); HRMS: [M+NH$_4$]$^+$ calcd for $C_{48}H_{50}O_{11}NH_4$ 820.36914, found 820.36792.

Disaccharide 47B



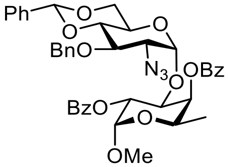
Title compound was obtained as white foam via the general procedure for Ph$_2$SO/Tf$_2$O mediated glycosylations with donor **A** and acceptor **47**. Yield: 68 mg, 92 µmol, 92%, α:β = 9:1. Data for the α-anomer: ^{1}H NMR (500 MHz, CDCl$_3$) δ 8.09 (dt, *J* = 8.4, 1.8 Hz, 2H, CH$_{arom}$), 7.73 – 7.69 (m, 2H, CH$_{arom}$), 7.68 – 7.63 (m, 1H, CH$_{arom}$), 7.61 – 7.52 (m, 2H, CH$_{arom}$), 7.48 – 7.41 (m, 7H, CH$_{arom}$), 7.41 – 7.35 (m, 3H, CH$_{arom}$), 7.33 – 7.19 (m, 9H, CH$_{arom}$), 5.70 (dd, *J* = 10.5, 3.7 Hz, 1H, H-2), 5.57 (s, 1H, C*H*Ph), 5.29 (d, *J* = 3.8 Hz, 1H, H-1'), 5.04 (d, *J* = 3.7 Hz, 1H, H-1), 4.95 (d, *J* = 11.8 Hz, 1H, C*H*H Bn), 4.82 (d, *J* = 11.1 Hz, 1H, C*H*H Bn), 4.74 (d, *J* = 11.6 Hz, 1H, CH*H* Bn), 4.65 (d, *J* = 11.1 Hz, 1H, CH*H* Bn), 4.40 (dd, *J* = 10.6, 2.8 Hz, 1H, H-3), 4.29 (dd, *J* = 10.4, 4.8 Hz, 1H, H-6'), 4.06 – 3.95 (m, 2H, H-5, H-5'), 3.90 (t, *J* = 9.6 Hz, 1H, H-3'), 3.77 (t, *J* = 10.4 Hz, 1H, H-6'), 3.70 (d, *J* = 2.8 Hz, 1H, H-4), 3.67 (t, *J* = 9.3 Hz, 1H, H-3'), 3.35 (s, 3H, CH$_3$ OMe), 3.20 (dd, *J* = 10.0, 3.7 Hz, 1H, H-2'), 1.25 (d, *J* = 6.5 Hz, 3H, H-6); ^{13}C NMR (126 MHz, CDCl$_3$) δ 165.9 (C=O), 138.1, 137.7, 137.2 (C$_q$), 135.3, 134.5, 133.2, 131.7, 131.6, 131.1, 130.3, 130.3 (CH$_{arom}$), 130.0 (C$_q$), 129.9, 129.7, 129.2, 128.6, 128.5, 128.5, 128.4, 128.4, 128.3, 128.3, 127.9, 127.9, 126.1, 126.0 (CH$_{arom}$), 101.6 (CHPh), 100.1 (C-1'), 97.6 (C-1), 82.8 (C-4'), 80.2 (C-4), 75.7 (C-3), 75.5 (CH$_2$ Bn), 75.4 (C-3'), 74.9 (CH$_2$ Bn), 71.8 (C-2), 68.9 (C-6'), 66.6 (C-5'), 63.8 (C-5), 62.8 (C-2'), 55.5 (CH$_3$ OMe), 16.8 (C-6); diagnostic peaks for the β-anomer: ^{1}H NMR (500 MHz, CDCl$_3$) δ 5.42 (s, 1H, C*H*Ph), 5.00 (d, *J* = 3.8 Hz, 1H, H-1), 4.69 (d, *J* = 11.6 Hz, 1H, C*H*H Bn), 3.58 (dd, *J* = 9.9, 4.5 Hz, 1H), 3.46 – 3.41 (m, 1H), 1.20 (d, *J* = 6.5 Hz, 3H, H-6); ^{13}C NMR (126 MHz, CDCl$_3$) δ 102.6 (C-1'), 101.2 (CHPh), 97.8 (C-1), 81.5, 79.7, 79.6, 78.5, 75.4, 74.9, 70.2, 66.8, 66.3, 16.6 (C-6); HRMS: [M+NH$_4$]$^+$ calcd for $C_{41}H_{43}N_3O_{10}NH_4$ 755.32867, found 755.32747.

Disaccharide 48A



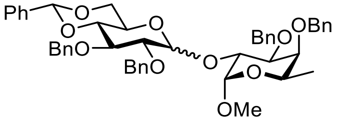
Title compound was obtained as colourless oil via the general procedure for Ph$_2$SO/Tf$_2$O mediated glycosylations with donor **A** and acceptor **48**. Yield: 82 mg, 100 μmol, 100%, α:β >20:1. ^{1}H NMR (400 MHz, CDCl$_3$) δ 8.21 – 8.16 (m, 2H, CH$_{\text{arom}}$), 8.10 – 8.03 (m, 2H, CH$_{\text{arom}}$), 7.77 – 7.65 (m, 2H, CH$_{\text{arom}}$), 7.60 – 7.53 (m, 2H, CH$_{\text{arom}}$), 7.52 – 7.42 (m, 4H, CH$_{\text{arom}}$), 7.40 – 7.32 (m, 8H, CH$_{\text{arom}}$), 7.21 – 7.11 (m, 8H, CH$_{\text{arom}}$), 6.99 – 6.94 (m, 2H, CH$_{\text{arom}}$), 5.64 – 5.58 (m, 2H, H-2, H-4), 5.40 (s, 1H, C*H*Ph), 5.17 (d, *J* = 3.7 Hz, 1H, H-1), 5.07 (d, *J* = 3.6 Hz, 1H, H-1'), 4.57 – 4.47 (m, 2H, H-3, C*H*H Bn), 4.37 (d, *J* = 11.3 Hz, 1H, CH*H* Bn), 4.31 – 4.19 (m, 3H, H-5, CH$_2$ Bn), 4.12 (dd, *J* = 10.1, 4.8 Hz, 1H, H-6'), 3.86 (td, *J* = 9.9, 4.8 Hz, 1H, H-5'), 3.73 (t, *J* = 9.3 Hz, 1H, H-3'), 3.55 (t, *J* = 10.2 Hz, 1H, H-6'), 3.47 – 3.39 (m, 4H, H-4', CH$_3$ OMe), 3.35 (dd, *J* = 9.4, 3.6 Hz, 1H, H-2'), 1.26 (d, *J* = 6.6 Hz, 3H, H-6); ^{13}C NMR (101 MHz, CDCl$_3$) δ 166.6, 166.0 (C=O), 138.9, 138.3, 137.8 (C$_q$), 134.5, 133.4, 133.2, 131.6, 131.2, 130.2, 130.1, 130.0, 129.9, 128.9, 128.7, 128.5, 128.3, 128.2, 128.2, 128.0, 127.5, 126.4 (CH$_{\text{arom}}$), 101.5 (CHPh), 99.2 (C-1'), 97.8 (C-1), 81.9 (C-4'), 78.9 (C-2'), 78.2 (C-3'), 75.2 (CH$_2$ Bn), 73.5, 73.4 (C-3, C-4), 72.4 (CH$_2$ Bn), 71.4 (C-2), 69.0 (C-6), 65.2 (C-5), 63.6 (C-5'), 55.8 (CH$_3$ OMe), 16.5 (C-6); HRMS: [M+NH$_4$]$^+$ calcd for C$_{48}$H$_{48}$O$_{12}$NH$_4$ 834.34840, found 834.34735.

Disaccharide 48B



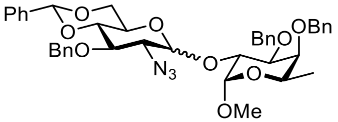
Title compound was obtained as colourless oil via the general procedure for Ph$_2$SO/Tf$_2$O mediated glycosylations with donor **B** and acceptor **48**. Yield: 75 mg, 100 μmol, 100%, α:β >20:1. ^{1}H NMR (400 MHz, CDCl$_3$) δ 8.22 – 8.17 (m, 2H, CH$_{\text{arom}}$), 8.14 – 8.08 (m, 2H, CH$_{\text{arom}}$), 7.74 – 7.65 (m, 3H, CH$_{\text{arom}}$), 7.62 – 7.53 (m, 3H, CH$_{\text{arom}}$), 7.50 – 7.44 (m, 6H, CH$_{\text{arom}}$), 7.41 – 7.35 (m, 5H, CH$_{\text{arom}}$), 7.20 – 7.11 (m, 5H, CH$_{\text{arom}}$), 5.65 (dd, *J* = 3.5, 1.3 Hz, 1H, H-4), 5.62 (dd, *J* = 10.5, 3.6 Hz, 1H, H-2), 5.46 (s, 1H, C*H*Ph), 5.19 – 5.10 (m, 2H, H-1, H-1'), 4.65 (d, *J* = 10.9 Hz, 1H, C*H*H Bn), 4.49 (dd, *J* = 10.5, 3.5 Hz, 1H, H-3), 4.38 (d, *J* = 10.9 Hz, 1H, CH*H* Bn), 4.34 – 4.21 (m, 2H, H-5, H-6'), 3.93 (td, *J* = 9.9, 4.8 Hz, 1H, H-5'), 3.70 (dd, *J* = 10.1, 9.1 Hz, 1H, H-3'), 3.65 (t, *J* = 10.2 Hz, 1H, H-6'), 3.54 (t, *J* = 9.3 Hz, 1H, H-4'), 3.42 (s, 3H, CH$_3$ OMe), 3.15 (dd, *J* = 10.0, 3.7 Hz, 1H, H-2'), 1.26 (d, *J* = 6.5 Hz, 3H, H-6); ^{13}C NMR (101 MHz, CDCl$_3$) δ 166.6, 166.1 (C=O), 137.8, 137.6 (C$_q$), 135.4, 134.5, 133.5, 133.3, 131.7, 131.6, 131.1, 130.4, 130.3, 130.2, 129.9, 129.8, 129.6, 129.1 (CH$_{\text{arom}}$), 128.7 (C$_q$), 128.6 (CH$_{\text{arom}}$), 128.4 (C$_q$), 128.4, 128.3, 128.2, 128.2, 127.8, 126.4 (CH$_{\text{arom}}$), 101.6 (CHPh), 100.8 (C-1'), 97.7 (C-1), 82.6 (C-4'), 75.8 (C-3'), 75.0 (CH$_2$ Bn), 74.7 (C-3), 73.7 (C-4), 71.1 (C-2), 68.8 (C-6'), 65.2 (C-5), 63.6 (C-5'), 62.9 (C-2'), 55.7 (CH$_3$ OMe), 16.4 (C-6); HRMS: [M+NH$_4$]$^+$ calcd for C$_{41}$H$_{41}$N$_3$O$_{11}$ 769.30793, found 769.30661

Disaccharide 49A



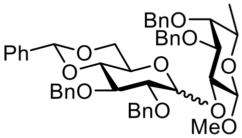
Title compound was obtained as colourless oil via the general procedure for Ph$_2$SO/Tf$_2$O mediated glycosylations with donor **A** and acceptor **49** Yield: 70 mg, 89 μmol, 89%, α:β = 1.3:1. Data reported for a 1:1 mixture of anomers: ^{1}H NMR (400 MHz, CDCl$_3$) δ 7.67 (h, *J* = 7.0 Hz, 3H), 7.56 – 7.44 (m, 5H), 7.44 – 7.21 (m, 40H), 7.18 (dt, *J* = 4.7, 1.7 Hz, 2H), 5.55 (s, 1H, C*H*Phα), 5.52 (s, 1H, C*H*Phβ), 5.05 – 4.98 (m, 5H), 4.97 – 4.85 (m, 5H), 4.82 (d, *J* = 3.6 Hz, 1H, H-1α), 4.81 – 4.75 (m, 2H), 4.72 – 4.63 (m, 7H), 4.44 (dd, *J* = 10.1, 3.5 Hz, 1H, H-3β), 4.22 – 4.16 (m, 2H), 4.15 – 4.09 (m, 2H), 4.05 (dt, *J* = 10.0, 5.0 Hz, 1H), 3.95 – 3.90 (m, 2H), 3.88 – 3.80 (m, 2H), 3.76 (t, *J* = 8.9 Hz, 1H), 3.73 – 3.56 (m, 6H), 3.55 – 3.48 (m, 2H, H-2'αβ), 3.37 (s, 4H), 3.27 (s, 3H), 1.14 (dd, *J* = 6.6, 4.0 Hz, 6H, H-6αβ); ^{13}C NMR (101 MHz, CDCl$_3$) δ 139.5, 139.4, 138.9, 138.7, 138.7, 138.6, 138.3, 137.6, 137.5, 135.4, 134.6, 131.8, 131.7, 131.2, 130.4, 130.3, 129.0, 128.6, 128.5, 128.4, 128.4, 128.4, 128.3, 128.3, 128.3, 128.1, 128.0, 127.9, 127.9, 127.8, 127.7, 127.7, 127.6, 127.4, 127.4, 127.4, 127.3, 127.3, 126.2, 126.1, 124.9, 102.4 (C-1'β), 101.4 (CHPhα), 101.1 (CHPhβ), 100.8 (C-1'α), 99.8 (C-1α), 97.9 (C-1β), 82.4, 82.3, 81.6, 81.1, 79.3, 79.2, 78.5, 78.3, 78.2, 77.9, 77.6, 75.8, 75.2, 75.2, 75.2, 75.1, 75.0, 73.7, 73.3, 73.0, 69.3, 68.9, 66.3, 66.1, 66.1, 63.0, 55.2, 55.2, 16.7, 16.6; HRMS: [M+NH$_4$]$^+$ calcd for C$_{48}$H$_{52}$O$_{10}$NH$_4$ 806.38987, found 806.38802.

Disaccharide 49B



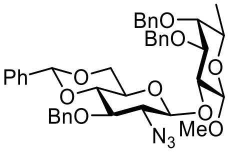
Title compound was obtained as colourless oil via the general procedure for Ph$_2$SO/Tf$_2$O mediated glycosylations with donor **B** and acceptor **49**. Yield: 69 mg, 95 μmol, 95%, α:β = 1:5.5. Data for the β-anomer: ^{1}H NMR (400 MHz, CDCl$_3$) δ 7.50 – 7.25 (m, 20H, CH$_{arom}$), 5.53 (s, 1H, C*H*Ph), 4.98 (d, *J* = 11.6 Hz, 1H, C*H*H Bn), 4.94 – 4.88 (m, 2H, 2x C*H*H Bn), 4.87 (d, *J* = 3.7 Hz, 1H, H-1), 4.79 (d, *J* = 11.3 Hz, 1H, CH*H* Bn), 4.68 (d, *J* = 11.9 Hz, 1H, CH*H* Bn), 4.63 (d, *J* = 11.5 Hz, 1H, CH*H* Bn), 4.47 (d, *J* = 7.9 Hz, 1H, H-1'), 4.35 (dd, *J* = 10.1, 3.6 Hz, 1H, H-2), 4.12 (dd, *J* = 10.6, 5.0 Hz, 1H, H-6'), 3.94 – 3.83 (m, 2H, H-3, H-5), 3.71 – 3.62 (m, 3H, H-4, H-4', H-6'), 3.58 (t, *J* = 9.2 Hz, 1H, H-3'), 3.49 (dd, *J* = 9.3, 7.8 Hz, 1H, H-2'), 3.42 (s, 3H, CH$_3$ OMe), 3.30 (td, *J* = 9.7, 5.0 Hz, 1H, H-5'), 1.14 (d, *J* = 6.4 Hz, 3H, H-6); ^{13}C NMR (101 MHz, CDCl$_3$) δ 139.2, 138.6, 137.9, 137.3 (C$_q$), 135.4, 134.3, 131.5, 129.1, 128.6, 128.5, 128.4, 128.3, 128.3, 128.3, 128.0, 127.8, 127.5, 127.3, 126.1 (CH$_{arom}$), 101.6 (C-1'), 101.3 (CHPh), 98.2 (C-1), 81.6 (C-4'), 79.4 (C-3'), 78.1 (C-4), 77.9 (C-3), 76.7 (C-2), 75.2, 75.0, 73.3 (CH$_2$ Bn), 68.6 (C-6'), 66.7 (C-2'), 66.4, 66.3 (C-5, C-5'), 55.5 (CH$_3$ OMe), 16.7 (C-6); diagnostic peaks for the α-anomer: ^{1}H NMR (400 MHz, CDCl$_3$) δ 5.58 (s, 1H, C*H*Ph), 5.21 (d, *J* = 3.8 Hz, 1H, H-1'), 4.21 (dd, *J* = 10.4, 4.9 Hz, 1H, H-6'), 4.01 (td, *J* = 10.0, 4.9 Hz, 1H, H-5'), 3.40 (s, 3H, CH$_3$ OMe); ^{13}C NMR (101 MHz, CDCl$_3$) δ 101.5 (CHPh), 100.4 (C-1'), 99.6 (C-1), 82.9, 78.8, 75.1, 73.4, 70.0, 63.4, 61.9, 55.3; HRMS: [M+NH$_4$]$^+$ calcd for C$_{41}$H$_{45}$N$_3$O$_9$ 741.34941, found 741.34828.

Disaccharide 50A



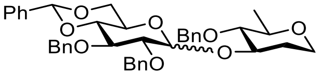
Title compound was obtained as colourless oil via the general procedure for Ph_2SO/Tf_2O mediated glycosylations with donor **A** and acceptor **50**. Yield: 68 mg, 86 μmol, 86%, α:β = 1:1.2. Data reported for a 1:1 mixture: ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.39 – 7.23 (m, 50H), 5.53 (s, 1H, C*H*Phα), 5.52 (d, *J* = 4.0 Hz, 1H, H-1'α), 5.50 (s, 1H, C*H*Phβ), 5.04 (d, *J* = 7.6 Hz, 1H, H-1'β), 4.96 (d, *J* = 11.7 Hz, 1H), 4.93 (d, *J* = 11.5 Hz, 1H), 4.91 (d, *J* = 7.8 Hz, 1H), 4.90 – 4.86 (m, 3H), 4.81 (d, *J* = 11.7 Hz, 1H), 4.79 – 4.75 (m, 3H), 4.72 – 4.58 (m, 5H), 4.51 (d, *J* = 12.1 Hz, 1H), 4.35 (d, *J* = 7.6 Hz, 1H), 4.34 – 4.29 (m, 1H), 4.29 – 4.23 (m, 1H), 4.18 – 4.16 (m, 2H), 4.12 (dd, *J* = 9.7, 7.6 Hz, 1H), 4.05 (t, *J* = 9.3 Hz, 1H), 3.78 (t, *J* = 8.9 Hz, 1H), 3.73 (dd, *J* = 9.8, 2.8 Hz, 1H), 3.68 – 3.59 (m, 4H), 3.58 – 3.53 (m, 5H), 3.51 – 3.42 (m, 4H), 3.41 (s, 3H), 3.35 (td, *J* = 9.7, 5.1 Hz, 1H), 1.22 (d, *J* = 6.4 Hz, 3H, H-6α), 1.19 (d, *J* = 6.4 Hz, 3H, H-6β); ^{13}C NMR (126 MHz, $CDCl_3$) δ 139.1, 138.9, 138.9, 138.7, 138.4, 138.3, 137.8, 137.6, 135.3, 134.2, 131.9, 131.4, 131.2, 130.3, 130.2, 128.9, 128.9, 128.5, 128.5, 128.4, 128.4, 128.4, 128.3, 128.3, 128.3, 128.3, 128.2, 128.2, 128.1, 128.1, 128.1, 128.0, 128.0, 127.8, 127.7, 127.6, 127.6, 127.6, 127.5, 127.5, 127.3, 126.5, 126.2, 126.1, 104.5 (C-1β), 102.8 (C-1α), 102.7 (C-1'β), 101.2 (CHPhα), 101.1 (CHPhβ), 98.2 (C-1'α), 83.9, 83.0, 82.2, 81.8, 81.4, 81.2, 79.1, 78.7, 77.2, 76.6, 75.3, 75.1, 75.0, 74.9, 74.7, 74.6, 74.6, 73.1, 72.8, 71.5, 70.4, 70.2, 69.1, 65.7, 62.4, 56.9, 56.8, 17.1, 16.8; HRMS: $[M+NH_4]^+$ calcd for $C_{48}H_{52}O_{10}NH_4$ 806.38987, found 806.38795.

Disaccharide 50B



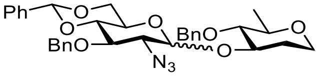
Title compound was obtained as white solid via the general procedure for Ph_2SO/Tf_2O mediated glycosylations with donor **B** and acceptor **51.** Yield: 68 mg, 93 μmol, 93%, α:β <1:20. Data for the β-anomer: ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.50 – 7.24 (m, 20H, CH_{arom}), 5.53 (s, 1H, C*H*Ph), 4.97 (d, *J* = 11.7 Hz, 1H, C*H*Ph), 4.92 – 4.87 (m, 3H, H-1', 2x CH*H* Bn), 4.79 (d, *J* = 11.3 Hz, 1H, CH*H* Bn), 4.69 – 4.64 (m, 2H, 2x CH*H* Bn), 4.33 – 4.26 (m, 2H, H-1, H-6'), 4.11 (dd, *J* = 9.7, 7.8 Hz, 1H, H-2), 3.67 – 3.62 (m, 2H, H-4', H-6'), 3.58 – 3.53 (m, 5H, H-3', H-4, CH_3 OMe), 3.50 – 3.45 (m, 2H, H-3, H-5), 3.41 (dd, *J* = 9.5, 8.1 Hz, 1H, H-2'), 3.36 (td, *J* = 9.7, 5.0 Hz, 1H, H-5'), 1.19 (d, *J* = 6.4 Hz, 3H, H-6); ^{13}C NMR (126 MHz, $CDCl_3$) δ 139.1, 138.7, 138.1, 137.4 (C_q), 135.4, 134.4, 131.8, 131.6, 131.1, 130.3, 129.1, 128.6, 128.6, 128.5, 128.5, 128.4, 128.3, 128.3, 128.3, 128.2, 128.2, 127.9, 127.6, 127.5, 127.4, 126.1 (CH_{arom}), 104.3 (C-1), 102.1 (C-1'), 101.4 (CHPh), 81.9 (C-4'), 81.0 (C-3), 79.1 (C-3'), 78.4 (C-2), 76.9 (C-4), 75.0, 74.7, 73.4 (CH_2 Bn), 70.5 (C-5'), 68.8 (C-6'), 66.8 (C-2'), 66.0 (C-5'), 57.0 (CH_3 OMe), 16.8 (C-6); Diagnostic peaks for the α-anomer: ^{1}H NMR (500 MHz, $CDCl_3$) δ 5.56 (s, 1H, C*H*Ph), 5.41 (d, *J* = 3.9 Hz, 1H, H-1'), 3.99 (dd, *J* = 9.8, 7.7 Hz, 1H); ^{13}C NMR (126 MHz, $CDCl_3$) δ 102.5 (C-1), 101.5 (CHPh), 98.9 (C-1'), 84.1, 82.7, 75.0, 72.6, 63.2, 62.5, 56.8 (CH_3 OMe), 17.0 (C-6); HRMS: $[M+NH_4]^+$ calcd for $C_{41}H_{45}N_3O_9NH_4$ 741.34941, found 741.34826.

Disaccharide 51A



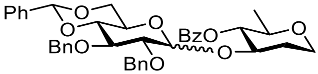
Title compound was obtained as colourless oil via the general procedure for Ph$_2$SO/Tf$_2$O mediated glycosylations with donor **A** and acceptor **51**. Yield: 53 mg, 81 μmol, 81%, α:β = 1:1.6. Data reported for a 1:1 mixture: ^{1}H NMR (500 MHz, CDCl$_3$) δ 7.41 – 7.22 (m, 27H), 5.56 (s, 2H, C*H*Phαβ), 5.12 – 5.07 (m, 2H, H-1'α, C*H*H Bn), 4.99 (d, *J* = 10.7 Hz, 1H), 4.97 – 4.91 (m, 2H), 4.89 (d, *J* = 10.9 Hz, 1H), 4.85 (d, *J* = 11.4 Hz, 1H), 4.82 – 4.78 (m, 2H), 4.74 (d, *J* = 12.1 Hz, 1H), 4.68 – 4.63 (m, 2H, H-1'β, CH*H* Bn), 4.62 – 4.58 (m, 2H), 4.29 (dd, *J* = 10.5, 5.0 Hz, 1H), 4.23 (dd, *J* = 10.3, 4.9 Hz, 1H), 4.12 (t, *J* = 9.3 Hz, 1H), 3.97 (tdd, *J* = 8.6, 7.2, 5.0 Hz, 2H), 3.88 (dddd, *J* = 20.8, 11.8, 4.9, 1.7 Hz, 2H), 3.80 – 3.68 (m, 4H), 3.64 (t, *J* = 9.4 Hz, 1H), 3.54 (dd, *J* = 9.4, 3.7 Hz, 1H, H-2'α), 3.47 (dd, *J* = 8.6, 7.6 Hz, 1H, H-2'β), 3.42 – 3.32 (m, 3H), 3.28 (ddt, *J* = 9.2, 6.5, 5.7 Hz, 2H), 3.15 – 3.01 (m, 2H), 2.15 – 2.03 (m, 2H), 1.84 (tdd, *J* = 12.8, 11.3, 5.0 Hz, 1H), 1.68 (tdd, *J* = 12.8, 11.4, 5.9 Hz, 1H), 1.32 (d, *J* = 6.1 Hz, 3H), 1.25 (d, *J* = 6.1 Hz, 3H); ^{13}C NMR (126 MHz, CDCl$_3$) δ 138.9, 138.8, 138.7, 138.6, 138.3, 138.1, 137.5, 137.4, 135.4, 134.4, 131.9, 131.5, 131.2, 130.4, 130.3, 129.1, 128.5, 128.4, 128.4, 128.4, 128.4, 128.3, 128.2, 128.2, 128.1, 128.0, 127.9, 127.8, 127.8, 127.8, 127.7, 127.5, 126.1, 125.3, 101.3 (CHPhα), 101.2 (CHPhβ), 100.9 (C-1'β), 100.0 (C-1'α), 83.4, 83.1, 82.5, 82.5, 82.5, 81.8, 81.2, 79.6, 79.1, 78.5, 76.2, 76.1, 75.6, 75.2, 75.1, 75.0, 73.7, 69.0, 69.0, 66.1, 65.3, 65.2, 63.1, 33.9, 31.4, 18.7, 18.6; HRMS: $[M+NH_4]^+$ calcd for $C_{40}H_{44}O_8NH_4$ 670.33744, found 670.33579.

Disaccharide 51B



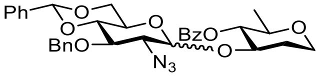
Title compound was obtained as colourless oil via the general procedure for Ph$_2$SO/Tf$_2$O mediated glycosylations with donor **B** and acceptor **51.** Yield: 50 mg, 85 μmol, 85%, α:β =1:13. Data for the β-anomer: ^{1}H NMR (400 MHz, CDCl$_3$) δ 7.50 – 7.46 (m, 2H, CH$_{arom}$), 7.42 – 7.27 (m, 13H, CH$_{arom}$), 5.57 (s, 1H, C*H*Ph), 4.96 (d, *J* = 10.7 Hz, 1H, C*H*H Bn), 4.92 (d, *J* = 11.3 Hz, 1H, C*H*H Bn), 4.80 (d, *J* = 11.3 Hz, 1H, CH*H* Bn), 4.61 (d, *J* = 10.7 Hz, 1H, CH*H* Bn), 4.51 (d, *J* = 7.9 Hz, 1H, H-1'), 4.27 (dd, *J* = 10.6, 5.0 Hz, 1H, H-6'), 3.99 – 3.88 (m, 2H, H-1$_{eq}$, H-3), 3.74 – 3.67 (m, 2H, H-4', H-6'), 3.54 (t, *J* = 9.3 Hz, 1H, H-3'), 3.43 (dd, *J* = 9.5, 7.9 Hz, 1H, H-2'), 3.41 – 3.32 (m, 2H, H-1$_{ax}$, H-5'), 3.27 (dq, *J* = 9.5, 6.1 Hz, 1H, H-5), 3.09 (t, *J* = 8.9 Hz, 1H, H-4), 2.12 (ddd, *J* = 13.2, 4.6, 2.2 Hz, 1H, H-2$_{eq}$), 1.77 (tdd, *J* = 12.8, 11.4, 4.9 Hz, 1H, H-2$_{ax}$), 1.31 (d, *J* = 6.1 Hz, 3H, H-6); ^{13}C NMR (101 MHz, CDCl$_3$) δ 138.7, 137.9, 137.1 (C$_q$), 129.1, 128.4, 128.4, 128.3, 128.3, 128.2, 128.1, 127.9, 127.7, 126.0 (CH$_{arom}$), 101.3 (CHPh), 99.9 (C-1'), 82.9 (C-4), 81.7 (C-4'), 80.3 (C-3), 78.9 (C-3'), 76.0 (C-5), 75.1, 74.9 (CH$_2$ Bn), 68.6 (C-6'), 66.7 (C-2'), 66.2 (C-5'), 65.1 (C-1), 31.1 (C-2), 18.5 (C-6); diagnostic peaks for the α-anomer: ^{1}H NMR (400 MHz, CDCl$_3$) δ 5.59 (s, 1H, C*H*Ph), 5.23 (d, *J* = 3.8 Hz, 1H, H-1'), 5.07 (d, *J* = 10.5 Hz, 1H, C*H*H Bn), 4.15 – 4.07 (m, 1H), 2.30 (tt, *J* = 8.7, 5.3 Hz, 2H, 2x H-2); ^{13}C NMR (101 MHz, CDCl$_3$) δ 99.5 (C-1'), 87.0, 84.8, 70.7, 69.6, 63.2, 63.1, 29.7 (C-2); HRMS: $[M+NH_4]^+$ calcd for $C_{33}H_{37}N_3O_7NH_4$ 605.29698, found 605.29618.

Disaccharide 52A



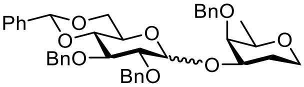
Title compound was obtained as colourless oil via the general procedure for Ph$_2$SO/Tf$_2$O mediated glycosylations with donor **A** and acceptor **52**. Yield: 35 mg, 53 mmol, 53%, α:β = 5:1. Data for the α-anomer: ^{1}H NMR (500 MHz, CDCl$_3$) δ 8.03 (dd, *J* = 8.3, 1.4 Hz, 2H, CH$_{\text{arom}}$), 7.54 – 7.50 (m, 1H, CH$_{\text{arom}}$), 7.48 – 7.43 (m, 3H, CH$_{\text{arom}}$), 7.42 – 7.30 (m, 7H, CH$_{\text{arom}}$), 7.28 – 7.22 (m, 7H, CH$_{\text{arom}}$), 7.20 – 7.09 (m, 3H, CH$_{\text{arom}}$), 6.95 (dt, *J* = 6.6, 1.6 Hz, 2H, CH$_{\text{arom}}$), 5.50 (s, 1H, C*H*Ph), 5.12 (t, *J* = 9.3 Hz, 1H, H-4), 4.97 (d, *J* = 3.7 Hz, 1H, H-1'), 4.80 (d, *J* = 11.1 Hz, 1H, C*H*H Bn), 4.67 (d, *J* = 11.1 Hz, 1H, CH*H* Bn), 4.31 (d, *J* = 12.4 Hz, 1H, C*H*H Bn), 4.23 (dd, *J* = 10.2, 4.9 Hz, 1H, H-6'), 4.15 (d, *J* = 12.3 Hz, 1H, CH*H* Bn), 4.04 – 3.98 (m, 2H, H-1$_{\text{eq}}$, H-3'), 3.96 – 3.89 (m, 2H, H-3, H-5'), 3.67 (t, *J* = 10.3 Hz, 1H, H-6'), 3.55 – 3.46 (m, 3H, H-1$_{\text{ax}}$, H-4', H-5), 3.34 (dd, *J* = 9.3, 3.7 Hz, 1H, H-2'), 2.14 – 1.96 (m, 2H, H-2$_{\text{ax}}$, H-2$_{\text{eq}}$), 1.24 (d, *J* = 6.2 Hz, 3H, H-6); ^{13}C NMR (126 MHz, CDCl$_3$) δ 165.5 (C=O), 138.8, 138.1, 137.4 (C$_q$), 133.2, 129.8, 129.0, 128.6, 128.3, 128.2, 128.2, 127.7, 127.6, 127.5, 126.1 (CH$_{\text{arom}}$), 101.3 (CHPh), 99.4 (C-1), 82.2 (C-4'), 78.4 (C-3'), 78.3 (C-2'), 77.8 (C-3), 76.8 (C-4), 75.4 (CH$_2$ Bn), 75.4 (C-5), 72.6 (CH$_2$ Bn), 69.0 (C-1), 65.5 (C-6'), 63.2 (C-5'), 33.5 (C-2), 18.2 (C-6); diagnostic peaks for the β-anomer: ^{1}H NMR (500 MHz, CDCl$_3$) δ 5.34 (s, 1H, C*H*Ph), 4.86 – 4.83 (m, 2H, 2x C*H*H Bn), 4.77 – 4.71 (m, 2H, 2x CH*H* Bn), 4.52 (d, *J* = 7.6 Hz, 1H, H-1'); ^{13}C NMR (126 MHz, CDCl$_3$) δ 165.8 (C=O), 102.9 (C-1'), 101.0 (CHPh), 81.4, 80.9, 79.1, 76.3, 75.6, 75.1, 75.0, 68.4, 66.0, 32.1 (C-2); HRMS: [M+NH$_4$]$^+$ calcd for C$_{40}$H$_{42}$O$_9$NH$_4$ 684.31671, found 684.31496.

Disaccharide 52B



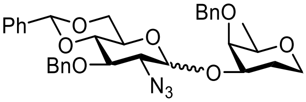
Title compound was obtained as colourless oil via the general procedure for Ph$_2$SO/Tf$_2$O mediated glycosylations with donor **B** and acceptor **52**. Yield: 36 mg, 60 µmol, 60%, α:β = 1.4:1. Data reported for a 1:1 mixture: ^{1}H NMR (500 MHz, CDCl$_3$) δ 8.11 – 8.05 (m, 5H), 7.75 – 7.70 (m, 6H), 7.69 – 7.65 (m, 4H), 7.62 – 7.54 (m, 6H), 7.52 – 7.46 (m, 11H), 7.43 – 7.27 (m, 24H), 5.57 (s, 1H, C*H*Phα), 5.36 (s, 1H, C*H*Phβ), 5.07 (t, *J* = 9.3 Hz, 1H, H-4α), 5.02 – 4.94 (m, 2H, H-1'α, H-4β), 4.90 (d, *J* = 10.8 Hz, 1H), 4.86 (d, *J* = 11.5 Hz, 1H) 4.75 (d, *J* = 11.5 Hz, 1H), 4.71 (d, *J* = 10.8 Hz, 1H), 4.38 (d, *J* = 7.9 Hz, 1H, h-1'β), 4.26 (dd, *J* = 10.3, 4.9 Hz, 1H), 4.06 – 3.92 (m, 6H), 3.88 (ddd, *J* = 11.3, 9.2, 5.3 Hz, 1H), 3.74 (t, *J* = 10.4 Hz, 1H), 3.65 (t, *J* = 9.3 Hz, 1H), 3.61 – 3.58 (m, 1H), 3.56 – 3.47 (m, 6H), 3.45 (t, *J* = 9.0 Hz, 1H), 3.36 (dd, *J* = 9.3, 8.0 Hz, 1H), 3.25 (dd, *J* = 9.9, 3.8 Hz, 1H, H-2'α), 3.16 – 3.06 (m, 2H), 2.19 (ddt, *J* = 13.1, 5.3, 1.9 Hz, 1H), 2.13 – 2.07 (m, 1H), 2.05 – 1.93 (m, 2H), 1.38 – 0.98 (m, 6H); ^{13}C NMR (126 MHz, CDCl$_3$) δ 165.8, 165.6, 149.6, 137.9, 137.9, 137.2, 137.1, 135.3, 134.5, 133.3, 133.1, 131.8, 131.7, 131.6, 131.1, 130.5, 130.3, 130.3, 130.2, 129.8, 129.6, 129.2, 129.1, 128.5, 128.5, 128.4, 128.4, 128.4, 128.3, 128.2, 128.2, 127.9, 126.1, 126.0, 125.1, 119.4, 102.2 (C-1'β), 101.5 (CHPhα), 101.2 (CHPhβ), 100.2 (C-1'α), 82.8, 81.3, 80.3, 79.4, 78.9, 76.6, 76.5, 76.1, 75.3, 75.1, 75.1, 74.8, 68.8, 68.0, 66.5, 66.1, 65.5, 65.4, 63.2, 63.2, 33.6, 32.2, 18.2, 18.1; HRMS: [M+NH$_4$]$^+$ calcd for C$_{33}$H$_{35}$N$_3$O$_8$NH$_4$ 619.27624, found 619.27524.

Disaccharide 53A



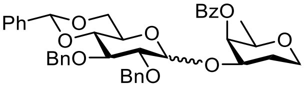
Title compound was obtained as colourless oil via the general procedure for Ph_2SO/Tf_2O mediated glycosylations with donor **A** and acceptor **53.** Yield: 63 mg, 97 µmol, 97%, α:β =4:1. Data for the α-anomer: ^1H NMR (400 MHz, $CDCl_3$) δ 7.42 – 7.20 (m, 20H, CH_{arom}), 5.57 (s, 1H, C*H*Ph), 5.01 – 4.96 (m, 2H, H-1', C*H*H Bn), 4.93 – 4.86 (m, 2H, 2x C*H*H Bn), 4.81 (d, *J* = 11.5 Hz, 1H, CH*H* Bn), 4.70 (d, *J* = 11.9 Hz, 1H, CH*H* Bn), 4.62 (d, *J* = 11.6 Hz, 1H, CH*H* Bn), 4.24 (dd, *J* = 10.2, 4.8 Hz, 1H, H-6'), 4.09 (t, *J* = 9.3 Hz, 1H, H-3'), 4.03 – 3.94 (m, 2H, H-1, H-5'), 3.71 (t, *J* = 10.3 Hz, 1H, H-6'), 3.68 – 3.57 (m, 3H, H-2', H-3, H-4'), 3.47 (d, *J* = 2.7 Hz, 1H, H-4), 3.43 – 3.30 (m, 2H, H-1, H-5), 2.28 (qd, *J* = 12.2, 4.7 Hz, 1H, H-2), 1.74 – 1.67 (m, 1H, H-2), 1.11 (d, *J* = 6.3 Hz, 3H, H-6); ^{13}C NMR (101 MHz, $CDCl_3$) δ 138.9, 138.6, 138.4, 137.5 (C_q), 131.6, 129.0, 128.8, 128.5, 128.4, 128.4, 128.4, 128.4, 128.3, 128.2, 128.2, 128.2, 128.1, 128.1, 127.9, 127.9, 127.7, 127.5, 126.1, 126.1 (CH_{arom}), 101.3 (CHPh), 99.4 (C-1'), 82.4 (C-4'), 81.1 (C-3), 79.7 (C-2'), 78.4 (C-3'), 76.2 (C-4), 75.2 (CH_2 Bn), 75.0 (C-5), 74.6, 73.9 (CH_2 Bn), 69.0 (C-6'), 65.9 (C-1), 63.1 (C-5'), 28.8 (C-2), 17.7 (C-6); diagnostic peaks for the β-anomer: ^1H NMR (400 MHz, $CDCl_3$) δ 5.59 (s, 1H, C*H*Ph), 4.66 (d, *J* = 7.7 Hz, 1H, H-1), 4.37 (dd, *J* = 10.4, 5.0 Hz, 1H, H-6'), 4.16 (ddd, *J* = 8.6, 6.5, 3.1 Hz, 1H), 3.90 (ddd, *J* = 11.9, 4.6, 2.7 Hz, 1H); ^{13}C NMR (101 MHz, $CDCl_3$) δ 102.5 (C-1), 101.2 (CHPh), 82.3, 81.6, 80.9, 79.0, 78.0, 75.5, 75.2, 74.8, 17.6; HRMS: $[M+NH_4]^+$ calcd for $C_{40}H_{44}O_8NH_4$ 670.33744, found 670.33601.

Disaccharide 53B



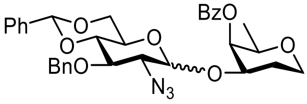
Title compound was obtained as colourless oil via the general procedure for Ph_2SO/Tf_2O mediated glycosylations with donor **B** and acceptor **53**. Yield: 39 mg, 67 µmol, 67%, α:β =1:1.4. Data reported for a 1:1 mixture: ^1H NMR (400 MHz, $CDCl_3$) δ 7.79 – 7.60 (m, 7H, CH_{arom}), 7.56 – 7.23 (m, 28H, CH_{arom}), 5.59 (s, 2H, 2x C*H*Ph), 5.06 (d, *J* = 3.6 Hz, 1H, H-1'α), 4.99 – 4.88 (m, 4H), 4.80 (d, *J* = 11.3 Hz, 1H), 4.75 (d, *J* = 11.1 Hz, 1H), 4.66 (t, *J* = 11.3 Hz, 2H), 4.51 (d, *J* = 7.9 Hz, 1H, H-1'β), 4.36 (dd, *J* = 10.5, 5.0 Hz, 1H), 4.25 (dd, *J* = 10.3, 4.9 Hz, 1H), 4.10 – 3.97 (m, 3H), 3.88 (ddd, *J* = 11.9, 4.6, 2.6 Hz, 1H), 3.84 – 3.68 (m, 5H), 3.59 – 3.52 (m, 3H), 3.51 – 3.35 (m, 7H), 2.42 – 2.17 (m, 2H), 1.82 – 1.68 (m, 2H), 1.22 – 0.90 (m, 6H, H-6αβ); ^{13}C NMR (101 MHz, $CDCl_3$) δ 138.9, 137.9, 137.7, 137.3, 137.1, 135.4, 134.4, 131.9, 131.6, 131.5, 131.2, 130.3, 130.2, 129.2, 129.2, 128.7, 128.5, 128.5, 128.4, 128.3, 128.3, 128.3, 128.2, 128.0, 128.0, 127.7, 127.6, 126.1, 126.1, 125.3, 101.5 (CHPhα), 101.4 (CHPhβ), 101.3 (C-1'β), 98.7 (C-1'α), 83.0, 81.6, 80.8, 79.8, 78.9, 77.9, 76.7, 76.1, 75.0, 75.0, 75.0, 75.0, 74.8, 68.8, 68.7, 66.6, 66.3, 65.9, 65.8, 63.4, 63.3, 28.5, 26.5, 17.7, 17.7; HRMS: $[M+NH_4]^+$ calcd for $C_{33}H_{37}N_3O_7NH_4$ 605.29698, found 605.29612.

Disaccharide 54A



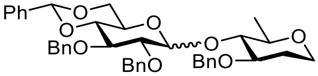
Title compound was obtained as colourless oil via the general procedure for Ph_2SO/Tf_2O mediated glycosylations with donor **A** and acceptor **54**. Yield: 67 mg, 100 µmol, 100%, α:β = 8:1. Data for the α-anomer: ^1H NMR (400 MHz, $CDCl_3$) δ 8.13 – 8.07 (m, 2H, CH_{arom}), 7.77 – 7.59 (m, 3H, CH_{arom}), 7.56 – 7.34 (m, 10H, CH_{arom}), 7.28 – 7.09 (m, 12H, CH_{arom}), 5.55 (d, *J* = 3.2 Hz, 1H, H-4), 5.53 (s, 1H, C*H*Ph), 5.28 (d, *J* = 3.5 Hz, 1H, H-1'), 4.78 (d, *J* = 11.2 Hz, 1H, C*H*H Bn), 4.67 (d, *J* = 11.3 Hz, 1H, CH*H* Bn), 4.55 (d, *J* = 12.0 Hz, 1H, C*H*H Bn), 4.45 (d, *J* = 12.1 Hz, 1H, CH*H* Bn), 4.28 (dd, *J* = 9.6, 4.1 Hz, 1H, H-6'), 4.15 (ddd, *J* = 11.8, 4.9, 1.7 Hz, 1H, H-1_{eq}), 4.00 – 3.92 (m, 2H, H-3, H-3'), 3.81 – 3.75 (m, 1H, H-5'), 3.71 (t, *J* = 9.9 Hz, 1H, H-6'), 3.67 – 3.62 (m, 1H, H-5), 3.61 – 3.54 (m, 2H, H-4', H-6'), 3.52 (dd, *J* = 9.3, 3.7 Hz, 1H, H-2'), 2.34 (qd, *J* = 12.6, 4.9 Hz, 1H, H-2_{ax}), 1.80 (ddt, *J* = 11.1, 5.0, 1.7 Hz, 1H, H-2_{eq}), 1.21 (d, *J* = 6.4 Hz, 3H, H-6); ^{13}C NMR (101 MHz, $CDCl_3$) δ 166.6 (C=O), 138.8, 138.1, 137.4 (C_q), 135.3, 134.4, 133.2, 131.9, 131.5 (CH_{arom}), 131.2 (C_q), 130.3, 130.2, 130.1, 129.9 (CH_{arom}), 129.9 (C_q), 129.0, 128.5, 128.3, 128.3, 128.3, 128.2, 128.2, 128.0, 128.0, 127.9, 127.8, 127.5, 127.5, 126.1, 126.0, 125.2 (CH_{arom}), 101.2 (CHPh), 94.0 (C-1'), 82.1 (C-4'), 78.6 (C-2'), 78.2 (C-3'), 75.3 (CH_2 Bn), 73.8 (C-5), 72.7 (CH_2 Bn), 71.8 (C-3), 69.0 (C-6'), 68.8 (C-4), 66.3 (C-1), 63.1 (C-5'), 28.2 (C-2), 17.5 (C-6); diagnostic peaks for the β-anomer: ^1H NMR (400 MHz, $CDCl_3$) δ 5.48 (d, *J* = 3.1 Hz, 1H, H-4), 4.85 (d, *J* = 11.5 Hz, 1H, C*H*H Bn), 4.73 (d, *J* = 11.5 Hz, 1H, CH*H* Bn), 4.62 (d, *J* = 9.1 Hz, 1H, H-1'), 4.34 (dd, *J* = 10.5, 5.0 Hz, 1H), 1.96 – 1.89 (m, 1H); ^{13}C NMR (101 MHz, $CDCl_3$) δ 166.0 (C=O), 101.1 (CHPh), 100.8 (C-1'), 82.0, 81.3, 80.8, 75.2, 75.0, 74.7, 74.1, 64.7, 26.9; HRMS: $[M+NH_4]^+$ calcd for $C_{40}H_{42}O_9NH_4$ 684.31671, found 684.31519.

Disaccharide 54B



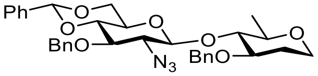
Title compound was obtained as colourless oil via the general procedure for Ph_2SO/Tf_2O mediated glycosylations with donor **B** and acceptor **54**. Yield: 60 mg, 100 µmol, 100%, α:β = 1.5:1. Data reported for a 1:1 mixture: ^1H NMR (400 MHz, $CDCl_3$) δ 8.21 – 8.14 (m, 2H), 8.13 – 8.08 (m, 1H), 7.75 – 7.62 (m, 6H), 7.61 – 7.51 (m, 3H), 7.48 – 7.42 (m, 8H), 7.37 (ddd, *J* = 5.3, 3.3, 2.1 Hz, 4H), 7.34 – 7.20 (m, 12H), 5.56 (s, 1H, C*H*Phα), 5.52 – 5.49 (m, 2H, H-4α, C*H*Phβ), 5.42 (d, *J* = 3.1 Hz, 1H, C-4β), 5.26 (d, *J* = 3.7 Hz, 1H, H-1'α), 4.88 – 4.81 (m, 2H), 4.73 (d, *J* = 11.4 Hz, 1H), 4.65 (d, *J* = 10.9 Hz, 1H), 4.49 (d, *J* = 7.9 Hz, 1H, H-1'β), 4.36 – 4.25 (m, 2H), 4.14 (dtd, *J* = 11.7, 3.9, 1.7 Hz, 1H), 4.03 (dddd, *J* = 13.5, 12.0, 4.9, 3.2 Hz, 2H), 3.96 (dd, *J* = 9.9, 9.0 Hz, 1H), 3.84 (td, *J* = 9.8, 4.4 Hz, 1H), 3.75 (t, *J* = 10.1 Hz, 1H), 3.71 – 3.51 (m, 6H), 3.45 (t, *J* = 9.3 Hz, 1H), 3.39 – 3.29 (m, 2H), 2.33 – 2.16 (m, 2H), 1.93 (dd, *J* = 13.4, 4.4 Hz, 1H), 1.79 (ddt, *J* = 11.3, 5.2, 1.7 Hz, 1H), 1.22 (d, *J* = 6.4 Hz, 3H), 1.20 (d, *J* = 6.5 Hz, 3H); ^{13}C NMR (101 MHz, $CDCl_3$) δ 166.6, 166.4, 137.9, 137.9, 137.2, 137.2, 135.3, 134.6, 133.2, 133.0, 131.7, 131.7, 131.0, 130.4, 130.3, 130.3, 130.0, 130.0, 129.1, 129.1, 128.5, 128.4, 128.4, 128.4, 128.3, 128.2, 128.1, 128.1, 127.9, 126.1, 126.0, 124.9, 101.4 (CHPhα), 101.3 (CHPhβ), 100.4 (C-1'β), 94.7 (C-1'α), 82.6, 81.3, 78.8, 76.2, 76.1, 75.0, 74.8, 74.0, 73.6, 72.2, 71.6, 68.9, 68.5, 68.2, 66.3, 66.1, 66.1, 65.8, 63.2, 62.8, 28.1, 27.1, 17.5, 17.4; HRMS: $[M+NH_4]^+$ calcd for $C_{33}H_{35}N_3O_8NH_4$ 619.27624, found 619.27510.

Disaccharide 55A



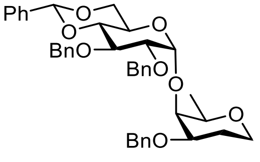
Title compound was obtained as colourless oil via the general procedure for Ph_2SO/Tf_2O mediated glycosylations with donor **A** and acceptor **55**. Yield: 64 mg, 98 μmol, 98%, α:β =1:1.6. Data reported for a 1:1 mixture: ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.71 – 7.17 (m, 40H), 5.87 (d, *J* = 4.1 Hz, 1H, H-1'α), 5.54 (s, 1H, C*H*Phα), 5.53 (s, 1H, C*H*Phβ), 4.94 – 4.88 (m, 2H), 4.84 (s, 2H), 4.81 (d, *J* = 11.4 Hz, 1H), 4.79 – 4.71 (m, 3H, H-1'β, 2x C*H*H Bn), 4.70 – 4.62 (m, 3H), 4.58 (d, *J* = 12.1 Hz, 1H), 4.40 (d, *J* = 11.8 Hz, 1H), 4.32 – 4.19 (m, 2H), 4.00 (t, *J* = 9.4 Hz, 1H), 3.96 – 3.87 (m, 2H), 3.84 – 3.74 (m, 2H), 3.72 – 3.66 (m, 1H), 3.65 – 3.58 (m, 2H), 3.53 (ddd, *J* = 11.7, 5.5, 2.6 Hz, 2H), 3.50 – 3.37 (m, 4H), 3.37 – 3.28 (m, 2H), 2.15 – 2.02 (m, 2H), 1.79 – 1.58 (m, 2H), 1.39 (d, *J* = 6.0 Hz, 3H), 1.34 (d, *J* = 6.0 Hz, 3H); ^{13}C NMR (101 MHz, $CDCl_3$) δ 139.2, 138.8, 138.6, 138.3, 138.1, 137.5, 137.4, 135.3, 134.4, 131.8, 131.6, 131.6, 131.1, 130.3, 130.2, 129.0, 129.0, 128.5, 128.4, 128.4, 128.4, 128.3, 128.3, 128.3, 128.1, 128.1, 127.9, 127.8, 127.8, 127.7, 127.6, 127.6, 127.5, 127.3, 127.0, 127.0, 126.1, 126.1, 103.7 (C-1'β), 101.2 (CHPhβ), 101.1 (CHPhα), 97.8 (C-1'α), 84.2, 82.9, 82.1, 81.8, 81.7, 81.5, 79.2, 78.8, 78.7, 78.6, 76.2, 75.7, 75.4, 75.2, 75.1, 72.9, 71.9, 69.8, 68.9, 66.0, 65.4, 65.3, 63.2, 32.0, 31.3, 19.8, 18.7; HRMS: $[M+NH_4]^+$ calcd for $C_{40}H_{44}O_8NH_4$ 670.33744, found 670.33617.

Disaccharide 55B



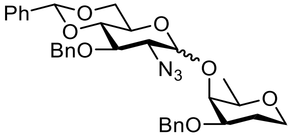
Title compound was obtained as colourless oil via the general procedure for Ph_2SO/Tf_2O mediated glycosylations with donor **B** and acceptor **55**. Yield: 57 mg, 97 μmol, 97%, α:β =1:16. Data for the β-anomer: ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.49 – 7.26 (m, 15H, CH_{arom}), 5.52 (s, 1H, C*H*Ph), 4.92 (d, *J* = 11.1 Hz, 1H, C*H*H Bn), 4.78 (d, *J* = 11.1 Hz, 1H, CH*H* Bn), 4.69 – 4.61 (m, 2H, CH_2 Bn), 4.60 (d, *J* = 8.1 Hz, 1H, H-1'), 4.13 (dd, *J* = 10.5, 4.9 Hz, 1H, H-6'), 3.95 – 3.85 (m, 1H, H-1_{eq}), 3.67 (t, *J* = 9.2 Hz, 1H, H-4'), 3.64 – 3.50 (m, 3H, H-3, H-3', H-6'), 3.45 – 3.30 (m, 4H, H-1_{ax}, H-2', H-4, H-5), 3.24 (td, *J* = 9.7, 5.0 Hz, 1H, H-5'), 2.06 (dd, *J* = 13.1, 5.0 Hz, 1H, H-2_{eq}), 1.76 – 1.60 (m, 1H, H-2_{ax}), 1.40 (d, *J* = 5.9 Hz, 3H, H-6); ^{13}C NMR (101 MHz, $CDCl_3$) δ 138.9, 137.8, 137.2 (C_q), 129.1, 128.5, 128.5, 128.4, 128.4, 128.3, 128.2, 128.0, 127.9, 127.6, 127.1, 126.0 (CH_{arom}), 102.2 (C-1'), 101.3 (CHPh), 84.4 (C-4), 81.7 (C-4'), 79.4, 79.2 (C-3, C-3'), 75.7 (C-5), 75.0, 71.6 (CH_2 Bn), 68.6 (C-6'), 67.4 (C-2'), 66.1 (C-5'), 65.4 (C-1), 31.8 (C-2), 18.6 (C-6); Diagnostic peaks for the α-anomer: ^{1}H NMR (400 MHz, $CDCl_3$) δ 5.73 (d, *J* = 4.1 Hz, 1H, H-1'), 5.57 (s, 1H, C*H*Ph), 4.24 (dd, *J* = 10.4, 4.9 Hz, 1H), 4.04 (t, *J* = 9.5 Hz, 1H), 2.16 (dd, *J* = 12.8, 5.1 Hz, 1H, H-2_{eq}); ^{13}C NMR (101 MHz, $CDCl_3$) δ 101.9 (CHPh), 98.8 (C-1'), 84.3, 83.0, 82.6, 81.6, 80.9, 78.8, 75.9, 75.7, 72.2, 71.0, 70.8, 66.9, 63.2, 62.9, 62.4; HRMS: $[M+NH_4]^+$ calcd for $C_{33}H_{37}N_3O_7NH_4$ 605.29698, found 605.29595.

Disaccharide 56A



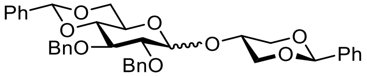
Title compound was obtained as colourless oil via the general procedure for Ph$_2$SO/Tf$_2$O mediated glycosylations with donor **A** and acceptor **56.** Yield: 65 mg, 100 µmol, 100%, α:β =11:1. Data for the α-anomer: ^{1}H NMR (400 MHz, CDCl$_3$) δ 7.56 – 7.43 (m, 5H, CH$_{arom}$), 7.42 – 7.25 (m, 15H, CH$_{arom}$), 5.50 (s, 1H, C*H*Ph), 4.97 (d, *J* = 11.2 Hz, 1H, C*H*H Bn), 4.92 – 4.87 (m, 2H, C-1', C*H*H Bn), 4.84 (d, *J* = 11.2 Hz, 1H, CH*H* Bn), 4.76 (d, *J* = 12.0 Hz, 1H, CH*H* Bn), 4.61 – 4.56 (m, 2H, CH$_2$ Bn), 4.32 (td, *J* = 10.0, 4.9 Hz, 1H, H-5'), 4.21 (t, *J* = 9.3 Hz, 1H, H-3'), 4.04 (ddd, *J* = 11.6, 4.8, 2.0 Hz, 1H, H-1$_{eq}$), 3.90 (dd, *J* = 10.1, 5.0 Hz, 1H, H-6), 3.70 (dd, *J* = 2.6, 1.3 Hz, 1H, H-4), 3.62 – 3.56 (m, 2H, H-2', H-4'), 3.51 (t, *J* = 10.2 Hz, 1H, H-6), 3.47 – 3.34 (m, 3H, H-1$_{ax}$, H-3, H-5), 2.14 – 2.01 (m, 1H, H-2), 1.77 – 1.65 (m, 1H, H-2), 1.34 (d, *J* = 6.4 Hz, 3H, H-6); ^{13}C NMR (101 MHz, CDCl$_3$) δ 139.0, 138.5, 138.3, 137.8 (C$_q$), 135.3, 134.6, 131.7, 131.6, 131.0, 130.4, 128.8, 128.6, 128.6, 128.5, 128.5, 128.4, 128.4, 128.4, 128.2, 128.0, 127.8, 127.8, 127.7, 127.7, 127.6, 127.6, 126.1 (CH$_{arom}$), 101.1 (CHPh), 100.5 (C-1'), 82.9 (C-4'), 79.6 (C-2'), 78.9 (C-3'), 78.2 (C-4), 77.6 (C-3), 75.2 (CH$_2$ Bn), 75.1 (C-5), 74.2 (CH$_2$ Bn), 70.2 (CH$_2$ Bn), 69.2 (C-6'), 66.0 (C-1), 62.8, 27.1 (C-2), 17.7 (C-6); diagnostic peaks for the β-anomer: ^{1}H NMR (400 MHz, CDCl$_3$) δ 5.56 (s, 1H, CHPh), 5.17 (d, *J* = 11.1 Hz, 1H, C*H*H Bn); ^{13}C NMR (101 MHz, CDCl$_3$) δ 103.3 (C-1'), 101.1 (CHPh), 82.6, 81.6, 81.0; HRMS: [M+NH$_4$]$^+$ calcd for C$_{40}$H$_{44}$O$_8$NH$_4$ 670.33744, found 670.33600.

Disaccharide 56B



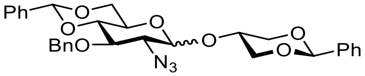
Title compound was obtained as colourless oil via the general procedure for Ph$_2$SO/Tf$_2$O mediated glycosylations with donor **B** and acceptor **56**. Yield: 55 mg, 93 µmol, 93%, α:β = 1.4:1. Data reported for a 1:1 mixture of anomers: ^{1}H NMR (400 MHz, CDCl$_3$) δ 7.56 – 7.51 (m, 4H), 7.51 – 7.44 (m, 6H), 7.41 – 7.27 (m, 26H), 5.56 (s, 1H, C*H*Phβ), 5.53 (s, 1H, C*H*Phα), 5.03 – 4.96 (m, 2H, H-1'α, C*H*H Bn), 4.94 – 4.88 (m, 1H), 4.84 – 4.77 (m, 3H, H-1'β, 2x CH*H* Bn), 4.71 (d, *J* = 12.3 Hz, 1H), 4.61 (d, *J* = 1.4 Hz, 2H), 4.53 (d, *J* = 12.2 Hz, 1H), 4.41 (td, *J* = 10.0, 5.0 Hz, 1H), 4.28 (dd, *J* = 10.5, 5.0 Hz, 1H), 4.19 (t, *J* = 9.6 Hz, 1H), 4.09 – 4.00 (m, 2H), 3.92 – 3.86 (m, 2H), 3.79 – 3.73 (m, 2H), 3.68 (dd, *J* = 10.3, 8.8 Hz, 2H), 3.59 – 3.35 (m, 10H), 3.33 – 3.25 (m, 1H), 2.22 (td, *J* = 12.4, 4.9 Hz, 1H), 2.04 (qd, *J* = 12.4, 4.9 Hz, 1H), 1.85 – 1.67 (m, 2H), 1.38 (d, *J* = 6.6 Hz, 3H, H-6α), 1.22 (d, *J* = 6.5 Hz, 3H, H-6β); ^{13}C NMR (101 MHz, CDCl$_3$) δ 138.3, 138.1, 137.6, 137.3, 135.4, 134.6, 131.7, 131.6, 131.0, 130.4, 130.3, 129.8, 129.1, 129.0, 128.6, 128.6, 128.5, 128.5, 128.5, 128.4, 128.4, 128.3, 128.3, 128.2, 128.2, 128.0, 127.9, 127.9, 127.8, 127.8, 127.7, 127.3, 127.3, 126.1, 126.1, 124.8, 102.1 (C-1'β), 101.3 (CHPhβ), 101.2 (CHPhα), 99.7 (C-1'α), 83.1, 81.7, 79.2, 78.0, 77.3, 77.2, 76.8, 75.5, 75.2, 75.0, 74.9, 74.5, 70.3, 70.0, 68.9, 68.7, 66.5, 66.1, 65.9, 63.9, 63.9, 62.8, 27.0, 26.4, 17.8; HRMS: [M+NH$_4$]$^+$ calcd for C$_{33}$H$_{37}$N$_3$O$_7$NH$_4$ 605.29698, found 605.29626.

Disaccharide 57A



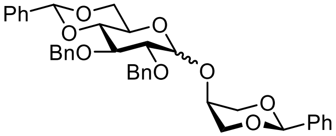
Title compound was obtained as colourless oil via the general procedure for Ph$_2$SO/Tf$_2$O mediated glycosylations with donor **A** and acceptor **57**, with the exceptions that 2,4,6-Tri-*tert*-butylpyridine was used instead of TTBP. Yield: 61 mg, 100 µmol, 100%, α:β = 6:1. Data for the α-anomer: ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.57 – 7.49 (m, 5H, CH_{arom}), 7.48 – 7.31 (m, 15H, CH_{arom}), 5.62 (s, 1H, C*H*Ph), 5.47 (s, 1H, C*H*Ph), 4.99 (d, *J* = 11.2 Hz, 1H, C*H*H Bn), 4.92 (d, *J* = 11.9 Hz, 1H, C*H*H Bn), 4.89 (d, *J* = 11.5 Hz, 1H, CH*H* Bn), 4.82 (d, *J* = 3.9 Hz, 1H, H-1), 4.69 (d, *J* = 12.0 Hz, 1H, CH*H* Bn), 4.44 – 4.36 (m, 2H, 2x C*H*H glycerol), 4.31 (dd, *J* = 10.2, 4.8 Hz, 1H, H-6), 4.05 (t, *J* = 9.3 Hz, 1H, H-3), 4.00 – 3.87 (m, 2H, H-5, CH Glycerol), 3.86 – 3.73 (m, 3H, H-6, 2x CH*H* glycerol), 3.68 (t, *J* = 9.4 Hz, 1H, H-4), 3.60 (dd, *J* = 9.4, 3.9 Hz, 1H, H-2); ^{13}C NMR (101 MHz, $CDCl_3$) δ 138.7, 138.1, 137.5, 137.3 (C_q), 129.4, 129.1, 129.0, 128.7, 128.4, 128.4, 128.3, 128.2, 128.1, 128.0, 127.7, 126.1, 126.0, 124.8 (CH_{arom}), 101.3 (CHPh), 101.2 (CHPh), 98.2 (C-1), 82.0 (C-4), 79.2 (C-2), 78.4 (C-3), 75.4, 74.1 (CH_2 Bn), 70.6, 69.5 (CH_2 glycerol), 68.8 (C-6), 67.9 (CH glycerol), 63.0 (C-5); diagnostic peaks for the β-anomer: ^{1}H NMR (400 MHz, $CDCl_3$) δ 4.65 (d, *J* = 7.7 Hz, 1H, H-1), 4.49 (ddd, *J* = 10.8, 5.0, 2.1 Hz, 1H, C*H*H Glycerol); ^{13}C NMR (101 MHz, $CDCl_3$) δ 103.9 (C-1), 81.9, 81.4, 80.9, 75.6, 75.2, 71.1, 69.6, 69.5, 68.7, 66.2; HRMS: $[M+NH_4]^+$ calcd for $C_{37}H_{38}O_8NH_4$ 628.29049, found 628.28946.

Disaccharide 57B



Title compound was obtained as colourless oil via the general procedure for Ph_2SO/Tf_2O mediated glycosylations with donor **B** and acceptor **57**, with the exceptions that 2,4,6-Tri-*tert*-butylpyridine was used instead of TTBP. Yield: 55 mg, 100 µmol, 100%, α:β = 2.9:1. Data for the α-anomer: ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.52 – 7.44 (m, 3H, CH_{arom}), 7.42 – 7.29 (m, 12H, CH_{arom}), 5.59 (s, 1H, C*H*Ph), 5.42 (s, 1H, C*H*Ph), 5.00 (d, *J* = 3.7 Hz, 1H, H-1), 4.97 (d, *J* = 11.0 Hz, 1H, C*H*H Bn), 4.80 (d, *J* = 11.0 Hz, 1H, CH*H* Bn), 4.44 – 4.37 (m, 2H, 2x C*H*H glycerol), 4.28 (dd, *J* = 10.3, 4.8 Hz, 1H, H-6), 4.04 (dd, *J* = 9.9, 9.2 Hz, 1H, H-3), 4.01 – 3.94 (m, 1H, CH glycerol), 3.90 (td, *J* = 9.9, 4.6 Hz, 1H, H-5), 3.80 – 3.70 (m, 4H, H-4, H-6, 2x CH*H* glycerol), 3.35 (dd, *J* = 10.0, 3.8 Hz, 1H, H-2); ^{13}C NMR (101 MHz, $CDCl_3$) δ 137.8, 137.4, 137.1, 129.2 (C_q), 128.6, 128.4, 128.3, 128.1, 126.2, 126.1, 126.0 (CH_{arom}), 101.5, 101.4 (CHPh), 98.9 (C-1), 82.6 (C-4), 75.8 (C-3), 75.2 (CH_2 Bn), 70.5, 69.3 (CH_2 glycerol), 68.7 (C-6), 68.6 (CH glycerol), 63.4 (C-5), 62.8 (C-2); diagnostic peaks for the β-anomer: ^{1}H NMR (400 MHz, $CDCl_3$) δ 5.56 (s, 1H, C*H*Ph), 5.41 (s, 1H, C*H*Ph), 4.91 (d, *J* = 11.3 Hz, 1H, C*H*H Bn), 3.53 (t, *J* = 9.3 Hz, 1H), 3.40 (dd, *J* = 9.5, 8.0 Hz, 1H, H-2); ^{13}C NMR (101 MHz, $CDCl_3$) δ 102.5 (C-1), 101.4 (CHPh), 101.3 (CHPh), 81.4, 78.8, 75.1, 70.9, 70.3, 69.7, 68.5, 66.4, 66.1, 65.0; HRMS: $[M+NH_4]^+$ calcd for $C_{30}H_{31}N_3O_7NH_4$ 563.25003, found 563.24913.

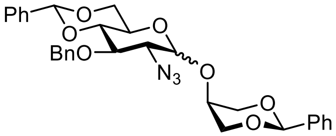
Disaccharide 58A



Title compound was obtained as colourless oil via the general procedure for Ph_2SO/Tf_2O mediated glycosylations with donor **A** and acceptor **58**, with the exceptions that 2,4,6-Tri-*tert*-butylpyridine was used instead of TTBP. Yield: 48 mg, 79 µmol, 79%, α:β = 1.6:1. Data reported for a 2:1 mixture of anomers: ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.55 – 7.46 (m, 20H), 7.41 – 7.24 (m, 40H), 5.58 (s, 1H, C*H*Phβ), 5.57 (s, 2H, C*H*Phα), 5.57 (s, 1H, C*H*Phβ), 5.56 (s, 2H, C*H*Phα), 5.16 (d, *J* = 10.6 Hz, 1H, C*H*H Bnβ), 5.07 (d, *J* = 3.8 Hz, 2H, H-1α), 4.92 (d, *J* = 11.3 Hz, 1H), 4.86 –

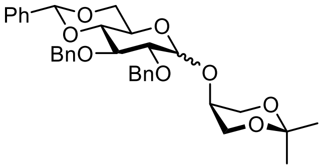
4.82 (m, 5H), 4.79 (d, *J* = 10.7 Hz, 1H, CH*H* Bnβ), 4.71 (d, *J* = 11.8 Hz, 2H), 4.38 (d, *J* = 12.1 Hz, 6H, 2x C*H*H glycerolαβ), 4.32 (dd, *J* = 10.5, 5.0 Hz, 1H), 4.26 – 4.12 (m, 7H), 4.11 – 4.01 (m, 6H), 3.82 – 3.68 (m, 7H), 3.67 – 3.58 (m, 5H), 3.53 (d, *J* = 1.6 Hz, 2H, CH glycerolα), 3.39 (dt, *J* = 9.8, 4.9 Hz, 1H, H-5β); ^{13}C NMR (101 MHz, $CDCl_3$) δ 139.0, 138.6, 138.4, 138.2, 137.6, 137.4, 135.4, 134.6, 131.6, 131.0, 130.4, 130.3, 129.1, 129.0, 129.0, 128.6, 128.5, 128.4, 128.4, 128.3, 128.3, 128.3, 128.1, 128.0, 128.0, 127.8, 127.7, 127.6, 126.4, 126.3, 126.2, 126.1, 102.5 (C-1β), 101.6 (CHPhα), 101.4 (CHPhβ), 101.4 (CHPhα), 101.2 (CHPhβ), 96.8 (C-1α), 82.3, 81.8, 81.3, 80.9, 79.5, 78.5, 75.4, 75.4, 75.3, 73.0, 70.8, 70.1, 70.0, 69.6, 69.1, 68.8, 68.3, 68.1, 66.2, 62.9; HRMS: $[M+NH_4]^+$ calcd for $C_{37}H_{38}O_8NH_4$ 628.29049, found 628.28956.

Disaccharide 58B



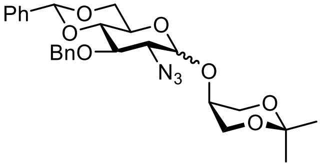
Title compound was obtained as colourless oil via the general procedure for Ph_2SO/Tf_2O mediated glycosylations with donor **B** and acceptor **58**, with the exceptions that 2,4,6-Tri-*tert*-butylpyridine was used instead of TTBP. Yield: 17 mg, 31 µmol, 31%, α:β = 1:3. Data for the β-anomer: ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.52 – 7.44 (m, 5H, CH_{arom}), 7.43 – 7.29 (m, 10H, CH_{arom}), 5.57 (s, 1H, C*H*Ph), 5.42 (s, 1H, C*H*Ph), 4.91 (d, *J* = 11.3 Hz, 1H, C*H*H Bn), 4.79 (d, *J* = 11.3 Hz, 1H, CH*H* Bn), 4.45 (d, *J* = 8.0 Hz, 1H, C-1), 4.40 (dd, *J* = 11.3, 5.2 Hz, 2H, 2x C*H*H glycerol), 4.33 (dd, *J* = 10.5, 5.0 Hz, 1H, H-6), 4.05 – 3.99 (m, 1H, CH glycerol), 3.83 – 3.65 (m, 4H, H-4, H-6, 2x CH*H* glycerol), 3.54 (t, *J* = 9.3 Hz, 1H, H-3), 3.44 – 3.36 (m, 2H, H-2, H-5); ^{13}C NMR (101 MHz, $CDCl_3$) δ 137.8, 137.5, 137.1 (C_q), 129.3, 128.5, 128.5, 128.4, 128.1, 126.2, 126.1 (CH_{arom}), 102.5 (C-1), 101.5, 101.4 (CHPh), 81.5 (C-4), 78.8 (C-3), 75.1 (CH_2 Bn), 72.0 (CH_2 glycerol), 69.5 (CH glycerol), 69.5 (CH_2 glycerol), 68.6 (C-6), 66.8, 66.1 (C-2, C-5); diagnostic peaks for the α-anomer: ^{1}H NMR (400 MHz, $CDCl_3$) δ 5.60 (s, 1H, C*H*Ph), 5.43 (s, 1H, C*H*Ph), 5.02 (d, *J* = 3.7 Hz, 1H, H-1), 4.97 (d, *J* = 11.0 Hz, 1H), 4.29 (dd, *J* = 10.3, 4.8 Hz, 1H), 3.90 (td, *J* = 9.9, 4.7 Hz, 1H); ^{13}C NMR (101 MHz, $CDCl_3$) δ 101.5 (CHPh), 99.0 (C-1), 82.7, 75.8, 75.2, 70.6, 69.4, 68.8, 68.7, 63.4, 62.8; HRMS: $[M+NH_4]^+$ calcd for $C_{30}H_{31}N_3O_7NH_4$ 563.25003, found 563.24936.

Disaccharide 59A



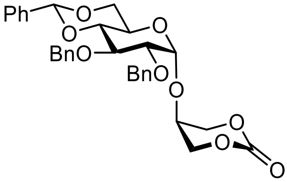
Title compound was obtained as colourless oil via the general procedure for Ph_2SO/Tf_2O mediated glycosylations with donor **A** and acceptor **59**, with the exceptions that 2,4,6-Tri-*tert*-butylpyridine was used instead of TTBP. Yield: 54 mg, 96 µmol, 96% α:β = 1:1. Data reported for a 1:1 mixture: ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.61 – 7.48 (m, 8H), 7.47 – 7.30 (m, 28H), 5.60 – 5.59 (m, 2H, C*H*Phαβ), 5.01 – 4.93 (m, 3H), 4.88 (dd, *J* = 12.2, 7.6 Hz, 3H), 4.83 – 4.79 (m, 2H, H-1α, CH*H* Bn), 4.68 (d, *J* = 12.0 Hz, 1H), 4.60 (d, *J* = 7.7 Hz, 1H, H-1β), 4.35 (dd, *J* = 10.5, 5.0 Hz, 1H), 4.27 (dd, *J* = 10.2, 4.9 Hz, 1H), 4.12 – 4.04 (m, 2H), 4.03 – 3.93 (m, 3H), 3.92 – 3.83 (m, 6H), 3.82 – 3.69 (m, 5H), 3.65 (t, *J* = 9.4 Hz, 1H), 3.59 (dd, *J* = 9.4, 3.9 Hz, 1H, H-2α), 3.55 – 3.50 (m, 1H), 3.43 (td, *J* = 9.9, 5.0 Hz, 1H), 1.51 (s, 3H), 1.49 (s, 3H), 1.46 (s, 3H), 1.44 (s, 3H); ^{13}C NMR (101 MHz, $CDCl_3$) δ 138.8, 138.5, 138.3, 138.2, 137.4, 137.3, 135.3, 134.6, 131.8, 131.7, 131.6, 131.1, 131.0, 130.4, 130.3, 129.1, 129.0, 128.6, 128.5, 128.4, 128.3, 128.1, 128.0, 127.9, 127.7, 127.7, 126.1, 126.1, 103.4 (C-1β), 101.3, 101.2 (CHPhα, CHPhβ)98.3, 98.3 (C$_q$ isopropylidene α, C$_q$ isopropylidene β), 97.9 (C-1α,) 82.1, 81.9, 81.4, 80.9, 79.3, 78.5, 75.6, 75.4, 75.2, 73.9, 71.0, 69.5, 68.9, 68.8, 66.2, 63.9, 63.5, 62.9, 62.4, 62.1, 26.4, 24.3, 23.1, 21.0.; HRMS: $[M+NH_4]^+$ calcd for $C_{33}H_{38}O_8NH_4$ 580.29049, found 580.29002

Disaccharide 59B



Title compound was obtained as colourless oil via the general procedure for Ph_2SO/Tf_2O mediated glycosylations with donor **B** and acceptor **59**, with the exceptions that 2,4,6-Tri-*tert*-butylpyridine was used instead of TTBP**.** Yield: 50 mg, 100 μmol, 100% α:β = 1:10. Data for the β-anomer: ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.75 – 7.66 (m, 3H, CH$_{arom}$), 7.55 – 7.52 (m, 1H, CH$_{arom}$), 7.47 (qd, *J* = 5.7, 4.9, 2.3 Hz, 3H, CH$_{arom}$), 7.42 – 7.26 (m, 10H, CH$_{arom}$), 5.56 (s, 1H, C*H*Ph), 4.90 (d, *J* = 11.3 Hz, 1H, C*H*H Bn), 4.79 (d, *J* = 11.3 Hz, 1H, CH*H* Bn), 4.42 (d, *J* = 7.8 Hz, 1H, H-1), 4.30 (dd, *J* = 10.5, 5.0 Hz, 1H, H-6), 4.05 – 3.94 (m, 2H, 2x C*H*H Glycerol), 3.85 – 3.74 (m, 4H, H-6, CH glycerol, 2x CH*H* glycerol), 3.69 (t, *J* = 9.1 Hz, 1H, H-4), 3.53 (t, *J* = 9.2 Hz, 1H, H-3), 3.45 (dd, *J* = 9.5, 7.9 Hz, 1H, H-2), 3.37 (td, *J* = 9.8, 5.0 Hz, 1H, H-5), 1.46 (s, 3H, CH_3 isopropylidene), 1.40 (s, 3H, CH_3 isopropylidene); ^{13}C NMR (101 MHz, $CDCl_3$) δ 137.8, 137.1 (C$_q$), 135.3, 134.6, 131.7, 131.6, 131.0, 130.4, 129.2, 128.5, 128.4, 128.4, 128.3, 128.0, 126.1 (CH$_{arom}$), 102.2 (C-1), 101.4 (CHPh), 98.4 (C$_q$ isopropylidene), 81.4 (C-4), 78.9 (C-3), 75.0 (CH_2 Bn), 71.4 (CH glycerol), 68.6 (C-6), 66.3 (C-5), 66.1 (C-2), 63.7, 62.2 (CH_2 glycerol), 25.2, 22.0 (CH_3 isopropylidene); diagnostic peaks for the α-anomer: ^{1}H NMR (400 MHz, $CDCl_3$) δ 5.62 (s, 1H, C*H*Ph), 5.03 – 4.98 (m, 2H, H-1, C*H*H Bn), 4.16 (dd, *J* = 10.0, 9.1 Hz, 1H); ^{13}C NMR (101 MHz, $CDCl_3$) δ 101.5 (CHPh), 98.4 (C-1), 84.5, 75.9, 69.9, 63.2, 62.8, 24.2, 23.3.; HRMS: $[M+NH_4]^+$ calcd for $C_{26}H_{31}N_3O_7NH_4$ 515.25003, found 515.24996.

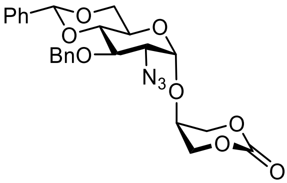
Disaccharide 60A



Title compound was obtained as colourless oil via the general procedure for Ph_2SO/Tf_2O mediated glycosylations with donor **A** and acceptor **60,** with the exceptions that 2,4,6-Tri-*tert*-butylpyridine was used instead of TTBP and that the acceptor was added neat, rather than in solution. Yield: 53 mg, 97 μmol, 97%, α:β >20:1. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.49 (dd, *J* = 7.5, 2.1 Hz, 2H, CH$_{arom}$), 7.42 – 7.26 (m, 13H, CH$_{arom}$), 5.54 (s, 1H, C*H*Ph), 4.91 (d, *J* = 11.2 Hz, 1H, C*H*H Bn), 4.86 (d, *J* = 12.0 Hz, 1H, C*H*H Bn), 4.84 – 4.79 (m, 2H, H-1, CH*H* Bn), 4.61 (d, *J* = 12.0

Hz, 1H, CH*H* Bn), 4.49 – 4.45 (m, 2H, 2x C*H*H glycerol), 4.41 (t, *J* = 2.8 Hz, 2H, 2x CH*H* glycerol), 4.23 (dd, *J* = 10.2, 4.8 Hz, 1H, H-6), 4.04 (t, *J* = 9.3 Hz, 1H, H-3), 3.95 (p, *J* = 2.8 Hz, 1H, CH glycerol), 3.85 (td, *J* = 10.0, 4.8 Hz, 1H, H-5), 3.69 (t, *J* = 10.3 Hz, 1H, H-6), 3.65 – 3.60 (m, 1H, H-4), 3.60 – 3.57 (m, 1H, H-2); ^{13}C NMR (101 MHz, $CDCl_3$) δ 147.6 (C=O), 138.6, 138.3, 137.2 (C_q), 129.1, 128.7, 128.4, 128.3, 128.2, 128.1, 128.1, 127.8, 126.1 (CH_{arom}), 101.4 (CHPh), 97.7 (C-1), 81.9 (C-4), 79.2 (C-2), 78.2 (C-3), 75.5, 74.1 (CH_2 Bn), 70.6, 69.1 (CH_2 glycerol), 68.8 (C-6), 66.2 (CH glycerol), 63.5 (C-5); HRMS: $[M+NH_4]^+$ calcd for $C_{31}H_{32}O_9NH_4$ 566.23846, found 566.23774.

Disaccharide 60B



Title compound was obtained as colourless oil via the general procedure for Ph_2SO/Tf_2O mediated glycosylations with donor **B** and acceptor **60,** with the exceptions that 2,4,6-Tri-*tert*-butylpyridine was used instead of TTBP and that the acceptor was added neat, rather than in solution. Yield: 48 mg, 99 μmol, 99%, α:β >20:1. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.49 (dd, *J* = 7.3, 2.3 Hz, 2H, CH_{arom}), 7.43 – 7.28 (m, 8H, CH_{arom}), 5.57 (s, 1H, C*H*Ph), 5.05 (d, *J* = 3.8 Hz, 1H, H-1), 4.96 (d, *J* = 10.9 Hz, 1H, C*H*H Bn), 4.79 (d, *J* = 10.9 Hz, 1H, CH*H* Bn), 4.51 (d, *J* = 2.4 Hz, 4H, 2x CH_2 glycerol), 4.27 (dd, *J* = 10.3, 4.9 Hz, 1H, H-6), 4.15 – 4.05 (m, 2H, H-3, CH glycerol), 3.94 (td, *J* = 9.9, 4.8 Hz, 1H, H-5), 3.78 – 3.69 (m, 2H, H-4, H-6), 3.42 (dd, *J* = 10.1, 3.8 Hz, 1H, H-2); ^{13}C NMR (101 MHz, $CDCl_3$) δ 147.4 (C=O), 137.7, 137.0 (C_q), 129.3, 128.6, 128.4, 128.3, 128.1, 126.1 (CH_{arom}), 101.6 (CHPh), 98.5 (C-1), 82.5 (C-4), 75.8 (C-3), 75.3 (CH_2 Bn), 70.3, 69.9 (CH_2 glycerol), 68.6 (C-6), 67.2 (CH glycerol), 63.9 (C-5), 62.6 (C-2); HRMS: $[M+NH_4]^+$ calcd for $C_{24}H_{25}N_3O_8NH_4$ 501.19799, found 501.19736.

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5

Chapter 5: Influence of N-protecting groups on the reactivity of glycosyl acceptors

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Introduction

2-Deoxy-2-aminosugars are important constituents of many biologically relevant carbohydrates and glycoconjugates, such as the glycosaminoglycans,[1, 2] various cell surface carbohydrate antigens, such as the blood group determinants, bacterial oligosaccharides,[3, 4] including pathogenic bacteria such as *Acinetobacter Baumannii,* an opportunistic pathogen with high rates of antibiotic resistance[5] or *Vibrio vulnificus,* a bacterium that causes sepsis and necrotizing fasciitis, related to *Vibrio cholera,* the causative agent of cholera[6] as well as in many secondary metabolites.[7] (***Figure 1)***. Many different aminosugars are found in nature, varying in the position on the carbohydrate ring (with a C-2-amino group occurring most often), the stereochemistry, as well as the nature of the substituent on the amine, which can be an *N*-alkyl, *N*-acyl/acetyl, *N*-sulfate, *N*-phosphate group. Non-substituted amines also commonly occur.

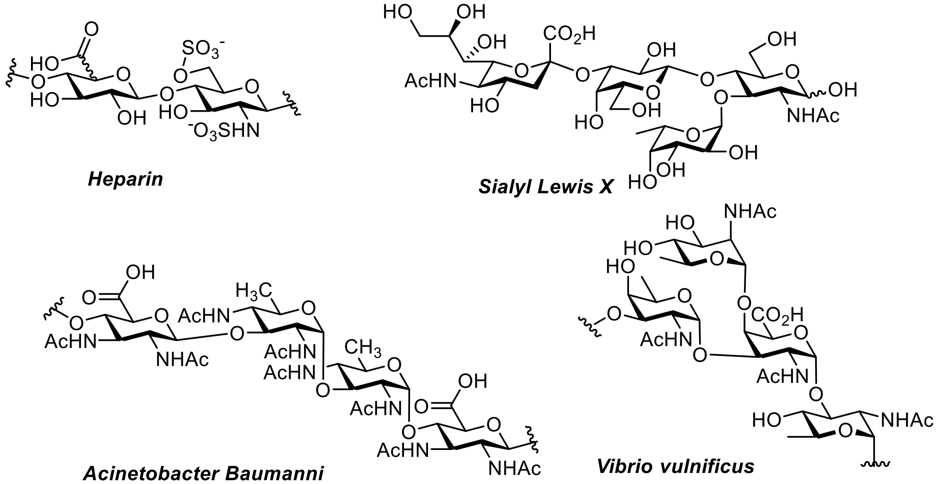


***Figure 1**: Representative structures of glycosaminoglycans (Heparin), carbohydrate antigens (sialyl Lewis X) and bacterial oligosaccharides (A. Baumannii and V. vulnificus) containing deoxy-amino sugars.*

Because of their biological relevance, many 2-deoxy-2-aminosugar containing oligosaccharides have been synthesised to date.[8, 9] To mask the amino group in the building blocks different types of protecting groups have been used. The *N*-protecting group in the donor glycoside is primarily selected based on the type of glycosidic linkage that has to be constructed. To install *cis*-glycosidic linkages, an azide on C-2 is by far the most commonly applied (and indeed almost solely used), while the construction of *trans*-linkages can be controlled by the use carbamate functionalities of amide groups. The previous chapter has shown that the nature of the functional groups on the carbohydrate ring also critically influence the nucleophilicity of the alcohol function in the acceptor. A systematic series of 60 ether and ester protected acceptors was tested and showed that the reactivity of the acceptor is dependent on both the configuration and the protecting group pattern of the acceptor: equatorial alcohols in acceptors are more reactive than axial alcohols. Also, the configuration of the protected alcohols next to the OH-group are important, and acceptors in which the neighbouring protected alcohols take up an equatorial position, are more reactive than acceptors in which one of the flanking protected alcohols is axial. With regard to protecting group patterns, benzoyl protected acceptors are less reactive than benzyl protected acceptors. It is important to note that the configuration of the ester is also important, and substituting an axial ether for an ester has significantly less effect on the reactivity of the acceptor than substituting an equatorial ether for an ester.

It has long been recognized that the nature of the *N*-protecting group can have a significant effect on the reactivity of the aminosugar alcohol acceptor, although systematic investigations are relatively scarse.[10] A prime example is presented by the *N*-acetyl glucosamine C-4-OH, which is a notoriously difficult acceptor to glycosylate.[11-16] Through a systematic survey Crich and Dudkin determined that intramolecular hydrogen bonding by the acetamide functionality was a prime factor in reducing the reactivity of the C-4-OH. Through the use of different *N*-protecting groups (a phthalimide or azide) the reactivity of the GlcN-C-4-OH could be effectively enhanced.

This chapter describes the influence of three different *N*-protecting groups on the reactivity of glycosyl alcohol nucleophiles: an azide, a trifluoroacetyl (TFA) and trichloroacetyl (TCA) group, as these are amongst the most commonly employed *N*-protecting groups.[17-19] The influence of these protecting groups on the reactivity of the acceptor is investigated for both the C-3-OH and C-4-OH glucosamine acceptors. To investigate whether the orientation of the *N*-protecting groups is important for its effect on the reactivity of the acceptor, just like in the *O*-protecting groups in ether/ester protected acceptors, both glucosamine and mannosamine acceptors are probed.

The method used for measuring the reactivity of the acceptors is based on the stereoselectivity observed in glycosylation reactions with phenyl 2,3-di-*O*-benzyl-4,6-*O*-benzylidene-1-thio-β-D-glucopyranoside (**Donor A**, ***Figure 2A***) and phenyl 2-deoxy-2-azido-3-*O*-benzyl-4,6-*O*-benzylidene-1-thio-β-D-glucopyranoside (**Donor B**). As described before, the stereoselectivity of glycosylation reactions of these is a measure for the reactivity of the acceptor.[20] More nucleophilic acceptors, provide β-selective glycosylations, while less nucleophilic acceptors lead to α-selectivity. The mechanism to explain the change in stereoselectivity is shown in ***Figure 2***. Both thioglycoside donors form an α-triflate upon activation with Ph_2SO and Tf_2O. The more reactive acceptors can substitute this triflate in an S_N2 like mechanism, while less nucleophilic acceptors react with the corresponding β-triflate or an oxocarbenium ion-like species to form the α-product.[21] **Donor B** shows higher β-selectivity with the same acceptor than **Donor A** because the electron-withdrawing azide on C-2 stabilises the anomeric triflate rendering the S_N2 substitution of the α-triflate more predominant.[22]

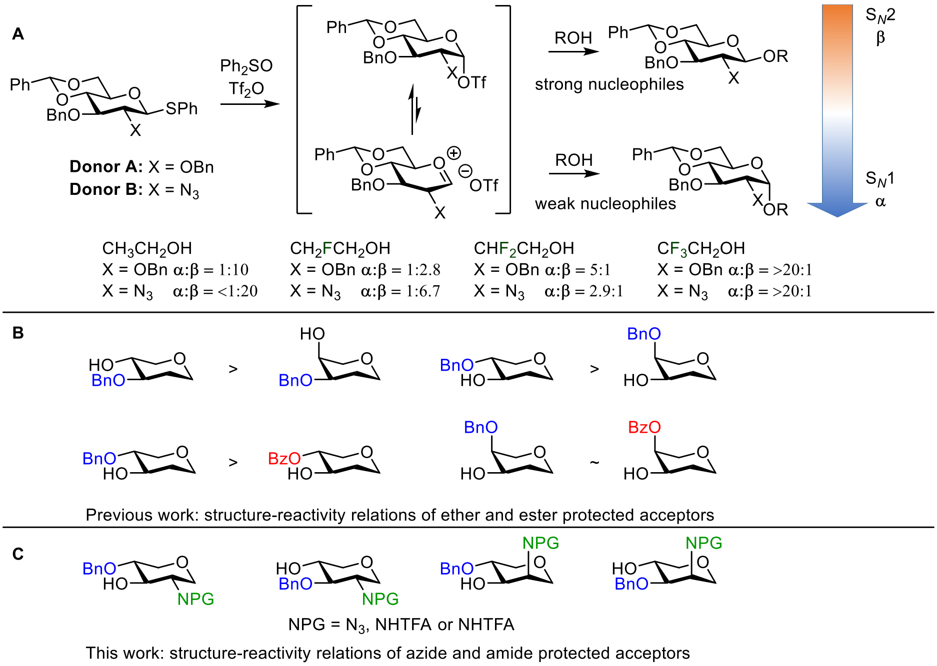
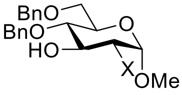
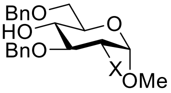
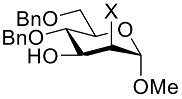
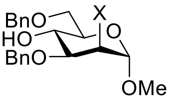


Figure 2: ***A:*** *Glycosylation mechanisms and the relation between stereoselectivity of* ***donor A*** *and* ***Donor B*** *and nucleophilicity of the acceptor,* ***B:*** *the reactivity trends found in chapter 4 and* ***C:*** *the structure-reactivity relations investigated in this work.*

Results and discussion

In this study, 12 acceptors that can be divided in four groups based on the type of 2-deoxy-2-aminosugar and the position of the hydroxyl function, were reacted with **Donor A** and **Donor B**: 1) glucosamine C-3-OH acceptors **1c-1e**; 2) glucosamine C-4-OH acceptors **2b-2d**; 3) mannosamine C-3-OH acceptors **3c-3e** and 4) mannosamine C-4-OH acceptors **2b-2d**. The results are summarized in ***table 1***, in which also the results of the corresponding glucose and mannose acceptors **1a**, **1b**, **2a**, **3a**, **3b** and **4a** are provided a reference (see Chapter 4). When looking at the results of the glucosamine C-3-OH acceptors, it becomes apparent that the nature of the protecting group next to the alcohol has a significant influence its reactivity. An azide flanking the free hydroxy group decreases the reactivity of the acceptor more than a neighboring benzyl ether and about as much as as a benzoyl group (acceptors **1a**-**1c**). The trichloroand trifluoroacetamides next to the alcohol decrease the reactivity of the acceptor even more, with the disarming effect of the trifluoroacetamide being stronger than that of the trichloroacetamide (acceptors **1d** and **1e**). Note how switching an *O*-benzyl group to a *N*-trifuoroacetyl group completely reverses the stereoselectivity of the acceptor, with acceptor **1a** giving full β-selectivity with **Donor B**, while acceptor **1d** gives nearly full α-selectivity with **Donor B**. On the other hand, the nature of the *N*-protecting group has an almost negligible effect on the reactivity of the C-4-OH glucose acceptors. All tested C-4-OH acceptors tested in this work provide high yielding glycosylations with very similar stereoselectivity with both **Donor A** and **Donor B**, regardless of the nature of the group on C-2 being an *O*-benzyl, an azide, a *N*-trifluoroacetamide or a *N*-trichloroacetamide (acceptors **2a**-**2d**). The results in the C-3-OH mannosamine series, show that, in line with the survey on *O*-protecting groups, not only the nature of the *N*-protecting groups is important, but also the configuration of the *N*-functional group next to the acceptor alcohol is relevant for the reactivity of the acceptor. Similar to the differences in reactivity observed between glucose and mannose (acceptors **1a** and **3a**), where the alcohol next to an axial benzyl group is less reactive than the alcohol next to the equatorial one, the acceptor next to the equatorial azide (acceptor **1a**) is more reactive than the acceptor next to the axial azide (acceptor **3a**). Furthermore, in line with the reactivity of benzoylated glucose/galactose/mannose systems of the previous chapter, it turns out that the difference in reactivity between an axial benzyl group and an axial azide is less than the difference between an equatorial benzyl group and the corresponding azide (acceptor **1a** vs **1c** and acceptor **3a** vs **3c**). Similarly, there is little difference between the axial azide and the axial *N*-trifluoroacetyl or *N*-trichloroacetyl groups (acceptors **3c**-**3e**) in contrast to the different effects when these groups are flanking the nucleophilic hydroxy group in an equatorial orientation (acceptor **1c**-**1e**). It is noteworthy however, that in acceptors **3c**-**3e** the *N*-trifluoroacetyl protected acceptor (**3d**) seems to be more reactive than *N*-trichloroacetyl protected acceptor **3e**, which is more reactive than azide acceptor **3c**. Finally, the nature of the protecting group has very little effect on the reactivity of the mannosamine C-4-OH acceptors. In line with the glucose/glucosamine series above, the mannose C-4-OH is not strongly effected by the nature of the function group at C-2. Whether it is an *O*-benzyl, an azide, a *N*-trifluoroacetamide or a *N*-trichloroacetamide (acceptors **4a**-**4d**) the stereoselectivity with both **Donor A** and **Donor B** is all very similar, and all glycosylations are high yielding.

Table 1: *Results of glucosamine and mannosamine acceptors with different protecting groups. The results for glucose and mannose acceptors are given for reference*

		Donor A		**Donor B**	
Position	Acceptor	Product (yield)	α:β	Product (yield)	α:β
3-OH glucose 	**1a** X = OBn	**1aA** (78%)	**1:2.7**	**1aB** (70%)	**<1:20**
	1b X = OBz	**1bA** (99%)	**1.8:1**	**1bB** (93%)	**1:4**
	1c X = N_3	**1cA** (83%)	**1.6:1**	**1cB** (85%)	**1:2.5**
	1d X = NHTFA	**1dA** (96%)	**>20:1**	**1dB** (100%)	**12:1**
	1e X = NHTCA	**1eA** (65%)	**11:1**	**1eB** (63%)	**3:1**
4-OH glucose 	**2a** X = OBn	**2aA** (82%)	**1:1**	**2aB** (88%)	**1:7**
	2b X = N_3	**2bA** (94%)	**1:1.1**	**2bB** (100%)	**1:3.3**
	2c X = NHTFA	**2cA** (82%)	**1.3:1**	**2cB** (100%)	**1:2.5**
	2d X = NHTCA	**2dA** (81%)	**1.1:1**	**2dB** (100%)	**1:3.5**
3-OH mannose 	**3a** X = OBn	**3aA** (82%)	**8:1**	**3aB** (70%)	**1.1:1**
	3b X = OBz	**3bA** (82%)	**10:1**	**3bB** (93%)	**1:1**
	3c X = N_3	**3cA** (100%)	**7:1**	**3cB** (75%)	**1.8:1**
	3d X = NHTFA	**3dA** (80%)	**2.3:1**	**3dB** (92%)	**1:1.2**
	3e X = NHTCA	**3eA** (57%)	**5:1**	**3eB** (80%)	**1:1**
4-OH mannose 	**4a** X = OBn	**4aA** (76%)	**1:2**	**4aB** (72%)	**<1:20**
	4b X = N_3	**4bA** (100%)	**1:2.5**	**4bB** (100%)	**1:14**
	4c X = NHTFA	**4cA** (71%)	**1:1.4**	**4cB** (77%)	**1:10**
	4d X = NHTCA	**4dA** (77%)	**1:2.7**	**4dB** (100%)	**<1:20**

Conclusion

In conclusion, structure-reactivity relationships for a set of glycosyl acceptors with different *N*-protecting groups have been established, based on the stereoselectivity of these acceptors in glycosylations with two conformationally restricted glucosyl donors. Three different *N*-protecting groups were used in this study: an azide, a trifluoroacetamide and a trichloroacetamide group. These were surveyed on the 2-position of both glucosamine and mannosamine acceptors, to investigate the difference between equatorially and axially oriented *N*-functional groups, as it was found previously that the orientation of the flanking *O*-functional groups has a large influence on the reactivity of the acceptor alcohol. Both the C-3-OH and C-4-OH acceptors in the glucosamine and mannosamine series were investigated. The orientation of the *N*-protecting group proved to be important for its effect on the reactivity of the acceptor. It was found that, in line with the previsouly studied ether/ester protected acceptors, the influence of the protecting group on the reactivity is much larger when the group next to the alcohol is equatorial then when it is placed axial. The nature of the protecting group is also important for the reactivity with the disarming effect of an azide being similar to that of an benzoyl ester and the trichloroacetamide and trifluoroacetamide group having an larger influence on the reactivity. The difference in reactivity between the mannosamine acceptor having either an axial azide or amide is smaller with the *N*-trifluoroacetamide mannosamine C-3-OH being the most reactive in the series. The different *N*-protecting groups do not significantly influence the reactivity of the glucosamine and mannosamine C-4-OH acceptors. Overall this study has shown that the reactivity of glycosamine acceptors can be tuned by the changing the nature of the *N*-protecting group, if this is suitable positioned. The effects observed in this study can likely be transposed to galactosamine and fucosamine systems and aid in the assembly of bacterial glycans.[23, 24]

Experimental

General experimental procedures

General experimental procedures: All chemicals were of commercial grade and used as received unless stated otherwise. Dichloromethane (DCM) was stored over activated 4 Å molecular sieves for at least 24 h before use. Trifluoromethanesulfonic anhydride (Tf_2O) was distilled over P_2O_5 and stored at -20°C under a nitrogen atmosphere. Overnight temperature control was achieved by a FT902 Immersion Cooler (Julabo). Flash column chromatography was performed on silica gel 60 Å (0.04 – 0.063 mm, Screening Devices B.V.). Size-exclusion chromatography was performed on Sephadex (LH-20, GE Healthcare Life Sciences) by isocratic elution with DCM/MeOH (1/1, v/v). Thin-layer chromatography (TLC) analysis was conducted on TLC silica gel 60 plates (Kieselgel 60 F254, Merck) with UV detection by (254 nm) and by spraying with 20% sulfuric acid in ethanol or by spraying with a solution of $(NH_4)_6Mo_7O_{24}\cdot H_2O$ (25 g/L) and $(NH_4)_4Ce(SO4)_4\cdot 2H_2O$ (10 g/L) in 10% aq. sulfuric acid followed by charring at ±250 °C. High-resolution mass spectrometry (HRMS) was performed on a Thermo Finnigan LTQ Orbitrap mass spectrometer equipped with an electrospray ion source in positive-ion mode (source voltage 3.5 kV, sheath gas flow 10, capillary temperature 275 °C) with resolution R = 60.000 at *m/z* 400 (mass range of 150-4000) and dioctylphtalate (m/z=391.28428) as lock mass, or on a Waters Synapt G2-Si (TOF) equipped with an electrospray ion source in positive mode (source voltage 3.5 kV) and LeuEnk (m/z = 556.2771). as internal lock mass. 1H and 13C NMR spectra were recorded on Bruker AV-400, Bruker DMX-400, and Bruker AV-500 NMR instruments. Chemical shifts (δ) are given in parts per million (ppm) relative to tetramethylsilane as an internal standard or the residual signal of the deuterated solvent. Coupling constants (J) are given in Hertz (Hz). All presented 13C-APT spectra are proton-decoupled. NMR peak assignments were made using COSY and HSQC. When necessary, additional NOESY, HMBC and HMBC-GATED experiments were used to further elucidate the structure. The anomeric product ratios were based on careful analysis of the crude reaction mixture and the purified reaction product by integration of representative 1H NMR signals. IR spectra were recorded on a Shimadzu FTIR-

8300 IR spectrometer and are reported in cm-1. Specific rotations were measured on a Propol automatic polarimeter or an Anton-Paar MCP-100 modular circular polarimeter at 589 nm unless otherwise stated.

General procedure I: Ph_2SO/Tf_2O meditated glycosylations

Donor (0.1 mmol, 1 eq), Ph_2SO (0.13 mmol, 1.3 eq) and TTBP (0.25 mmol, 2.5 eq) were coevaporated twice with toluene, dissolved in 2 mL DCM and stirred for 30 min at RT with 3A molecular sieves. The solution was cooled to -80 ^{0}C and Tf_2O (22 µL, 0.13 mmol, 2 eq) was added. The reaction mixture was allowed to warm to −60 ^{0}C and then recooled to −78 ^{0}C, after which the acceptor (0.2 mmol, 2 eq) in DCM (0.4 mL, 0.5 M) was added. The reaction mixture was allowed to warm to −40 ^{0}C for and stirred between 4-24 hr at that temperature. The reaction was quenched with 1 mL sat aq $NaHCO_3$, and the mixture was diluted with DCM. The solution was transferred to a separatory funnel, water was added, the layers were separated, and the water phase was extracted once more with DCM. The combined organic layers were dried over MgSO4, filtered, and concentrated in vacuo. Purification by silica gel flash column chromatography and/or sephadex LH-20 size-exclusion chromatography yielded the glycosylation product as a mixture of anomers.

General procedure II: azide reduction

The azide (1 eq) was dissolved in anhydrous THF, after which $LiAlH_4$ (1.5 eq, soln in Et_2O, THF or 2-MeTHF) was added dropwise while gaseous by-products were allowed to escape. After full conversion, the reaction mixture was cooled to 0 °C, and excess reagents were destroyed by careful and dropwise addition of water. The precipitated aluminium salts were filtered off and the solution was concentrated under reduced pressure. The residue was purified over silica or used directly in subsequent reactions.

General procedure III: TFA installation

The amine (1 eq) was dissolved in DCM, after which TEA (1.5 eq) and TFAA (1.5 eq) were added. After TLC indicates full conversion, the reaction mixture was diluted with DCM and washed with water. The organic phase was dried with $MgSO_4$ and concentrated under reduced pressure. The residue was purified by silica chromatography to yield the title compound.

General procedure IV: TCA installation

The amine (1 eq) was dissolved in DCM, after which TEA (1.5 eq) and trichloroacetyl chloride (1.5 eq) were added. After TLC indicates full conversion, the reaction mixture was diluted with DCM and washed with water. The organic phase was dried with $MgSO_4$ and concentrated under reduced pressure. The residue was purified by silica chromatography to yield the title compound.

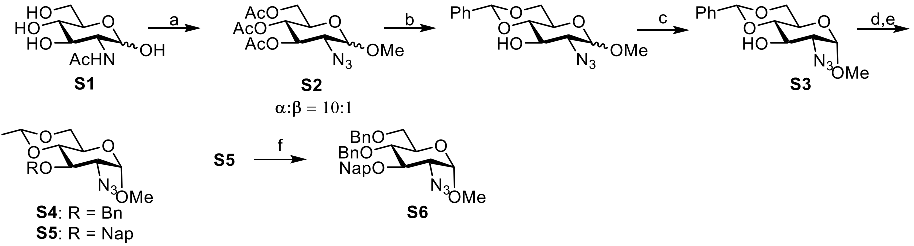
General procedure V: DDQ mediated Nap deprotection

Nap protected acceptor (1 eq) was dissolved in 9:1 DCM/H_2O with DDQ (2 eq). After After TLC indicates full conversion, the reaction mixture was diluted with DCM and washed twice with sat. aq. $NaHCO_3$. The organic phase was dried with $MgSO_4$ and concentrated under reduced pressure. The residue was purified by silica chromatography to yield the title compound.

General procedure VI: reductive benzylidene opening

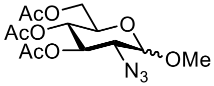
The benzylidene (1 eq) was dissolved in DCM and cooled to 0 °C, after which triethylsilane (10 eq) and TFA (10 eq) were added. After TLC indicates full conversion, the reaction mixture was quenched with sat. aq. $NaHCO_3$ and extracted twice with DCM. Combined organic phases were washed with sat .aq $NaHCO_3$. The organic phase was dried with $MgSO_4$ and concentrated under reduced pressure. The residue was purified by silica chromatography to yield the title compound.

Preparations of acceptors



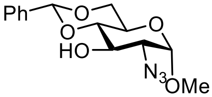
***Scheme S1**: preparation of α-OMe glucosazide intermediates: reagents and conditions: a) i: amberlite-H^+, methanol, reflux, ii: $Ba(OH)_2$, water, reflux, iii: Imidazole-1-sulfonyl azide-H_2SO_4, K_2CO_3, $CuSO_4(H_2O)_5$, methanol, iv: Ac_2O, pyridine, DMAP, 65% over 4 steps; b) i: Na, methanol, ii: PTSA, $PhCH(OMe)_2$, acetonitrile, 60 °C, 300 mbar, 71% over 2 steps; c) recrystallization from acetone/pentane; d) for **S4**: BnBr, NaH, DMF, 87%, e) for **S5**: NapBr, NaH, DMF, 88%; f) i: PTSA, methanol, 50 °C, ii: BnBr, NaH, DMF, 100% over 2 steps*

Methyl 2-deoxy-2-azido-3,4,6-tri-*O*-acetyl-α,β-D-glucopyranoside (S2)



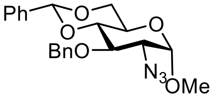
N-acetylglucosamine (**S1**, 30 g, 136 mmol) was dissolved in 700 mL methanol with 50 g amberlite-H^+ and heated to a reflux overnight, after which the reaction mixture was filtered and concentrated under reduced pressure. The residue was dissolved in 1 L water with 50 g $BaOH(H_2O)_8$. After overnight reflux, the reaction mixture was cooled to RT and neutralised with dry ice (pH 7). Salts were removed by filtration and the solution was concentrated under reduced pressure. The residue was dissolved in methanol with K_2CO_3 (47 g, 340 mmol, 2.5 eq) and imidazole-1-sulfonyl azide hydrogen sulfate[25] (42,1 g, 163 mmol, 1.2 eq) and $CuSO_4(H_2O)_5$ (340 mg, 1.36 mmol, 0.01 eq). When TLC (EA/MeOH/H_2O 8:1:1, Rf = 0.6) shows a single spot, the reaction mixture was concentrated and dissolved in pyridine (274 mL, 3.4 mol, 25 eq). The solution was cooled to 0 °C and Ac_2O (103 mL, 1.08 mol, 8 eq) and DMAP (1.66 g, 13.6 mmol, 0.1 eq) were added. The reaction mixture was allowed to warm to RT overnight and concentrated. The residue was dissolved in ethyl acetate and washed with 1M HCl and sat. aq. $NaHCO_3$. The organic phase was dried with $MgSO_4$ and concentrated under reduced pressure, yielding the title compound as a red oil. Yield: 30.6 g, 89 mmol, 65%, α:β = 10:1. Data for the α-anomer: ^1H NMR (400 MHz, $CDCl_3$) δ 5.48 (dd, J = 10.6, 9.2 Hz, 1H, H-3), 5.05 (dd, J = 10.2, 9.2 Hz, 1H, H-4), 4.88 (d, J = 3.5 Hz, 1H, H-1), 4.29 (dd, J = 12.4, 4.6 Hz, 1H, H-6), 4.10 (dd, J = 12.4, 2.3 Hz, 1H, H-6), 4.01 (ddd, *J* = 10.1, 4.6, 2.3 Hz, 1H, H-5), 3.47 (s, 3H, CH_3 OMe), 3.38 (dd, *J* = 10.6, 3.5 Hz, 1H, H-2), 2.10 (s, 3H, CH_3 Ac), 2.09 (s, 3H, CH_3 Ac), 2.04 (s, 3H, CH_3 Ac); ^{13}C NMR (101 MHz, $CDCl_3$) δ 170.7, 170.1, 169.8 (C=O), 98.8 (C-1), 70.6 (C-3), 68.6 (C-4), 67.6 (C-5), 62.0 (C-6), 61.1 (C-2), 55.7 (CH_3 OMe), 20.8, 20.8, 20.7 (CH_3 Ac). Spectra in agreement with literature.[26]

Methyl 2-deoxy-2-azido-4,6-*O*-benzylidene-α-D-glucopyranoside (S3)



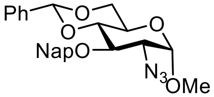
Compound **S2** (30.7 g, 89.0 mmol) was dissolved in MeOH, and a catalytic amount of sodium was added. When TLC shows full deacetylation, the reaction mixture was acidified (pH = 5) using amberlite-H$^+$, filtered, concentrated and coevaporated twice with toluene. The residue was dissolved in acetonitrile with PTSA-H_2O (1.69 g, 8.90 mmol, 0.1 eq) and benzaldehyde dimethyl acetal (18.8 mL, 125 mmol, 1.4 eq) and heated to 60 °C at 300 mbar. After full conversion, the reaction mixture was quenched with Et_3N (1.88 mL, 13.4 mL, 0.15 eq) and concentrated under reduced pressure. Silica chromatography (10%→20% acectone in pentane) yields the title compound as white solid. Yield: 19.5 g, 63.5 mmol, 71%, α:β = 10:1. Recrystallization from acetone/pentane yields 10 g of pure α-anomer as a white solid. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.52 – 7.47 (m, 2H, CH_{arom}), 7.41 – 7.35 (m, 3H, CH_{arom}), 5.52 (s, 1H, C*H*Ph), 4.78 (d, *J* = 3.6 Hz, 1H, H-1), 4.27 (dd, *J* = 10.0, 4.6 Hz, 1H, H-6), 4.16 (ddd, *J* = 10.0, 9.1, 2.8 Hz, 1H, H-3), 3.82 (td, *J* = 9.7, 4.6 Hz, 1H, H-5), 3.73 (t, *J* = 10.2 Hz, 1H, H-6), 3.49 (t, *J* = 9.3 Hz, 1H, H-4), 3.43 (s, 3H, CH_3 OMe), 3.31 (dd, *J* = 10.0, 3.6 Hz, 1H, H-2), 2.93 (d, *J* = 2.9 Hz, 1H, 3-OH); ^{13}C NMR (101 MHz, $CDCl_3$) δ 137.0 (C_q), 129.5, 128.5, 126.4 (CH_{arom}), 102.2 (CHPh), 99.5 (C-1), 81.9 (C-4), 69.2 (C-3), 68.9 (C-6), 63.3 (C-2), 62.3 (C-5), 55.6 (CH_3 OMe). Spectra in agreement with literature.[27]

Methyl 2-deoxy-2-azido-3-*O*-benzyl-4,6-*O*-benzylidene-α-D-glucopyranoside (S4)



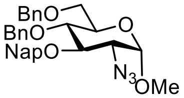
Compound **S3** (4.00 g, 13.0 mmol) was dissolved in DMF, after which BnBr (2.32 mL, 19.5 mmol, 1.5 eq) and NaH (60% dispersion in mineral oil, 781 mg, 19.5 mmol, 1.5 eq) were added. After TLC shows full conversion, the reaction mixture was quenched with 5x the volume in water. Precipitated solids were collected by filtration, dissolved in $CHCl_3$ and washed with water. The organic phase was dried with $MgSO_4$ and concentrated to yield the title compound as white powder. Yield: 4.52 g, 11.3 mmol, 87%. ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.51 – 7.48 (m, 2H, CH_{arom}), 7.38 (ddt, *J* = 7.0, 5.8, 1.0 Hz, 5H, CH_{arom}), 7.34 – 7.27 (m, 3H, CH_{arom}), 5.58 (s, 1H, C*H*Ph), 4.94 (d, *J* = 11.0 Hz, 1H, C*H*H Bn), 4.80 (d, *J* = 11.1 Hz, 1H, CH*H* Bn), 4.78 (d, *J* = 3.6 Hz, 1H, H-1), 4.29 (dd, *J* = 10.2, 4.8 Hz, 1H, H-6), 4.06 (dd, *J* = 9.9, 9.0 Hz, 1H, H-3), 3.87 (td, *J* = 9.9, 4.7 Hz, 1H, H-5), 3.76 (t, *J* = 10.3 Hz, 1H, H-6), 3.70 (t, *J* = 9.3 Hz, 1H, H-4), 3.46 – 3.42 (m, 4H, H-2, CH_3 OMe); ^{13}C NMR (126 MHz, $CDCl_3$) δ 137.9, 137.3 (C_q), 129.2, 128.5, 128.4, 128.4, 128.0, 126.1 (CH_{arom}), 101.6 (CHPh), 99.5 (C-1), 82.9 (C-4), 76.5 (C-3), 75.2 (CH_2 Bn), 69.0 (C-6), 63.3 (C-2), 62.7 (C-5), 55.5 (CH_3 OMe). Spectra in agreement with literature.[28]

Methyl 2-deoxy-2-azido-3-*O*-(2-naphtyl)methyl-4,6-*O*-benzylidene-α-D-glucopyranoside (S5)

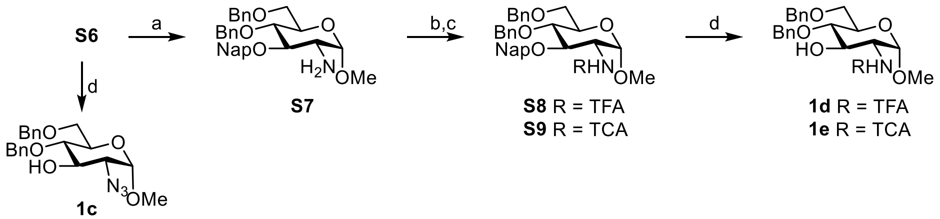


The title compound was synthesised from **S3** as described for **S4** but 2-(Bromomethyl)naphthalene was used instead of benzyl bromide. Yield: 7.73 g, 17.3 mmol, 88%. ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.80 (td, *J* = 6.0, 5.4, 3.5 Hz, 3H, CH_{arom}), 7.77 – 7.73 (m, 1H, CH_{arom}), 7.53 – 7.48 (m, 3H, CH_{arom}), 7.47 – 7.43 (m, 2H, CH_{arom}), 7.40 (dt, *J* = 4.6, 2.8 Hz, 3H, CH_{arom}), 5.60 (s, 1H, C*H*Ph), 5.09 (d, *J* = 11.3 Hz, 1H, C*H*H Nap), 4.97 (d, *J* = 11.3 Hz, 1H, CH*H* Nap), 4.79 (d, *J* = 3.6 Hz, 1H, H-1), 4.30 (dd, *J* = 10.2, 4.7 Hz, 1H, H-6), 4.11 (dd, *J* = 9.9, 9.0 Hz, 1H, H-3), 3.88 (td, *J* = 9.9, 4.7 Hz, 1H, H-5), 3.80 – 3.71 (m, 2H, H-4, H-6), 3.47 (dd, *J* = 9.9, 3.6 Hz, 1H, H-2), 3.43 (s, 3H, CH_3 OMe); ^{13}C NMR (126 MHz, $CDCl_3$) δ 137.3, 135.4, 133.4, 133.2 (C_q), 129.2, 128.5, 128.3, 128.1, 127.8, 127.2, 126.3, 126.2, 126.1, 126.0 (CH_{arom}), 101.7 (CHPh), 99.5 (C-1), 82.9 (C-4), 76.5 (C-3), 75.2 (CH_2 Nap), 69.1 (C-6), 63.4 (C-2), 62.7 (C-5), 55.6 (CH_3 OMe); HRMS: $[M+NH_4]^+$ calcd for $C_{25}H_{25}N_3O_5NH_4$ 465.21325, found 465.21285

Methyl 2-deoxy-2-azido-4,6-di-*O*-benzyl-3-O-(2-naphtyl)methyl-α-D-glucopyranoside (S6)

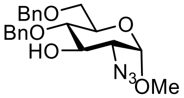


Compound **S5** (7.70 g, 17.2 mmol) was dissolved in methanol with PTSA-H_2O (327 mg, 1.72 mmol, 0.1 eq) and heated to 50 °C. After removal of the benzylidene, Et_3N (0.48 mL, 3.44 mmol, 0.2 eq) was added and the reaction mixture was concentrated under reduced pressure. The residue was coevaporated with toluene and dissolved in DMF, after which benzyl bromide (6.13 mL, 51.6 mmol, 3 eq) and sodium hydride (60% dispersion in mineral oil, 2.07 g, 51.6 mmol, 3 eq) were added. After full conversion, the reaction was quenched with water and extracted with diethyl ether. The organic phase was dried with $MgSO_4$ and concentrated. The residue was purified over silica (10% acetone in pentane) to yield the title compound as a colourless oil that slowly solidifies. Yield: 9.29 g, 17.4 mmol, 100%. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.83 – 7.74 (m, 4H, CH_{arom}), 7.51 – 7.43 (m, 3H, CH_{arom}), 7.35 – 7.30 (m, 4H, CH_{arom}), 7.30 – 7.25 (m, 4H, CH_{arom}), 7.14 (dd, *J* = 6.7, 2.9 Hz, 2H, CH_{arom}), 5.04 (d, *J* = 10.9 Hz, 1H, C*H*H Bn/Nap), 4.99 (d, *J* = 10.9 Hz, 1H, CH*H* Bn/Nap), 4.87 – 4.78 (m, 2H, H-1, C*H*H Bn/Nap), 4.63 (d, *J* = 12.1 Hz, 1H, C*H*H Bn), 4.56 – 4.47 (m, 2H, 2x CH*H* Bn/Nap), 4.03 (dd, *J* = 10.2, 8.6 Hz, 1H, H-3), 3.84 – 3.71 (m, 3H, H-4, H-5, H-6), 3.68 (dd, *J* = 10.6, 1.9 Hz, 1H, H-6), 3.48 (dd, *J* = 10.2, 3.5 Hz, 1H, H-2), 3.42 (s, 3H, CH_3 OMe); ^{13}C NMR (101 MHz, $CDCl_3$) δ 138.1, 137.9, 135.5, 133.4, 133.2 (C_q), 128.5, 128.5, 128.3, 128.1, 128.0, 127.9, 127.8, 127.0, 126.1, 126.1, 126.0 (CH_{arom}), 98.8 (C-1), 80.7 (C-3), 78.3 (C-4), 75.6, 75.1, 73.7 (CH_2 Bn/Nap), 70.7 (C-5), 68.4 (C-6), 63.8 (C-2), 55.3 (CH_3 OMe); HRMS: $[M+NH_4]^+$ calcd for $C_{32}H_{33}N_3O_5NH_4$ 557.27585, found 557.25700



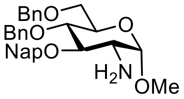
Scheme S2**: preparation of 3-OH glucosamine acceptors: reagents and conditions: a) $LiAlH_4$, THF, 99%; b) for **S8**: TFAA, Et_3N, DCM, 77%; c) for **S9**: trichloroacetyl chloride, Et_3N, DCM, 98%; d) DDQ, 9:1 DCM/H_2O 88% for **1c**, 93% for **1d**, 70% for **1e

Methyl 2-deoxy-2-azido-4,6-di-*O*-benzyl-α-D-glucopyranoside (1c)



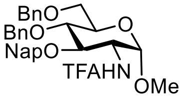
Title compound was synthesised from **S6** according to general procedure V as a colourless oil. Yield: 1.05 g, 2.64 mmol, 88%. $[\alpha]_D^{25}$ = 106.0° (c = 0.91, $CHCl_3$); IR (thin film): 698, 737, 1047, 1105, 2106; ^1H NMR (400 MHz, $CDCl_3$) δ 7.39 – 7.17 (m, 10H, CH_{arom}), 4.80 (d, *J* = 3.6 Hz, 1H, H-1), 4.72 – 4.63 (m, 2H, 2x C*H*H Bn), 4.58 (d, *J* = 11.3 Hz, 1H, CH*H* Bn), 4.52 (d, *J* = 12.1 Hz, 1H, CH*H* Bn), 4.05 (ddd, *J* = 10.3, 8.7, 3.4 Hz, 1H, H-3), 3.79 – 3.71 (m, 2H, H-5, H-6), 3.71 – 3.66 (m, 1H, H-6), 3.57 (dd, *J* = 9.8, 8.7 Hz, 1H, H-4), 3.40 (s, 3H, CH_3 OMe), 3.28 (dd, *J* = 10.3, 3.6 Hz, 1H, H-2), 2.49 (d, *J* = 3.4 Hz, 1H, 3-OH); ^{13}C NMR (101 MHz, $CDCl_3$) δ 138.1, 137.8 (C_q), 128.7, 128.5, 128.1, 128.1, 128.0, 127.9 (CH_{arom}), 98.8 (C-1), 78.3 (C-4), 74.9, 73.7 (CH_2 Bn), 72.3 (C-3), 70.2 (C-5), 68.4 (C-6), 63.3 (C-2), 55.4 (CH_3 OMe); HRMS: $[M+NH_4]^+$ calcd for $C_{21}H_{25}N_3O_5NH_4$ 417.21325, found 417.21254

Methyl 2-deoxy-2-amino-4,6-di-*O*-benzyl-3-O-(2-naphtyl)methyl-α-D-glucopyranoside (S7)



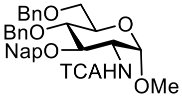
Title compound was synthesised form **S6** according to general procedure II as a colourless oil. Yield: 7.11 g, 13.8 mmol, 99%. ^1H NMR (400 MHz, $CDCl_3$) δ 7.83 – 7.72 (m, 4H, CH_{arom}), 7.48 – 7.42 (m, 3H, CH_{arom}), 7.37 – 7.24 (m, 8H, CH_{arom}), 7.19 – 7.14 (m, 2H, CH_{arom}), 5.09 (d, *J* = 11.7 Hz, 1H, C*H*H Bn/Nap), 4.86 (d, *J* = 11.6 Hz, 1H, CH*H* Bn/Nap), 4.81 (d, *J* = 10.9 Hz, 1H, C*H*H Bn/Nap), 4.75 (d, *J* = 3.6 Hz, 1H, H-1), 4.66 (d, *J* = 12.1 Hz, 1H, C*H*H Bn/Nap), 4.58 – 4.47 (m, 2H, 2x CH*H* Bn/Nap), 3.82 – 3.75 (m, 2H, H-5, H-6), 3.71 – 3.65 (m, 2H, H-4, H-6), 3.60 (t, *J* = 9.3 Hz, 1H, H-3), 3.35 (s, 3H, CH_3 OMe), 2.85 (dd, *J* = 9.7, 3.6 Hz, 1H, H-2); ^{13}C NMR (101 MHz, $CDCl_3$) δ 138.2, 138.0, 136.1, 133.3, 133.0 (C_q), 128.4, 128.4, 128.3, 128.0, 127.9, 127.9, 127.8, 127.7, 127.7, 126.5, 126.2, 125.9, 125.8 (CH_{arom}), 100.7 (C-1), 84.0 (C-3), 78.9 (C-4), 75.6, 74.7, 73.6 (CH_2 Bn/Nap), 70.9 (C-5), 68.6 (C-6), 56.0 (C-2), 55.1 (CH_3 OMe); HRMS: $[M+H]^+$ calcd for $C_{32}H_{35}NO_5H$ 514.25880, found 514.25759

Methyl 2-deoxy-2-*N*-trifluoroacetyl-4,6-di-*O*-benzyl-3-O-(2-naphtyl)methyl-α-D-glucopyranoside (S8)



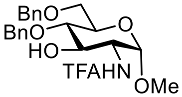
The title compound was prepared from **S7** according to general procedure III as a white solid. Yield: 1.40 g, 2.23 mmol, 77%. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.84 – 7.74 (m, 3H, CH$_{\mathrm{arom}}$), 7.65 (d, *J* = 1.6 Hz, 1H, CH$_{\mathrm{arom}}$), 7.47 (dt, *J* = 6.9, 3.5 Hz, 2H, CH$_{\mathrm{arom}}$), 7.40 – 7.27 (m, 9H, CH$_{\mathrm{arom}}$), 7.19 (dt, *J* = 5.5, 2.2 Hz, 2H, CH$_{\mathrm{arom}}$), 6.22 (d, *J* = 9.5 Hz, 1H, NH), 4.96 (d, *J* = 11.5 Hz, 1H, C*H*H Bn/Nap), 4.83 (d, *J* = 7.0 Hz, 1H, C*H*H Bn/Nap), 4.80 (d, *J* = 7.6 Hz, 1H, CH*H* Bn/Nap), 4.74 (d, *J* = 3.6 Hz, 1H, H-1), 4.65 (d, *J* = 12.1 Hz, 1H, C*H*H Bn/Nap), 4.55 (dd, *J* = 11.5, 9.9 Hz, 2H, 2x CH*H* Bn/Nap), 4.30 (td, *J* = 9.4, 3.4 Hz, 1H, H-2), 3.84 – 3.74 (m, 4H, H-3, H-4, H-5, H-6), 3.73 – 3.66 (m, 1H, H-6), 3.35 (s, 3H, CH_3 OMe); ^{13}C NMR (101 MHz, $CDCl_3$) δ 137.9, 135.2, 133.3, 133.2 (C$_q$), 128.6, 128.6, 128.1, 128.0, 128.0, 128.0, 127.9, 127.8, 127.1, 126.3, 126.2, 126.0 (CH$_{\mathrm{arom}}$), 97.9 (C-1), 79.4, 78.6 (C-3, C-4), 75.3, 75.2, 73.7 (CH_2 Bn/Nap), 71.1 (C-5), 68.3 (C-6), 55.2 (CH_3 OMe), 53.3 (C-2); HRMS: $[M+NH_4]^+$ calcd for $C_{34}H_{34}F_3NO_6$ 627.26765, found 627.26665

Methyl 2-deoxy-2-*N*-trichloroacetyl-4,6-di-*O*-benzyl-3-O-(2-naphtyl)methyl-α-D-glucopyranoside (S9)



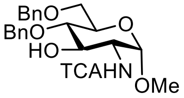
The title compound was prepared from **S7** according general procedure IV as a yellow oil that slowly solidifies. Yield: 1.93g, 2.93 mmol, 98%. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.82 – 7.74 (m, 3H, CH$_{\mathrm{arom}}$), 7.71 – 7.68 (m, 1H, CH$_{\mathrm{arom}}$), 7.47 – 7.43 (m, 2H, CH$_{\mathrm{arom}}$), 7.41 (dd, *J* = 8.4, 1.7 Hz, 1H, CH$_{\mathrm{arom}}$), 7.37 – 7.31 (m, 4H, CH$_{\mathrm{arom}}$), 7.31 – 7.26 (m, 4H, CH$_{\mathrm{arom}}$), 7.18 – 7.12 (m, 2H, CH$_{\mathrm{arom}}$), 6.81 (d, *J* = 9.3 Hz, 1H, NH), 4.94 (d, *J* = 11.2 Hz, 1H, C*H*H Bn/Nap), 4.88 (d, *J* = 11.2 Hz, 1H, CH*H* Bn/Nap), 4.82 – 4.77 (m, 2H, H-1, C*H*H Bn/Nap), 4.65 (d, *J* = 12.1 Hz, 1H, C*H*H Bn), 4.57 – 4.50 (m, 2H, 2x CH*H* Bn), 4.29 (td, *J* = 9.6, 3.7 Hz, 1H, H-2), 3.89 – 3.75 (m, 4H, -3, H-4, H-5, H-6), 3.75 – 3.68 (m, 1H, H-6), 3.40 (s, 3H, CH_3 OMe); ^{13}C NMR (101 MHz, $CDCl_3$) δ 161.9 (C=O), 138.0, 137.9, 135.3, 133.3, 133.1 (C$_q$), 128.6, 128.4, 128.1, 128.0, 128.0, 128.0, 127.9, 127.8, 126.8, 126.2, 126.0, 126.0 (CH$_{\mathrm{arom}}$), 98.1 (C-1), 80.3, 78.3 (C-3, C-4), 75.5, 75.1, 73.7 (CH_2 Bn/Nap), 71.0 (C-5), 68.4 (C-6), 55.4 (CH_3 OMe), 55.0 (C-2); HRMS: $[M+NH_4]^+$ calcd for $C_{34}H_{34}Cl_3NO_6NH_4$ 675.17900, found 675.17786

Methyl 2-deoxy-2-*N*-trifluoroacetyl-4,6-di-*O*-benzyl-α-D-glucopyranoside (1d)

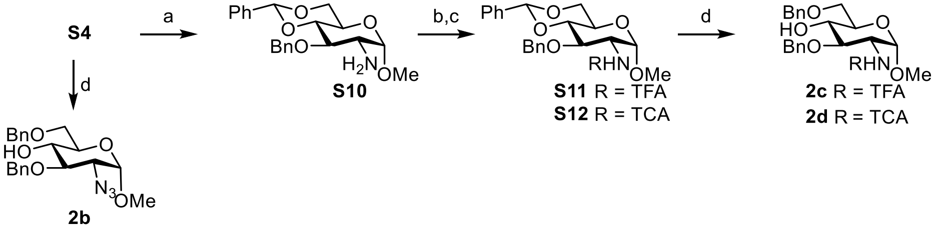


The title compound was prepared from **S8** according to general procedure V as colourless oil that slowly solidifies. Yield: 980 mg, 2.08 mmol, 93%. $[\alpha]_D^{25}$ = 46.3° (c = 1.01, $CHCl_3$); IR (thin film): 698, 1051, 1152, 1717; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.38 – 7.27 (m, 8H, CH$_{\mathrm{arom}}$), 7.23 – 7.18 (m, 2H, CH$_{\mathrm{arom}}$), 6.54 (d, *J* = 9.0 Hz, 1H, NH), 4.78 (d, *J* = 3.7 Hz, 1H, H-1), 4.71 (d, *J* = 11.2 Hz, 1H, C*H*H Bn), 4.66 (d, *J* = 12.1 Hz, 1H, C*H*H Bn), 4.58 (d, *J* = 11.2 Hz, 1H, CH*H* Bn), 4.54 (d, *J* = 12.1 Hz, 1H, CH*H* Bn), 4.15 (ddd, *J* = 10.4, 9.0, 3.7 Hz, 1H, H-2), 3.86 – 3.80 (m, 1H, H-3), 3.80 – 3.68 (m, 3H, H-5, 2x H-6), 3.64 – 3.56 (m, 1H, H-4), 3.37 (s, 3H, CH_3 OMe), 2.45 (d, *J* = 4.7 Hz, 1H, OH); ^{13}C NMR (101 MHz, $CDCl_3$) δ 157.8 (q, *J* = 37.4 Hz, C=O), 138.0, 137.9 (C_q), 128.7, 128.6, 128.2, 128.1, 128.0, 127.9 (CH_{arom}), 115.9 (d, *J* = 287.9 Hz, CF_3) 97.6 (C-1), 78.3 (C-4), 75.0, 73.7 (CH_2 Bn), 73.1 (C-3), 70.6 (C-5), 68.4 (C-6), 55.3 (CH_3 OMe), 54.1 (C-2); HRMS: $[M+NH_4]^+$ calcd for $C_{23}H_{26}F_3NO_6$ 487.20505, found 487.20455

Methyl 2-deoxy-2-*N*-trichloroacetyl-4,6-di-*O*-benzyl-α-D-glucopyranoside (1e)

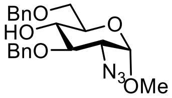


The title compound was prepared from **S9** according to general procedure V as yellow oil. Yield: 1.04 g, 2.00 mmol, 70%. $[\alpha]_D^{25}$ = 56.5° (c = 1.14, $CHCl_3$); IR (thin film): 698, 738, 820, 1053, 1118, 1515, 1713; ^1H NMR (400 MHz, $CDCl_3$) δ 7.39 – 7.27 (m, 8H, CH_{arom}), 7.22 (dd, *J* = 7.6, 1.9 Hz, 2H, CH_{arom}), 6.90 (d, *J* = 8.8 Hz, 1H, NH), 4.81 (d, *J* = 3.7 Hz, 1H, H-1), 4.75 (d, *J* = 11.2 Hz, 1H, C*H*H Bn), 4.66 (d, *J* = 12.1 Hz, 1H, C*H*H Bn), 4.58 (d, *J* = 11.2 Hz, 1H, CH*H* Bn), 4.54 (d, *J* = 12.1 Hz, 1H, CH*H* Bn), 4.10 (ddd, *J* = 10.5, 8.9, 3.8 Hz, 1H, H-2), 3.88 (ddd, *J* = 10.4, 8.6, 4.3 Hz, 1H, H-3), 3.80 – 3.68 (m, 3H, H-5, 2x H-6), 3.62 (t, *J* = 9.0 Hz, 1H, H-4), 3.39 (s, 3H, CH_3 OMe), 2.47 (d, *J* = 4.8 Hz, 1H, OH); ^{13}C NMR (101 MHz, $CDCl_3$) δ 162.7 (C=O), 138.1, 137.9 (C_q), 128.7, 128.5, 128.1, 128.0, 127.9 (CH_{arom}), 97.7 (C-1), 92.5 (CCl_3), 78.4 (C-4), 75.0, 73.7 (CH_2 Bn), 73.6 (C-3), 70.6 (C-5), 68.5 (C-6), 55.5, 55.4 (C-2, CH_3 OMe); HRMS: $[M+NH_4]^+$ calcd for $C_{23}H_{26}Cl_3NO_6NH_4$ 535.11640, found 535.11599



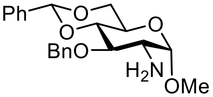
Scheme S3**: preparation of 4-OH glucosamine acceptors: reagents and conditions: a) $LiAlH_4$, THF, 98%; b) for **S11**: TFAA, Et_3N, DCM, 77%; c) for **S12**: trichloroacetyl chloride, Et_3N, DCM, 77%; d) TES-H, TFA, DCM, 0 °C, 83% for **2b**, 78% for **2c**, 67% for **2d

Methyl 2-deoxy-2-azido-3,6-di-*O*-benzyl-α-D-glucopyranoside (2b)



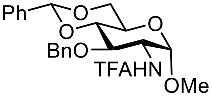
Title compound was prepared from **S4** according to general procedure VI as a colourless oil. Yield: 661 mg, 1.66 mmol, 83%. ^1H NMR (400 MHz, $CDCl_3$) δ 7.44 – 7.27 (m, 10H, CH_{arom}), 4.91 (d, *J* = 11.2 Hz, 1H, C*H*H Bn), 4.83 – 4.76 (m, 2H, H-1, CH*H* Bn), 4.61 (d, *J* = 12.0 Hz, 1H, C*H*H Bn), 4.54 (d, *J* = 12.0 Hz, 1H, CH*H* Bn), 3.80 (dd, *J* = 10.0, 8.1 Hz, 1H, H-3), 3.77 – 3.64 (m, 4H, H-4, H-5, 2x H-6), 3.42 (s, 3H, CH_3 OMe), 3.37 (dd, *J* = 10.0, 3.6 Hz, 1H, H-2), 2.51 (d, *J* = 2.5 Hz, 1H, OH); ^{13}C NMR (101 MHz, $CDCl_3$) δ 138.2, 137.8 (C_q), 128.8, 128.6, 128.3, 128.2, 128.0, 127.8 (CH_{arom}), 98.9 (C-1), 80.2 (C-3), 75.2, 73.8 (CH_2 Bn), 72.2 (C-4), 70.1 (C-5), 69.8 (C-6), 63.2 (C-2), 55.4 (CH_3 OBn). Spectra in agreement with literature.[28]

Methyl 2-deoxy-2-amino-3-*O*-benzyl-4,6-*O*-benzylidene-α-D-glucopyranoside (S10)



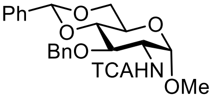
Title compound was prepared from **S4** according to general procedure II as a white solid. 3.40 g, 9.15 mmol, 98%. ^1H NMR (400 MHz, $CDCl_3$) δ 7.53 – 7.47 (m, 2H, CH_{arom}), 7.41 – 7.26 (m, 8H, CH_{arom}), 5.58 (s, 1H, C*H*Ph), 5.01 (d, *J* = 11.5 Hz, 1H, C*H*H Bn), 4.74 (d, *J* = 3.7 Hz, 1H, H-1), 4.68 (d, *J* = 11.4 Hz, 1H, CH*H* Bn), 4.29 (dd, *J* = 9.8, 4.4 Hz, 1H, H-6), 3.85 (ddd, *J* = 10.3, 8.5, 4.3 Hz, 1H, H-5), 3.80 – 3.74 (m, 1H, H-6), 3.70 – 3.58 (m, 2H, H-3, H-4), 3.39 (s, 3H, CH_3 OMe), 2.84 (dd, *J* = 9.3, 3.7 Hz, 1H, H-2), 1.49 (s, 2H, NH_2); ^{13}C NMR (101 MHz, $CDCl_3$) δ 138.6, 137.6 (C_q), 129.0, 128.6, 128.4, 128.2, 127.9, 126.1 (CH_{arom}), 101.3, 101.2 (C-1, CHPh), 83.3, 80.1 (C-3, C-4), 75.0 (CH_2 Bn), 69.3 (C-6), 62.9 (C-5), 56.0 (C-2), 55.4 (CH_3 OMe). Spectra in agreement with literature.[29]

Methyl 2-deoxy-2-*N*-trifluoroacetyl-3-*O*-benzyl-4,6-*O*-benzylidene-α-D-glucopyranoside (S11)



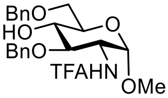
Title compound was prepared from **S10** according to general procedure III as white solid. Yield: 790 mg, 1.69 mmol, 77%.^1H NMR (400 MHz, $CDCl_3$) δ 7.53 – 7.49 (m, 2H, CH_{arom}), 7.44 – 7.37 (m, 3H, CH_{arom}), 7.35 – 7.28 (m, 3H, CH_{arom}), 7.27 – 7.23 (m, 2H, CH_{arom}), 6.24 (d, *J* = 9.3 Hz, 1H, NH), 5.61 (s, 1H, C*H*Ph), 4.89 (d, *J* = 12.0 Hz, 1H, C*H*H Bn), 4.75 (d, *J* = 3.8 Hz, 1H, H-1), 4.66 (d, *J* = 12.0 Hz, 1H, CH*H* Bn), 4.33 – 4.22 (m, 2H, H-2, H-6), 3.85 – 3.72 (m, 4H, H-3, H-4, H-5, H-6), 3.37 (s, 3H, CH_3 OMe); ^{13}C NMR (101 MHz, $CDCl_3$) δ 137.9, 137.3 (C_q), 129.2, 128.6, 128.5, 128.2, 128.1, 126.1 (CH_{arom}), 101.5 (CHPh), 98.4 (C-1), 82.8 (C-3), 75.1 (C-4), 74.3 (CH_2 Bn), 68.9 (C-6), 62.8 (C-5), 55.5 (CH_3 OMe), 53.1 (C-2). Spectra in agreement with literature.[30]

Methyl 2-deoxy-2-*N*-trichloroacetyl-3-*O*-benzyl-4,6-*O*-benzylidene-α-D-glucopyranoside (S12)



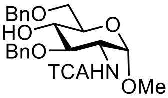
Title compound was prepared from **S10** according to general procedure IV as white solid. Yield: 870 mg, 1.68 mmol, 77%. ^1H NMR (400 MHz, $CDCl_3$) δ 7.56 – 7.47 (m, 2H, CH_{arom}), 7.47 – 7.36 (m, 3H, CH_{arom}), 7.34 – 7.27 (m, 5H, CH_{arom}), 6.76 (d, *J* = 9.1 Hz, 1H, NH), 5.61 (s, 1H, C*H*Ph), 4.90 (d, *J* = 11.7 Hz, 1H, C*H*H Bn), 4.80 (d, *J* = 3.7 Hz, 1H, H-1), 4.71 (d, *J* = 11.8 Hz, 1H, CH*H* Bn), 4.34 – 4.28 (m, 1H, H-6), 4.23 (td, *J* = 9.3, 3.8 Hz, 1H, H-2), 3.87 – 3.80 (m, 4H, H-3, H-4, H-5, H-6), 3.41 (s, 3H, CH_3 OMe); ^{13}C NMR (101 MHz, $CDCl_3$) δ 161.9 (C=O), 138.0, 137.3 (C_q), 129.2, 128.6, 128.4, 128.1, 127.9, 126.1 ($\mathrm{CH_{arom}}$), 101.5 (CHPh), 98.5 (C-1), 82.8 (C-3), 75.8 (C-4), 74.5 ($\mathrm{CH_2}$ Bn), 69.0 (C-6), 62.8 (C-5), 55.6 ($\mathrm{CH_3}$ OMe), 54.7 (C-2); HRMS: $[\mathrm{M+Na}]^+$ calcd for $\mathrm{C_{23}H_{24}Cl_3NO_6NH_4}$ 538.05614, found 538.05516

Methyl 2-deoxy-2-*N*-trifluoroacetyl-3,6-di-*O*-benzyl-α-D-glucopyranoside (2c)

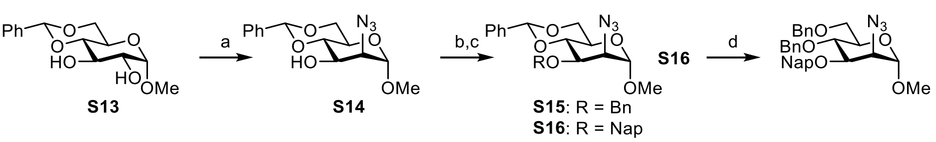


The title compound was prepared from **S11** according to general procedure VI as a white solid. Yield: 600 mg, 1.28 mmol, 78%. ^{1}H NMR (400 MHz, $\mathrm{CDCl_3}$) δ 7.41 – 7.27 (m, 10H, $\mathrm{CH_{arom}}$), 6.28 (d, *J* = 9.3 Hz, 1H, NH), 4.76 (d, *J* = 11.6 Hz, 1H, C*H*H Bn), 4.75 – 4.67 (m, 2H, H-1, CH*H* Bn), 4.63 (d, *J* = 12.0 Hz, 1H, C*H*H Bn), 4.56 (d, *J* = 11.9 Hz, 1H, CH*H* Bn), 4.21 (td, *J* = 9.9, 3.6 Hz, 1H, H-2), 3.81 (td, *J* = 8.8, 2.7 Hz, 1H, H-4), 3.77 – 3.68 (m, 3H, H-5, 2x H-6), 3.60 (dd, *J* = 10.5, 8.5 Hz, 1H, H-3), 3.37 (s, 3H, $\mathrm{CH_3}$ OMe), 2.71 (d, *J* = 2.7 Hz, 1H, OH); ^{13}C NMR (101 MHz, $\mathrm{CDCl_3}$) δ 138.0, 137.7 ($\mathrm{C_q}$), 128.8, 128.7, 128.2, 128.1, 127.9 ($\mathrm{CH_{arom}}$), 97.9 (C-1), 79.2 (C-3), 74.6, 73.9 ($\mathrm{CH_2}$ Bn), 72.7 (C-4), 70.2 (C-6), 70.0 (C-5), 55.4 ($\mathrm{CH_3}$ OMe), 52.7 (C-2). Spectra in agreement with literature.[30]

Methyl 2-deoxy-2-*N*-trichloroacetyl-3,6-di-*O*-benzyl-α-D-glucopyranoside (2d)

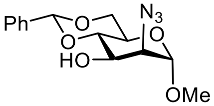


The title compound was prepared from **S12** according to general procedure VI as colourless oil. Yield: 570 mg, 1.10 mmol, 67%. $[\alpha]_D^{25}$ = 52.8° (c = 0.73, $\mathrm{CHCl_3}$); IR (thin film): 698, 737, 820, 1029, 1055, 1515, 1713; ^{1}H NMR (400 MHz, $\mathrm{CDCl_3}$) δ 7.38 – 7.26 (m, 10H, $\mathrm{CH_{arom}}$), 6.83 (d, *J* = 9.3 Hz, 1H, NH), 4.81 – 4.76 (m, 2H, H-1, C*H*H Bn), 4.72 (d, *J* = 11.3 Hz, 1H, CH*H* Bn), 4.63 (d, *J* = 12.0 Hz, 1H, C*H*H Bn), 4.56 (d, *J* = 12.0 Hz, 1H, CH*H* Bn), 4.20 (ddd, *J* = 10.3, 9.2, 3.7 Hz, 1H, H-2), 3.82 – 3.70 (m, 4H, H-4, H-5, 2x H-6), 3.66 (dd, *J* = 10.4, 8.1 Hz, 1H, H-3), 3.41 (s, 3H, $\mathrm{CH_3}$ OMe), 2.66 (d, *J* = 2.4 Hz, 1H, OH); ^{13}C NMR (101 MHz, $\mathrm{CDCl_3}$) δ 161.8 (C=O), 138.1, 137.8 ($\mathrm{C_q}$), 128.7, 128.6, 128.1, 128.1, 128.0, 127.9 ($\mathrm{CH_{arom}}$), 98.2 (C-1), 92.6 ($\mathrm{CCl_3}$), 80.0 (C-3), 74.7, 73.9 ($\mathrm{CH_2}$ Bn), 72.1 (C-4), 70.2 (C-5), 70.0 (C-6), 55.5 ($\mathrm{CH_3}$ OMe), 54.4 (C-2); HRMS: $[\mathrm{M+NH_4}]^+$ calcd for $\mathrm{C_{23}H_{26}Cl_3NO_6NH_4}$ 535.11640, found 535.11593



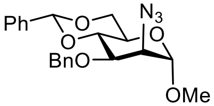
***Scheme S4**: preparation of α-OMe mannosazide intermediates: reagents and conditions: a) i: Tf_2O, pyridine, DCM, -20 °C, ii: NaN_3, DMF, 70 °C, 51% over 2 steps; b) for **S15**: BnBr, NaH, DMF, 80%; c) for **S16**: NapBr, NaH, DMF 76%; d) i: PTSA, methanol, 50 °C, ii: BnBr, NaH, DMF, 79% over 2 steps*

Methyl 2-deoxy-2-azido-4,6-*O*-benzylidene-α-D-mannopyranoside (S14)



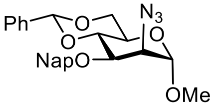
S13 (28.2 g, 100 mmol) and pyridine (16.1 mL, 200 mmol, 2 eq) were dissolved in DCM and cooled to -20 °C, after which triflic anhydride (19.3 mL, 115 mmol, 1.15 eq) was added dropwise. The reaction mixture was allowed to warm to RT and subsequently quenched with water. Phases were separated and the organic phase was dried with $MgSO_4$ and concentrated. The residue was dissolved in DMF with NaN_3 (19.5 g, 300 mmol, 3 eq) and heated to 70 °C. After 18 hr, the reaction mixture was cooled to RT, diluted with water and extracted twice with diethyl ether. The organic phase was dried with $MgSO_4$ and concentrated. The residue was purified over silica (10%→20% acetone in pentane) to yield the title compound as yellow oil. Yield: 15.7 g, 51.2 mmol, 51%. ^1H NMR (400 MHz, $CDCl_3$) δ 7.50 – 7.46 (m, 2H, CH_{arom}), 7.38 (dd, *J* = 5.0, 2.0 Hz, 3H, CH_{arom}), 5.56 (s, 1H, C*H*Ph), 4.67 (d, *J* = 1.4 Hz, 1H, H-1), 4.28 – 4.18 (m, 2H, H-3, H-6), 3.92 (dd, *J* = 4.0, 1.5 Hz, 1H, H-2), 3.88 (t, *J* = 9.4 Hz, 1H, H-4), 3.83 – 3.71 (m, 2H, H-5, H-6), 3.37 (s, 3H, CH_3 OMe), 2.77 (s, 1H, OH); ^{13}C NMR (101 MHz, $CDCl_3$) δ 137.1 (C_q), 129.5, 128.5, 126.4 (CH_{arom}), 102.4 (CHPh), 100.2 (C-1), 79.1 (C-4), 69.0 (C-3), 68.8 (C-6), 63.7 (C-2), 63.4 (C-5), 55.3 (CH_3 OMe). Data in agreement with literature.[31]

Methyl 2-deoxy-2-azido-3-*O*-benzyl-4,6-*O*-benzylidene-α-D-mannopyranoside (S15)



S14 (6.15 g, 20 mmol) was dissolved in DMF and cooled to 0°C, after which benzyl bromide (3.56 mL, 30 mmol, 1.5 eq) and sodium hydride (60% dispersion in mineral oil, 1.20 g, 30 mmol, 1.5 eq) were added. After full conversion, the reaction was quenched with water and extracted with diethyl ether. The organic phase was dried with $MgSO_4$ and concentrated. The residue was purified over silica (5% acetone in pentane) to yield the title compound as yellow oil. Yield: 6.35 g, 16.0 mmol, 80%. ^1H NMR (400 MHz, $CDCl_3$) δ 7.52 – 7.46 (m, 2H, CH_{arom}), 7.41 – 7.27 (m, 8H, CH_{arom}), 5.62 (s, 1H, C*H*Ph), 4.88 (d, *J* = 12.3 Hz, 1H, C*H*H bn), 4.73 (d, *J* = 12.1 Hz, 1H, CH*H* Bn), 4.65 (d, *J* = 1.5 Hz, 1H, H-1), 4.25 (dd, *J* = 9.7, 4.3 Hz, 1H, H-6), 4.15 – 4.06 (m, 2H, H-3, H-4), 4.00 – 3.97 (m, 1H, H-2), 3.88 – 3.79 (m, 1H, H-6), 3.80 – 3.73 (m, 1H, H-5), 3.34 (s, 3H, CH_3 OMe); ^{13}C NMR (101 MHz, $CDCl_3$) δ 138.1, 137.5 (C_q), 129.1, 128.5, 128.3, 127.8, 127.6, 126.2 (CH_{arom}), 101.7 (CHPh), 100.3 (C-1), 79.2, 75.7 (C-3, C-4), 73.3 (CH_2 Bn), 68.8 (C-6), 63.8 (C-5), 62.8 (C-2), 55.1 (CH_3 OMe). Spectra in agreement with literature.[32]

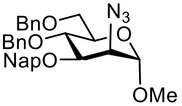
Methyl 2-deoxy-2-azido-3-*O*-(2-naphtyl)methyl-4,6-*O*-benzylidene-α-D-mannopyranoside (S16)



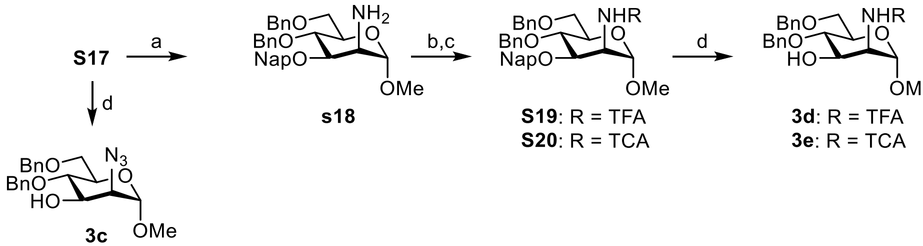
The title compound was prepared from **S14** as described for **S15**, but 2-(Bromomethyl)naphthalene was used instead of benzyl bromide. Yield: 4.98 g, 11.1 mmol, 76%.

^{1}H NMR (400 MHz, $CDCl_3$) δ 7.85 – 7.78 (m, 3H, CH_{arom}), 7.74 – 7.68 (m, 1H, CH_{arom}), 7.53 – 7.43 (m, 5H, CH_{arom}), 7.41 – 7.36 (m, 3H, CH_{arom}), 5.64 (s, 1H, C*H*Ph), 5.01 (d, *J* = 12.3 Hz, 1H, C*H*H Nap), 4.89 (d, *J* = 12.4 Hz, 1H, CH*H* Nap), 4.65 (d, *J* = 1.4 Hz, 1H, H-1), 4.25 (dd, *J* = 9.8, 4.4 Hz, 1H, H-6), 4.17 – 4.11 (m, 2H, H-3, H-4), 4.04 – 3.98 (m, 1H, H-2), 3.88 – 3.81 (m, 1H, H-6), 3.77 (ddd, *J* = 10.8, 5.5, 4.1 Hz, 1H, H-5), 3.32 (s, 3H, CH_3 OMe); ^{13}C NMR (101 MHz, $CDCl_3$) δ 137.5, 135.6, 133.4, 133.1 (C_q), 129.1, 128.4, 128.3, 128.1, 127.8, 126.3, 126.3, 126.2, 126.2, 126.0, 125.5 (CH_{arom}), 101.8 (CHPh), 100.2 (C-1), 79.1, 75.6 (C-3, C-4), 73.2 (CH_2 Nap), 68.8 (C-6), 63.7 (C-5), 62.7 (C-2), 55.1 (C-2); HRMS: $[M+NH_4]^+$ calcd for $C_{25}H_{25}N_3O_5NH_4$ 465.21325, found 465.21276

Methyl 2-deoxy-2-azido-4,6-di-*O*-benzyl-3-O-(2-naphtyl)methyl-α-D-mannopyranoside (S17)

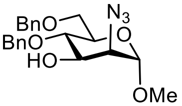


The title compound was prepared from **S16** as described for **S6**. Yield: 4.67 g, 8.65 mmol, 79%. ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.84 – 7.79 (m, 3H, CH_{arom}), 7.78 – 7.73 (m, 1H, CH_{arom}), 7.51 – 7.44 (m, 3H, CH_{arom}), 7.38 – 7.29 (m, 4H, CH_{arom}), 7.30 – 7.23 (m, 4H, CH_{arom}), 7.16 – 7.09 (m, 2H, CH_{arom}), 4.92 – 4.82 (m, 3H, C*H*H Bn/Nap, CH_2 Bn/Nap), 4.71 (d, *J* = 1.8 Hz, 1H, H-1), 4.66 (d, *J* = 12.2 Hz, 1H, C*H*H Bn/Nap), 4.53 (d, *J* = 12.3 Hz, 1H, CH*H* Bn/Nap), 4.50 (d, *J* = 10.8 Hz, 1H, CH*H* Bn/Nap), 4.09 (dd, *J* = 9.2, 3.7 Hz, 1H, H-3), 3.95 (dd, *J* = 3.7, 1.8 Hz, 1H, H-2), 3.91 (t, *J* = 9.4 Hz, 1H, H-4), 3.78 – 3.62 (m, 3H, H-5, 2x H-6), 3.32 (s, 3H, CH_3 OMe); ^{13}C NMR (126 MHz, $CDCl_3$) δ 138.3, 138.3, 135.4, 133.4, 133.2 (C_q), 128.5, 128.4, 128.1, 128.0, 128.0, 127.8, 127.8, 127.7, 126.7, 126.2, 126.1, 125.9 (CH_{arom}), 99.2 (C-1), 79.9 (C-3), 75.4 (CH_2 Bn/Nap), 74.6 (C-4), 73.6, 72.7 (CH_2 Bn/Nap), 71.6 (C-5), 68.8 (C-6), 61.4 (C-2), 55.0 (CH_3 OMe); HRMS: $[M+NH_4]^+$ calcd for $C_{32}N_{33}N_3O_5NH_4$ 557.27585, found 557.27509



Scheme S5**: preparation of 3-OH mannosamine acceptors: reagents and conditions: a) $LiAlH_4$, THF, 93%; b) for **S19**: TFAA, Et_3N, DCM, 80%; c) for **S20**: trichloroacetyl chloride, Et_3N, DCM, 97%; d) DDQ, 9:1 DCM/H_2O 65% for **3c**, 61% for **3d**, 61% for **3e

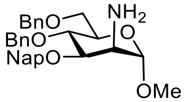
Methyl 2-deoxy-2-azido-4,6-di-*O*-benzyl-α-D-mannopyranoside (3c)



The title compound was prepared from **S17** according to general procedure V. Yield: 391 mg, 0.98 mmol, 65%. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.40 – 7.28 (m, 8H, CH_{arom}), 7.22 (dd, *J* = 7.7, 1.9

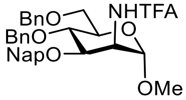
Hz, 2H, CH_{arom}), 4.75 (d, *J* = 1.7 Hz, 1H, H-1), 4.73 – 4.65 (m, 2H, 2x C*H*H Bn), 4.60 – 4.51 (m, 2H, 2x CH*H* Bn), 4.10 (ddd, *J* = 9.1, 5.4, 3.9 Hz, 1H, H-3), 3.88 (dd, *J* = 4.0, 1.7 Hz, 1H, H-2), 3.79 – 3.73 (m, 2H, H-4, H-6), 3.71 – 3.65 (m, 2H, H-5, H-6), 3.36 (s, 3H, CH_3 OMe), 2.27 (d, *J* = 5.4 Hz, 1H, OH); ^{13}C NMR (101 MHz, $CDCl_3$) δ 138.1 (C_q), 128.7, 128.5, 128.1, 128.1, 128.0, 127.8 (CH_{arom}), 99.2 (C-1), 76.1 (C-4), 75.0, 73.7 (CH_2 Bn), 71.6 (C-3), 71.3 (C-5), 68.8 (C-6), 63.8 (C-2), 55.2 (CH_3 OMe). Spectra in agreement with literature.[33]

Methyl 2-deoxy-2-amino-4,6-di-*O*-benzyl-3-O-(2-naphtyl)methyl-α-D-mannopyranoside (S18)



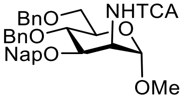
The title compound was prepared from **S17** according to general procedure II. Yield: 3.34 g, 6.50 mmol, 93%. ^1H NMR (400 MHz, $CDCl_3$) δ 7.83 – 7.78 (m, 3H, CH_{arom}), 7.75 (dd, *J* = 6.1, 3.4 Hz, 1H, CH_{arom}), 7.49 – 7.42 (m, 3H, CH_{arom}), 7.37 – 7.31 (m, 4H, CH_{arom}), 7.31 – 7.25 (m, 4H, CH_{arom}), 7.19 – 7.14 (m, 2H, CH_{arom}), 4.87 (d, *J* = 10.9 Hz, 1H, C*H*H Bn/Nap), 4.82 (d, *J* = 11.7 Hz, 1H, C*H*H Bn/Nap), 4.77 (d, *J* = 11.8 Hz, 1H, CH*H* Bn/Nap), 4.73 (d, *J* = 1.6 Hz, 1H, H-1), 4.65 (d, *J* = 12.1 Hz, 1H, C*H*H Bn/Nap), 4.56 – 4.45 (m, 2H, 2x C*H*H Bn/Nap), 3.93 (dd, *J* = 9.0, 3.9 Hz, 1H, H-3), 3.84 (t, *J* = 9.2 Hz, 1H, H-4), 3.80 – 3.72 (m, 2H, H-5, H-6), 3.71 – 3.67 (m, 1H, H-6), 3.36 – 3.31 (m, 4H, H-2, CH_3 OMe); ^{13}C NMR (101 MHz, $CDCl_3$) δ 138.5, 138.3, 135.9, 133.4, 133.1 (C_q), 128.5, 128.5, 128.4, 128.3, 128.0, 128.0, 128.0, 127.9, 127.8, 127.8, 127.7, 127.7, 126.5, 126.2, 126.0, 125.9 (CH_{arom}), 102.0 (C-1), 80.5 (C-3), 75.1 (CH_2 Bn/Nap), 74.1 (C-4), 73.6, 71.8 (CH_2 Bn/Nap), 71.1 (C-5), 69.0 (C-6), 55.0 (CH_3 OMe), 52.1 (C-2); HRMS: $[M+H]^+$ calcd for $C_{32}H_{35}NO_5H$ 514.25880, found 514.25811

Methyl 2-deoxy-2-*N*-trifluoroacetyl-4,6-di-*O*-benzyl-3-O-(2-naphtyl)methyl-α-D-mannopyranoside (S19)



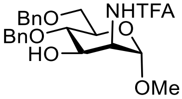
The title product was prepared from **S18** according to general procedure III as colourless oil. Yield: 777 mg, 1.28 mmol, 80%. ^1H NMR (400 MHz, $CDCl_3$) δ 7.86 – 7.68 (m, 4H, CH_{arom}), 7.50 – 7.39 (m, 3H, CH_{arom}), 7.38 – 7.22 (m, 8H, CH_{arom}), 7.14 (dd, *J* = 6.6, 3.0 Hz, 2H, CH_{arom}), 6.97 (d, *J* = 9.2 Hz, 1H, NH), 4.91 (d, *J* = 11.2 Hz, 1H, C*H*H Bn/Nap), 4.86 (d, *J* = 10.8 Hz, 1H, C*H*H Bn/Nap), 4.78 (d, *J* = 1.7 Hz, 1H, H-1), 4.70 (ddd, *J* = 9.4, 4.5, 1.7 Hz, 1H, H-2), 4.66 – 4.58 (m, 2H, C*H*H Bn/Nap, CH*H* Bn/Nap), 4.49 – 4.40 (m, 2H, 2x CH*H* Bn/Nap), 4.14 (dd, *J* = 8.4, 4.4 Hz, 1H, H-3), 3.81 – 3.63 (m, 4H, H-4, H-5, 2x H-6), 3.36 (s, 3H, CH_3 OMe); ^{13}C NMR (101 MHz, $CDCl_3$) δ 138.2, 137.7, 135.2, 133.4, 133.2 (C_q), 128.6, 128.5, 128.3, 128.1, 128.1, 128.0, 128.0, 127.9, 127.8, 127.2, 126.3, 126.2, 126.1 (CH_{arom}), 99.4 (C-1), 77.4 (C-3), 75.3 (CH_2 Bn/Nap), 73.7 (C-4), 73.7, 71.8 (CH_2 Bn/Nap), 70.7 (C-5), 68.5 (C-6), 55.3 (CH_3 OMe), 50.0 (C-2); HRMS: $[M+NH_4]^+$ calcd for $C_{34}H_{34}F_3NO_6NH_4$ 627.26765, found 627.26653

Methyl 2-deoxy-2-*N*-trichloroacetyl-4,6-di-*O*-benzyl-3-O-(2-naphtyl)methyl-α-D-mannopyranoside (S20)



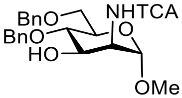
The title product was prepared from **S18** according to general procedure IV as colourless oil. Yield: 1.03 g, 1.56 mmol, 97%. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.82 – 7.70 (m, 4H, CH_{arom}), 7.49 – 7.41 (m, 3H, CH_{arom}), 7.33 – 7.23 (m, 8H, CH_{arom}), 7.16 (dd, *J* = 6.7, 3.0 Hz, 2H, CH_{arom}), 7.01 (d, *J* = 9.1 Hz, 1H, NH), 4.95 (d, *J* = 11.1 Hz, 1H, C*H*H Bn/Nap), 4.87 (d, *J* = 10.9 Hz, 1H, C*H*H Bn/Nap), 4.84 (d, *J* = 1.8 Hz, 1H, H-1), 4.67 – 4.57 (m, 3H, H-2, C*H*H Bn/Nap, CH*H* Bn/Nap), 4.48 (d, *J* = 10.9 Hz, 1H, CH*H* Bn/Nap), 4.44 (d, *J* = 11.7 Hz, 1H, CH*H* Bn/Nap), 4.18 (q, *J* = 4.4 Hz, 1H, H-3), 3.81 – 3.74 (m, 3H, H-4, H-5, H-6), 3.70 (d, *J* = 9.7 Hz, 1H, H-6), 3.38 (s, 3H, CH_3 OMe); ^{13}C NMR (101 MHz, $CDCl_3$) δ 162.3 (C=O), 138.2, 138.0, 135.3, 133.4, 133.1 (C_q), 128.5, 128.5, 128.2, 128.1, 127.9, 127.8, 127.8, 127.2, 126.4, 126.1, 126.0 (CH_{arom}), 99.3 (C-1), 77.7 (C-3), 75.3 (CH_2 Bn/Nap), 73.6 (C-4), 73.6, 71.5 (CH_2 Bn/Nap), 70.9 (C-5), 68.6 (C-6), 55.4 (CH_3 OMe), 51.1 (C-2); HRMS: $[M+NH_4]^+$ calcd for $C_{34}H_{34}Cl_3NO_6NH_4$ 675.17900, found 675.17798

Methyl 2-deoxy-2-*N*-trifluoroacetyl-4,6-di-*O*-benzyl-α-D-mannopyranoside (3d)



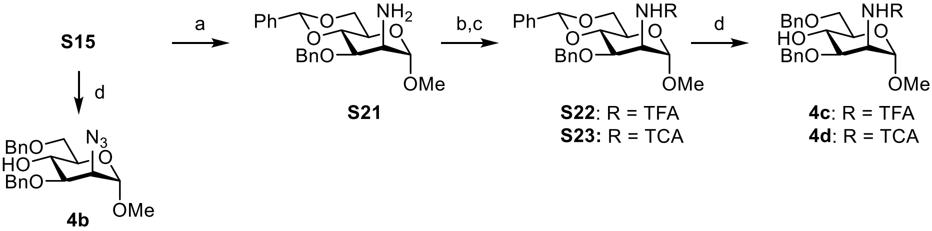
The title product was prepared from **S19** according to general procedure V as colourless oil. Yield: 350 mg, 0.746 mmol, 61%. $[\alpha]_D^{25}$ = 56.6° (c = 0.35, $CHCl_3$); IR (thin film): 689, 1065, 1133, 1160,1209, 1721; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.39 – 7.26 (m, 8H, CH_{arom}), 7.22 (dd, *J* = 7.7, 1.8 Hz, 2H, CH_{arom}), 7.03 (d, *J* = 8.6 Hz, 1H, NH), 4.78 – 4.71 (m, 2H, H-1, C*H*H Bn), 4.64 (d, *J* = 11.8 Hz, 1H, C*H*H Bn), 4.54 (d, *J* = 11.2 Hz, 1H, CH*H* Bn), 4.49 (d, *J* = 11.8 Hz, 1H, CH*H* Bn), 4.40 (ddd, *J* = 8.7, 4.6, 1.6 Hz, 1H, H-2), 4.23 (ddd, *J* = 9.2, 4.5, 3.2 Hz, 1H, H-3), 3.80 (dd, *J* = 10.3, 2.8 Hz, 1H, H-6), 3.76 – 3.67 (m, 2H, H-5, H-6), 3.62 (t, *J* = 9.3 Hz, 1H, H-4), 3.36 (s, 3H, CH_3 OMe), 2.34 (d, *J* = 3.3 Hz, 1H, OH); ^{13}C NMR (101 MHz, $CDCl_3$) δ 138.1, 137.6 (C_q), 128.7, 128.6, 128.1, 128.1, 128.0 (CH_{arom}), 99.2 (C-1), 75.1 (C-4), 75.0, 73.8 (CH_2 Bn), 70.5 (C-5), 70.2 (C-3), 68.5 (C-6), 55.4 (CH_3 OMe), 53.7 (C-2); HRMS: $[M+NH_4]^+$ calcd for $C_{23}H_{26}F_3NO_6$ 487.20505, found 487.20455

Methyl 2-deoxy-2-*N*-trichloroacetyl-4,6-di-*O*-benzyl-α-D-mannopyranoside (3e)



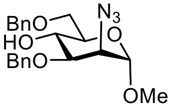
The title product was prepared from **S20** according to general procedure V as colourless oil. Yield: 482 mg, 0.929 mmol, 61%. $[\alpha]_D^{25}$ = 42.1° (c = 0.35, $CHCl_3$); IR (thin film): 697, 821, 1069, 1515, 1720; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.36 – 7.22 (m, 10H, CH_{arom}), 6.95 (d, *J* = 8.3 Hz, 1H, NH), 4.78 (d, *J* = 1.8 Hz, 1H, H-1), 4.76 (d, *J* = 11.3 Hz, 1H, C*H*H Bn), 4.64 (d, *J* = 11.7 Hz, 1H, C*H*H Bn), 4.59 (d, *J* = 11.3 Hz, 1H, CH*H* Bn), 4.49 (d, *J* = 11.6 Hz, 1H, CH*H* Bn), 4.32 (ddd, *J* = 8.3, 4.3, 1.7 Hz, 1H, H-2), 4.27 (ddd, *J* = 8.9, 4.3, 3.1 Hz, 1H, H-3), 3.84 – 3.70 (m, 3H, H-5, 2x H-6), 3.68 (t, *J* = 9.2 Hz, 1H, H-4), 3.39 (s, 3H, CH_3 OMe), 2.26 (d, *J* = 3.3 Hz, 1H, OH); ^{13}C NMR

(101 MHz, $CDCl_3$) δ 162.9 (C=o), 138.1, 138.0 (C_q), 128.7, 128.5, 128.3, 128.2, 127.9, 127.8 (CH_{arom}), 99.1 (C-1), 74.9 (CH_2 Bn), 74.9 (C-4), 73.6 (CH_2 Bn), 70.8 (C-5), 70.5 (C-3), 68.6 (C-6), 55.4 (CH_3 OMe), 54.9 (C-2); HRMS: $[M+NH_4]^+$ calcd for $C_{23}H_{26}Cl_3NO_6NH_4$ 535.11640, found 535.11565



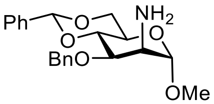
Scheme S6**: preparation of 4-OH mannosamine acceptors: reagents and conditions: a) $LiAlH_4$, THF, 85%; b) for **S22**: TFAA, Et_3N, DCM, 100%; c) for **S23**: trichloroacetyl chloride, Et_3N, DCM, 100%; d) TES-H, TFA, DCM, 0 °C, 70% for **4b**, 60% for **4c**, 73% for **4d

Methyl 2-deoxy-2-azido-3,6-di-*O*-benzyl-α-D-mannopyranoside (4b)



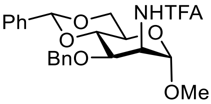
The title product was prepared from **S15** according to general procedure VI as colourless oil. Yield: 705 mg, 1.77 mmol, 70%. $[\alpha]_D^{25}$ = 19.5° (c = 0.28, $CHCl_3$); IR (thin film): 698, 970, 1070, 1138, 1365, 1454, 2105; ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.43 – 7.26 (m, 10H, CH_{arom}), 4.75 (d, *J* = 11.6 Hz, 1H, C*H*H Bn), 4.69 (d, *J* = 1.7 Hz, 1H, H-1), 4.66 – 4.60 (m, 2H, C*H*H Bn, CH*H* Bn), 4.57 (d, *J* = 12.1 Hz, 1H, CH*H* Bn), 3.98 – 3.91 (m, 2H, H-2, H-4), 3.86 (dd, *J* = 9.2, 3.6 Hz, 1H, H-3), 3.76 – 3.67 (m, 3H, H-5, 2x H-6), 3.35 (s, 3H, CH_3 OMe), 2.58 (d, *J* = 2.4 Hz, 1H, OH); ^{13}C NMR (126 MHz, $CDCl_3$) δ 138.1, 137.7 (C_q), 128.8, 128.5, 128.2, 128.1, 127.8, 127.8 (CH_{arom}), 99.4 (C-1), 79.4 (C-3), 73.7, 72.6 (CH_2 Bn), 71.1 (C-5), 70.2 (C-6), 68.0 (C-4), 60.4 (C-2), 55.1 (CH_3 OMe); HRMS: $[M+NH_4]^+$ calcd for $C_{21}H_{25}N_3O_5NH_4$ 417.21325, found 417.21277

Methyl 2-deoxy-2-amino-3-*O*-benzyl-4,6-*O*-benzylidene-α-D-mannopyranoside (S21)



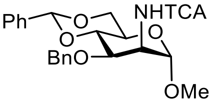
The title compound was prepared from **S15** according to general procedure II as colourless oil. Yield: 4.23 g, 11.4 mmol, 85%. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.53 – 7.47 (m, 2H, CH_{arom}), 7.41 – 7.27 (m, 8H, CH_{arom}), 5.62 (s, 1H, C*H*Ph), 4.81 (d, *J* = 12.0 Hz, 1H, C*H*H Bn), 4.73 – 4.64 (m, 2H, H-1, CH*H* Bn), 4.29 – 4.24 (m, 1H, H-6), 4.07 – 4.00 (m, 1H, H-4), 3.92 (dd, *J* = 9.7, 4.2 Hz, 1H, H-3), 3.87 – 3.80 (m, 2H, H-5, H-6), 3.41 (dd, *J* = 4.3, 1.3 Hz, 1H, H-2), 3.36 (s, 3H, CH_3 OMe), 1.45 (s, 2H, NH_2); ^{13}C NMR (101 MHz, $CDCl_3$) δ 138.6, 137.7 (C_q), 129.0, 128.5, 128.3, 127.8, 127.8, 126.2 (CH_{arom}), 103.1 (C-1), 101.8 (CHPh), 79.0 (C-4), 75.7 (C-3), 72.8 (CH_2 Bn), 69.1 (C-6), 63.6 (C-5), 55.1 (CH_3 OMe), 53.7 (C-2). Spectra in agreement with literature.[34]

Methyl 2-deoxy-2-*N*-trifluoroacetyl-3-*O*-benzyl-4,6-*O*-benzylidene-α-D-mannopyranoside (S22)



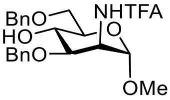
The title compound was prepared from **S21** according to general procedure II as yellowish oil. Yield: 1.20 g, 2.57 mmol, 100 %. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.53 – 7.46 (m, 2H, CH_{arom}), 7.42 – 7.36 (m, 3H, CH_{arom}), 7.34 – 7.26 (m, 5H, CH_{arom}), 6.56 (d, *J* = 7.6 Hz, 1H, NH), 5.62 (s, 1H, C*H*Ph), 4.85 (d, *J* = 1.3 Hz, 1H, H-1), 4.70 (d, *J* = 12.0 Hz, 1H, C*H*H Bn), 4.65 (d, *J* = 12.0 Hz, 1H, CH*H* Bn), 4.57 – 4.49 (m, 1H, H-2), 4.28 (dd, *J* = 9.4, 3.8 Hz, 1H, H-6), 4.13 (dd, *J* = 10.0, 4.9 Hz, 1H, H-3), 3.88 (ddd, *J* = 10.4, 9.0, 4.0 Hz, 1H, H-5), 3.85 – 3.78 (m, 1H, H-6), 3.76 – 3.70 (m, 1H, H-4), 3.38 (s, 3H, CH_3 OMe); ^{13}C NMR (101 MHz, $CDCl_3$) δ 137.5, 137.2 (C_q), 129.2, 128.6, 128.4, 128.1, 127.9, 126.2 (C_q), 102.0 (CHPh), 99.7 (C-1), 78.7 (C-4), 72.7 (C-3), 72.3 (CH_2 Bn), 68.8 (C-6), 63.0 (C-5), 55.4 (CH_3 OMe), 51.9 (C-2); HRMS: $[M+NH_4]^+$ calcd for $C_{23}H_{24}F_3NO_6NH_4$ 485.18940, found 485.18902

Methyl 2-deoxy-2-*N*-trichloroacetyl-3-*O*-benzyl-4,6-*O*-benzylidene-α-D-mannopyranoside (S23)



The title compound was prepared from **S21** according to general procedure III as yellowish oil. Yield: 1.30 g, 2.52 mmol, 100%. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.53 – 7.48 (m, 2H, CH_{arom}), 7.42 – 7.26 (m, 8H, CH_{arom}), 7.02 (d, *J* = 7.3 Hz, 1H, NH), 5.63 (s, 1H, C*H*Ph), 4.90 (d, *J* = 1.3 Hz, 1H, H-1), 4.71 (d, *J* = 12.0 Hz, 1H, C*H*H Bn), 4.64 (d, *J* = 12.0 Hz, 1H, CH*H* Bn), 4.48 (ddd, *J* = 7.4, 5.0, 1.4 Hz, 1H, H-2), 4.28 (dd, *J* = 9.7, 4.2 Hz, 1H, H-6), 4.15 (dd, *J* = 10.0, 4.9 Hz, 1H, H-3), 3.93 – 3.86 (m, 1H, H-5), 3.85 – 3.79 (m, 1H, H-6), 3.73 (t, *J* = 9.6 Hz, 1H, H-4), 3.39 (s, 3H, CH_3 OMe); ^{13}C NMR (101 MHz, $CDCl_3$) δ 162.5 (C=O), 137.6, 137.2 (C_q), 129.2, 128.5, 128.3, 127.9, 127.8, 126.2 (CH_{arom}), 101.9 (CHPh), 99.7 (C-1), 92.4 (CCl_3), 78.8 (C-4), 72.9 (C-3), 72.0 (CH_2 Bn), 68.9 (C-6), 62.9 (C-5), 55.4 (CH_3 OMe), 52.9 (C-2); HRMS: $[M+NH_4]^+$ calcd for $C_{23}H_{24}Cl_3NO_6NH_4$ 533.10075, found 533.10041

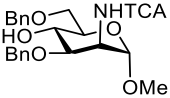
Methyl 2-deoxy-2-*N*-trifluoroacetyl-3,6-di-*O*-benzyl-α-D-mannopyranoside (4c)



The title product was prepared from **S22** according to general procedure VI as colourless oil. Yield: 700 mg, 1.49 mmol, 60%. $[\alpha]_D^{25}$ = 20.2° (c = 0.55, $CHCl_3$); IR (thin film): 698, 1072, 1135, 1162, 1453, 1724 ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.37 – 7.27 (m, 10H, CH_{arom}), 6.95 (d, *J* = 9.1 Hz, 1H, NH), 4.81 – 4.74 (m, 2H, H-1, C*H*H Bn), 4.65 – 4.59 (m, 2H, H-2, C*H*H Bn), 4.56 (d, *J* = 11.9 Hz, 1H, CH*H* Bn), 4.41 (d, *J* = 10.9 Hz, 1H, CH*H* Bn), 3.92 – 3.84 (m, 1H, H-3), 3.83 – 3.68 (m, 4H, H-4, H-5, 2x H-6), 3.38 (s, 3H, CH_3 OMe), 2.55 (d, *J* = 1.5 Hz, 1H, OH); ^{13}C NMR (101 MHz, $CDCl_3$) δ 137.8, 137.3 (C_q), 128.7, 128.6, 128.5, 128.3, 128.0, 127.8 (CH_{arom}), 99.6 (C-1), 77.0 (C-

3), 73.8, 71.8 (CH_2 Bn), 70.6 (C-4), 69.1 (C-6), 66.7 (C-6), 55.4 (CH_3 OMe), 49.6 (C-2); HRMS: $[M+NH_4]^+$ calcd for $C_{23}H_{26}F_3NO_6NH_4$ 487.20505, found 487.20446

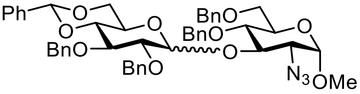
Methyl 2-deoxy-2-*N*-trichloroacetyl-3,6-di-*O*-benzyl-α-D-mannopyranoside (4d)



The title product was prepared from **S23** according to general procedure VI as colourless oil. Yield: 950 mg, 1.83 mmol, 73%. $[\alpha]_D^{25}$ = -1.26° (c = 1.35, $CHCl_3$); IR (thin film): 698, 819, 1073, 1133, 1203, 1281, 1367, 1454, 1515, 1720; ^1H NMR (400 MHz, $CDCl_3$) δ 7.37 – 7.27 (m, 10H, CH_{arom}), 6.95 (d, *J* = 8.8 Hz, 1H, NH), 4.85 (d, *J* = 1.7 Hz, 1H, H-1), 4.80 (d, *J* = 10.8 Hz, 1H, C*H*H Bn), 4.63 (d, *J* = 11.8 Hz, 1H, C*H*H Bn), 4.60 – 4.51 (m, 2H, H-2, CH*H* Bn), 4.42 (d, *J* = 10.8 Hz, 1H, CH*H* Bn), 3.92 (dd, *J* = 8.6, 4.2 Hz, 1H, H-3), 3.85 – 3.73 (m, 4H, H-4, H-5, 2x H-6), 3.41 (s, 3H, CH_3 OMe), 2.52 (d, *J* = 1.9 Hz, 1H, OH); ^{13}C NMR (101 MHz, $CDCl_3$) δ 162.2 (C=O), 138.1, 137.4 (C_q), 128.7, 128.5, 128.5, 128.3, 127.8, 127.6 (CH_{arom}), 99.5 (C-1), 92.5 (CCl_3), 77.2 (C-3), 73.8, 71.6 (CH_2 Bn), 70.8 (C-4), 69.2 (CH_2 Bn), 66.8 (C-5), 55.5 (CH_3 OMe), 50.6 (C-2); HRMS: $[M+NH_4]^+$ calcd for $C_{23}H_{26}Cl_3NO_6NH_4$ 535.11640, found 535.11757

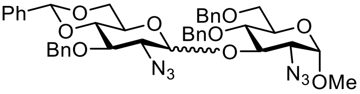
Characterisation of glycosylation products

Disaccharide 1cA



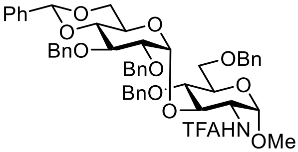
The title compound was synthesised from donor **A** and acceptor **1c** according to general procedure I as colourless oil. Yield: 69 mg, 83 μmol, 83%, α:β = 1.6:1. Data reported for a 1:1 mixture of anomers: ^1H NMR (400 MHz, $CDCl_3$) δ 7.42 – 7.10 (m, 50H), 5.55 (s, 1H, C*H*Phα), 5.51 (s, 1H, C*H*Phβ), 5.44 (d, *J* = 3.8 Hz, 1H, H-1'α), 4.98 – 4.85 (m, 7H), 4.85 – 4.75 (m, 3H), 4.64 (d, *J* = 12.1 Hz, 1H), 4.61 – 4.54 (m, 2H), 4.52 (d, *J* = 12.0 Hz, 1H), 4.46 – 4.35 (m, 3H), 4.31 (d, *J* = 12.6 Hz, 1H), 4.28 – 4.12 (m, 5H), 3.84 – 3.69 (m, 5H), 3.69 – 3.50 (m, 6H), 3.47 (dd, *J* = 8.7, 7.6 Hz, 1H, H-2'β), 3.42 (d, *J* = 4.1 Hz, 7H), 3.33 (dd, *J* = 10.2, 3.5 Hz, 1H, H-2β), 3.25 (dd, *J* = 10.3, 3.6 Hz, 1H, H-2α); ^{13}C NMR (101 MHz, $CDCl_3$) δ 138.7, 138.6, 138.5, 138.4, 138.4, 138.0, 137.9, 137.8, 137.6, 137.4, 135.4, 134.4, 131.9, 131.5, 131.2, 130.3, 130.3, 129.0, 128.9, 128.5, 128.5, 128.4, 128.4, 128.3, 128.3, 128.3, 128.3, 128.1, 128.1, 128.1, 128.0, 127.9, 127.9, 127.8, 127.8, 127.8, 127.7, 127.7, 127.6, 127.4, 126.7, 126.2, 126.1, 125.3, 102.9 (C-1'β), 101.4 (CHPhα), 101.2 (CHPhβ), 99.5 (C-1'α), 99.3 (C-1α), 98.9 (C-1β, 82.8, 82.7, 81.8, 81.3, 78.9, 78.6, 78.5, 77.0, 76.8, 76.0, 75.6, 75.4, 75.3, 75.0, 74.2, 73.7, 73.7, 73.6, 70.2, 70.1, 69.5, 68.8, 68.3, 68.3, 65.9, 63.9, 63.5, 62.2, 55.3 (CH_3 OMeβ), 55.2 (CH_3 OMeα); HRMS: $[M+NH_4]^+$ calcd for $C_{48}H_{51}N_3O_{10}$ 847.39127, found 847.38982

Disaccharide 1cB



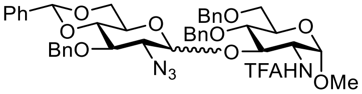
The title compound was synthesised from donor **B** and acceptor **1c** according to general procedure I as colourless oil. Yield: 65 mg, 85 µmol, 85%, α:β = 1:2.5. Data for the β-anomer: ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.42 – 7.25 (m, 20H, CH_{arom}), 5.52 (s, 1H, C*H*Ph), 4.95 – 4.86 (m, 3H, H-1, CH_2 Bn), 4.84 – 4.76 (m, 2H, H-1', C*H*H Bn), 4.63 (d, *J* = 12.1 Hz, 1H, C*H*H Bn), 4.51 (d, *J* = 12.0 Hz, 1H, CH*H* Bn), 4.42 (d, *J* = 10.6 Hz, 1H, CH*H* Bn), 4.25 – 4.08 (m, 3H), 3.82 – 3.71 (m, 2H), 3.70 – 3.63 (m, 2H, H-4', H-6'), 3.60 (t, *J* = 9.1 Hz, 1H), 3.55 – 3.44 (m, 3H, H-2, H-2', H-6'), 3.42 (s, 3H, CH_3 OMe), 3.40 – 3.29 (m, 1H, H-5'); ^{13}C NMR (101 MHz, $CDCl_3$) δ 138.3, 137.9, 137.9, 137.2 (C_q), 128.6, 128.5, 128.5, 128.5, 128.4, 128.4, 128.3, 128.2, 128.1, 128.0, 127.9, 127.8, 127.8, 126.1 (CH_{arom}), 102.2 (C-1'), 101.4 (CHPh), 98.7 (C-1'), 81.7 (C-4'), 79.3, 78.7, 76.0, 75.2, 75.0, 73.7, 70.3, 68.6, 68.3, 66.7, 66.1, 64.1, 55.3 (CH_3 OMe); diagnostic peaks for the α-anomer: ^{1}H NMR (400 MHz, $CDCl_3$) δ 5.57 (s, 1H, C*H*Ph), 5.45 (d, *J* = 3.9 Hz, 1H, H-1'), 4.68 (d, *J* = 12.1 Hz, 1H, C*H*H Bn), 3.17 (dd, *J* = 10.4, 3.6 Hz, 1H, H-2); ^{13}C NMR (101 MHz, $CDCl_3$) δ 101.5 (CHPh), 99.3, 99.3 (C-1, C-1'), 82.9, 78.9, 76.3, 76.3, 74.1, 73.8, 69.4, 68.1, 63.5, 63.0, 61.7, 55.3; product contaminated with TTBP; HRMS: $[M+NH_4]^+$ calcd for $C_{41}H_{44}N_6O_9NH_4$ 782.35080, found 782.34978

Disaccharide 1dA



The title compound was synthesised from donor **A** and acceptor **1d** according to general procedure I as colourless oil. Yield: 86 mg, 96 µmol, 96%, α:β > 20:1. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.72 – 7.61 (m, 3H, CH_{arom}), 7.57 – 7.52 (m, 1H, CH_{arom}), 7.50 – 7.43 (m, 3H, CH_{arom}), 7.41 – 7.30 (m, 8H, CH_{arom}), 7.30 – 7.17 (m, 16H, CH_{arom}), 7.09 – 7.02 (m, 2H, CH_{arom}), 6.54 (d, *J* = 9.6 Hz, 1H, NH), 5.50 (s, 1H, C*H*Ph), 5.07 (d, *J* = 3.6 Hz, 1H, H-1'), 5.00 (d, *J* = 11.1 Hz, 1H, C*H*H Bn), 4.86 (d, *J* = 11.2 Hz, 1H, C*H*H Bn), 4.78 – 4.70 (m, 3H, H-1, C*H*H Bn, CH*H* Bn), 4.62 – 4.54 (m, 2H, C*H*H Bn, CH*H* Bn), 4.48 (d, *J* = 12.0 Hz, 1H, CH*H* Bn), 4.38 – 4.25 (m, 3H, H-2, H-6', CH*H* Bn), 4.02 (t, *J* = 9.2 Hz, 1H, H-3'), 3.94 (ddt, *J* = 10.8, 5.2, 2.7 Hz, 1H, H-3), 3.88 (dt, *J* = 10.0, 5.0 Hz, 1H, H-5'), 3.78 – 3.75 (m, 2H, H-4, H-5), 3.74 – 3.69 (m, 1H, H-6), 3.66 – 3.55 (m, 3H, H-4', H-6, H-6'), 3.53 (dd, *J* = 9.3, 3.6 Hz, 1H, H-2'), 3.37 (s, 3H, CH_3 OMe); ^{13}C NMR (101 MHz, $CDCl_3$) δ 138.5, 138.4, 138.2, 137.9, 137.6 (C_q), 135.3, 134.5, 131.6, 131.6, 131.0, 130.3, 128.9, 128.5, 128.4, 128.3, 128.3, 128.2, 128.1, 128.1, 127.9, 127.8, 127.7, 127.6, 127.5, 127.5, 126.2 (CH_{arom}), 101.5 (CHPh), 99.8 (C-1'), 97.9 (C-1), 82.3 (C-4'), 79.8 (C-3), 79.2 (C-2'), 78.3 (C-3'), 77.6 (C-4), 75.2, 74.7, 73.8, 73.6 (CH_2 Bn), 70.5 (C-5), 68.8 (C-6'), 68.4 (C-6), 63.7 (C-5'), 55.3 (CH_3 OMe), 53.2 (C-2); HRMS: $[M+NH_4]^+$ calcd for $C_{50}H_{52}F_3NO_{11}NH_4$ 917.38307, found 917.38163.

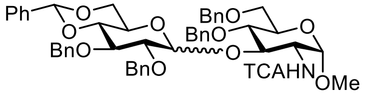
Disaccharide 1dB



The title compound was synthesised from donor **B** and acceptor **1d** according to general procedure I as colourless oil. Yield: 83 mg, 100 µmol, 100%, α:β = 12:1. Data for the α-anomer: ^{1}H

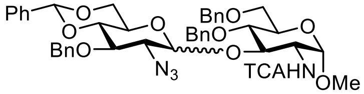
NMR (400 MHz, $CDCl_3$) δ 7.41 – 7.24 (m, 20H, CH_{arom}), 6.52 (d, *J* = 9.7 Hz, 1H, NH), 5.50 (s, 1H, C*H*Ph), 5.40 (d, *J* = 3.9 Hz, 1H, H-1'), 4.97 – 4.88 (m, 2H, 2x C*H*H Bn), 4.76 – 4.71 (m, 2H, H-1, CH*H* Bn), 4.67 (d, *J* = 12.1 Hz, 1H, C*H*H Bn), 4.58 – 4.50 (m, 2H, CH*H* Bn), 4.34 (td, *J* = 10.0, 3.7 Hz, 1H, H-2), 4.24 (dd, *J* = 10.3, 4.6 Hz, 1H, H-6), 4.04 – 3.94 (m, 2H, H-3, H-4), 3.86 (t, *J* = 9.2 Hz, 1H, H-3'), 3.83 – 3.73 (m, 3H, H-5, H-5', H-6), 3.71 (dd, *J* = 10.6, 1.8 Hz, 1H, H-6), 3.68 – 3.60 (m, 2H, H-4', H-6'), 3.42 – 3.34 (m, 4H, H-2', CH_3 OMe); ^{13}C NMR (101 MHz, $CDCl_3$) δ 157.4 (d, *J* = 37.3 Hz, C=O), 137.8, 137.7, 137.3 (C_q), 131.6, 131.0, 129.1, 128.6, 128.6, 128.5, 128.5, 128.5, 128.4, 128.3, 128.0, 128.0, 127.9, 127.9, 127.5, 126.3 (CH_{arom}), 115.8 (d, *J* = 288.4 Hz, CF_3), 101.9 (CHPh), 98.9 (C-1'), 97.8 (C-1), 82.8 (C-4'), 78.6 (C-3'), 77.2 (C-4), 76.1 (C-3), 75.2, 74.3, 73.7 (CH_2 Bn), 70.7 (C-5), 68.6 (C-6'), 68.1 (C-6), 63.5 (C-5'), 63.0 (C-2'), 55.3 (CH_3 OMe), 52.7 (C-2); diagnostic peaks for the β-anomer: ^1H NMR (400 MHz, $CDCl_3$) δ 6.62 (d, *J* = 9.3 Hz, 1H, NH), 5.48 (s, 1H, C*H*Ph); ^{13}C NMR (101 MHz, $CDCl_3$) δ 103.2 (C-1'), 101.3 (CHPh), 81.6, 80.2, 79.6, 75.0, 66.4; HRMS: $[M+NH_4]^+$ calcd for $C_{43}H_{45}F_3N_4O_{10}NH_4$ 852.34260, found 852.34131.

Disaccharide 1eA



The title compound was synthesised from donor **A** and acceptor **1e** according to general procedure I as colourless oil. Yield: 62 mg, 65 µmol, 65%, α:β = 11:1. Data for the α-anomer: ^1H NMR (400 MHz, $CDCl_3$) δ 7.48 – 7.43 (m, 3H, CH_{arom}), 7.40 – 7.16 (m, 20H, CH_{arom}), 7.08 – 7.02 (m, 2H, CH_{arom}), 6.74 (d, *J* = 9.6 Hz, 1H, NH), 5.51 (s, 1H, C*H*Ph), 5.20 (d, *J* = 3.7 Hz, 1H, H-1'), 4.94 (d, *J* = 11.2 Hz, 1H, C*H*H Bn), 4.86 (d, *J* = 11.3 Hz, 1H, C*H*H Bn), 4.81 (d, *J* = 12.0 Hz, 1H, C*H*H Bn), 4.75 – 4.71 (m, 2H, H-1, CH*H* Bn), 4.61 (d, *J* = 12.0 Hz, 1H, C*H*H Bn), 4.56 (d, *J* = 12.0 Hz, 1H, CH*H* Bn), 4.49 (d, *J* = 12.0 Hz, 1H, C*H*H Bn), 4.41 – 4.32 (m, 2H, H-6, C*H*H Bn), 4.23 (td, *J* = 9.9, 3.7 Hz, 1H, H-2), 4.06 (t, *J* = 9.3 Hz, 1H, H-3'), 4.04 – 3.93 (m, 2H, H-3, H-5'), 3.82 – 3.76 (m, 2H, H-4, H-5), 3.72 (dd, *J* = 11.4, 2.1 Hz, 1H, H-6), 3.69 – 3.56 (m, 3H, H-4', H-6, H-6'), 3.53 (dd, *J* = 9.3, 3.7 Hz, 1H, H-2'), 3.39 (s, 3H, CH_3 OMe); ^{13}C NMR (101 MHz, $CDCl_3$) δ 161.9 (C=O), 138.6, 138.3, 138.3, 137.9, 137.6 (C_q), 128.9, 128.5, 128.4, 128.4, 128.4, 128.3, 128.2, 128.1, 128.1, 127.9, 127.8, 127.7, 127.7, 127.5, 127.4, 126.2 (CH_{arom}), 101.4 (CHPh), 99.1 (C-1'), 97.9 (C-1), 92.6 (CCl_3), 82.5 (C-4'), 79.3 (C-2'), 78.2, 78.1, 78.0 (C-3, C-3', C-4), 75.2, 74.3, 74.0, 73.6 (CH_2 Bn), 70.5 (C-5), 69.1 (C-6'), 68.4 (C-6), 63.4 (C-5'), 55.5 (CH_3 OMe), 54.6 (C-2); diagnostic peaks for the β-anomer: ^1H NMR (400 MHz, $CDCl_3$) δ 5.48 (s, 1H, C*H*Ph); ^{13}C NMR (101 MHz, $CDCl_3$) δ 161.5 (C=O), 103.3 (C-1'), 101.2 (CHPh), 98.1 (C-1), 81.9, 81.6; HRMS: $[M+NH_4]^+$ calcd for $C_{50}H_{52}Cl_3NO_{11}NH_4$ 965.29442, found 965.29281.

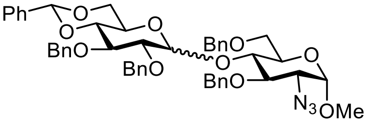
Disaccharide 1eB



The title compound was synthesised from donor **A** and acceptor **1e** according to general procedure I as colourless oil. Yield: 56 mg, 63 µmol, 63%, α:β = 3:1. Data for the α-anomer: ^1H NMR (400 MHz, $CDCl_3$) δ 7.47 – 7.25 (m, 20H, CH_{arom}), 5.53 (d, *J* = 3.9 Hz, 1H, H-1'), 5.51 (s, 1H, C*H*Ph), 4.96 – 4.86 (m, 2H, 2x C*H*H Bn), 4.80 – 4.73 (m, 2H, H-1, CH*H* Bn), 4.69 (d, *J* = 12.0

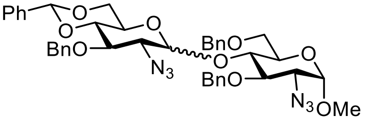
Hz, 1H, C*H*H Bn), 4.61 – 4.53 (m, 2H, 2x CH*H* Bn), 4.31 – 4.21 (m, 2H, H-2, H-6'), 4.10 – 4.01 (m, 2H, H-3, H-3'), 3.95 (td, *J* = 9.9, 4.9 Hz, 1H, H-5'), 3.89 (dd, *J* = 9.7, 8.6 Hz, 1H, H-4), 3.83 – 3.59 (m, 5H, H-4', H-5, 2x H-6, H-6'), 3.40 (s, 3H, CH$_3$ OMe), 3.34 (dd, *J* = 10.0, 3.9 Hz, 1H, H-2'); ^{13}C NMR (101 MHz, CDCl$_3$) δ 162.3 (C=O), 137.8, 137.8, 137.7, 137.3 (C$_q$), 131.6, 131.0, 129.1, 128.6, 128.6, 128.5, 128.5, 128.4, 128.3, 128.0, 128.0, 127.9, 127.9, 127.9, 127.5, 126.2 (CH$_{arom}$), 101.6 (CHPh), 98.4 (C-1'), 97.9 (C-1), 92.4 (CCl$_3$), 82.9 (C-4'), 79.1 (C-4), 75.9, 75.8 (C-3, C-3'), 75.2, 74.1, 73.7 (CH$_2$ Bn), 70.7 (C-5), 68.8 (C-6'), 68.1 (C-6), 63.1 (C-5'), 63.0 (C-2'), 55.5 (CH$_3$ OMe), 54.4 (C-2); diagnostic peaks for the β-anomer: ^{1}H NMR (400 MHz, CDCl$_3$) δ 6.76 (d, *J* = 9.5 Hz, 1H, NH), 4.64 (d, *J* = 12.1 Hz, 1H, C*H*H Bn), 4.46 (d, *J* = 10.6 Hz, 1H, CH*H* Bn), 4.34 (ddd, *J* = 10.5, 9.5, 3.6 Hz, 1H, H-2), 4.15 (dd, *J* = 10.5, 5.0 Hz, 1H, H-6), 3.28 – 3.21 (m, 1H, H-5'); ^{13}C NMR (101 MHz, CDCl$_3$) δ 161.6 (C=O), 102.7 (C-1'), 101.3 (CHPh), 98.0 (C-1), 81.6, 79.6, 79.0, 76.1, 74.9, 73.6, 68.5, 68.4, 66.5, 66.4, 55.4, 55.0; HRMS: [M+NH$_4$]$^+$ calcd for C$_{43}$H$_{45}$Cl$_3$N$_4$O$_{10}$NH$_4$ 900.25395, found 900.25272.

Disaccharide 2bA



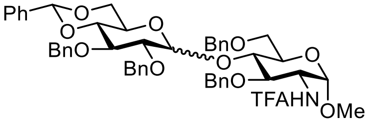
The title compound was synthesised from donor **A** and acceptor **2b** according to general procedure I as colourless oil. Yield: 87 mg, 94 µmol, 94%, α:β = 1.1:1. Data reported for a 1:1 mixture of anomers: ^{1}H NMR (400 MHz, CDCl$_3$) δ 7.53 – 7.23 (m, 50H), 5.56 (d, *J* = 3.5 Hz, 1H, H-1'α), 5.54 (s, 1H, C*H*Phα), 5.48 (s, 1H, C*H*Phβ), 4.99 (d, *J* = 10.3 Hz, 1H), 4.90 (d, *J* = 11.3 Hz, 2H), 4.87 – 4.53 (m, 14H), 4.39 (d, *J* = 7.9 Hz, 1H, H-1'β), 4.34 (d, *J* = 12.0 Hz, 1H), 4.21 – 4.10 (m, 3H), 4.09 – 3.96 (m, 3H), 3.94 – 3.79 (m, 6H), 3.70 – 3.54 (m, 7H), 3.53 – 3.33 (m, 11H), 3.10 (q, *J* = 7.8 Hz, 1H); ^{13}C NMR (101 MHz, CDCl$_3$) δ 138.5, 138.1, 138.0, 137.6, 137.5, 131.6, 131.1, 129.1, 129.0, 128.6, 128.5, 128.4, 128.4, 128.3, 128.3, 128.2, 128.2, 128.1, 128.1, 128.0, 127.9, 127.8, 127.7, 127.6, 127.3, 126.1, 102.9 (C-1'β), 101.3, 101.2 (CHPhαβ), 98.7 (C-1αβ), 97.8 (C-1'α), 82.7, 82.3, 81.8, 81.1, 80.6, 78.9, 78.8, 78.5, 76.9, 75.7, 75.4, 75.3, 75.1, 74.0, 73.5, 73.5, 73.5, 72.8, 70.5, 70.1, 69.0, 68.8, 68.7, 67.5, 65.9, 63.5, 63.5, 63.0, 55.5, 55.4; HRMS: [M+NH$_4$]$^+$ calcd for C$_{48}$H$_{51}$N$_3$O$_{10}$NH$_4$ 847.39127, found 847.39020.

Disaccharide 2bB



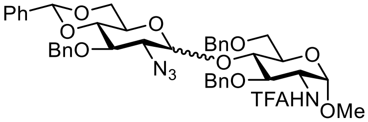
The title compound was synthesised from donor **B** and acceptor **2b** according to general procedure I as colourless oil. Yield: 76 mg, 100 µmol, 100%, α:β = 1:3.3. Data for the β-anomer: ^{1}H NMR (400 MHz, CDCl$_3$) δ 7.42 – 7.25 (m, 20H, CH$_{arom}$), 5.46 (s, 1H, C*H*Ph), 4.96 – 4.87 (m, 2H, 2x C*H*H Bn), 4.79 – 4.70 (m, 4H, H-1, C*H*H Bn, 2x CH*H* Bn), 4.43 (d, *J* = 12.0 Hz, 1H, CH*H* Bn), 4.20 (d, *J* = 8.0 Hz, 1H, H-1'), 4.12 – 3.98 (m, 3H, H-4, H-6, H-6'), 3.88 (dd, *J* = 10.2, 8.9 Hz, 1H, H-3), 3.83 – 3.76 (m, 1H, H-5), 3.74 – 3.66 (m, 1H, H-6), 3.61 – 3.53 (m, 1H, H-4'), 3.49 – 3.41 (m, 4H, H-2, CH$_3$ OMe), 3.36 – 3.29 (m, 3H, H-2', H-3', H-6'), 3.00 (td, *J* = 9.8, 5.0 Hz, 1H, H-5'); ^{13}C NMR (101 MHz, CDCl$_3$) δ 138.4, 137.8, 137.7, 137.2 (C$_q$), 135.3, 134.5, 131.7, 131.6, 131.0, 130.3, 129.2, 128.7, 128.6, 128.5, 128.5, 128.4, 128.4, 128.4, 128.3, 128.3, 128.2, 128.0, 127.9, 127.9, 127.7, 127.5, 126.1, 126.1 (CH_{arom}), 101.3 (CHPh), 101.2 (C-1’), 98.6 (C-1), 81.7 (C-4’), 79.1 (C-3’), 78.4 (C-3), 76.9 (C-3), 75.2, 74.8, 73.6 (CH_2 Bn), 70.3 (C-5), 68.4 (C-6’), 67.7 (C-6), 66.5 (C-2’), 65.9 (C-5’), 63.1 (C-2), 55.5 (CH_3 OMe); diagnostic peaks for the α-anomer: ^{1}H NMR (400 MHz, $CDCl_3$) δ 5.63 (d, *J* = 4.0 Hz, 1H, H-1’), 5.54 (s, 1H, C*H*Ph), 4.85 (d, *J* = 3.5 Hz, 1H, H-1), 4.65 (d, *J* = 12.1 Hz, 1H, C*H*H Bn), 4.59 (d, *J* = 12.1 Hz, 1H, CH*H* Bn); HRMS: $[M+NH_4]^+$ calcd for $C_{41}H_{44}N_6O_9NH_4$ 782.35080, found 782.34972.

Disaccharide 2cA



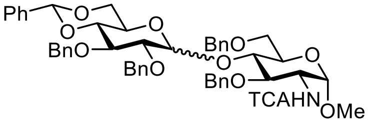
The title compound was synthesised from donor **A** and acceptor **2c** according to general procedure I as colourless oil. Yield: 74 mg, 82 μmol, 82%. α:β = 1.3:1. Data reported for a 1:1 mixture of anomers: ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.57 – 7.42 (m, 6H), 7.44 – 7.17 (m, 41H), 7.20 – 7.12 (m, 3H), 6.31 (d, *J* = 9.3 Hz, 1H, NHα), 6.19 (d, *J* = 9.2 Hz, 1H, NHβ), 5.55 (s, 1H, C*H*Phα), 5.48 (s, 1H, C*H*Phβ), 5.46 (d, *J* = 3.8 Hz, 1H, H-1’α), 4.94 – 4.89 (m, 2H), 4.89 – 4.82 (m, 2H), 4.81 – 4.71 (m, 7H), 4.68 (d, *J* = 7.9 Hz, 1H), 4.64 – 4.56 (m, 5H), 4.52 (d, *J* = 11.2 Hz, 1H), 4.43 (d, *J* = 7.8 Hz, 1H, H-1’β), 4.43 – 4.32 (m, 2H), 4.25 – 4.12 (m, 4H), 4.09 (dd, *J* = 9.9, 8.9 Hz, 1H), 3.99 (t, *J* = 9.3 Hz, 1H), 3.95 – 3.89 (m, 3H), 3.89 – 3.81 (m, 3H), 3.70 (dd, *J* = 10.9, 2.1 Hz, 1H), 3.68 – 3.52 (m, 5H), 3.56 – 3.48 (m, 2H), 3.43 (t, *J* = 10.3 Hz, 1H), 3.40 – 3.32 (m, 7H), 3.21 – 3.05 (m, 1H); ^{13}C NMR (101 MHz, $CDCl_3$) δ 138.7, 138.5, 138.4, 138.4, 138.1, 137.9, 137.8, 137.6, 137.5, 137.5, 131.6, 131.0, 129.1, 129.0, 128.7, 128.7, 128.7, 128.6, 128.6, 128.6, 128.5, 128.5, 128.5, 128.4, 128.4, 128.4, 128.4, 128.3, 128.2, 128.2, 128.1, 128.1, 128.1, 128.0, 128.0, 128.0, 127.9, 127.9, 127.9, 127.8, 127.8, 127.8, 127.7, 127.7, 127.7, 126.1, 102.9 (C-1’β), 101.3 (CHPhα), 101.2 (CHPhβ), 97.9 (C-1’α), 97.6 (C-1β), 97.6 (C-1α), 82.7, 82.2, 81.8, 81.1, 79.5, 78.9, 78.5, 77.1, 76.8, 75.7, 75.3, 75.1, 74.4, 73.8, 73.5, 73.4, 72.7, 72.6, 70.8, 70.6, 69.0, 68.8, 68.6, 67.4, 65.8, 63.6, 55.4, 55.3, 52.8, 52.3; HRMS: $[M+NH_4]^+$ calcd for $C_{50}H_{52}F_3NO_{11}NH_4$ 917.38307, found 917.38154.

Disaccharide 2cB



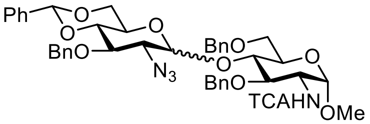
The title compound was synthesised from donor **A** and acceptor **2c** according to general procedure I as colourless oil. Yield: 84 mg, 100 μmol, 100%. α:β = 1:2.5. Data for the β-anomer: ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.56 – 7.51 (m, 2H, CH_{arom}), 7.47 – 7.30 (m, 18H, CH_{arom}), 6.26 (d, *J* = 9.2 Hz, 1H, NH), 5.52 (s, 1H, C*H*Ph), 4.96 (d, *J* = 11.1 Hz, 1H, C*H*H Bn), 4.88 (d, *J* = 11.4 Hz, 1H, C*H*H Bn), 4.83 – 4.76 (m, 3H, H-1, C*H*H Bn, CH*H* Bn), 4.61 (d, *J* = 11.4 Hz, 1H, CH*H* Bn), 4.51 (d, *J* = 12.0 Hz, 1H, CH*H* Bn), 4.32 – 4.23 (m, 2H, H-1’, H-2), 4.23 – 4.14 (m, 2H, H-4, H-6), 4.09 – 4.03 (m, 1H, H-2’), 3.84 – 3.72 (m, 2H, H-5, H-6), 3.69 (dd, *J* = 10.6, 8.9 Hz, 1H, H-3), 3.62 (t, *J* = 9.2 Hz, 1H, H-4’), 3.45 – 3.37 (m, 6H, H-2’, H-3’, H-6’, CH_3 OMe), 3.08 (td, *J* = 9.8, 5.0 Hz, 1H, H-5’); ^{13}C NMR (101 MHz, $CDCl_3$) δ 138.2, 137.8, 137.8, 137.2 (C_q), 129.2, 128.7, 128.7, 128.5, 128.5, 128.5, 128.5, 128.4, 128.4, 128.3, 128.3, 128.2, 128.1, 128.0, 127.9, 127.8, 127.5, 126.1, 126.1 (CH$_{\text{arom}}$), 101.3 (CHPh), 101.2 (C-1'), 97.7 (C-1), 81.8 (C-4'), 79.2 (C-3'), 77.1 (C-3), 76.8 (C-4), 74.9, 74.6, 73.6 (CH$_2$ Bn), 70.5 (C-5), 68.5 (C-6'), 67.7 (C-6), 66.6 (C-2'), 65.9 (C-5'), 55.4 (CH$_3$ OMe), 52.9 (C-2); diagnostic peaks for the α-anomer: ^{1}H NMR (400 MHz, $CDCl_3$) δ 6.57 (d, *J* = 9.7 Hz, 1H, NH), 5.64 (d, *J* = 4.0 Hz, 1H, H-1'), 5.60 (s, 1H, CHPh), 5.02 (d, *J* = 10.9 Hz, 1H, CH*H* Bn), 4.78 (d, *J* = 3.7 Hz, 1H, H-1); ^{13}C NMR (101 MHz, $CDCl_3$) δ 97.9, 97.8 (C-1, C-1'), 82.6, 81.1, 76.3, 75.1, 74.5, 73.7, 72.3, 70.4, 68.7, 68.7, 63.6, 62.9, 53.3 (C-2); HRMS: $[M+NH_4]^+$ calcd for $C_{43}H_{45}F_3N_4O_{10}NH_4$ 852.34260, found 852.34132.

Disaccharide 2dA



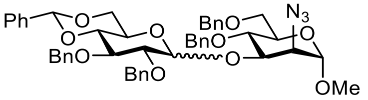
The title compound was synthesised from donor **A** and acceptor **2c** according to general procedure I as colourless oil. Yield: 77 mg, 82 μmol, 81%. α:β = 1.1:1. Data reported for a 1:1 mixture of anomers: ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.54 – 7.42 (m, 6H), 7.40 – 7.17 (m, 44H), 6.83 (d, *J* = 9.4 Hz, 1H, NHα), 6.73 (d, *J* = 8.9 Hz, 1H, NHβ), 5.54 (s, 1H, C*H*Phα), 5.52 (d, *J* = 3.8 Hz, 1H, H-1'α), 5.45 (s, 1H, C*H*Phβ), 4.93 – 4.87 (m, 3H), 4.85 – 4.74 (m, 7H), 4.69 – 4.55 (m, 7H), 4.44 (d, *J* = 7.8 Hz, 1H, H-1β), 4.40 – 4.34 (m, 2H), 4.25 (dd, *J* = 9.7, 8.8 Hz, 1H), 4.21 – 4.07 (m, 4H), 4.01 – 3.96 (m, 2H), 3.95 – 3.83 (m, 4H), 3.73 – 3.64 (m, 2H), 3.63 – 3.52 (m, 6H), 3.48 (dd, *J* = 9.5, 3.8 Hz, 1H), 3.41 – 3.35 (m, 7H), 3.32 (t, *J* = 10.3 Hz, 1H), 3.14 – 3.08 (m, 1H); ^{13}C NMR (126 MHz, $CDCl_3$) δ 161.7, 161.7 (C=Oαβ), 138.7, 138.5, 138.5, 138.5, 138.1, 137.9, 137.9, 137.7, 137.6, 137.5, 135.3, 134.3, 131.9, 131.5, 131.2, 130.3, 129.0, 129.0, 128.6, 128.5, 128.4, 128.4, 128.4, 128.4, 128.3, 128.3, 128.1, 128.1, 128.0, 128.0, 127.9, 127.8, 127.8, 127.8, 127.7, 127.6, 127.6, 127.6, 127.4, 126.1, 102.9 (C-1β), 101.2, 101.1 (CHPhαβ), 97.8, 97.8 (C-1αβ), 97.6 (C-1'α), 92.6, 92.5 (CCl_3αβ), 82.7, 82.2, 81.8, 81.1, 80.3, 78.8, 78.6, 77.9, 76.6, 75.6, 75.3, 75.0, 74.4, 73.6, 73.6, 73.5, 72.2, 71.9, 70.8, 70.4, 69.0, 68.7, 67.5, 65.8, 63.5, 55.6, 55.4, 54.3, 53.9; HRMS: $[M+NH_4]^+$ calcd for $C_{50}H_{52}Cl_3NO_{11}NH_4$ 965.29442, found 965.29364.

Disaccharide 2dB



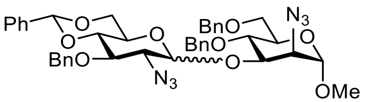
The title compound was synthesised from donor **A** and acceptor **2c** according to general procedure I as colourless oil. Yield: 88 mg, 100 μmol, 100%. α:β = 1:3.5. Data for the β-anomer: ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.41 – 7.24 (m, 20H, CH$_{\text{arom}}$), 6.74 (d, *J* = 9.0 Hz, 1H, NH), 5.43 (s, 1H, C*H*Ph), 4.90 (d, *J* = 11.1 Hz, 1H, C*H*H Bn), 4.85 (d, *J* = 11.1 Hz, 1H, C*H*H Bn), 4.82 (d, *J* = 3.7 Hz, 1H, H-1), 4.77 – 4.73 (m, 2H, C*H*H Bn, CH*H*Bn), 4.61 (d, *J* = 11.0 Hz, 1H, CH*H* Bn), 4.46 (d, *J* = 12.0 Hz, 1H, CH*H* Bn), 4.25 (d, *J* = 7.7 Hz, 1H, H-1'), 4.20 (ddd, *J* = 10.5, 9.1, 3.7 Hz, 1H, H-2), 4.12 (dd, *J* = 10.0, 8.9 Hz, 1H, H-4), 4.06 (dd, *J* = 10.6, 5.0 Hz, 1H, H-6'), 4.02 (dd, *J* = 11.0, 2.9 Hz, 1H, H-6), 3.79 (dt, *J* = 9.9, 2.3 Hz, 1H, H-5), 3.76 – 3.68 (m, 2H, H-3, H-6), 3.53 (t, *J* = 9.2 Hz, 1H, H-4'), 3.41 (s, 3H, CH$_3$ OMe), 3.37 – 3.32 (m, 2H, H-2', H-3'), 3.25 (t, *J* = 10.3 Hz, 1H, H-6'), 3.00 (td, *J* = 9.7, 5.0 Hz, 1H, H-5'); ^{13}C NMR (126 MHz, $CDCl_3$) δ 161.7 (C=O), 138.4, 137.8, 137.8, 137.2 (C$_q$), 131.9, 131.6, 129.1, 128.7, 128.5, 128.5, 128.5, 128.4, 128.4, 128.4, 128.3, 128.3, 128.3, 128.2, 128.2, 128.0, 128.0, 127.9, 127.6, 127.6, 127.5, 126.1, 126.1 (CH$_{arom}$), 101.3 (CHPh), 101.1 (C-1’), 97.9 (C-1), 92.6 (CCl$_3$), 81.7 (C-4’), 79.1 (C-3’), 77.9 (C-3), 76.7 (C-4), 74.8, 74.7, 73.6 (CH$_2$ Bn), 70.5 (C-5), 68.4 (C-6’), 67.8 (C-6), 66.6 (C-2’), 65.8 (C-5’), 55.6 (CH$_3$ OMe) 54.4 (C-2); diagnostic peaks for the α-anomer: ^{1}H NMR (500 MHz, CDCl$_3$) δ 6.96 (d, *J* = 9.7 Hz, 1H, NH), 5.61 (d, *J* = 4.0 Hz, 1H, H-1’), 5.54 (s, 1H, C*H*Ph), 4.96 (d, *J* = 11.0 Hz, 1H, C*H*H Bn), 4.36 (td, *J* = 9.9, 3.7 Hz, 1H, H-2); ^{13}C NMR (126 MHz, CDCl$_3$) δ 161.6 (C=O), 101.3 (CHPh), 98.0 (C-1’), 82.6, 81.5, 76.3, 75.1, 74.4, 72.3, 70.2, 68.8, 68.7, 63.5, 62.8, 55.5 (CH$_3$ OMe), 55.0 (C-2); HRMS: [M+NH$_4$]$^+$ calcd for $C_{43}H_{45}Cl_3N_4O_{10}NH_4$ 900.25395, found 900.25318.

Disaccharide 3cA



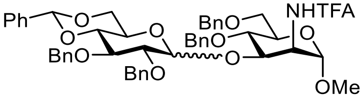
The title compound was synthesised from donor **A** and acceptor **3c** according to general procedure I as colourless oil. Yield: 83 mg, 100 μmol, 100%. α:β = 7:1. Data for the α-anomer: ^{1}H NMR (400 MHz, CDCl$_3$) δ 7.51 (dd, *J* = 7.8, 1.9 Hz, 2H, CH$_{arom}$), 7.41 – 7.16 (m, 21H, CH$_{arom}$), 7.10 – 7.05 (m, 2H, CH$_{arom}$), 5.55 (s, 1H, C*H*Ph), 5.09 (d, *J* = 3.7 Hz, 1H, H-1’), 5.01 (d, *J* = 11.3 Hz, 1H, C*H*H Bn), 4.92 (d, *J* = 11.3 Hz, 1H, C*H*H Bn), 4.83 – 4.77 (m, 2H, H-1, CH*H* Bn), 4.73 (d, *J* = 12.2 Hz, 1H, CH*H* Bn), 4.65 – 4.58 (m, 2H, C*H*H Bn, CH*H* Bn), 4.49 (d, *J* = 12.2 Hz, 1H, CH*H* Bn), 4.42 (d, *J* = 11.3 Hz, 1H, CH*H* Bn), 4.32 (dd, *J* = 10.3, 4.9 Hz, 1H, H-6’), 4.19 – 4.07 (m, 3H, H-3, H-3’, H-5’), 3.93 (dd, *J* = 3.8, 1.8 Hz, 1H, H-2), 3.89 (t, *J* = 9.5 Hz, 1H, H-4), 3.77 – 3.59 (m, 5H, H-4’, H-5, 2x H-6, H-6’), 3.55 (dd, *J* = 9.4, 3.7 Hz, 1H, H-2’), 3.37 (s, 3H, CH$_3$ OMe); ^{13}C NMR (101 MHz, CDCl$_3$) δ 138.7, 138.6, 138.2, 138.1, 137.5 (C$_q$), 129.0, 128.5, 128.5, 128.4, 128.4, 128.4, 128.3, 128.3, 128.2, 128.1, 128.0, 128.0, 127.9, 127.9, 127.8, 127.7, 127.7, 127.6, 127.5, 126.2, 126.1 (C$_q$), 101.4 (CHPh), 100.3 (C-1’), 99.0 (C-1), 82.4 (C-4’), 79.7 (C-3), 78.9 (C-2’), 78.3 (C-3’), 75.3, 74.8 (CH$_2$ Bn), 74.0 (C-4), 73.6, 73.6 (CH$_2$ Bn), 71.7 (C-5), 69.2, 68.8 (C-6, C-6’), 63.9 (C-5’), 63.2 (C-2), 55.1 (CH$_3$ OMe); diagnostic peaks for the β-anomer: ^{1}H NMR (400 MHz, CDCl$_3$) δ 5.51 (s, 1H, C*H*PH); ^{13}C NMR (101 MHz, CDCl$_3$) δ 101.9 (C-1’), 101.2 (CHPh), 99.1 (C-1), 81.9, 81.7, 81.4, 79.1, 77.9, 75.1, 75.0, 73.7, 71.6, 68.5, 66.1; HRMS: [M+NH$_4$]$^+$ calcd for $C_{48}H_{51}N_3O_{10}NH_4$ 847.39127, found 847.39022.

Disaccharide 3cB



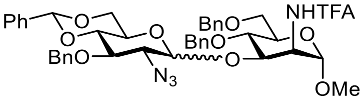
The title compound was synthesised from donor **B** and acceptor **3c** according to general procedure I as colourless oil. Yield: 57 mg, 75 μmol, 75%. α:β = 1.8:1. Data reported for a 2:1 mixture of anomers: ^{1}H NMR (400 MHz, CDCl$_3$) δ 7.57 – 7.14 (m, 60H), 5.58 (s, 2H, C*H*Phα), 5.55 (s, 1H, C*H*Phβ), 5.28 (d, *J* = 3.8 Hz, 2H, H-1’α), 4.95 (dd, *J* = 10.8, 5.3 Hz, 5H), 4.87 (d, *J* = 10.6 Hz, 1H), 4.83 – 4.77 (m, 4H), 4.74 – 4.64 (m, 6H), 4.59 – 4.45 (m, 6H), 4.43 – 4.38 (m, 2H, H-1’β, CH*H* Bn), 4.31 (dd, *J* = 10.4, 4.9 Hz, 2H), 4.24 (dd, *J* = 9.3, 3.7 Hz, 3H), 4.21 – 4.11 (m, 3H), 4.05 – 3.94 (m, 5H), 3.91 (dd, *J* = 3.8, 1.8 Hz, 2H), 3.87 (t, *J* = 9.2 Hz, 1H), 3.79 – 3.58 (m, 17H), 3.53 – 3.42 (m, 3H, H-2’αβ)), 3.35 (d, *J* = 1.6 Hz, 10H, H-5’β, CH$_3$ OMeαβ); ^{13}C NMR (101 MHz, CDCl$_3$) δ 138.4, 138.1, 137.8, 137.2, 137.1, 129.2, 128.6, 128.5, 128.5, 128.4, 128.4, 128.1, 128.1, 128.0, 127.9, 127.9, 127.8, 127.8, 127.8, 126.2, 126.1, 101.6 (CHPhα), 101.5 (CHPhβ), 101.4 (C-1'β), 99.9 (C-1'α), 99.3 (C-1β), 99.0 (C-1α), 82.9, 81.7, 80.3, 79.8, 77.7, 76.2, 75.3, 75.0, 74.9, 74.8, 73.7, 73.6, 73.4, 71.7, 71.7, 68.9, 68.7, 68.6, 68.5, 66.5, 66.4, 63.9, 63.5, 63.2, 62.0, 55.1 (CH_3 OMeαβ); HRMS: $[M+NH_4]^+$ calcd for $C_{41}N_{44}N_6O_9NH_4$ 782.35080, found 782.34970.

Disaccharide 3dA



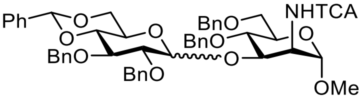
The title compound was synthesised from donor **A** and acceptor **3c** according to general procedure I as colourless oil. Yield: 72 mg, 80 µmol, 80%. α:β = 2.3:1. Data for the α-anomer: ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.38 – 7.17 (m, 25H), 5.50 (s, 1H, C*H*Ph), 5.06 (d, *J* = 3.7 Hz, 1H, H-1'), 5.01 (d, *J* = 11.3 Hz, 1H, C*H*H Bn), 4.88 (d, *J* = 11.4 Hz, 1H, C*H*H Bn), 4.82 (d, *J* = 11.3 Hz, 1H, C*H*H Bn), 4.71 (d, *J* = 2.5 Hz, 1H, H-1), 4.62 – 4.55 (m, 2H, C*H*H Bn, CH*H* Bn), 4.54 – 4.47 (m, 2H, H-2, C*H*H Bn), 4.44 – 4.39 (m, 2H, 2x CH*H* Bn), 4.31 – 4.19 (m, 2H, H-3, H-6'), 4.02 (t, *J* = 9.4 Hz, 1H, H-3'), 3.87 (td, *J* = 9.9, 4.7 Hz, 1H, H-5'), 3.82 – 3.69 (m, 3H, H-4, H-5, H-6), 3.66 – 3.60 (m, 2H, H-6, H-6'), 3.57 (t, *J* = 9.5 Hz, 1H, H-4'), 3.52 (dd, *J* = 9.5, 3.7 Hz, 1H, H-2'), 3.37 (s, 3H, CH_3 OMe); ^{13}C NMR (101 MHz, $CDCl_3$) δ 138.7, 138.4, 138.1, 137.7 (C_q), 128.6, 128.6, 128.5, 128.4, 128.4, 128.4, 128.3, 128.3, 128.2, 128.1, 128.1, 128.0, 128.0, 128.0, 127.8, 127.7, 127.6, 127.6, 127.5, 126.3, 126.1 (CH_{arom}), 101.6 (CHPh), 100.3 (C-1'), 99.1 (C-1), 82.4 (C-4'), 78.8 (C-2'), 78.3 (C-3'), 77.6 (C-3), 75.2, 74.9 (CH_2 Bn), 73.9 (C-4), 73.8, 73.7 (CH_2 Bn), 70.9 (C-5), 69.0 (C-6'), 68.4 (C-6), 64.0 (C-5'), 55.4 (CH_3 OMe), 53.0 (C-2); diagnostic peaks for the β-anomer: ^{1}H NMR (400 MHz, $CDCl_3$) δ 5.39 (s, 1H, C*H*Ph), 4.67 (d, *J* = 11.2 Hz, 1H, C*H*H Bn), 4.37 (d, *J* = 11.0 Hz, 1H, CH*H* Bn), 3.45 (t, *J* = 7.2 Hz, 1H, H-2'), 3.35 (s, 3H, CH_3 OMe); ^{13}C NMR (101 MHz, $CDCl_3$) δ 101.2 (CHPh), 99.7 (C-1'), 99.3 (C-1), 81.5, 81.2, 81.0, 74.8, 74.7, 74.4, 74.3, 73.7, 73.5, 70.7, 68.5, 65.9, 50.0; HRMS: $[M+NH_4]^+$ calcd for $C_{50}H_{52}F_3NO_{11}NH_4$ 917.38307, found 917.38211.

Disaccharide 3dB



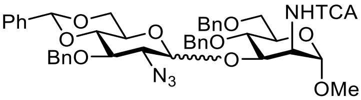
The title compound was synthesised from donor **B** and acceptor **3c** according to general procedure I as colourless oil. Yield: 77 mg, 92 µmol, 92%. α:β = 1:1.2. Data reported for a 1:1 mixture of anomers: ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.49 (dtt, *J* = 14.2, 4.4, 2.1 Hz, 5H), 7.41 – 7.25 (m, 32H), 7.20 (ddd, *J* = 7.4, 5.9, 1.7 Hz, 3H), 5.56 (s, 1H, C*H*Phβ), 5.54 (s, 1H, C*H*Phα), 5.28 (d, *J* = 3.7 Hz, 1H, H-1'α), 4.94 (d, *J* = 11.2 Hz, 1H), 4.90 (d, *J* = 11.2 Hz, 2H), 4.83 (d, *J* = 10.8 Hz, 1H), 4.80 – 4.75 (m, 2H), 4.73 (d, *J* = 11.1 Hz, 1H), 4.68 (d, *J* = 1.6 Hz, 1H, H-1α), 4.66 (d, *J* = 8.0 Hz, 1H), 4.64 – 4.59 (m, 2H), 4.53 – 4.44 (m, 7H), 4.41 (d, *J* = 10.7 Hz, 1H), 4.36 – 4.26 (m, 3H), 4.11 (td, *J* = 9.9, 4.9 Hz, 1H), 4.03 (t, *J* = 9.6 Hz, 1H), 3.87 – 3.72 (m, 7H), 3.72 – 3.61 (m, 7H), 3.45 – 3.34 (m, 8H), 3.31 (dd, *J* = 10.1, 3.8 Hz, 1H, H-2'α); ^{13}C NMR (101 MHz, $CDCl_3$) δ 138.1, 137.9, 137.8, 137.8, 137.5, 137.5, 137.4, 137.1, 135.4, 134.3, 132.0, 131.5, 131.3, 130.3, 129.2, 129.1, 128.7, 128.6, 128.6, 128.5, 128.5, 128.5, 128.4, 128.4, 128.4, 128.3, 128.2, 128.1, 128.1, 128.0, 128.0, 127.9, 127.8, 126.4, 126.1, 101.7, 101.4 (CHPhαβ), 99.9 (C-1'α), 99.4, 99.3 (C-1αβ), 98.4 (C-1'β), 82.8, 81.8, 79.4, 75.6, 75.2, 75.1, 75.1, 75.0, 74.9, 74.9, 74.7, 73.8, 73.7, 72.8, 71.0, 70.5, 68.8, 68.6, 68.2, 68.2, 66.6, 66.3, 63.5, 63.0, 55.3, 53.1, 49.5; HRMS: [M+NH$_4$]$^+$ calcd for $C_{43}H_{45}F_3N_4O_{10}NH_4$ 852.34260, found 852.34134.

Disaccharide 3eA



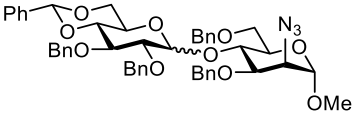
The title compound was synthesised from donor **A** and acceptor **3c** according to general procedure I as colourless oil. Yield: 54 mg, 57 μmol, 57%. α:β = 5:1. Data for the α-anomer: ^{1}H NMR (400 MHz, CDCl$_3$) δ 7.54 – 7.11 (m, 25H, CH$_{\mathrm{arom}}$), 5.50 (s, 1H, C*H*Ph), 5.07 (d, *J* = 3.8 Hz, 1H, H-1'), 5.04 (d, *J* = 11.4 Hz, 1H, C*H*H Bn), 4.88 (d, *J* = 11.3 Hz, 1H, C*H*H Bn), 4.79 – 4.69 (m, 3H, H-1, C*H*H Bn, CH*H* Bn), 4.61 (d, *J* = 12.1 Hz, 1H, CH*H* Bn), 4.56 (d, *J* = 11.7 Hz, 1H, C*H*H Bn), 4.50 – 4.36 (m, 3H, H-2, 2x CH*H* Bn), 4.35 – 4.26 (m, 2H, H-3, H-6'), 4.05 (t, *J* = 9.4 Hz, 1H, H-3'), 3.92 (td, *J* = 9.9, 4.8 Hz, 1H, H-5'), 3.85 – 3.75 (m, 2H, H-4, H-5), 3.72 (dd, *J* = 10.5, 2.9 Hz, 1H, H-6), 3.70 – 3.53 (m, 3H, H-4', H-6, H-6'), 3.52 (dd, *J* = 9.5, 3.8 Hz, 1H, H-2'), 3.39 (s, 3H, CH$_3$ OMe); ^{13}C NMR (101 MHz, CDCl$_3$) δ 162.2 (C=O), 138.7, 138.4, 138.1, 138.0, 137.7 (C$_q$), 131.6, 131.1, 128.9, 128.6, 128.5, 128.5, 128.5, 128.4, 128.4, 128.4, 128.3, 128.3, 128.2, 128.2, 128.1, 128.1, 128.0, 127.9, 127.9, 127.8, 127.8, 127.8, 127.7, 127.6, 127.6, 127.6, 127.5, 127.1, 126.4 (CH$_{\mathrm{arom}}$), 101.4 (CHPh), 100.7 (C-1'), 98.9 (C-1), 92.5 (CCl$_3$), 82.4 (C-4'), 78.9 (C-2'), 78.3, 78.2 (C-3, C-3'), 75.1, 75.0 (CH$_2$ Bn), 73.7 (C-4), 73.7, 73.5 (CH$_2$ Bn), 71.1 (C-5), 69.0 (C-6'), 68.5 (C-6), 63.8 (C-5'), 55.4 (CH$_3$ OMe), 54.4 (C-2); ^{1}H NMR (400 MHz, CDCl$_3$) δ 5.32 (s, 1H, C*H*Ph), 4.99 (d, *J* = 11.7 Hz, 1H, C*H*H Bn), 4.23 (dd, *J* = 10.2, 4.8 Hz, 1H, H-6'); ^{13}C NMR (101 MHz, CDCl$_3$) δ 101.1 (CHPh), 99.7 (C-1'), 99.1 (C-1), 81.4, 81.3, 81.0, 79.1, 76.4, 75.4, 74.7, 74.5, 74.3, 74.2, 73.2, 72.6, 71.4, 71.2, 54.5; HRMS: [M+NH$_4$]$^+$ calcd for $C_{50}H_{52}Cl_3NO_{11}NH_4$ 965.29442, found 965.29366.

Disaccharide 3eB



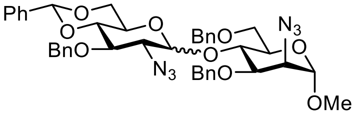
The title compound was synthesised from donor **B** and acceptor **3c** according to general procedure I as colourless oil. Yield: 70 mg, 80 μmol, 80%. α:β = 1:1.1. Data reported for a 1:1 mixture of anomers: ^{1}H NMR (400 MHz, CDCl$_3$) δ 7.41 – 7.20 (m, 40H), 7.08 – 6.98 (m, 2H, NHαβ), 5.56 (s, 1H, C*H*Phα), 5.54 (s, 1H, C*H*Phβ), 5.24 (d, *J* = 3.7 Hz, 1H, H-1'α), 4.97 (d, *J* = 10.5 Hz, 1H), 4.94 – 4.89 (m, 2H), 4.85 (d, *J* = 10.8 Hz, 1H), 4.81 (d, *J* = 1.7 Hz, 1H, H-1α/β), 4.78 (d, *J* = 11.0 Hz, 1H), 4.75 – 4.71 (m, 2H), 4.65 (d, *J* = 10.3 Hz, 1H), 4.62 (d, *J* = 10.1 Hz, 1H), 4.56 (d, *J* = 7.9 Hz, 1H, H-1'β), 4.54 – 4.43 (m, 5H), 4.40 (ddd, *J* = 8.9, 4.3, 1.8 Hz, 1H), 4.37 – 4.29 (m, 3H), 4.14 – 4.02 (m, 2H), 3.88 (t, *J* = 9.6 Hz, 1H), 3.84 – 3.64 (m, 12H), 3.46 – 3.35 (m, 9H); ^{13}C NMR (101 MHz, CDCl$_3$) δ 162.2, 162.1 (C=O), 138.1, 137.9, 137.9, 137.8, 137.8, 137.5, 137.1 (C$_q$), 135.4, 134.5, 131.7, 131.6, 131.0, 130.4, 130.3, 129.2, 129.0, 129.0, 128.6, 128.6, 128.5, 128.5, 128.5, 128.4, 128.4, 128.3, 128.3, 128.1, 128.0, 128.0, 127.9, 127.9, 127.8, 126.4, 126.1 (CH$_{\mathrm{arom}}$), 101.6, 101.4 (CHPhαβ), 100.2 (C-1'α), 99.1, 99.1 (C-1αβ), 98.2 (C-1'β), 82.8, 81.8, 79.5, 75.9, 75.8, 75.2, 75.0, 75.0, 74.8, 73.6, 73.6, 72.9, 71.2, 70.8, 68.8, 68.7, 68.3, 66.6, 66.3, 63.5, 63.2, 55.4, 55.3, 54.5, 50.8; HRMS: [M+NH$_4$]$^+$ calcd for $C_{43}H_{45}Cl_3N_4O_{10}NH_4$ 900.25395, found 900.25352.

Disaccharide 4bA



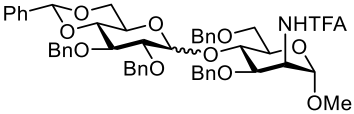
The title compound was synthesised from donor **A** and acceptor **4b** according to general procedure I as colourless oil. Yield: 83 mg, 100 µmol, 100%. α:β = 1:2.5. Data for the β-anomer: ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.39 – 7.25 (m, 25H, CH_{arom}), 5.46 (s, 1H, C*H*Ph), 4.92 – 4.84 (m, 2H, 2x C*H*H Bn), 4.79 (d, *J* = 11.4 Hz, 1H, C*H*H Bn), 4.74 (d, *J* = 11.0 Hz, 1H, C*H*H Bn), 4.69 – 4.65 (m, 2H, H-1, CH*H* Bn), 4.61 – 4.56 (m, 2H, 2x CH*H* Bn), 4.43 (d, *J* = 7.7 Hz, 1H, H-1'), 4.36 (d, *J* = 12.1 Hz, 1H, CH*H* Bn), 4.21 – 4.09 (m, 2H, H-4, H-6'), 3.92 – 3.87 (m, 2H, H-2, H-3), 3.80 (dd, *J* = 10.8, 4.0 Hz, 1H, H-6), 3.62 – 3.54 (m, 4H, H-3', H-4', H-5, H-6), 3.45 – 3.38 (m, 1H, H-6'), 3.36 (s, 3H, CH_3 OMe), 3.34 – 3.30 (m, 1H, H-2'), 3.16 (td, *J* = 9.4, 5.0 Hz, 1H, H-5'); ^{13}C NMR (101 MHz, $CDCl_3$) δ 138.8, 138.5, 138.4, 138.2, 137.5 (C_q), 135.3, 134.3, 131.9, 131.5, 131.2, 130.3, 129.0, 128.6, 128.5, 128.4, 128.3, 128.3, 128.3, 128.1, 128.0, 128.0, 127.9, 127.8, 127.7, 127.7, 127.7, 127.6, 127.4, 127.3, 127.1, 126.1 (CH_{arom}), 103.2 (C-1'), 101.1 (CHPh), 99.1 (C-1), 82.6 (C-2'), 81.7 (C-4'), 81.1 (C-3'), 77.3 (C-3), 75.5 (CH_2 Bn), 75.0 (C-4), 75.0, 73.4, 73.1 (CH_2 Bn), 71.5 (C-5), 68.8 (C-6'), 68.0 (C-6), 65.7 (C-5'), 62.2 (C-2), 55.2 (CH_3 OMe); diagnostic peaks for the α-anomer: ^{1}H NMR (400 MHz, $CDCl_3$) δ 5.65 (d, *J* = 3.9 Hz, 1H, H-1'), 5.52 (s, 1H, C*H*Ph), 4.54 (d, *J* = 11.9 Hz, 1H), 4.31 (d, *J* = 9.1 Hz, 1H); ^{13}C NMR (101 MHz, $CDCl_3$) δ 101.1 (CHPh), 99.0 (C-1), 97.8 (C-1'), 82.2, 80.5, 78.9, 78.6, 75.3, 71.7, 70.9, 70.1, 69.1, 68.9, 63.4, 60.5, 55.0; HRMS: $[M+NH_4]^+$ calcd for $C_{48}H_{51}N_3O_{10}NH_4$ 847.39127, found 847.39012.

Disaccharide 4bB



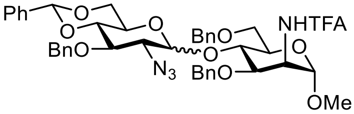
The title compound was synthesised from donor **B** and acceptor **4b** according to general procedure I as colourless oil. Yield: 83 mg, 100 µmol, 100%. α:β = 1:14. Data for the β-anomer: ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.78 – 7.60 (m, 3H, CH_{arom}), 7.46 (dq, *J* = 4.4, 2.4 Hz, 3H, CH_{arom}), 7.42 – 7.26 (m, 19H, CH_{arom}), 5.45 (s, 1H, C*H*Ph), 4.89 (d, *J* = 11.2 Hz, 1H, C*H*H Bn), 4.80 (d, *J* = 11.8 Hz, 1H, C*H*H Bn), 4.78 – 4.72 (m, 2H, C*H*H Bn, CH*H* Bn), 4.70 (d, *J* = 1.6 Hz, 1H, H-1), 4.66 (d, *J* = 11.8 Hz, 1H, CH*H* Bn), 4.49 (d, *J* = 12.1 Hz, 1H, CH*H* Bn), 4.25 (d, *J* = 8.1 Hz, 1H, H-1'), 4.18 (t, *J* = 9.3 Hz, 1H, H-4'), 4.10 (dd, *J* = 10.6, 5.0 Hz, 1H, H-6'), 3.96 – 3.90 (m, 2H, C-3, C-6), 3.88 (dd, *J* = 3.8, 1.7 Hz, 1H, H-2'), 3.76 – 3.68 (m, 2H, H-5, H-6), 3.54 (t, *J* = 9.2 Hz, 1H, H-4'), 3.42 – 3.37 (m, 2H, H-4', H-6'), 3.36 (s, 3H, CH_3 OMe), 3.28 (dd, *J* = 9.4, 8.1 Hz, 1H, H-2'), 3.07 (td, *J* = 9.7, 5.0 Hz, 1H); ^{13}C NMR (101 MHz, $CDCl_3$) δ 138.6, 138.1, 137.8, 137.3 (C_q), 135.4, 134.4, 131.8, 131.5, 131.2, 130.3, 130.3, 129.1, 128.6, 128.5, 128.4, 128.3, 128.3, 128.0, 127.9, 127.5, 127.0, 126.1 (CH_{arom}), 101.6 (C-1'), 101.3 (CHPh), 99.2 (C-1), 81.7 (C-4'), 79.3 (C-3'), 77.5 (C-3), 75.0 (C-4), 74.9, 73.6, 73.1 (CH_2 Bn), 71.1 (C-5), 68.6 (C-6'), 68.2 (C-6), 66.7 (C-2'), 65.9 (C-5'), 62.1 (C-2), 55.1 (CH_3 OMe); diagnostic peaks for the α-anomer: ^{1}H NMR (400 MHz, $CDCl_3$) δ 5.63 (d, *J* = 4.0 Hz, 1H, H-1'), 5.54 (s, 1H, C*H*Ph); HRMS: $[M+NH_4]^+$ calcd for $C_{41}H_{44}N_6O_9NH_4$ 782.35080, found 782.34981.

Disaccharide 4cA



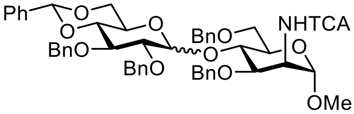
The title compound was synthesised from donor **A** and acceptor **4c** according to general procedure I as colourless oil. Yield: 64 mg, 71 µmol, 71%. α:β = 1:1.4. Data reported for a 1:1 mixture of anomers: ^{1}H NMR (400 MHz, CDCl$_3$) δ 7.43 – 7.18 (m, 50H), 7.04 (d, *J* = 9.1 Hz, 1H, NHα), 6.87 (d, *J* = 8.6 Hz, 1H, NHβ) 5.70 (d, *J* = 3.9 Hz, 1H, H-1'α), 5.54 (s, 1H, C*H*Phα), 5.51 (s, 1H, C*H*Phβ), 4.93 – 4.88 (m, 2H), 4.85 – 4.72 (m, 7H), 4.70 – 4.64 (m, 4H), 4.61 (s, 2H), 4.58 – 4.49 (m, 3H), 4.39 (d, *J* = 7.7 Hz, 1H, H-1'β), 4.36 – 4.31 (m, 2H), 4.25 (dd, *J* = 9.0, 4.3 Hz, 1H), 4.21 – 4.07 (m, 3H), 4.00 – 3.88 (m, 5H), 3.83 (dd, *J* = 10.7, 3.2 Hz, 1H), 3.76 (ddd, *J* = 12.4, 8.5, 3.7 Hz, 1H), 3.73 – 3.69 (m, 1H), 3.67 – 3.57 (m, 6H), 3.57 – 3.52 (m, 1H), 3.51 – 3.46 (m, 2H), 3.41 – 3.33 (m, 7H), 3.18 (tt, *J* = 9.3, 4.8 Hz, 1H); ^{13}C NMR (101 MHz, CDCl$_3$) δ 138.8, 138.5, 138.4, 138.1, 137.9, 137.8, 137.7, 137.5, 137.5, 137.3, 135.4, 134.2, 132.0, 131.4, 131.3, 130.3, 130.2, 129.1, 129.0, 128.6, 128.5, 128.4, 128.4, 128.4, 128.3, 128.2, 128.1, 128.1, 128.0, 127.9, 127.8, 127.8, 127.8, 127.7, 127.6, 127.5, 127.4, 126.1, 126.1, 125.7, 103.4 (C-1'β), 101.2 (CHPhαβ), 99.1 (C-1αβ), 97.4 (C-1'α), 82.5, 82.2, 81.7, 81.2, 78.9, 78.5, 78.2, 75.6, 75.4, 75.1, 75.0, 74.5, 73.6, 73.4, 73.3, 71.9, 71.0, 70.6, 70.0, 69.0, 69.0, 68.9, 68.9, 68.0, 65.9, 63.6, 55.5, 55.4, 50.6, 49.5; HRMS: [M+NH$_4$]$^+$ calcd for $C_{50}H_{52}F_3NO_{11}NH_4$ 917.38307, found 917.38203.

Disaccharide 4cB



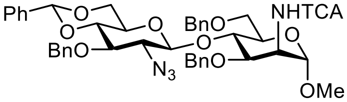
The title compound was synthesised from donor **B** and acceptor **4c** according to general procedure I as colourless oil. Yield: 64 mg, 77 µmol, 77%. α:β = 1:10. Data for the β-anomer: ^{1}H NMR (400 MHz, CDCl$_3$) δ 7.76 – 7.60 (m, 3H, CH$_{\text{arom}}$), 7.49 – 7.45 (m, 3H, CH$_{\text{arom}}$), 7.42 – 7.26 (m, 19H, CH$_{\text{arom}}$), 6.94 (d, *J* = 8.8 Hz, 1H, NH), 5.49 (s, 1H, C*H*Ph), 4.90 (d, *J* = 11.1 Hz, 1H, C*H*H Bn), 4.78 – 4.74 (m, 2H, H-1, CH*H* Bn), 4.72 – 4.66 (m, 2H, 2x C*H*H Bn), 4.60 – 4.49 (m, 3H, H-2, 2x CH*H* Bn), 4.24 (d, *J* = 8.1 Hz, 1H, H-1'), 4.05 (dd, *J* = 10.5, 5.0 Hz, 1H, H-6'), 4.01 – 3.92 (m, 3H, H-3, H-4, H-5), 3.79 (d, *J* = 8.8 Hz, 1H, H-5), 3.74 (dd, *J* = 10.6, 1.8 Hz, 1H, H-6), 3.60 (t, *J* = 9.2 Hz, 1H, H-4'), 3.53 (t, *J* = 10.3 Hz, 1H, H-6'), 3.44 (t, *J* = 9.3 Hz, 1H, H-3'), 3.38 (s, 3H, CH$_3$ OMe), 3.30 (dd, *J* = 9.4, 8.2 Hz, 1H, H-2'), 3.06 (td, *J* = 9.7, 5.0 Hz, 1H, H-5'); ^{13}C NMR (101 MHz, CDCl$_3$) δ 138.0, 137.8, 137.6, 137.2 (C$_q$), 135.4, 134.4, 131.9, 131.5, 131.2, 130.3, 129.2, 128.7, 128.6, 128.5, 128.5, 128.4, 128.4, 128.3, 128.2, 128.2, 128.1, 127.7, 127.3, 126.1, 126.0 (CH$_{\text{arom}}$), 101.7 (C-1'), 101.4 (CHPh), 99.1 (C-1), 81.7 (C-4'), 79.3 (C-3'), 75.4 (C-3), 74.9 (CH$_2$ Bn), 74.6 (C-4), 73.7, 71.8 (CH$_2$ Bn), 70.2 (C-5), 68.6 (C-6'), 68.1 (C-6), 66.8 (C-2'), 66.0 (C-5'), 55.4 (CH$_3$ OMe), 50.3 (C-2); diagnostic peaks for the α-anomer: ^{1}H NMR (400 MHz, CDCl$_3$) δ 5.59 (d, *J* = 4.1 Hz, 1H, H-1'), 5.56 (s, 1H, C*H*Ph); HRMS: [M+NH$_4$]$^+$ calcd for $C_{43}H_{45}F_3N_4O_{10}NH_4$ 852.34260, found 875.34206.

Disaccharide 4dA



The title compound was synthesised from donor **A** and acceptor **4d** according to general procedure I as colourless oil. Yield: 73 mg, 77 μmol, 77%. α:β = 1:2.7. Data for the β-anomer: ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.49 – 7.15 (m, 25H, CH$_{arom}$), 6.92 (d, *J* = 8.5 Hz, 1H, NH), 5.48 (s, 1H, C*H*Ph), 4.89 (d, *J* = 11.3 Hz, 1H, C*H*H Bn), 4.85 – 4.80 (m, 2H, H-1, C*H*H Bn), 4.76 – 4.68 (m, 2H, C*H*H Bn, CH*H* Bn), 4.62 – 4.54 (m, 2H, 2x CH*H* Bn), 4.55 – 4.45 (m, 3H, H-1', H-2, C*H*H Bn), 4.35 (d, *J* = 11.7 Hz, 1H, CH*H* Bn), 4.07 (dd, *J* = 10.5, 5.1 Hz, 1H, H-6'), 4.02 – 3.94 (m, 2H, H-3, H-4), 3.84 (dd, *J* = 10.7, 3.3 Hz, 1H, H-6), 3.72 (td, *J* = 9.2, 2.3 Hz, 1H, H-5), 3.65 – 3.51 (m, 4H, H-2', H-3', H-6, H-6'), 3.40 – 3.33 (m, 4H, H-4', CH_3 OMe), 3.13 (td, *J* = 9.3, 4.9 Hz, 1H, H-5'); ^{13}C NMR (101 MHz, $CDCl_3$) δ 162.1 (C=O), 138.5, 138.4, 138.3, 138.1, 137.4 (C$_q$), 129.1, 128.5, 128.4, 128.4, 128.4, 128.4, 128.3, 128.3, 128.3, 128.1, 128.0, 127.9, 127.8, 127.8, 127.8, 127.8, 127.7, 127.7, 127.5, 127.5, 127.3, 127.3, 126.1, 126.1 (CH$_{arom}$), 103.3 (C-1'), 101.2 (CHPh), 99.0 (C-1'), 82.6 (C-4'), 81.7, 81.2 (C-2', C-3'), 75.5 (CH_2 Bn), 75.4 (C-3), 75.1 (CH_2 Bn), 74.5 (C-4), 73.3, 71.5 (CH_2 Bn), 70.8 (C-5), 68.8 (C-6'), 68.2 (C-6), 65.8 (C-5'), 55.5 (CH_3 OMe), 51.6 (C-2); ^{1}H NMR (400 MHz, $CDCl_3$) δ 5.73 (d, *J* = 4.0 Hz, 1H, H-1'), 5.51 (s, 1H, C*H*Ph); ^{13}C NMR (101 MHz, $CDCl_3$) δ 97.5 (C-1'), 82.2, 78.8, 78.5, 78.3, 77.5, 75.4, 75.4, 73.5, 73.2, 70.2, 69.1, 69.1, 68.9, 63.6, 55.5, 50.6; HRMS: $[M+NH_4]^+$ calcd for $C_{50}H_{52}Cl_3NO_{11}NH_4$ 965.29442, found 965.29360.

Disaccharide 4dB



The title compound was synthesised from donor **B** and acceptor **4d** according to general procedure I as colourless oil. Yield: 88 mg, 100 μmol, 100%, α:β < 1:20. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.47 – 7.41 (m, 2H, CH$_{arom}$), 7.42 – 7.26 (m, 18H, CH$_{arom}$), 6.96 (d, *J* = 8.8 Hz, 1H, NH), 5.47 (s, 1H, NH), 4.89 (d, *J* = 11.2 Hz, 1H, C*H*H Bn), 4.83 (d, *J* = 1.9 Hz, 1H, H-1), 4.77 (d, *J* = 9.7 Hz, 1H, C*H*H Bn), 4.74 (d, *J* = 9.7 Hz, 1H, CH*H* Bn), 4.67 (d, *J* = 11.7 Hz, 1H, C*H*H Bn), 4.58 – 4.46 (m, 3H, H-2, 2x CH*H* Bn), 4.33 (d, *J* = 8.1 Hz, 1H, H-1'), 4.06 – 3.93 (m, 4H, H-3, H-4, H6, H-6'), 3.83 – 3.80 (m, 1H, H-5), 3.77 (dd, *J* = 10.6, 1.9 Hz, 1H, H-6), 3.59 (t, *J* = 9.2 Hz, 1H, H-4'), 3.56 – 3.42 (m, 2H, H-3', H-6'), 3.40 (s, 3H, CH_3 OMe), 3.32 (dd, *J* = 9.4, 8.2 Hz, 1H, H-2'), 3.02 (td, *J* = 9.8, 5.0 Hz, 1H, H-5'); ^{13}C NMR (101 MHz, $CDCl_3$) δ 162.1 (C=O), 138.1, 138.0, 137.8, 137.2 (C$_q$), 134.9, 133.4, 132.3, 131.9, 131.6, 131.5, 131.1, 129.2, 128.6, 128.5, 128.4, 128.3, 128.3, 128.1, 128.0, 127.9, 127.6, 127.2, 126.1 (CH$_{arom}$), 101.8 (C-1'), 101.3 (CHPh), 99.0 (C-1), 81.7 (C-4'), 79.3 (C-3'), 75.7 (C-3), 74.9 (CH_2 Bn), 74.7 (C-4), 73.6, 71.4 (CH_2 Bn), 70.3 (C-5), 68.5, 68.3 (C-6, C-6'), 66.9 (C-2'), 66.0 (C-5'), 55.5 (CH_3 OMe), 51.3 (C-2); HRMS: $[M+NH_4]^+$ calcd for $C_{43}H_{45}Cl_3N_4O_{10}NH_4$ 900.25395, found 900.25314.

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Chapter 6: Mapping the reactivity of 2,3-di-N-acetyl glucuronic acid and 2,4-di-N-acetyl bacillosamine building blocks in the synthesis of a highly N-acetylated Acinetobacter Baumannii LUH5554 tetrasaccharide

Jacob M.A. van Hengst, Daan de Bra, Joey G.C. Vlaming, Joeri Schoenmakers, Hermen S. Overkleeft, Gijsbert A. van der Marel and Jeroen D.C. Codée

Introduction

The bacterial glycome presents an immensely diverse collection of polysaccharide structures and while the mammalian glycans are built up using a relatively small palette of monosaccharides with little structural variation, bacterial glycans are built up form hundreds of different monosaccharides having an enormous structural variety. Because of their unique structures, bacterial exopolysaccharides and capsular polysaccharides represent attractive targets for our immune system and these structures have been very successfully exploited in the development of vaccines to prevent bacterial infections.

Acinetobacter Baumannii is a Gram-negative bacterium and an opportunistic pathogen, primarily infecting people with a weakened immune system.[1] It is the "A" in the ESKAPE pathogens, six bacteria that have been identified by the World Health Organisation (WHO) as high risk pathogens because of their high rate of antibiotic resistance and (hospital-derived) infections.[2,3] Because of the threat they present to global health, alternative strategies to combat the ESKAPE pathogens are direly needed and the development of active or passive immunisation strategies present attractive options. *A. baumannii* strains express a polysaccharide capsule, shielding the bacterial cell from its surrounding and environmental influences,[4] and these carbohydrates may be attractive targets for vaccine development.[5, 6] Synthetic fragments of these capsular polysaccharides can serve as well-defined antigens and be used for epitope mapping studies. They also allow for structural and interaction studies with binding partners, such as antibodies and immune cell receptors, at the atomic level.[7-9]

The capsular polysaccharide of *A. baumannii* LUH 5554 is built up of two rare monosaccharides, 2,4-di-*N*-acetyl-α-D-quinovose (2,4-di-*N*-acetyl bacillosamine, QuiNAc4NAc) and 2,3-di-*N*-acetyl-β-D-glucuronic acid (GlcNAc3NAcA) that form tetrasaccharide repeating units, with the structure [→4)-β-D-Glc*p*NAc3NAcA-(1→3)-α-D-Qui*p*NAc4NAc-(1→3)-α-D-Qui*p*NAc4NAc-(1→4)-β-D-Glc*p*NAc3NAcA-(1→] (***Figure 1***).[10] Strikingly, the repeating unit does not contain a single alcohol functionality but only features deoxy centres, carboxylates and acetamide groups! This Chapter describes the assembly of the *A. baumannii* LUH 5554 tetrasaccharide repeating unit. It presents effective multi-Gram scale routes of synthesis towards the monosaccharide building blocks and maps their reactivity in model glycosylation reactions. These studies have allowed the stereoselective assembly of the tetrasaccharide and will be of benefit in synthesis campaigns directed at the assembly of other bacterial glycans. For example, the rare GlcNAc3NAcA and QuiNAc4NAc constituents can also be found in other bacteria such as *Fusobacterium nucleatum*, an anaerobic bacterium that lives in the human mouth where it causes periodontitis, furthermore the bacterium has been linked to colorectal cancer and pregnancy complications,[11] *Neisseria meningitidis*, which causes meningitis and other meningococcal diseases,[12] the halophilic bacterium *Haloferax denitrificans,*[13] *Psychrobacter cryohalolentis*, a bacterium that lives in cold briny environments,[14] *Plesiomonas shigelloides*, which is responsible for severe cases of travellers' diarrhoea,[15] and the marine bacterium *Pseudoalteromonas*.[16]

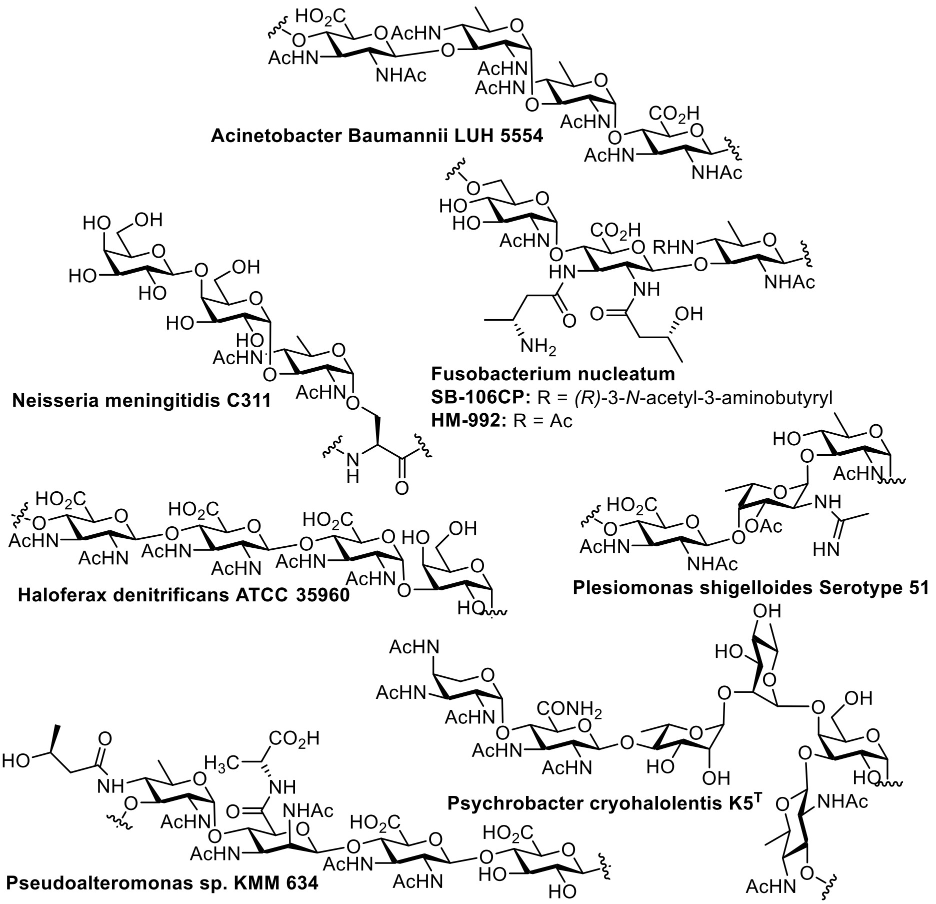


***Figure 1:** Representative structures of bacterial oligosaccharides containing 2,3-di-N-Acetyl glucuronic acid and/or 2,4-di-N-acylated bacillosamine.*

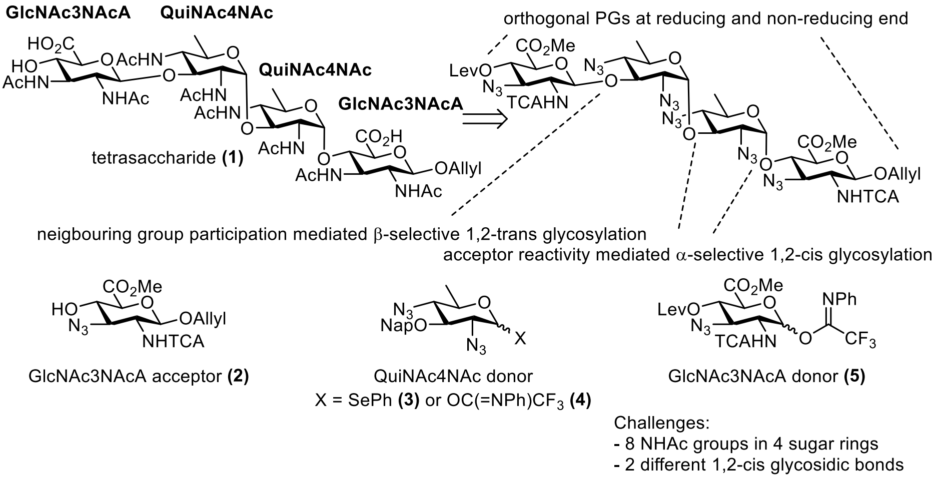
Results and discussion

Retrosynthetic analysis

The retrosynthetic strategy towards the target *A. Baumannii* repeating tetrasaccharide is depicted in ***Scheme 1***. It contains an *O*-allyl group on the reducing end which can be used for future conjugation or immobilisation purposes, but can also serve as a temporary protecting group to create a donor synthon to generate longer oligosaccharide fragments.

The hydroxyl at the non-reducing end is protected with a levulinoyl (Lev) ester, that can be removed orthogonally to all other used protecting groups. The designed protecting group strategy should thus allow for the generation of a tetrasaccharide donor and tetrasaccharide acceptor building block that can be exploited in the [4n+4] assembly of larger oligomers.

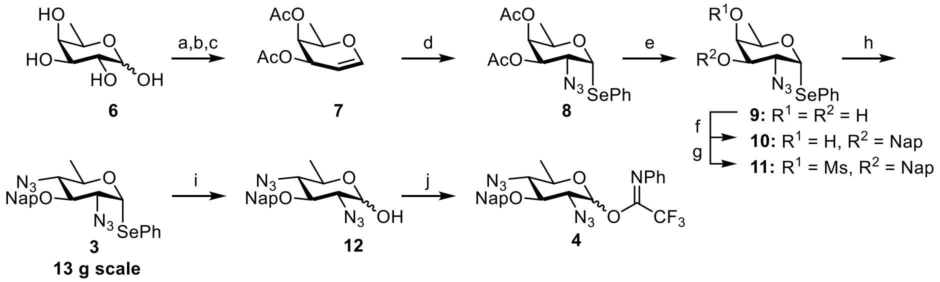
The GlcNAc3NAcA units in the *A. baumannii* tetrasaccharide are liked in a 1,2-*trans* fashion, so a stereoselective glycosylation can be accomplished using neighbouring group participation. Previously, 2,3-di-*N*-troc protected GlcNAc3NAcA building blocks[17] as well as a building block with a C-3-acetamide[18] have been unsuccessful and therefore it was decided to use an *N*-trichloroacetyl protected building block (**5**). The bacillosamine units in the tetrasaccharide are linked in a 1,2-*cis* fashion and relatively little is known about the stereoselectivity of glycosylations of bacillosamine donors carrying non-participating groups.[19] Approaches have been reported based on the use of '*in situ* anomerisation' strategy,[20] and indirect methods, based on glycosylations with a galactose- or fucose donor followed by C-4 inversion have also been used.[21, 22] Thus, here three building blocks were identified for the synthesis of the protected tetrasaccharide: a GlcNAc3NAcA acceptor for the reducing end with the anomeric allyl linker (**2**), a bacillosamine (QuiNAc4NAc) donor, which can be either a selenophenyl or *N*-phenyl trifluoroacetimidate (PTFAI) donor (**3** or **4**, respectively) and which has a C-2-azide as a non-participating masked amino functionality, and GlcNAc3NAcA donor **5** for the non-reducing end.



Scheme 1: *Synthetic targets and retrosynthetic analysis.*

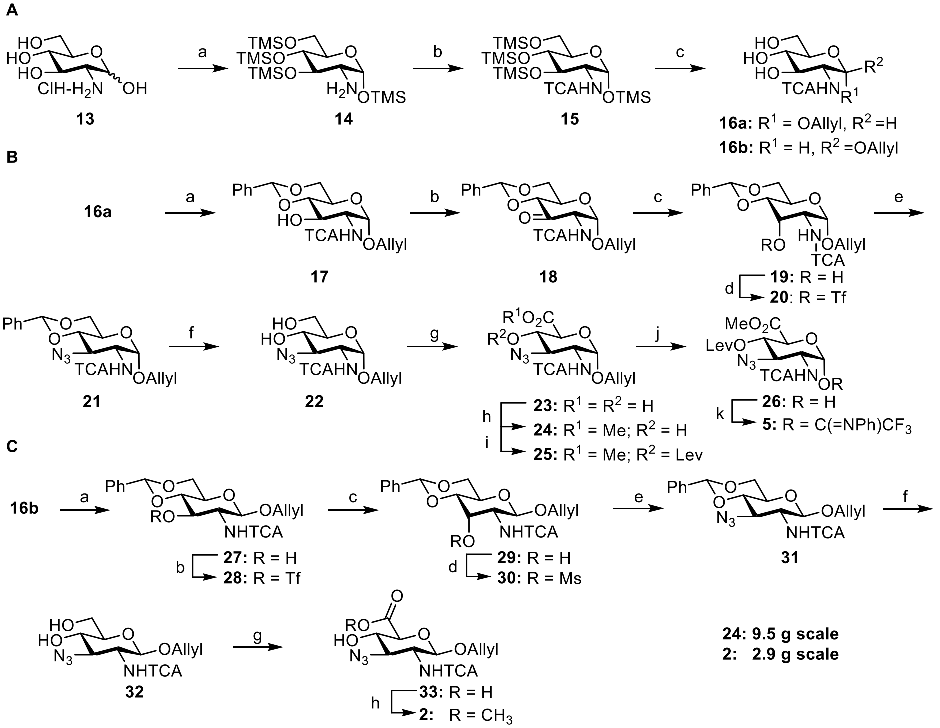
Synthesis of 2,4-di-*N*-acetyl bacillosamine and 2,3-di-*N*-acetyl glucuronic acid building blocks

The synthesis of the bacillosamine building block (***Scheme 2***) starts from D-fucose (**6**), which is transformed into 3,4-di-*O*-acetyl-D-fucal (**7**) in high yield over 3 steps. In the next step, the anomeric selenophenol and the C-2-azide were simultaneously installed.[23, 24] After deacetylation under Zemplén conditions, a 2-naphthylmethyl (NAP) ether was regioselectively introduced *via* the intermediate dibutyltin ketal. The installation of the axial C-4-azide was first attempted using the C-4-triflate, but this proved unsuccessful because the triflate could not be isolated due to decomposition. The reaction between the C-4-mesylate and NaN_3 showed no conversion of the starting material but when the mesylate was treated with NaN_3 and TBABr at 70 °C,[19,24] the desired di-azide was obtained in 71%. This synthesis could be performed on large scale and selenophenyl donor **3** was generated on a 26 mmol scale. Compound **3** can be used directly as donor or converted to PTFAI-donor **4** by NIS mediated hydrolysis followed by conversion into the imidate.



Scheme 2: *Synthesis of the bacillosamine building blocks. Reagents and conditions: a) Ac_2O, pyridine; b) HBr/HOAc, DCM; c) Zn, NH_4Cl, EtOAc, 70 °C, 90% over 3 steps; d) Ph_2Se, BAIB, $TMSN_3$, DCM, -30 °C to -10 °C, 77%; e) NaOMe, MeOH, 82%; f) i: DBTO, toluene, 130 °C, ii: NapBr, TBAI, toluene, 100 °C, 81 %; g) MsCl, pyridine, 80%; h) NaN_3, TBABr, DMF, 70 °C, 71%; i) NIS, THF/H_2O, 99%; j) PTFAI-Cl, NaH, DCM, 64%.*

The design of the α-*O*-allyl-2,3-diamino glucuronic acid building block was inspired by the work of Yin and Seeberger and coworkers, who reported the preparation of allyl 2-deoxy-2-*N*-trichloroacetyl-α-D-glucopyranoside (**16a**, ***Scheme 3A***) from glucosamine in 37% over 6 steps.[18] Here, a more efficient route is presented, based on the work of Lin and Wang and coworkers.[25] First, glucosamine hydrochloride was selectively *O*-silylated using HMDS in acetonitrile. Next, the trichloroacetyl protecting group was installed in excellent yield. In one pot, the silyl ethers were cleaved and the anomeric allyl group was installed through a Fischer glycosylation. This method yielded compound **16a** in 53% over 3 steps. In addition, 32% of β-anomer **16b** was obtained (***Scheme 3A***). The anomers were separated and both converted to the two corresponding glucuronic acid building blocks. The synthesis of glucuronic acid building blocks from the α-anomer (***Scheme 3B***) starts with protection of the C-4- and C-6-alcohols with a benzylidene acetal. Subsequently the C-3 alcohol was inverted by oxidation with Dess-Martin periodinane followed by reduction with $NaBH_4$ to form *allo*-configured building block **19**. The C-3-azide was installed by triflation of the axial alcohol, followed by substitution with NaN_3. The benzylidene was then removed using PTSA in methanol, yielding building block **22**. The regioselective oxidation of the primary alcohol was effected with TEMPO/BAIB to give, after methylation, acceptor **24**. The latter building block was assembled on 24 mmol scale and can be used as an acceptor, or turned into PTFAI-donor **5** by protection of the C-4-OH in a Steglich esterification with levulinic acid, deprotection of the anomeric allyl group using $PdCl_2$ and installation of the imidate. Acceptor **2** was synthesized in a similar fashion starting from β-anomer **16b** (***Scheme 3C***). The inversion of C-3-alcohol however, was achieved using a different strategy, because the oxidation-reduction sequence led to the formation of *gluco*-epimer alongside decomposition products. Thus, inversion of the C-3-alcohol in **27** was achieved by a Latrell-Dax epimerisation, through triflation of the alcohol followed by a substitution with $NaNO_2$. Next triflation of the *allose*-configured compound **29** was attempted. This reaction was significantly slower than the reaction on the corresponding α-anomer and the generated triflate decomposed with extended reaction times. Therefore, a mesylate was installed instead, which was subsequently substituted using tetrabutylammonium azide at 70 °C.



Scheme 3: *Synthesis of 2,3-di-N-acetyl glucuronic acid building blocks* ***A:*** *synthesis of 1-allyl-2-trichloroacetamide glucosamine. Reagents and conditions: a) HMDS, ACN; b) TCACl, DCM/pyr 7:3, 0°C to RT, 99% over 2 steps; c) AcCl, allyl-OH, 0 to 80 °C, 53% of* ***16a*** *and 32% of* ***16b; B:*** *synthesis of α-O-allyl acceptor* ***24*** *and α-PTFAI donor* ***5****. Reagents and conditions: a) $PhCH(OMe)_2$, PTSA, ACN, 60 °C, 300 mbar 86%; b) Dess-Martin periodinane, DCM; c) $NaBH_4$, MeOH, -10 °C to RT, 70% over 2 steps; d) Tf_2O, DMAP, DCM, 0 °C; e) NaN_3, DMF, 94% over 2 steps; f) PTSA, MeOH, reflux, 76%; g) TEMPO, BAIB, DCM/H_2O 2:1; h) MeI, $NaHCO_3$, DMF, 60% over 2 steps; i) LevOH, EDCI-HCl, DMAP, DCM, 100%; j) $PdCl_2$, MeOH/DCM, 3:2, 92% k) PTFAI-Cl, K_2CO_3, DCM/H_2O, 10:1, 70%;* ***C:*** *Synthesis of β-O-allyl acceptor* ***2****. Reagents and conditions: a) $PhCH(OMe)_2$, PTSA, ACN, 60 °C, 300 mbar 94%; b) Tf_2O, pyridine, DCM, - 10 °C; c) $NaNO_2$, DMF, 54% over 2 steps; d) MsCl, pyridine; e: Bu_4NN_3, acetonitrile, 70 °C, 65% over 2 steps; f) PTSA, methanol, 60 °C, 97%; g) TEMPO, BAIB, DCM/H_2O 2:1; h) MeI, $NaHCO_3$, DMF, 52% over 2 steps.*

Bacillosamine glycosylations

To study the glycosylating properties of the bacillosamine donors **3** and **4** their activation and the formation of reactive intermediates was studied by VT-NMR (***Figure 2***). When a mixture of donor **3** and Ph_2SO in CD_2Cl_2 was treated with Tf_2O at -80 °C, three new species were formed, which were identified as the α-triflate (**A**, H-1: 6.10 (d, *J* = 3.0 Hz)), the α-oxosulfonium triflate (**B**, H-1: 6.31 (d, *J* = 3.5 Hz)) and the β-oxosulfonium triflate (**C**, H-1: 5.61 (d, *J* = 8.3 Hz)). When the NMR probe was slowly warmed with 10 °C increments, the β-oxosulfoxonium triflate proved to be the least stable of the three intermediates and it almost fully disappeared at -40 °C, while decomposition of the other species started around -30 °C. When imidate donor **4** was treated with triflic acid at -80 °C, clean formation of the α-triflate was observed.

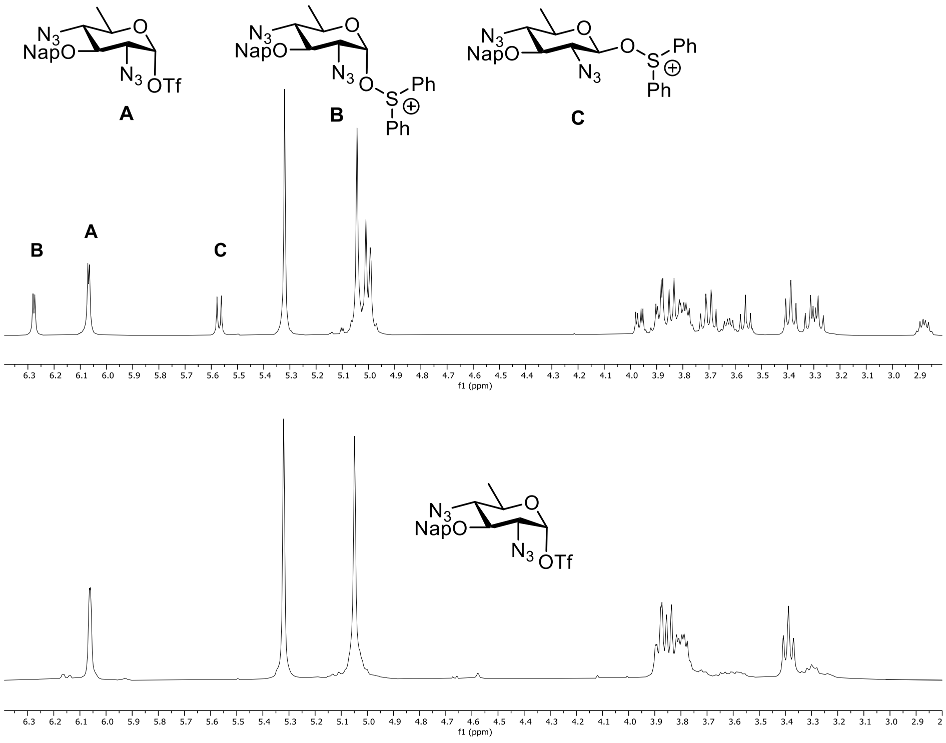
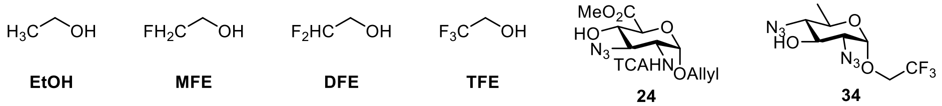
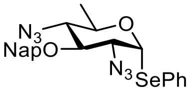


***Figure 2**: NMR spectra obtained upon activation of donors **3** (using Tf_2O/Ph_2SO, top) and **4** (using TfOH, bottom) at -50 ^{o}C in CD_2Cl_2.*

Next, the glycosylations of bacillosamine donor **3** were investigated in a series of Ph_2SO/Tf_2O mediated glycosylations (***Table 1***) with model acceptors of gradually varying nucleophilicity (EtOH-TFE).[23, 26-28] These glycosylation showed that the stereochemical outcome of glycosylations with donor **3** is highly dependent on the nucleophilicity of the acceptor, with the glycosylation of ethanol giving nearly complete β-selectivity, while glycosylation of trifluoroethanol provided primarily the α-product. Next 2,3-di-*N*-acetyl glucuronic acid acceptor **24** and bacillosamine acceptor **34,** obtained by treatment of glycosylation product **3D** with DDQ, were glycosylated with **3**. Based on previous studies both the CO_2Me group[29] as well as the azide (*this thesis*, chapter 5) were expected to have a strong disarming effect on the neighbouring alcohol, lowering its nucleophilicity and thus rendering the glycosylations with the acceptor α-selective. Indeed, the glycosylations of **3** with acceptor **24** and acceptor **34** provided the desired α-product with good selectivity. The yield of the reaction with the diaminoglucuronic acid acceptor **24** was moderate.

Table 1*: Stereoselectivity of bacillosamine donor* ***3****, α:β ratios, yield in parentheses.*



Donor	EtOH	MFE	DFE	TFE	24	34
	**3A** **1:8** (84%)	**3B** **1:2** (75%)	**3C** **2.9:1** (66%)	**3D** **22:1** (94%)	**3E** **12:1** (42%)	**3F** **6.6:1** (75%)

Conditions for pre-activation: 0.05 M donor in DCM, 1.3 eq Ph_2SO, 1.3 eq Tf_2O, 2.5 eq TTBP, 2 eq acceptor. Activation from -80 °C to -60 °C, glycosylation from -80 °C to -60 °C.

A potential mechanistic explanation for the stereochemical outcome of the glycosylations of donor **3** is given in ***Figure 3***. Upon activation of donor **3** with Ph_2SO and Tf_2O, three reactive species are formed, the α-triflate, the α-oxosulfonium triflate and the β-oxosulfonium triflate, with the latter being the least stable. Strong nucleophiles can react with one of the (more stable) α-species in an S_N2-type reaction to form the β-product, while less reactive nucleophiles require a stronger electrophile, such as the more reactive β-oxosulfonium triflate to form the α-product. The least reactive nucleophiles react likely react with an oxocarbenium ion intermediate in an S_N1-like reaction to form the α-product.

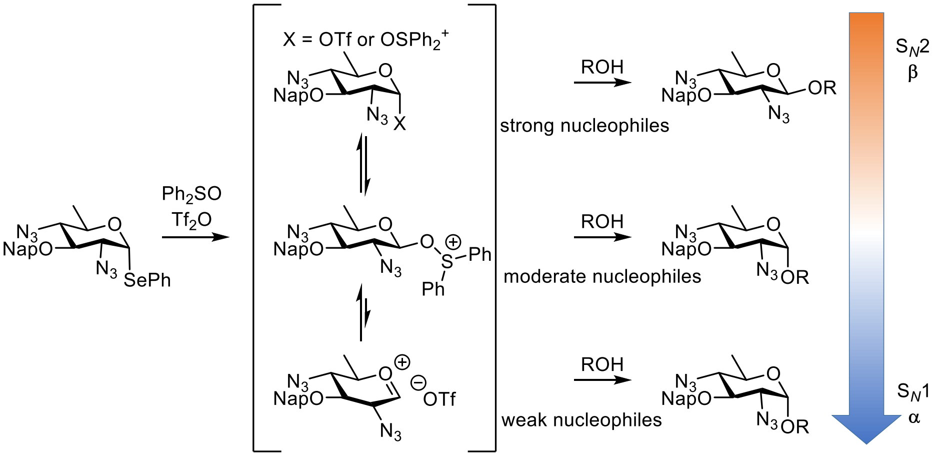
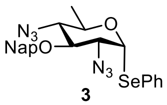


***Figure 3:** Mechanistic rationale for the observed stereoselectivity of donor **3**.*

Synthesis of the tetrasaccharide

Next, the assembly of the target tetrasaccharide was undertaken, starting with optimization of the glycosylation between the bacillosamine donor and diaminoglucuronic acid acceptor (***Table 2***). Although the glycosylation of donor **3** and acceptor **24** under pre-activation conditions proceeded with high α-selectivity, the yield was relatively poor (Table 2, entries **1** and **2**). When imidate donor **4** was reacted with the same acceptor using in-situ activation conditions, the desired product was obtained in high yield, but with no stereoselectivity (entry **3**). When Ph_2SO was added to this activation procedure the α-selectivity was significantly improved, at the expense of a lower yield (entry **4**). The increased stereoselectivity in the latter glycosylation suggests that the oxosulfonium triflates play an important role in determining the stereoselective outcome of the glycosylation reaction, with the most reactive covalent species **C** (Figure 2), providing the desired α-product. The yield of the pre-activation glycosylation could be further improved by decreasing the amount of Ph_2SO and Tf_2O and raising the temperature of the glycosylation reaction (entries **5-7**). It has previously been shown that selenoglycosides can be completely activated using half an equivalent of Ph_2SO and Tf_2O.[23] The excess of diphenylsulfonium bistriflate, generated in the glycosylations described in entries 1 and 2, that is not used for the activation of the selenoglycoside may react with the acceptor alcohol, preventing it from being glycosylated.[30, 31] Indeed, the use of a bit more than half an equivalent of the activator led to complete activation of the bacillosamine donor and the desired increase in yield. The glycosylation with β-*O*-allyl acceptor **2** proceeded best and delivered the target disaccharide with the highest yield (entry **7**).

Table 2: *Optimisation of the glycosylations of the bacillosamine donors.*



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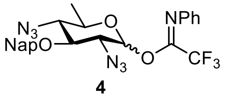

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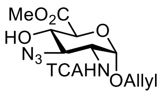

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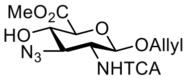

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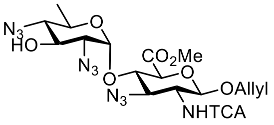

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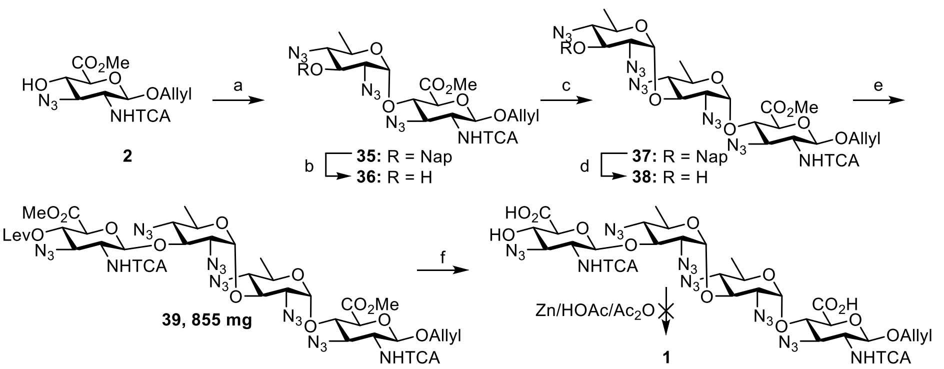
Entry	Donor (eq)	Acceptor (eq)	Activator (eq)	Additive (eq)	Solvent Temp [°C]	Product (yield)	α:β
1	**3** (1)	**24** (2)	Ph_2SO/Tf_2O (1.3/1.3)	TTBP (2.5)	DCM -80 → -60	**3E** (42%)	**12:1**
2	**3** (1.3)	**24** (1)	Ph_2SO/Tf_2O (1.3/1.3)	TTBP (2.5)	DCM -80 → -60	**3E** (31%)	**10:1**
3	**4** (1.3)	**24** (1)	TMSOTf (0.2)	-	DCM -80 → 0	**3E** (83%)	**1:1**
4	**4** (1.3)	**24** (1)	TMSOTf (0.2)	Ph_2SO (1.5)	DCM -80 → 0	**3E** (38%)	**9:1**
5	**3** (1.3)	**24** (1)	Ph_2SO/Tf_2O (1.3/0.65)	TTBP (2.5)	DCM -80 → 0	**3E** (55%)	**13:1**
6	**3** (1.3)	**24** (1)	Ph_2SO/Tf_2O (0.65/0.65)	TTBP (2.5)	DCM -80 → 0	**3E** (65%)	**13:1**
7	**3** (1.3)	**2** (1)	Ph_2SO/Tf_2O (0.65/0.65)	TTBP (2.5)	DCM -80 → 0	**35** (74%)[a]	**10:1**
8	**3** (1.3)	**36** (1)	Ph_2SO/Tf_2O (0.65/0.65)	TTBP (2.5)	DCM -80 → 0	**37** (38%)	**4.5:1**
9	**3** (1.3)	**36** (1)	Ph_2SO/Tf_2O (0.65/0.65)	TTBP (2.5)	1:1 Et_2O/DCM -80 → 0	**37** (81%)	**10:1**

Reactions with 3 A molecular sieves (rods, 3/16"). Entries 1-7 were performed with a donor concentration of 0.05 M. in entries 8 and 9, the concentration of the donor was 0.025 M due to lower solubility of acceptor ***36.*** *a: yield based on 0.1 mmol scale. On 4 mmol scale, the yield was 81%*

With disaccharide **35** the assembly of the target tetrasaccharide was continued (***scheme** 4*). Thus, product **35** was treated with DDQ to obtain disaccharide acceptor **36**. It was observed that this disaccharide had a relatively low solubility and therefore it was used in the ensuing glycosylation reaction at a lower concentration (0.025 M *vs* 0.05M used for the condensation before). This led to formation of the trisaccharide in moderate yield and with moderate α-selectivity (table 2, entry **8**). [§] Switching the solvent from DCM to a 1:1 mixture of DCM and diethyl ether increased both the α-selectivity and the yield (table 2, entry **9**). Likely the decreased solvent polarity promotes the S_N2 reaction of the β-oxosulfonium triflate while leveraging its high reactivity. Unmasking the Nap ether with DDQ the delivered trisaccharide acceptor **38**, which was reacted with donor **5** under in-situ activation conditions, to yield tetrasaccharide **39** in 59% yield on 670 μmol scale. Deprotection of the tetrasaccharide started with removal of the methyl and levulinoyl esters, When the tetrasaccharide was treated with sodium hydroxide for 2 hr at RT, the esters were selectively removed leaving the trichloroacetamides unscathed. Unfortunately, the subsequent Zn/AcOH reduction and subsequent acetylation to transform both the azides and trichloroactyl groups into the corresponding acetamides was unsuccessful. Investigations towards a full deprotection and acetylation sequence to successfully transform tetrasaccharide **39** into the target tetrasaccharide **1** are currently in progress.



***Scheme 4:** assembly of tetrasaccharide **39** Reagents and conditions: a) first donor **3**, Ph_2SO, TTBP, Tf_2O, DCM, -80 °C → -60 °C → -80 °C, then acceptor **2**, -80 °C → 0 °C, 81%, α:β = 10:1; b) DDQ, 9:1 DCM/H_2O, 89%; c) first donor **3**, Ph_2SO, TTBP, Tf_2O, 1:1 Et_2O/DCM, -80 °C → -60 °C → -80 °C, then acceptor **36**, -80 °C → 0 °C, 81%, α:β = 10:1; d) DDQ, 9:1 DCM/H_2O, 62%; e) first donor **5** and acceptor **38**, DCM, 0 °C, then TMSOTf, 59%, α:β <1:20; f) 1:1 THF/1M aq. NaOH, 2 hr at RT*

[§] An attempt was made to increase the α-selectivity by using *N,N*-methylphenylformamide as additive, but this yielded only a trace amount of trisaccharide, with 1,1'-linked donor and unreacted acceptor as the main products

Conclusions

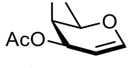
The synthesis of a highly *N*-acetylated oligosaccharide from the capsule of *Acinetobacter Baumannii,* consisting of 2,4-di-*N*-acetyl bacillosamine and 2,3-di-*N*-acetyl glucuronic acid, was accomplished. To this end, scalable routes towards the rare monosaccharide building blocks were developed. Bacillosamine building block **3** was prepared on 26 mmol scale and 2,3-di-*N*-acetyl glucuronic acid building block **24** on a 23 mmol scale. Next, the glycosylating properties of the bacillosamine donors were investigated by low temperature NMR characterisation of reactive species that were formed upon activation and a series of glycosylation reactions with a set of model acceptors, of gradually decreasing nucleophilicity. Activation of the bacillosamine selenophenyl donor **3** with Ph_2SO and Tf_2O led to the formation of three reactive species upon reaction, the anomeric α-triflate, α-oxosulfonium triflate and the β-oxosulfonium triflate. The latter β-oxosulfonium triflate proved to be the least stable of the three intermediates. PTFAI donor **4** generated only the α-triflate upon reaction with TfOH. It was found that the stereoselectivity of glycosylations of donor **3** under pre-activation conditions strongly depends on the nucleophilicity of the acceptor, as the stereoselectivity gradually changed from nearly completely β-selective for the most nucleophilic acceptor (ethanol) to completely α-selective for the weakest nucleophile (trifluoroethanol). The carbohydrate acceptors that were studied in the context of the assembly of the target *A. baumannii* tetrasaccharide provided α-selective glycosylations, which can be accounted for by the presence of the flanking de-activating groups in these acceptors (*i.e.* the neighboring methyl ester and azides). It was found that Ph_2SO played an important role in shaping the stereoselectivity of the glycosylations, pointing to the reactive β-oxosulfonium triflate as an important intermediate for the α-selective bacillosaminylation reactions. In these glycosylations, Ph_2SO thus functions as a nucleophilic additive to modulate the reactivity of the glycosylating species, similar to the formamide additives that have recently gained significant attention in the development of stereoselective glycosylation reactions. The developed protecting group scheme not only allowed to generate the target tetrasaccharide, it will also enable the generation of tetrasaccharide building blocks to assemble larger fragments of the *A. baumannii* polysaccharide in a [4n+4] glycosylation approach. These can be used to study the structural properties of these fascinating highly *N*-acetylated oligosaccharide structures and their interaction with components of the host immune system.

Experimental

General experimental procedures

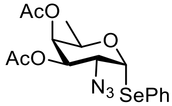
General experimental procedures: All chemicals were of commercial grade and used as received unless stated otherwise. Dichloromethane (DCM) was stored over activated 4 Å molecular sieves for at least 24 h before use. Trifluoromethanesulfonic anhydride (Tf_2O) was distilled over P_2O_5 and stored at -20°C under a nitrogen atmosphere. Overnight temperature control was achieved by a FT902 Immersion Cooler (Julabo). Flash column chromatography was performed on silica gel 60 Å (0.04 – 0.063 mm, Screening Devices B.V.). Size-exclusion chromatography was performed on Sephadex (LH-20, GE Healthcare Life Sciences) by isocratic elution with DCM/MeOH (1/1, v/v). Thin-layer chromatography (TLC) analysis was conducted on TLC silica gel 60 plates (Kieselgel 60 F254, Merck) with UV detection by (254 nm) and by spraying with 20% sulfuric acid in ethanol or by spraying with a solution of $(NH_4)_6Mo_7O_{24}{\cdot}H_2O$ (25 g/L) and $(NH_4)_4Ce(SO4)_4{\cdot}2H_2O$ (10 g/L) in 10% aq. sulfuric acid followed by charring at ±250 °C. High-resolution mass spectrometry (HRMS) was performed on a Thermo Finnigan LTQ Orbitrap mass spectrometer equipped with an electrospray ion source in positive-ion mode (source voltage 3.5 kV, sheath gas flow 10, capillary temperature 275 °C) with resolution R = 60.000 at m/z 400 (mass range of 150-4000) and dioctylphtalate (m/z=391.28428) as lock mass, or on a Waters Synapt G2-Si (TOF) equipped with an electrospray ion source in positive mode (source voltage 3.5 kV) and LeuEnk (m/z = 556.2771). as internal lock mass. 1H and 13C NMR spectra were recorded on Bruker AV-400, Bruker DMX-400, and Bruker AV-500 NMR instruments. Chemical shifts (δ) are given in parts per million (ppm) relative to tetramethylsilane as an internal standard or the residual signal of the deuterated solvent. Coupling constants (J) are given in Hertz (Hz). All presented 13C-APT spectra are proton-decoupled. NMR peak assignments were made using COSY and HSQC. When necessary, additional NOESY, HMBC and HMBC-GATED experiments were used to further elucidate the structure. The anomeric product ratios were based on careful analysis of the crude reaction mixture and the purified reaction product by integration of representative 1H NMR signals. IR spectra were recorded on a Shimadzu FTIR-8300 IR spectrometer and are reported in cm-1. Specific rotations were measured on a Propol automatic polarimeter or an Anton-Paar MCP-100 modular circular polarimeter at 589 nm unless otherwise stated.

3,4-di-*O*-acetyl-D-fucal (7)



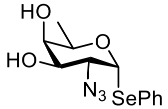
D-fucose (**6**, 10 g, 60.9 mmol) was dissolved in pyridine (0.2 M), after which Ac_2O (29 mL, 305 mmol, 5 eq) was added. The reaction mixture was stirred overnight and concentrated. The residue was dissolved in ethyl acetate and washed with 1M HCl and sat. aq. $NaHCO_3$. The organic phase was dried with $MgSO_4$ and concentrated under reduced pressure to obtain the crude per-acetylated fucose, which was used without further purification. Per-acetylated fucose was dissolved in DCM (0.25 M) and cooled to 0 °C. HBr (33% in HOAc, 77 mL, 425 mmol, 7.5 eq) was added dropwise and the reaction was allowed to warm to RT. After 2 hr, the reaction mixture was concentrated and azeotroped with toluene at 30 °C, yielding the anomeric bromide. The residue was dissolved in EtOAc (0.25 M) and washed with sat. aq. $NaHCO_3$. The organic phase was dried with $MgSO_4$, after which NH_4Cl (22.8 g, 425 mmol, 7.5 eq) and freshly activated zinc (27.8 g, 425 mmol, 7.5 eq) were added. The reaction mixture was heated to a reflux overnight, filtered and concentrated. The residue was purified over silica (5% Et_2O in pentane with 1% Et_3N) yielding the title compound as white solid. Yield: 10.9 g, 51 mmol, 90%. ^1H NMR (400 MHz, $CDCl_3$) δ 6.47 (dd, *J* = 6.3, 2.0 Hz, 1H, H-1), 5.58 (dtd, *J* = 4.9, 2.0, 1.1 Hz, 1H, H-3), 5.29 (dt, *J* = 4.9, 1.6 Hz, 1H, H-4), 4.64 (dt, *J* = 6.3, 1.9 Hz, 1H, H-2), 4.23 (qq, *J* = 6.5, 1.0 Hz, 1H, H-5), 2.16 (s, 3H, CH_3 Ac), 2.02 (s, 3H, CH_3 Ac), 1.28 (d, *J* = 6.6 Hz, 3H, H-6). ^{13}C NMR (101 MHz, $CDCl_3$) δ 170.8, 170.5 (C=O), 146.2 (C-1), 98.4 (C-2), 71.6 (C-5), 66.3 (C-4), 65.1 (C-4), 20.9, 20.8 (CH_3 Ac), 16.6 (C-6). Spectra in agreement with literature.[32]

Phenyl 2-deoxy-2-azido-3,4,-di-*O*-acetyl-1-seleno-α-D-fucopyranoside (8)



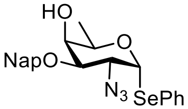
Compound **7** (19.38 g, 90.47 mmol) and diphenyl diselenide (28.24 g, 90.47 mmol, 1 eq) were dissolved in DCM (0.2M) and degassed with N_2 in an ultrasonic bath. After this, the solution was cooled to -30 °C and BIAB (29.14 g, 90.47 mmol, 1 eq) and $TMSN_3$ (23.69 mL, 180.9 mmol, 2 eq) were added. The reaction mixture was allowed to warm to -10 °C and kept at that temperature overnight. Excess reagents were quenched by the addition of 20 mL cyclohexene, after which the reaction mixture was allowed to warm to RT and concentrated under reduced pressure. Silica chromatography (2% acetone in pentane) yields the title compound as yellow oil. Yield: 28.70 g, 69.61 mmol, 77%. ^1H NMR (500 MHz, $CDCl_3$) δ 7.61 – 7.52 (m, 2H, CH_{arom}), 7.34 – 7.27 (m, 3H, CH_{arom}), 5.95 (d, *J* = 5.4 Hz, 1H, H-1), 5.32 (dd, *J* = 3.3, 1.2 Hz, 1H, H-4), 5.13 (dd, *J* = 10.8, 3.2 Hz, 1H, H-3), 4.50 (dd, *J* = 6.4 Hz, 1.2 Hz, 1H, H-5), 4.23 (dd, *J* = 10.8, 5.4 Hz, 1H, H-2), 2.17 (s, 3H, CH_3 Ac), 2.07 (s, 3H, CH_3 Ac), 1.09 (d, *J* = 6.5 Hz, 3H, H-6); ^{13}C NMR (126 MHz, $CDCl_3$) δ 170.5, 169.9 (C=O), 134.9, 129.4 (CH_{arom}), 128.3 (C_q), 128.2 (CH_{arom}), 84.6 (C-1), 71.8 (C-3), 70.3 (C-4), 67.7 (C-5), 59.0 (C-2), 20.9, 20.8 (CH_3 Ac), 16.0 (C-6). Spectra in agreement with literature.

Phenyl 2-deoxy-2-azido-1-seleno-α-D-fucopyranoside (9)



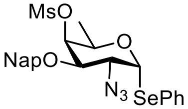
Product **7** (28.70 g, 69.61 mmol) was dissolved in MeOH (0.5 M) and NaOMe (1.88 g, 34.80 mmol, 0.5 eq) was added. The mixture was stirred for 17 h after which the reaction was neutralized with Amberlite-H^+, filtered and concentrated under reduced pressure. The product was recrystallized using EtOAc/pentane and concentrated mother liquor was purified via silica chromatography (15% acetone in pentane), yielding product 1**8** as a white solid. Total yield: 18.80 g, 57.28 mmol, 82%. ^1H NMR (300 MHz, $CDCl_3$) δ 7.65 – 7.52 (m, 2H, CH_{arom}), 7.37 – 7.22 (m, 3H, CH_{arom}), 5.91 (d, *J* = 5.3 Hz, 1H, H-1), 4.38 (q, *J* = 6.6 Hz, 1H, H-5), 4.06 (dd, *J* = 9.9, 5.3 Hz, 1H, H-2), 3.88 – 3.75 (m, 2H, H-3, H-4), 2.67 (s, 2H, 3-OH, 4-OH), 1.26 (d, *J* = 6.6 Hz, 3H, H-6); ^{13}C NMR (75 MHz, $CDCl_3$) 134.7, 129.4 (CH_{arom}), 128.7 (C_q), 128.1 (CH_{arom}), 85.2 (C-1), 71.7, 71.5 (C-3, C-4), 68.9 (C-5), 62.1 (C-2), 16.2 (C-6). Spectra in agreement with literature.[33]

Phenyl 2-deoxy-2-azido-3-*O*-(2-naphthyl)methyl-1-seleno-α-D-fucopyranoside (10)



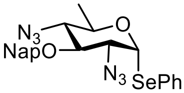
Compound **9** (18.8 g, 57.3 mmol) and Bu_2SnO (14.5 g, 58.4 mmol, 1.02 eq) were dissolved in toluene in a flask equipped with a Dean-Stark apparatus. The reaction mixture was heated to a vigorous reflux for under removal of water for 2 hr, after which NapBr (13.3 g, 60.1 mmol, 1.05 eq) and TBABr (19.4 g, 60.1 mmol, 1.05 eq) were added at 60 °C. The reaction mixture was then heated to a reflux for 1 hr, after which it was cooled to RT and quenched with 10% aq. KF solution. The phases were separated and the aqueous phase was extracted with ethyl acetate. Combined organic phases were washed with brine, dried with $MgSO_4$ and concentrated. The residue was purified over silica (5% acetone in pentane) to yield the title compound as yellow solid. Yield: 21.7 g, 46.3 mmol, 81%. ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.90 – 7.81 (m, 4H, CH_{arom}), 7.60 – 7.54 (m, 2H, CH_{arom}), 7.55 – 7.46 (m, 3H, CH_{arom}), 7.31 – 7.23 (m, 4H, CH_{arom}), 5.89 (d, *J* = 5.4 Hz, 1H, H-1), 4.91 (d, *J* = 11.2 Hz, 1H, C*H*H Nap), 4.85 (d, *J* = 11.5 Hz, 1H, CH*H* Nap), 4.28 (q, *J* = 6.6 Hz, 1H, H-5), 4.20 (dd, *J* = 10.2, 5.3 Hz, 1H, H-2), 3.89 (dt, *J* = 3.1, 1.5 Hz, 1H, H-4), 3.74 (dd, *J* = 10.2, 3.1 Hz, 1H, H-3), 2.42 (t, *J* = 1.6 Hz, 1H, 4-OH), 1.24 (d, *J* = 6.6 Hz, 3H, H-6); ^{13}C NMR (126 MHz, $CDCl_3$) δ 134.6 (CH_{arom}), 133.4, 133.3 (C_q), 129.2, 128.8 (CH_{arom}), 128.6 (C_q), 128.1, 128.0, 127.9, 127.9, 127.1, 126.5, 126.4, 125.8 (CH_{arom}), 85.3 (C-1), 79.4 (C-3), 72.4 (CH_2 Nap), 68.7, 68.7 (C-4, C-5), 60.4 (C-2), 16.2 (C-6). Spectra in agreement with literature.[24]

Phenyl 2-deoxy-2-azido-3-*O*-(2-naphthyl)methyl-4-*O*-methanesulfonyl-1-seleno-α-D-fucopyranoside (11)



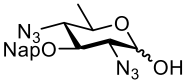
Compound **10** (21.7g, 46.3 mmol) was dissolved in pyridine (0.5 M), after which methanesulfonyl chloride (5.4 mL, 69.4 mmol, 1.5 eq) was added dropwise. After full conversion as indicated by TLC, the reaction mixture was concentrated under reduced pressure. The residue was dissolved in DCM and washed with 1M HCl and sat. aq. $NaHCO_3$. The organic phase was dried with $MgSO_4$ and concentrated. Silica chromatography (15% acetone in pentane) yields the title compound as yellow oil. Yield: 20.3 g, 37.1 mmol, 80%). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.91 – 7.80 (m, 4H, CH_{arom}), 7.59 – 7.54 (m, 3H, CH_{arom}), 7.54 – 7.48 (m, 2H, CH_{arom}), 7.33 – 7.26 (m, 3H, CH_{arom}), 5.93 (d, *J* = 5.4 Hz, 1H, H-1), 5.11 (dd, *J* = 3.0, 1.1 Hz, 1H, H-4), 4.99 (d, *J* = 10.6 Hz, 1H, C*H*H Nap), 4.88 (d, *J* = 10.6 Hz, 1H, CH*H* Nap), 4.49 – 4.39 (m, 1H, H-5), 4.14 (dd, *J* = 10.4, 5.3 Hz, 1H, H-2), 3.85 (dd, *J* = 10.4, 3.0 Hz, 1H, H-3), 2.99 (s, 3H, CH_3 Ms), 1.27 (d, *J* = 6.5 Hz, 3H, H-6); ^{13}C NMR (101 MHz, $CDCl_3$) δ 134.8 (CH_{arom}), 133.8, 133.4, 133.3 (C_q), 129.4, 128.7, 128.2, 128.2 (CH_{arom}), 127.9 (C_q), 127.9, 127.8, 126.5, 126.5, 126.2 (CH_{arom}), 84.6 (C-1), 79.0 (C-4), 77.5 (C-3), 73.2 (CH_2 Nap), 67.9 (C-5), 60.6 (C-2), 39.3 (CH_3 Ms), 16.6 (C-6). Spectra in agreement with literature.[24]

Phenyl 2,4-dideoxy-2,4-diazido-3-*O*-(2-naphthyl)methyl-1-seleno-α-D-quinopyranoside (3)



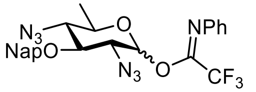
Compound **9** (20.3 g, 37.1 mmol) was dissolved in DMF with NaN_3 (24.1 g, 371 mmol, 10 eq) and TBABr (35.8 g, 111 mmol, 3 eq), after which the reaction mixture was heated to 70 °C. When TLC showed full conversion of the starting material, the mixture was cooled to RT, diluted with water and extracted with diethyl ether. The organic phase was dried with $MgSO_4$ and concentrated under reduced pressure. The residue was purified over silica (1% acetone in pentane) yielding the title compound as a yellow oil. Yield: 13.0 g, 26.4 mmol, 71%. $[\alpha]_D^{25}$ = 176.3° (c = 0.48, $CHCl_3$); IR (thin film): 741, 1084, 1269, 2105; ^1H NMR (400 MHz, $CDCl_3$) δ 7.92 – 7.79 (m, 4H, CH_{arom}), 7.61 – 7.53 (m, 3H, CH_{arom}), 7.51 – 7.44 (m, 2H, CH_{arom}), 7.33 – 7.25 (m, 3H, CH_{arom}), 5.81 (d, *J* = 5.3 Hz, 1H, H-1), 5.06 (d, *J* = 10.5 Hz, 1H, C*H*H Nap), 5.02 (d, *J* = 10.6 Hz, 1H, CH*H* Nap), 4.04 (dq, *J* = 10.1, 6.2 Hz, 1H, H-5), 3.87 (dd, *J* = 9.9, 5.3 Hz, 1H, H-2), 3.62 (t, *J* = 9.6 Hz, 1H, H-3), 3.20 (dd, *J* = 10.1, 9.3 Hz, 1H, H-4), 1.28 (d, *J* = 6.2 Hz, 3H, H-6); ^{13}C NMR (101 MHz, $CDCl_3$) δ 134.7 (CH_{arom}), 134.5, 133.4, 133.3 (C_q), 129.3, 128.4 (CH_{arom}), 128.3 (C_q), 128.2, 128.2, 127.8, 127.7, 126.4, 126.3, 126.3 (CH_{arom}), 84.7 (C-1), 81.0 (C-3), 76.0 (CH_2 Nap), 69.6 (C-5), 68.3 (C-4), 65.0 (C-2), 18.2 (C-6); HRMS: $[M+H]^+$ calcd for $C_{23}H_{22}N_6O_2SeH$ 495.10428 , found 495.10387.

2,4-dideoxy-2,4-diazido-3-*O*-(2-naphthyl)methyl-α,β-D-quinopyranose (12)



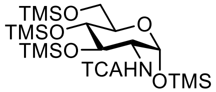
Compound **3** (1.80 g, 3.65 mmol) was dissolved in 0.25 M 1:1 and cooled to 0 °C. NIS (1.23 g, 5.47 mmol, 1.5 eq) was added and the reaction mixture was slowly allowed to warm to RT. After full conversion, excess NIS was quenched with sat. aq. $Na_2S_2O_3$. The reaction mixture was concentrated under reduced pressure, the residue was dissolved in DCM and washed with water. The organic phase was dried with $MgSO_4$ and concentrated under reduced pressure. The residue was purified over silica (10% → 20% acetone) yielding the title compound as white solid. Yield: 1.28 g, 3.62 mmol, 99%, α:β = 1:1.1; data reported for a 1:1 mixture of anomers: ^1H NMR (400 MHz, $CDCl_3$) δ 7.89 – 7.80 (m, 8H, CH_{arom}), 7.56 (td, *J* = 8.5, 1.7 Hz, 2H, CH_{arom}), 7.51 – 7.43 (m, 4H, CH_{arom}), 5.26 (t, *J* = 3.3 Hz, 1H, H-1α), 5.05 (d, *J* = 10.8 Hz, 3H, C*H*H Nap, CH_2 Nap), 4.97 (d, *J* = 10.7 Hz, 1H, CH*H* Nap), 4.51 (dd, *J* = 7.9, 4.4 Hz, 1H, H-1β), 3.94 – 3.83 (m, 2H, H-3α, H-5α), 3.62 (d, *J* = 4.6 Hz, 1H, 1-OHβ), 3.44 (dd, *J* = 10.1, 2.8 Hz, 1H, H-2α), 3.37 (dd, *J* = 9.7, 7.8 Hz, 1H, H-2β), 3.29 (dd, *J* = 9.7, 8.8 Hz, 1H, H-3β), 3.23 (dq, *J* = 9.6, 5.9 Hz, 1H, H-5β), 3.16 (ddd, *J* = 10.2, 9.2, 2.2 Hz, 2H, H-4αβ), 3.04 (dd, *J* = 3.5, 1.3 Hz, 1H, 1-OHα), 1.34 (d, *J* = 5.9 Hz, 3H, H-6β), 1.31 (d, *J* = 6.2 Hz, 3H, H-6α); ^{13}C NMR (101 MHz, $CDCl_3$) δ 134.7, 134.7, 133.4, 133.4, 133.3 (C_q), 128.5, 128.2, 128.2, 127.8, 127.8, 127.6, 127.6, 126.4, 126.3, 126.3, 126.3, 126.2 (CH_{arom}), 96.1 (C-1β), 92.1 (C-1α), 81.3 (C-3β), 78.5 (C-3α), 75.7, 75.7 (CH_2 Nap), 71.1 (C-5β), 68.7 (C-4β), 67.7 (C-2β, C-4α), 66.8 (C-5α), 64.2 (C-2α), 18.52 (C-6αβ); HRMS: $[M+H-N_2]^+$ calcd for $C_{17}H_{18}N_4O_3H$ 327.14517, found 327.14486

N-phenyl-*O*-(2,4-dideoxy-2,4-diazido-3-*O*-(2-naphthyl)methyl-α,β-D-quinopyranosyl) trifluoroacetimidate (4)



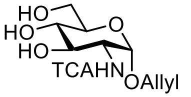
Compound **11** (1.28 g, 3.62 mmol) was dissolved in DCM, after which PTFAI-Cl (0.92 mL, 5.79 mmol, 1.6 eq) and NaH (60% dispersion in mineral oil, 220 mg, 5.43 mmol, 1.5 eq) were added. After 3 hr, an extra 0.5 eq of PTFAI-Cl and NaH were added. Upon full conversion, the reaction was quenched with water and extracted with DCM. The organic phase was dried with $MgSO_4$ and concentrated. The residue was purified over silica (98:1:1 pentane/Et_2O/Et_3N) to yield the title compound as a white solid. Yield: 1.21 g, 2.30 mmol, 64%, α:β = 1:3.5. Data reported for a 0.3:1 mixture. ^1H NMR (500 MHz, $CDCl_3$, 323 K) δ 7.84 (ddd, *J* = 13.2, 6.5, 4.2 Hz, 5.2H, CH_{arom}), 7.59 – 7.51 (m, 1.3H, CH_{arom}), 7.47 (p, *J* = 5.1 Hz, 2.6H, CH_{arom}), 7.30 (t, *J* = 7.7 Hz, 2.6H, CH_{arom}), 7.11 (td, *J* = 7.5, 1.2 Hz, 1.3H, CH_{arom}), 6.88 – 6.80 (m, 2.6H, CH_{arom}), 6.34 (s, 0.3H, H-1α), 5.44 (s, 1H, H-1β), 5.07 – 5.03 (m, 1.6H, C*H*H Napβ, CH_2 Napα), 5.00 (d, *J* = 10.9 Hz, 1H, CH*H* Napβ), 3.84 (t, *J* = 9.7 Hz, 0.3H, H-3α), 3.75 (dq, *J* = 12.2, 6.1 Hz, 0H, H-5α), 3.63 (t, *J* = 9.0 Hz, 1.3H, H-2αβ), 3.40 – 3.27 (m, 1H, H-3β), 3.25 – 3.08 (m, 2.3H, H-4αβ, H-5β), 1.38 – 1.33 (m, 3.9H, H-6αβ); ^{13}C NMR (126 MHz, $CDCl_3$, 323 K) δ 143.3, 134.8, 133.6, 133.5 (C_q), 129.0, 129.0, 128.5, 128.3, 128.2, 127.9, 127.9, 127.6, 127.5, 126.4, 126.3, 126.3, 126.3, 124.8, 119.6, 119.5, (CH_{arom}) 95.8 (C-1β), 93.9 (C-1α), 81.5 (C-3β), 78.8 (C-3α), 75.9 (CH_2 Napα), 75.8 (CH_2 Napβ), 72.1 (C-5β), 69.6 (C-5α), 68.3 (C-4α), 67.7 (C-4β), 65.9 (C-2β), 63.6 (C-2α), 18.5 (C-6α), 18.4 (C-6β); HRMS: $[M+H-N_2]^+$, calcd for $C_{25}H_{22}F_3N_5O_3H$ 498.17475, found 498.17448

2-Deoxy-2-trichloroacetamido-1,3,4,6-tetra-*O*-trimethylsilyl-α-D-glucopyranose (15)



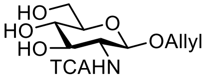
D-glucosamine hydrochloride (**13**, 43.1 g, 200 mmol) and HMDS (105 mL, 500 mmol, 2.5 eq) were dissolved in 500 mL acetonitrile and stirred for 3 hr at RT, after which the solids were filtered off and the reaction mixture was concentrated under reduced pressure, yielding **14**. The residue was dissolved in 1L 7:3 DCM/pyridine and cooled to 0 °C. Trichloroacetyl chloride (24.7 mL) was added dropwise and the reaction mixture was allowed to warm to RT overnight after which solvents were removed under reduced pressure. The residue was dissolved in DCM and washed with water. The organic phase was dried with $MgSO_4$ and concentrated under reduced pressure, yielding the title compound as amber coloured oil, which was used without further purification. Yield: 121.7 g, 198 mmol, 99%. ^1H NMR (400 MHz, $CDCl_3$) δ 6.84 (d, *J* = 9.6 Hz, 1H, NH), 5.12 (d, *J* = 3.4 Hz, 1H, H-1), 3.94 (td, *J* = 9.6, 3.4 Hz, 1H, H-2), 3.79 (dd, *J* = 9.5, 7.7 Hz, 1H, H-3), 3.76 – 3.69 (m, 2H, 2x H-6), 3.68 – 3.60 (m, 2H, H-4, H-5), 0.19 (s, 9H, CH_3 TMS), 0.17 (s, 9H, CH_3 TMS), 0.16 (s, 9H, CH_3 TMS), 0.11 (s, 9H, CH_3 TMS); ^{13}C NMR (101 MHz, $CDCl_3$) δ 161.8 (C=O), 91.9 (C-1), 73.5 (C-3), 73.1, 71.9 (C-4, C-5), 61.6 (C-6), 57.0 (C-2), 1.2 (CH_3 TMS), 0.9 (CH_3 TMS), 0.0 (CH_3 TMS), -0.2 (CH_3 TMS). Spectra in agreement with literature.[25]

Allyl 2-deoxy-2-trichloroacetamido-α-D-glucopyranoside (16a)



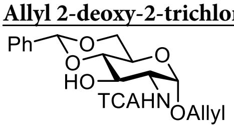
Compound **15** (117 g, 191 mmol) was dissolved in 500 mL allyl alcohol and cooled to 0 °C, after which acetyl chloride (13.6 mL, 191 mmol, 1 eq) was added. When TLC shows full removal of the TMS groups, the temperature was raised to 80 °C. When TLC shows disappearance of the starting material, the temperature is lowered to 0 °C and the reaction in quenched with $NaHCO_3$ (32.1 g, 382 mmol, 2 eq). Solids were filtered off and the solvent was removed under vacuum. The residue is purified with silica chromatography (5% methanol in DCM), yielding the title compound as off-white solid. Yield: 37.1 g, 102 mmol, 53%. ^1H NMR (400 MHz, MeOD) δ 5.92 (dddd, *J* = 17.1, 10.5, 6.2, 5.1 Hz, 1H, CH_2-C*H*=CH_2), 5.32 (dq, *J* = 17.3, 1.7 Hz, 1H, CH_2-CH=C*H*H), 5.21 – 5.15 (m, 1H, CH_2-CH=CH*H*), 4.95 (d, *J* = 2.8 Hz, 1H, H-1), 4.23 (ddt, *J* = 13.2, 5.1, 1.5 Hz, 1H, C*H*H-CH=CH_2), 4.03 (ddt, *J* = 13.2, 6.2, 1.3 Hz, 1H, CH*H*-CH=CH_2), 3.88 – 3.80 (m, 3H, H-2, H-3, H-6), 3.71 (dd, *J* = 11.8, 5.6 Hz, 1H, H-6), 3.63 (ddd, *J* = 9.7, 5.6, 2.2 Hz, 1H, H-5), 3.42 – 3.36 (m, 1H, H-4); ^{13}C NMR (101 MHz, MeOD) δ 164.2 (C=O), 135.2 (CH_2-*C*H=CH_2), 118.0 (CH_2-CH=*C*H_2), 96.9 (C-1), 74.1 (C-5), 72.2 (C-3, C-4), 69.3 (*C*H_2-CH=CH_2), 62.6 (C-6), 57.5 (C-2). Spectra in agreement with literature.[34] Further elution also yielded the β-anomer as orange solid. Yield: 22.0 g, 60.3 mmol, 32%, giving a total yield of 85%

Allyl 2-deoxy-2-trichloroacetamido-β-D-glucopyranoside (16b)



^1H NMR (400 MHz, MeOD) δ 5.86 (ddt, *J* = 17.2, 10.7, 5.4 Hz, 1H, CH_2-C*H*=CH_2), 5.26 (dq, *J* = 17.3, 1.7 Hz, 1H, CH_2-CH=C*H*H), 5.10 (dq, *J* = 10.5, 1.5 Hz, 1H, CH_2-CH=CH*H*), 4.59 (d, *J* = 8.1 Hz, 1H, H-1), 4.33 (ddt, *J* = 13.2, 5.0, 1.6 Hz, 1H, C*H*H-CH=CH_2), 4.07 (ddt, *J* = 13.2, 5.7, 1.5 Hz, 1H, CH*H*-CH=CH_2), 3.88 (dd, *J* = 11.9, 2.1 Hz, 1H, H-6), 3.72 – 3.59 (m, 3H, H-2, , H-6), 3.35 – 3.24 (m, 2H); ^{13}C NMR (101 MHz, MeOD) δ 164.5, 135.4, 117.2, 101.3, 78.0, 75.0, 72.3, 71.0, 62.7, 59.2. spectra in agreement with literature.[35]

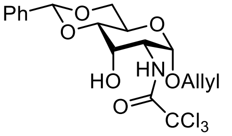
Allyl 2-deoxy-2-trichloroacetamido-4,6-*O*-benzylidene-α-D-glucopyranoside (17)



16a (37 g, 101 mmol), PTSA-H_2O (0.97 g, 5.1 mmol, 0.05 eq) and benzaldehyde dimethylacetal (16.8 mL, 112 mmol, 1.1 eq) were dissolved in 1L acetonitrile and heated to 60 °C at 300 mbar. After full conversion of the starting material, the reaction was quenched with 0.1 eq Et_3N and concentrated under reduced pressure. Crystallisation (DCM/pentane) yields the title compound as off-white solid. Yield: 39.7 g, 87 mmol, 86%. ^1H NMR (400 MHz, $CDCl_3$) δ 7.54 – 7.45 (m, 2H, CH_{arom}), 7.38 (qd, *J* = 3.7, 1.7 Hz, 3H, CH_{arom}), 6.96 (d, *J* = 8.7 Hz, 1H, NH), 5.88 (dddd, *J* = 16.9, 10.4, 6.4, 5.4 Hz, 1H, CH_2-C*H*=CH_2), 5.57 (s, 1H, C*H*Ph), 5.31 (dq, *J* = 17.2, 1.5 Hz, 1H, CH_2-CH=C*H*H), 5.26 (dq, *J* = 10.4, 1.2 Hz, 1H, CH_2-CH=CH*H*), 4.99 (d, *J* = 3.8 Hz, 1H, H-1), 4.29 (dd, *J* = 10.1, 4.7 Hz, 1H, H-6), 4.26 – 4.15 (m, 2H, H-2, C*H*H-CH=CH_2), 4.08 – 4.00 (m, 2H, H-3, CH*H*-CH=CH_2), 3.89 (td, *J* = 9.8, 4.7 Hz, 1H, H-5), 3.78 (t, *J* = 10.3 Hz, 1H, H-6), 3.61 (t, *J* =

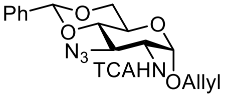
9.3 Hz, 1H, H-4), 2.63 (d, *J* = 3.2 Hz, 1H, OH); ^{13}C NMR (101 MHz, CDCl$_3$) δ 162.5 (C=O), 137.0 (C$_q$), 133.0 (CH$_2$-*C*H=CH$_2$), 129.5, 128.5, 126.4 (CH$_{arom}$), 118.9 (CH$_2$-CH=*C*H$_2$), 102.1 (CHPh), 96.4 (C-1), 81.8 (C-4), 70.0 (C-3), 69.0, 68.8 (C-6, *C*H$_2$-CH=CH$_2$), 62.9 (C-5), 55.5 (C-2). Spectra in agreement with literature.[18]

Allyl 2-deoxy-2-trichloroacetamido-4,6-*O*-benzylidene-α-D-allopyranoside (19)



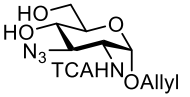
Compound **17** (39.1 g, 86 mmol) and Dess-Martin periodinane (47.6 g, 112 mmol, 1.3 eq) were dissolved in DCM and stirred until TLC showed full conversion. The reaction mixture was quenched with sat. aq. Na$_2$S$_2$O$_3$ and extracted with DCM. The combined organic phases were dried and concentrated to yield the crude ketone **18** which was used immediately in the next reaction. The ketone was dissolved in methanol and cooled to -10 °C, after which NaBH$_4$ (13.1 g, 345 mmol, 4 eq) was added in small portions. After the final addition, the reaction mixture was allowed to warm to RT. After full conversion of the starting material, the reaction mixture was concentrated under reduced pressure. The residue was dissolved in ethyl acetate and washed with water. The organic phase was dried with MgSO$_4$ and concentrated. Silica chromatography (20% Et$_2$O in pentane) yields the title compound as colourless oil that slowly solidifies. Yield: 27.4 g, 60.6 mmol, 70% over 2 steps. ^{1}H NMR (400 MHz, CDCl$_3$) δ 7.49 (dd, *J* = 6.6, 3.1 Hz, 2H, CH$_{arom}$), 7.44 (d, *J* = 8.8 Hz, 1H, NH), 7.40 – 7.35 (m, 3H, CH$_{arom}$), 5.87 (dddd, *J* = 17.0, 10.4, 6.5, 5.2 Hz, 1H, CH$_2$-C*H*=CH$_2$), 5.62 (s, 1H, C*H*Ph), 5.31 (dq, *J* = 17.2, 1.5 Hz, 1H, CH$_2$-CH=C*H*H), 5.24 (dq, *J* = 10.4, 1.2 Hz, 1H, CH$_2$-CH=CH*H*), 4.99 (d, *J* = 4.2 Hz, 1H, H-1), 4.37 (dd, *J* = 10.3, 5.1 Hz, 1H, H-6), 4.30 – 4.23 (m, 2H, H-3, C*H*H-CH=CH$_2$), 4.23 – 4.17 (m, 2H, H-2, H-5), 4.05 (ddt, *J* = 13.0, 6.5, 1.2 Hz, 1H, CH*H*-CH=CH$_2$), 3.79 (t, *J* = 10.3 Hz, 1H, H-6), 3.65 (dd, *J* = 9.7, 2.8 Hz, 1H, H-4), 2.75 (d, *J* = 5.9 Hz, 1H, OH); ^{13}C NMR (101 MHz, CDCl$_3$) δ 161.8 (C=O), 137.0 (C$_q$), 133.0 (CH$_2$-*C*H=CH$_2$), 129.4, 128.5, 126.3 (CH$_{arom}$), 118.9 (CH$_2$-CH=*C*H$_2$), 102.0 (CHPh), 96.0 (C-1), 92.3 (CCl$_3$), 78.2 (C-4), 69.5 (*C*H$_2$-CH=CH$_2$), 69.1 (C-6), 67.3 (C-3), 57.7 (C-5), 51.2 (C-2). Spectra in agreement with literature.[18]

Allyl 2,3-dideoxy-2-trichloroacetamido-3-azido-4,6-*O*-benzylidene-α-D-glucopyranoside (21)



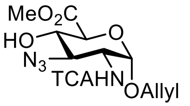
Compound **19** (27.4 g, 60.5 mmol) and DMAP (22.2 g, 182 mmol, 3 eq) were dissolved in DCM and cooled to -10 °C, after which triflic anhydride (20.3 mL, 121 mmol, 2 eq) was added dropwise, after which the reaction mixture was slowly allowed to warm to RT. After full of the starting material, the reaction mixture was acidified with 5 eq of acetic acid and washed with water. The organic phase was dried with MgSO$_4$ and concentrated at 25 °C, yielding triflate **20**. The crude triflate was dissolved in DMF with NaN$_3$ (19.7 g, 303 mmol, 5 eq) and stirred overnight, after which the reaction mixture was poured in 10x the volume of water under vigorous stirring. The precipitated solid was collected by filtration, washed with water, dissolved in DCM and washed with brine. Organic phase was dried with MgSO$_4$ and concentrated, yielding the slightly impure title compound as a white solid. Yield: 24.7 g, 51.6 mmol, 85% over 2 steps. ^{1}H NMR (400 MHz, CDCl$_3$) δ 7.52 – 7.46 (m, 2H, CH$_{\text{arom}}$), 7.38 (dq, J = 8.5, 2.3 Hz, 3H, CH$_{\text{arom}}$), 6.90 (d, J = 9.5 Hz, 1H, NH), 5.87 (dddd, J = 17.0, 10.3, 6.5, 5.4 Hz, 1H, CH$_2$-C*H*=CH$_2$), 5.63 (s, 1H, C*H*Ph), 5.35 – 5.25 (m, 2H, CH$_2$-CH=C*H$_2$*), 4.91 (d, J = 3.7 Hz, 1H, H-1), 4.32 (dd, J = 10.3, 4.8 Hz, 1H, H-6), 4.24 (ddt, J = 12.7, 5.4, 1.3 Hz, 1H, C*H*H-CH=CH$_2$), 4.13 (ddd, J = 10.8, 9.6, 3.7 Hz, 1H, H-2), 4.04 (ddt, J = 12.7, 6.6, 1.2 Hz, 1H, CH*H*-CH=CH$_2$), 3.98 – 3.89 (m, 2H, H-3, H-5), 3.80 (t, J = 10.3 Hz, 1H, H-6), 3.70 (t, J = 9.6 Hz, 1H, H-4); ^{13}C NMR (101 MHz, CDCl$_3$) δ 162.0 (C=O), 136.7 (C$_q$), 132.7 (CH$_2$-*C*H=CH$_2$), 129.3, 128.5, 126.0 (CH$_{\text{arom}}$), 119.3 (CH$_2$-CH=*C*H$_2$), 101.6 (CHPh), 96.0 (C-1), 80.4 (C-4), 69.0 (*C*H$_2$-CH=CH$_2$), 68.8 (C-6), 63.3 (C-5), 61.3 (C-3), 53.6 (C-2). Spectra in agreement with literature.[18]

Allyl 2,3-dideoxy-2-trichloroacetamido-3-azido-α-D-glucopyranoside (22)



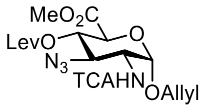
Compound **21** (24 g, 50.2 mmol) and PTSA-H$_2$O (0.96 g, 5.02 mmol, 0.1 eq) were dissolved in methanol (0.3 M) and heated to a gentle reflux. After full conversion, the reaction was cooled to RT, neutralised with 0.2 eq Et$_3$N and concentrated under reduced pressure. The residue was purified over silica (25% acetone in pentane) to yield the title compound as white solid. Yield: 14.9 g, 38.2 mmol, 76%. ^{1}H NMR (400 MHz, Acetone) δ 8.22 (d, J = 8.3 Hz, 1H, NH), 5.92 (dddd, J = 17.2, 10.7, 5.9, 5.0 Hz, 1H, CH$_2$-C*H*=CH$_2$), 5.35 (dq, J = 17.3, 1.7 Hz, 1H, CH$_2$-CH-C*H*H), 5.16 (dq, J = 10.5, 1.4 Hz, 1H, CH$_2$-CH=CH*H*), 5.08 (d, J = 5.7 Hz, 1H, 4-OH), 4.92 (d, J = 3.6 Hz, 1H, H-1), 4.24 (ddt, J = 13.4, 5.0, 1.6 Hz, 1H, C*H*H-CH=CH$_2$), 4.08 – 4.01 (m, 2H, H-3, C*H*H-CH=CH$_2$), 3.86 – 3.71 (m, 4H, 6-OH, H-2, 2x H-6), 3.70 – 3.59 (m, 2H, H-4, H-5); ^{13}C NMR (101 MHz, Acetone) δ 162.6 (C=O), 134.9 (CH$_2$-*C*H=CH$_2$), 117.4 (CH$_2$-CH=*C*H$_2$), 96.0 (C-1), 73.6 (C-4), 71.1 (C-5), 68.7 (*C*H$_2$-CH=CH$_2$), 64.7 (C-3), 62.1 (C-6), 54.9 (C-2). Spectra in agreement with literature[18]

Methyl (Allyl 2,3-dideoxy-2-trichloroacetamido-3-azido-α-D-glucopyranosyl uronate) (24)



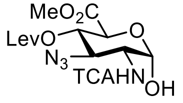
Compound **22** (14.8 g, 38.1 mmol) was dissolved in 300 mL 2:1 DCM/H$_2$O after which TEMPO (2.98 g, 19.1 mmol, 0.5 eq) and BAIB (30.7 g, 95 mmol, 2.5 eq) were added. After full conversion, the reaction mixture was concentrated under reduced pressure, yielding crude uronic acid **23**. The residue was coevaporated twice with toluene and dissolved in 200 mL DMF with NaHCO$_3$ (14.4 g, 171 mmol, 4.5 eq) and methyl iodide (17.8 mL, 286 mmol, 7.5 eq). After 18 hr, the reaction mixture was diluted with water and extracted twice with diethyl ether. Combined organic phases were dried with MgSO$_4$ and concentrated under reduced pressure. The residue was purified over silica (15% acetone in pentane) to yield the title compound as white solid. Yield: 9.5 g, 22.8 mmol, 60%. $[\alpha]_D^{25}$ = 70.5° (c = 0.63, CHCl$_3$); IR (thin film): 821, 1057, 1518, 1717, 2111; ^{1}H NMR (400 MHz, CDCl$_3$) δ 6.82 (d, J = 9.4 Hz, 1H, NH), 5.88 (dddd, J = 17.0, 10.3, 6.6, 5.4 Hz, 1H, CH$_2$-C*H*-CH$_2$), 5.34 (dq, J = 17.2, 1.4 Hz, 1H, CH$_2$-CH=C*H*H), 5.29 (dq, J = 10.4, 1.1 Hz, 1H, CH$_2$-CH=CH*H*), 4.99 (d, J = 3.6 Hz, 1H, H-1), 4.29 (ddt, J = 12.5, 5.1, 1.2 Hz, 1H, C*H*H-CH=CH_2), 4.24 (d, *J* = 9.7 Hz, 1H, H-5), 4.12 – 4.02 (m, 2, H-2, CH*H*-CH=CH_2), 3.92 (td, *J* = 9.6, 2.6 Hz, 1H, H-4), 3.87 (s, 3H, CH_3 CO_2Me), 3.77 (dd, *J* = 11.1, 9.3 Hz, 1H, H-3), 3.48 (d, *J* = 2.8 Hz, 1H, OH); ^{13}C NMR (101 MHz, $CDCl_3$) δ 170.3 (C-6), 162.0 (C=O), 132.5 (CH_2-*C*H=CH_2), 119.6 (CH_2-CH=*C*H_2), 95.6 (C-1), 92.3 (CCl_3), 71.3 (C-4), 70.4 (C-5), 69.3 (*C*H_2-CH=CH_2), 63.5 (C-3), 53.2 (CH_3 CO_2Me), 52.7 (C-2); HRMS: $[M+Na]^+$ calcd for $C_{12}H_{15}Cl_3N_4O_6Na$ 438.99494, found 438.99469.

Methyl (Allyl 2,3-dideoxy-2-trichloroacetamido-3-azido-4-levulinoyl-α-D-glucopyranosyl uronate) (25)



24 (3.13 g, 7.50 mmol), levulinic acid (1.15 mL, 11.3 mmol, 1.5 eq) and DMAP (2.75 g, 22.5 mmol, 3 eq) were dissolved dichloromethane, after which EDC-HCl (2.16 g, 11.3 mmol, 1.5 eq) was added in portions. After full conversion of the starting material, the reaction mixture was diluted with DCM and washed with 1M aq. HCl and with sat. aq. $NaHCO_3$. The organic phase was dried with $MgSO_4$ and concentrated under reduced pressure to yield the pure title compound as white solid. Yield: 3.87 g, 7.50 mmol, 100%. $[\alpha]_D^{25}$ = 89.8° (c = 0.25, $CHCl_3$); IR (thin film): 756, 1057, 1152, 1251, 1518, 1717, 1759, 2111; ^1H NMR (400 MHz, $CDCl_3$) δ 6.83 (d, *J* = 9.4 Hz, 1H, NH), 5.86 (dddd, *J* = 17.1, 10.3, 6.7, 5.4 Hz, 1H, CH_2-C*H*=CH_2), 5.37 – 5.26 (m, 2H, CH_2-CH=C*H*$_2$), 5.12 (t, *J* = 9.8 Hz, 1H, H-4), 5.03 (d, *J* = 3.6 Hz, 1H, H-1), 4.33 (d, *J* = 9.9 Hz, 1H, H-5), 4.28 (ddt, *J* = 12.7, 5.4, 1.3 Hz, 1H, C*H*H-CH=CH_2), 4.18 (ddd, *J* = 11.0, 9.4, 3.7 Hz, 1H, H-2), 4.08 (ddt, *J* = 12.8, 6.7, 1.1 Hz, 1H, CH*H*-CH=CH_2), 3.89 (dd, *J* = 11.0, 9.7 Hz, 1H, H-3), 3.77 (s, 3H, CH_3 CO_2Me), 2.89 – 2.78 (m, 1H, C*H*H Lev), 2.77 – 2.71 (m, 1H, CH*H* Lev), 2.71 – 2.65 (m, 1H, C*H*H Lev), 2.64 – 2.54 (m, 1H, CH*H* Lev), 2.20 (s, 3H, CH_3 Lev); ^{13}C NMR (101 MHz, $CDCl_3$) δ 206.0 (C=O), 171.4, 167.8 (C-6, C=O), 161.9 (C=O), 132.3 (CH_2-*C*H=CH_2), 119.9 (CH_2-CH=*C*H_2), 95.3 (C-1), 70.4 (C-4), 69.5 (*C*H_2-CH=CH_2), 69.0 (C-5), 61.9 (C-3), 53.3 (CH_3 CO_2Me), 52.7 (C-2), 37.7 (CH_2 Lev), 29.9 (CH_3 Lev), 27.7 (CH_2 Lev); HRMS: $[M+NH_4]^+$ calcd for $C_{17}H_{21}Cl_3N_4O_8NH_4$ 532.07632, found 532.07594.

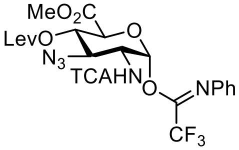
Methyl (2,3-dideoxy-2-trichloroacetamido-3-azido-4-levulinoyl-α-D-glucopyranosyl uronate) (26)



Compound **25** (5.93 g, 11.5 mmol) was dissolved in 100 mL 3:2 MeOH/DCM, and $PdCl_2$ (408 mg, 2.30 mmol, 0.2 eq) was added. After full conversion of the starting material the reaction mixture was filtered over celite and concentrated under reduced pressure. The residue was purified over silica (30% acetone in pentane) to yield the title compound as off-white foam. Yield: 5.01 g, 10.5 mmol, 92%. $[\alpha]_D^{25}$ = 131.3° (c = 0.08, $CHCl_3$); IR (thin film): 1063, 1150, 1713, 1753, 2111; ^1H NMR (400 MHz, $CDCl_3$) δ 6.94 (d, *J* = 9.3 Hz, 1H, NH), 5.41 (s, 1H, H-1), 5.12 (t, *J* = 9.7 Hz, 1H, H-4), 4.55 (d, *J* = 9.9 Hz, 1H, H-5), 4.24 (s, 1H, OH), 4.17 (ddd, *J* = 10.9, 9.4, 3.5 Hz, 1H, H-2), 3.95 (dd, *J* = 10.8, 9.6 Hz, 1H, H-3), 3.76 (s, 3H, CH_3 CO_2Me), 2.90 – 2.80 (m, 1H, C*H*H Lev), 2.77 – 2.73 (m, 1H, CH*H* Lev), 2.71 – 2.67 (m, 1H, C*H*H Lev), 2.64 – 2.56 (m, 1H, CH*H*

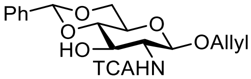
Lev), 2.21 (s, 3H, CH_3 Lev); ^{13}C NMR (101 MHz, $CDCl_3$) δ 171.5, 168.3 (C-6, C=O), 162.1 (C=O), 90.8 (C-1), 70.4 (C-4), 68.6 (C-5), 61.6 (C-3), 53.4 (CH_3 CO_2Me), 53.0 (C-2), 37.7 (CH_2 Lev), 30.0 (CH_3 Lev), 27.7 (CH_2 Lev); HRMS: $[M+NH_4]^+$ calcd for $C_{14}H_{17}Cl_3N_4O_8$ 492.04502, found 492.04478

N-Phenyl-O-(Methyl (2,3-dideoxy-2-trichloroacetamido-3-azido-4-levulinoyl-α-D-glucopyranosyl uronate)) trifluoroacetimidate (5)



Compound **26** (4.99 g, 10.5 mmol) was dissolved in 100 mL DCM with 10 mL water, K_2CO_3 (4.35 g, 31.5 mmol, 3 eq) and PTFAI-Cl (5 mL, 31.5 mmol, 3 eq). The reaction mixture was stirred vigorously until TLC showed full conversion of the starting material,after which the reaction mixture was diluted with water and extracted twice with DCM. Combined organic phases were dried with $MgSO_4$ and concentrated under reduced pressure. The residue was recrystallized from Et_2O to yield the title compound (pure α-anomer) as a white powder. The concentrated mother liquor was purified via silica chromatography (20%→30% acetone in pentane with 1% Et_3N) to obtain extra product (enriched in α-anomer) as an orange solid. Total yield: 4.78 g, 7.39 g, 70%. $[\alpha]_D^{25}$ = 80.2° (c = 0.27, $CHCl_3$); IR (thin film): 822, 1027, 1116, 1209, 1720, 1763, 2112; data for the α-anomer: ^1H NMR (400 MHz, $CDCl_3$) δ 7.30 (t, *J* = 7.9 Hz, 2H, CH_{arom}), 7.14 (t, *J* = 7.5 Hz, 1H, CH_{arom}), 6.84 – 6.74 (m, 3H, NH, CH_{arom}), 6.55 (s, 1H, H-1), 5.25 (t, *J* = 9.6 Hz, 1H, H-4), 4.40 (d, *J* = 9.7 Hz, 1H, H-5), 4.37 – 4.30 (m, 1H, H-2), 4.10 – 3.99 (m, 1H, H-3), 3.79 (s, 3H, CH_3 OMe), 2.90 – 2.59 (m, 4H, 2x CH_2 Lev), 2.21 (s, 3H, CH_3 Lev); ^{13}C NMR (101 MHz, $CDCl_3$) δ 171.4, 166.9 (C-6, C=O), 129.0, 125.1, 119.3 (CH_{arom}), 70.9 (C-5), 70.0 (C-4), 60.7 (C-3), 53.5 (CH_3 CO_2Me), 52.1 (C-2), 37.7 (CH_2 Lev), 29.9 (CH_3 Lev), 27.7 (CH_2 Lev); HRMS: $[M+Na]^+$ calcd for $C_{22}H_{21}Cl_3F_3N_5O_8Na$ 668.0300, found 668.02966

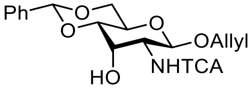
Allyl 2-deoxy-2-trichloroacetamido-4,6-*O*-benzylidene-β-D-glucopyranoside (27)



16b (21.9 g, 60 mmol), PTSA-H_2O (571 mg, 3 mmol, 0.05 eq) and benzaldehyde dimethylacetal (9.95 mL, 66 mmol, 1.1 eq) were dissolved in 1L acetonitrile and heated to 60 °C. After full conversion of the starting material, 0.1 eq of triethylamine was added and the reaction mixture was concentrated under reduced pressure. The residue was recrystallized from DCM/pentane to yield the title compound as off-white solid. Yield: 25.4 g, 56.1 mmol, 94%. ^1H NMR (400 MHz, Acetone) δ 8.30 (d, *J* = 9.1 Hz, 1H, NH), 7.50 (dd, *J* = 6.6, 3.1 Hz, 2H, CH_{arom}), 7.42 – 7.31 (m, 3H, CH_{arom}), 5.88 (ddt, *J* = 17.2, 10.6, 5.3 Hz, 1H, CH_2-C*H*=CH_2), 5.65 (s, 1H, C*H*Ph), 5.29 (dq, *J* = 17.3, 1.8 Hz, 1H, CH_2-CH=C*H*H), 5.11 (dq, *J* = 10.5, 1.5 Hz, 1H, CH_2-CH=CH*H*), 4.90 (d, *J* = 5.0 Hz, 1H, OH), 4.85 (d, *J* = 8.4 Hz, 1H, H-1), 4.35 – 4.21 (m, 2H, H-6, C*H*H-CH=CH_2), 4.16 – 4.05 (m, 2H, H-3, CH*H*-CH=CH_2), 3.88 (dt, *J* = 10.0, 9.1 Hz, 1H, H-2), 3.81 (t, *J* = 10.2 Hz, 1H, H-6), 3.59 (t, *J* = 9.2 Hz, 1H, H-4), 3.43 (td, *J* = 9.8, 5.0 Hz, 1H, H-5); ^{13}C NMR (101 MHz, Acetone) δ 162.6 (C=O), 139.1 (C_q), 135.2 (CH_2-*C*H=CH_2), 129.6, 128.8, 127.3 (CH_{arom}), 116.9 (CH_2-

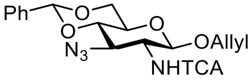
CH=CH$_2$), 102.1 (CHPh), 101.6 (C-1), 82.8 (C-4), 71.4 (C-3), 70.6 (*C*H$_2$-CH=CH$_2$), 69.1 (C-6), 67.3 (C-5), 59.5 (C-2). Spectra in agreement with literature.[35]

Allyl 2-deoxy-2-trichloroacetamido-4,6-*O*-benzylidene-β-D-allopyranoside (29)



Compound **27** (20.5 g, 45.3 mmol) and pyridine (9.1 mL, 113 mmol, 2.5 eq) were dissolved in 250 mL DCM and cooled to -10 °C, after which triflic anhydride (11.4 mL, 67.9 mmol, 1.5 eq) was added dropwise. After full conversion, the reaction mixture was washed twice with 1M aq. CuSO$_4$. The organic phase was dried with MgSO$_4$ and concentrated at 30 °C, yielding the crude triflate **28** which was used without further purification. The triflate was dissolved in 50 mL DMF with NaNO$_2$ (31.2 g, 453 mmol, 10 eq) and stirred for 48 hr, after which the reaction mixture was diluted with water and extracted twice with diethyl ether. Organic phases were combined, dried with MgSO$_4$ and concentrated under reduced pressure. Silica chromatography (20% acetone in pentane) yields the title compound as a white foam. Yield: 11.1 g, 24.4 mmol, 54%. $[\alpha]_D^{25}$ = -37.2° (c = 0.12, CHCl$_3$); IR (thin film): 757, 1089, 1513, 1717; ^{1}H NMR (400 MHz, CDCl$_3$) δ 7.48 (dd, *J* = 6.6, 3.2 Hz, 2H, CH$_{\text{arom}}$), 7.42 – 7.36 (m, 3H, CH$_{\text{arom}}$), 7.23 (d, *J* = 9.3 Hz, 1H, NH), 5.85 (dddd, *J* = 16.8, 10.7, 6.1, 4.9 Hz, 1H, CH$_2$-C*H*=CH$_2$), 5.62 (s, 1H, C*H*Ph), 5.30 (dq, *J* = 17.2, 1.6 Hz, 1H, CH$_2$-CH=C*H*H), 5.19 (dq, *J* = 10.5, 1.3 Hz, 1H, CH$_2$-CH=CH*H*), 4.79 (d, *J* = 8.4 Hz, 1H, H-1), 4.43 – 4.34 (m, 2H, H-6, C*H*H-CH=CH$_2$), 4.32 (s, 1H, H-3), 4.15 (td, *J* = 8.4, 2.6 Hz, 1H), 4.08 (ddt, *J* = 13.1, 6.1, 1.4 Hz, 1H, CH*H*-CH=CH$_2$), 4.00 (td, *J* = 9.9, 5.0 Hz, 1H, H-2), 3.82 (t, *J* = 10.3 Hz, 1H, H-6), 3.68 (dd, *J* = 9.4, 2.5 Hz, 1H, H-4), 2.60 (s, 1H, OH); ^{13}C NMR (101 MHz, CDCl$_3$) δ 161.6 (C=O), 136.9 (C$_q$), 133.5 (CH$_2$-*C*H=CH$_2$), 129.5, 128.6, 126.2 (CH$_{\text{arom}}$), 117.9 (CH$_2$-CH-*C*H$_2$), 101.9 (CHPh), 99.3 (C-1), 78.6 (C-4), 70.5 (*C*H$_2$-CH=CH$_2$), 69.1 (C-6), 68.4 (C-3), 63.5 (C-5), 53.8 (C-2); HRMS: [M+Na]$^+$ calcd for $C_{18}H_{20}Cl_3NO_6Na$ 474.02484, found 474.02447

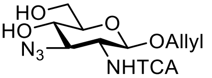
Allyl 2,3-dideoxy-2-trichloroacetamido-3-azido-4,6-*O*-benzylidene-β-D-glucopyranoside (31)



Compound **29** (10.5 g, 23.1 mmol) was dissolved in 25 mL pyridine, and mesyl chloride (3.59 mL, 46.4 mmol 2 eq) was added dropwise. After full conversion, the reaction mixture was diluted with ethyl acetate and washed twice with 1M aq. CuSO$_4$. The organic phase was dried with MgSO$_4$ and concentrated under reduced pressure, yielding the mesylate **30** as off-white foam, which was used directly without further purification. The crude mesylate was dissolved in 100 mL acetonitrile with freshly prepared tetrabutylammonium azide[36] (16.4 g, 57.5 mmol, 2.5 eq). The reaction mixture was heated to 70 °C until full conversion of the starting material. After which the reaction mixture was cooled to RT and poured in approx. 5 times the volume of water under vigorous stirring. The precipitate was collected by filtration, washed with water, dried and purified over silica (10%→20% acetone in pentane) yielding the impure title compound as white solid. Yield: 7.13 g, 14.9 mmol, 65%. $[\alpha]_D^{25}$ = -21.4° (c = 0.21, CHCl$_3$); IR (thin film): 750, 1088, 1368, 1694, 2108; ^{1}H NMR (400 MHz, CDCl$_3$) δ 7.52 – 7.47 (m, 2H, CH$_{\text{arom}}$), 7.43 – 7.33 (m, 3H, CH$_{\text{arom}}$), 7.00 (d, *J* = 7.6 Hz, 1H, H-1), 5.85 (dddd, *J* = 16.9, 10.4, 6.4, 5.4 Hz, 1H, CH$_2$-C*H*-CH$_2$), 5.59 (s, 1H, C*H*Ph), 5.29 (dq, *J* = 17.2, 1.5 Hz, 1H, CH$_2$-CH=C*H*H), 5.22 (dq, *J* = 10.3, 1.2 Hz, 1H,

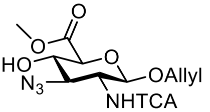
CH_2-CH=CH*H*), 5.04 (d, *J* = 8.3 Hz, 1H, H-1), 4.46 – 4.30 (m, 3H, H-3, H-6, C*H*H-CH=CH_2), 4.10 (ddt, *J* = 12.7, 6.4, 1.3 Hz, 1H, CH*H*-CH=CH_2), 3.85 – 3.77 (m, 1H, H-6), 3.64 – 3.56 (m, 2H, H-4, H-6), 3.35 (dt, *J* = 10.9, 8.0 Hz, 1H, H-2); ^{13}C NMR (101 MHz, $CDCl_3$) δ 162.3 (C=O), 136.7 (C_q), 133.1 (C_q), 129.3 (CH_2-*C*H=CH_2), 128.5, 126.2, 126.1 (CH_{arom}), 118.8 (CH_2-CH=*C*H_2), 101.6 (CHPh), 98.7 (C-1), 80.7 (C-4), 70.9 (*C*H_2-CH=CH_2), 68.7 (C-6), 67.2 (C-5), 60.7 (C-3), 58.1 (C-2); HRMS: $[M+Na]^+$ calcd for $C_{18}H_{19}Cl_3N_4O_5Na$ 499.03132 found 499.06137

Allyl 2,3-dideoxy-2-trichloroacetamido-3-azido-β-D-glucopyranoside (32)



Compound **31** (6.62 g, 13.8 mmol) and PTSA-H_2O (263 mg, 1.38 mmol, 0.1 eq) were dissolved in MeOH (0.25M) and heated to 60 °C. After full conversion, the reaction mixture was neutralised with triethylamine and concentrated under reduced pressure. The residue was precipitated using DCM/pentane, yielding the impure title compound as white solid. Yield: 5.20 g, 13.4 mmol, 97%. $[\alpha]_D^{25}$ = -164.8° (c = 0.19, $CHCl_3$); IR (thin film): 668, 1047, 1075, 1527, 1697, 2106; ^{1}H NMR (400 MHz, Acetone) δ 8.44 (d, *J* = 9.1 Hz, 1H, NH), 5.86 (dddd, *J* = 17.2, 10.6, 5.6, 5.0 Hz, 1H, CH_2-C*H*=CH_2), 5.26 (dq, *J* = 17.3, 1.8 Hz, 1H, CH_2-CH=C*H*H), 5.12 – 5.05 (m, 2H, OH, CH_2-CH=CH*H*), 4.76 (d, *J* = 8.3 Hz, 1H, H-1), 4.29 (ddt, *J* = 13.4, 4.9, 1.6 Hz, 1H, C*H*H-CH=CH_2), 4.08 (ddt, *J* = 13.4, 5.7, 1.6 Hz, 1H, CH*H*-CH=CH_2), 3.91 – 3.82 (m, 2H, H-3, H-6), 3.75 – 3.67 (m, 2H, H-2, H-6), 3.57 (td, *J* = 9.4, 5.8 Hz, 1H, H-4), 3.38 (ddd, *J* = 9.7, 5.2, 2.2 Hz, 1H, H-5); ^{13}C NMR (101 MHz, Acetone) δ 162.6 (C=O), 135.2 (CH_2-*C*H=CH_2), 116.9 (CH_2-CH=*C*H_2), 100.7 (C-1), 78.3 (C-5), 70.9 (C-4), 70.2 (*C*H_2-CH=CH_2), 67.8 (C-6), 62.3 (C-5), 56.7 (C-2); HRMS: $[M+Na]^+$ calcd for $C_{11}H_{15}Cl_3N_4O_5Na$ 411.00002, found 411.00021.

Methyl (Allyl 2,3-dideoxy-2-trichloroacetamido-3-azido-β-D-glucopyranosyl uronate) (2)



Compound **32** (5.20 g, 13.4 mmol) was suspended in 90 mL 2:1 DCM/H_2O and TEMPO (1.04 g, 6.67 mmol, 0.5 eq) and BAIB (10.8 g, 33.4 mmol, 2.5 eq) were added under vigorous stirring. After full conversion, the reaction mixture was concentrated under reduced pressure, yielding crude acid **33**. The residue was coevaporated 3x with toluene and dissolved in DMF. K_2CO_3 (5.05 g, 60.1 mmol, 4.5 eq) and methyl iodide (6.23 mL, 100 mmol, 7.5 eq) were added and the reaction mixture was stirred for 18 hr, after which it was diluted with water and extracted twice with diethyl ether. Organic phases were combined, dried with $MgSO_4$ and concentrated under reduced pressure. Silica chromatography (20% acetone in pentane) yields the title compound as a white solid. Yield: 2.87 g, 6.87 mmol, 52%. $[\alpha]_D^{25}$ = -18.1° (c = 0.28, $CHCl_3$); IR (thin film): 823, 1040, 1087, 1258, 1530, 1697, 1734, 2108; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.01 (d, *J* = 7.4 Hz, 1H, NH), 5.85 (dddd, *J* = 17.0, 10.4, 6.4, 5.3 Hz, 1H, CH_2-C*H*=CH_2), 5.29 (dq, *J* = 17.2, 1.4 Hz, 1H, CH_2-CH=C*H*H), 5.22 (dq, *J* = 10.4, 1.4 Hz, 1H, CH_2-CH=CH*H*), 5.07 (d, *J* = 8.2 Hz, 1H, H-1), 4.38 (ddt, *J* = 12.7, 5.3, 1.3 Hz, 1H, C*H*H-CH=CH_2), 4.25 (dd, *J* = 11.1, 9.2 Hz, 1H, H-3), 4.12 (ddt, *J* = 12.7, 6.5, 1.3 Hz, 1H, CH*H*-CH=CH_2), 3.99 (d, *J* = 9.7 Hz, 1H, H-5), 3.86 (s, 4H, H-4, CH_3 CO_2Me), 3.42 (s, 1H, OH), 3.26 (dt, *J* = 11.1, 7.8 Hz, 1H, H-2); ^{13}C NMR (101 MHz, $CDCl_3$) δ

169.6 (C-6), 162.3 (C=O), 133.0 (CH_2-*CH*=CH_2), 118.9 (CH_2-CH=*CH*$_2$), 98.3 (C-1), 74.5 (C-5), 72.0 (C-4), 70.9 (*CH*$_2$-CH=CH_2), 62.9 (C-3), 57.3 (C-2), 53.2 (CH_3 CO_2Me); HRMS: $[M+Na]^+$ calcd for $C_{12}H_{15}Cl_3N_4O_6$ 438.99494, found 438.994455.

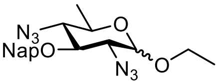
Procedure for VT-NMR experiments of bacillosamine donors

Donor **4** (30 µmol) or a mixture of donor **3** (30 µmol) and Ph_2SO (39 µmol) was coevaporated with toluene, dissolved in 0.6 mL of CD_2Cl_2 under nitrogen atmosphere and transferred to an oven-dried NMR tube flushed with nitrogen gas and sealed with an NMR tube septum. The magnet was cooled to -80 °C, locked, and shimmed and the sample was measured prior to activation. In a separate cold bath (-80 °C) the sample was treated with Tf_2O (donor **3**, 39 µmol) or TfOH (donor **4**, 39 µmol) and shaken and recooled 3x. Thecold sample was wiped dry and quickly inserted back in the cold magnet. The first ^1H NMR spectrum was immediately recorded. The sample was then reshimmed, and spectra were recorded in 10 °C intervals with at least 5 min of equilibration time for every temperature.

General procedure for model glycosylations

Donor (0.1 mmol, 1 eq), Ph_2SO (0.13 mmol, 1.3 eq) and TTBP (0.25 mmol, 2.5 eq) were coevaporated twice with toluene, dissolved in 2 mL DCM and stirred for 30 min at RT with 3 Å molecular sieves. The solution was cooled to -80 ^{0}C and Tf_2O (22 µL, 0.13 mmol, 2 eq) was added. The reaction mixture was allowed to warm to −60 ^{0}C and then recooled to −78 ^{0}C, after which the acceptor (0.2 mmol, 2 eq) in DCM (0.4 mL, 0.5 M) was added. The reaction mixture was allowed to warm to −60 ^{0}C for and stirred for 2 hr at that temperature. The reaction was quenched with 2 mL sat aq $NaHCO_3$, and the mixture was diluted with DCM. The solution was transferred to a separatory funnel, water was added, the layers were separated, and the water phase was extracted once more with DCM. The combined organic layers were dried over MgSO4, filtered, and concentrated in vacuo. Purification by silica gel flash column chromatography and/or sephadex LH-20 size-exclusion chromatography yielded the glycosylation product as a mixture of anomers.

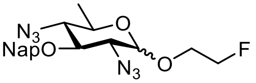
Ethyl 2,4-dideoxy-2,4-diazido-3-*O*-(2-naphthyl)methyl-α,β-D-quinopyranoside (3A)



The title comound was synthesised from donor **3** and ethanol according to the genereral procedure for model glycosylations as colourless oil. Yield: 32 mg, 84 µmol, 84%, α:β = 1:8. Data for the β-anomer: ^1H NMR (400 MHz, $CDCl_3$) δ 7.88 – 7.80 (m, 4H, CH_{arom}), 7.55 (dd, *J* = 8.6, 1.6 Hz, 1H, CH_{arom}), 7.50 – 7.44 (m, 2H, CH_{arom}), 5.06 (d, *J* = 10.8 Hz, 1H, C*H*H Nap), 4.96 (d, *J* = 10.8 Hz, 1H, CH*H* Nap), 4.25 (d, *J* = 8.0 Hz, 1H, H-1), 3.95 (dq, *J* = 9.4, 7.1 Hz, 1H, C*H*H Et), 3.62 (dq, *J* = 9.4, 7.1 Hz, 1H, CH*H* Et), 3.43 (dd, *J* = 9.7, 8.1 Hz, 1H, H-2), 3.28 (t, *J* = 9.3 Hz, 1H, H-3), 3.23 – 3.11 (m, 2H, H-4, H-5), 1.35 (d, *J* = 5.8 Hz, 3H, H-6), 1.28 (t, *J* = 7.1 Hz, 3H, CH_3 Et); ^{13}C NMR (101 MHz, $CDCl_3$) δ 134.9, 133.4, 133.3 (C_q), 128.4, 128.2, 128.2, 127.8, 127.8, 127.5, 127.5, 127.5, 126.3, 126.3, 126.2, 126.2, 126.2, 126.2 (CH_{arom}), 101.8 (C-1), 81.3 (C-3), 75.5 (CH_2 Nap), 70.8 (C-5), 67.8 (C-4), 66.3 (C-2), 66.0 (CH_2 Et), 18.5 (C-6), 15.2 (CH_2 Et); diagnostic peaks for the α-anomer: ^1H NMR (400 MHz, $CDCl_3$) δ 4.88 (d, *J* = 3.5 Hz, 1H, H-1), 3.89 (dd, *J* = 10.1, 9.2 Hz, 1H), 3.74 (dq, *J* = 9.8, 7.1 Hz, 1H, C*H*H Et), 3.34 (dd, *J* = 10.1, 3.5 Hz, 1H, H-2); ^{13}C NMR

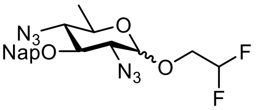
(101 MHz, $CDCl_3$) δ 97.5 (C-1), 78.7, 68.8, 66.5, 64.0, 63.6, 18.5, 15.1; HRMS: $[M+NH_4]^+$ calcd for $C_{19}H_{22}N_6O_3NH_4$ 400.20916, found 400.20904.

2-Fluoroethyl 2,4-dideoxy-2,4-diazido-3-*O*-(2-naphthyl)methyl-α,β-D-quinopyranoside (3B)



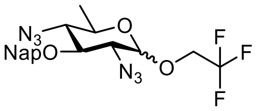
The title comound was synthesised from donor **3** and 2-fluoroethanol according to the genereral procedure for model glycosylations as colourless oil. Yield: 30 mg, 75 µmol, 75%, α:β = 1:2. Data reported for a 1:2 mixture of anomers: ^1H NMR (400 MHz, $CDCl_3$) δ 7.86 (dddt, *J* = 9.6, 7.7, 5.3, 2.4 Hz, 12H, CH_{arom}), 7.56 (ddd, *J* = 8.6, 7.1, 1.7 Hz, 3H, CH_{arom}), 7.51 – 7.43 (m, 6H, CH_{arom}), 5.08 – 5.02 (m, 4H, C*H*H Napαβ, CH*H* Napα), 4.96 (d, *J* = 10.8 Hz, 2H, CH*H* Napβ), 4.92 (d, *J* = 3.5 Hz, 1H, H-1α), 4.72 – 4.62 (m, 3H, CH_2-C*H*HFαβ), 4.60 – 4.49 (m, 3H, CH_2-CH*H*Fαβ), 4.31 (d, *J* = 8.1 Hz, 2H, H-1β), 4.13 – 3.98 (m, 2H, C*H*H-CH_2Fβ), 3.96 – 3.74 (m, 5H, H-5α, C*H*H-CH_2Fα, CH*H*-CH_2Fαβ), 3.74 – 3.66 (m, 1H, H-5α), 3.46 (dd, *J* = 9.7, 8.1 Hz, 2H, H-2β), 3.38 (dd, *J* = 10.1, 3.5 Hz, 1H, H-2α), 3.29 (t, *J* = 9.3 Hz, 2H, H-3β), 3.25 – 3.12 (m, 5H, H-4αβ, H-5β), 1.36 (d, *J* = 5.7 Hz, 6H, H-6β), 1.32 (d, *J* = 6.2 Hz, 3H, H-6α); ^{13}C NMR (101 MHz, $CDCl_3$) δ 134.7, 133.3, 133.3, 133.2 (C_q), 128.3, 128.1, 128.1, 127.7, 127.7, 127.4, 127.4, 126.3, 126.2, 126.2, 126.1, 126.1 (C_q), 102.1 (C-1β), 98.0 (C-1α) 82.7 (d, *J* = 170.1 Hz, CH_2-CH_2Fβ), 82.4 (d, *J* = 170.4 Hz, CH_2-CH_2Fα), 81.1 (C-3β), 78.4 (C-3α), 75.5, 75.5 (CH_2 Napαβ), 70.8 (C-5β), 68.9 (d, *J* = 20.2 Hz, *C*H_2-CH_2Fβ)) 68.6 (C-4α), 67.6 (C-4β), 67.3 (d, *J* = 20.1 Hz, *C*H_2-CH_2Fα), 66.7 (C-5α), 66.3 (C-2β), 63.5 (C-2α), 18.4 (C-6β), 18.4 (C-6α); HRMS: $[M+NH_4]^+$ calcd for $C_{19}H_{21}FN_6O_3NH_4$ 418.19974, found 418.19933.

2,2-Difluoroethyl 2,4-dideoxy-2,4-diazido-3-*O*-(2-naphthyl)methyl-α,β-D-quinopyranoside (3C)



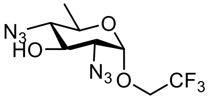
The title comound was synthesised from donor **3** and 2,2-difluoroethanol according to the genereral procedure for model glycosylations as colourless oil. Yield: 28 mg, 66 µmol, 66%, α:β = 2.9:1. Data for the α-anomer: ^1H NMR (400 MHz, $CDCl_3$) δ 7.89 – 7.80 (m, 4H, CH_{arom}), 7.56 (dd, *J* = 8.4, 1.7 Hz, 1H, CH_{arom}), 7.50 – 7.44 (m, 2H, CH_{arom}), 6.11 – 5.75 (m, 1H, CH_2-C*H*F_2), 5.03 (d, *J* = 1.8 Hz, 2H, CH_2 Nap), 4.90 (d, *J* = 3.5 Hz, 1H, H-1), 3.88 – 3.73 (m, 3H, H-3, C*H*$_2$-CHF_2), 3.69 – 3.61 (m, 1H, H-5), 3.39 (dd, *J* = 10.2, 3.5 Hz, 1H, H-2), 3.17 (dd, *J* = 10.2, 9.3 Hz, 1H, H-4), 1.33 (d, *J* = 6.2 Hz, 3H, H-6); ^{13}C NMR (101 MHz, $CDCl_3$) δ 134.7, 133.4, 133.3 (C_q), 128.4, 128.2, 127.8, 127.5, 126.3, 126.3, 126.2 (CH_{arom}), 113.8 (t, *J* = 241.0 Hz, CH_2-CHF_2), 98.5 (C-1), 78.3 (C-3), 75.7 (CH_2 Nap), 68.5 (C-4), 67.3 (t, *J* = 28.7 Hz, *C*H_2-CHF_2), 67.2 (C-5), 63.5 (C-2), 18.4 (C-6); diagnostic peaks for the β-anomer: ^1H NMR (400 MHz, $CDCl_3$) δ 5.05 (d, *J* = 10.7 Hz, 1H, C*H*H Nap), 4.97 (d, *J* = 10.7 Hz, 1H, CH*H* Nap), 4.29 (d, *J* = 8.0 Hz, 1H, H-1), 3.98 (dtd, *J* = 17.6, 12.0, 3.3 Hz, 1H, C*H*H-CHF_2), 3.45 (dd, *J* = 9.7, 8.0 Hz, 1H, H-2), 3.28 (t, *J* = 9.3 Hz, 1H, H-3), 1.36 (d, *J* = 5.8 Hz, 3H, H-6); ^{13}C NMR (101 MHz, $CDCl_3$) δ 102.3 (C-1), 81.1, 71.1, 67.6, 66.3, 18.4; HRMS: $[M+NH_4]^+$ calcd for $C_{19}H_{20}F_2N_6O_3NH_4$ 436.19032, found 436.19015

2,2,2-Trifluoroethyl 2,4-dideoxy-2,4-diazido-3-*O*-(2-naphthyl)methyl-α,β-D-quinopyranoside (3D)



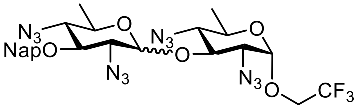
The title comound was synthesised from donor **3** and 2,2,2-trifluoroethanol according to the genereral procedure for model glycosylations as colourless oil. Yield: 41 mg, 94 µmol, 94%, α:β = 22:1. Data for the α-anomer: ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.91 – 7.80 (m, 4H, CH_{arom}), 7.56 (dd, *J* = 8.4, 1.7 Hz, 1H, CH_{arom}), 7.51 – 7.43 (m, 2H, CH_{arom}), 5.05 (d, *J* = 10.5 Hz, 1H, C*H*H Bn), 5.01 (d, *J* = 10.6 Hz, 1H, CH*H* Bn), 4.93 (d, *J* = 3.6 Hz, 1H, H-1), 3.95 (qd, *J* = 8.5, 1.7 Hz, 2H, $C\mathit{H_2}$-CF_3), 3.86 (dd, *J* = 10.2, 9.3 Hz, 1H, H-3), 3.64 (dq, *J* = 10.1, 6.2 Hz, 1H, H-5), 3.40 (dd, *J* = 10.1, 3.6 Hz, 1H, H-2), 3.17 (dd, *J* = 10.2, 9.3 Hz, 1H, H-4), 1.33 (d, *J* = 6.2 Hz, 3H, H-6); ^{13}C NMR (101 MHz, $CDCl_3$) δ 134.6, 133.4, 133.3 (C_q), 128.5, 128.2, 127.8, 127.5, 126.3, 126.3, 126.2 (CH_{arom}), 123.5 (q, *J* = 278.5 Hz, CH_2-CF_3), 98.6 (C-1), 78.2 (C-3), 75.7 (CH_2 Nap), 68.4 (C-4), 67.5 (C-5), 65.1 (q, *J* = 35.3 Hz, $\mathit{C}H_2$-CF_3), 63.3 (C-2), 18.4 (C-6); diagnostic peaks for the β-anomer: ^{1}H NMR (400 MHz, $CDCl_3$) δ 4.33 (d, *J* = 8.0 Hz, 1H, H-1), 4.14 (dq, *J* = 12.6, 8.7 Hz, 1H), 4.10 (s, 1H), 3.46 (dd, *J* = 9.7, 8.0 Hz, 1H, H-2), 3.28 (t, *J* = 9.3 Hz, 1H), 1.35 (d, *J* = 5.7 Hz, 3H, H-6); ^{13}C NMR (101 MHz, $CDCl_3$) δ 101.8 (C-1), 81.0, 71.2, 66.3; HRMS: $[M+NH_4]^+$ calcd for $C_{19}H_{19}F_3N_6O_3NH_4$ 454.18090, found 454.18074

2,2,2-Trifluoroethyl 2,4-dideoxy-2,4-diazido-α-D-quinopyranoside (34)



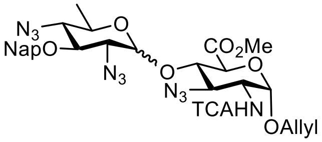
3D (166 mg, 0.38 mmol) and DDQ (129 mg, 0.57 mmol, 1.5 eq) were dissolved in 9:1 DCM/H_2O (0.3M) after full conversion, the reaction mixture was diluted with DCM and washed twice with sat. aq. $NaHCO_3$. The organic phase was dried with $MgSO_4$ and concentrated under reduced pressure. The residue was purified over silica (15% Et_2O in pentane) to yield the title product as colourless oil. Yield: 71 mg, 0.24 mmol, 63%. ^{1}H NMR (300 MHz, $CDCl_3$) δ 4.96 (d, *J* = 3.6 Hz, 1H, H-1), 4.06 – 3.89 (m, 3H, H-3, $C\mathit{H_2}$-CF_3), 3.66 (dqd, *J* = 10.1, 6.3, 0.7 Hz, 1H, H-5), 3.30 (dd, *J* = 10.2, 3.6 Hz, 1H, H-2), 3.11 (dd, *J* = 10.1, 9.3 Hz, 1H, H-4), 2.92 (d, *J* = 4.1 Hz, 1H, OH), 1.34 (d, *J* = 6.3 Hz, 3H, H-6); ^{13}C NMR (75 MHz, $CDCl_3$) δ 98.4 (C-1), 70.6 (C-3), 68.6 (C-4), 67.4 (C-5), 65.2 (q, *J* = 35.4 Hz, $\mathit{C}H_2$-CF_3) 63.1 (C-2), 18.3 (C-6)

Disaccharide 3E



The title comound was synthesised from donor **3** and acceptor **34** according to the genereral procedure for model glycosylations as colourless oil. Yield: 48 mg, 75 µmol, 75%, α:β = 6.6:1. Data for the α-anomer: ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.91 – 7.82 (m, 4H, CH_{arom}), 7.58 (dd, *J* = 8.4, 1.7 Hz, 1H, CH_{arom}), 7.51 – 7.45 (m, 2H, CH_{arom}), 5.31 (d, *J* = 3.7 Hz, 1H, H-1'), 5.04 (s, 2H, CH_2 Nap), 5.00 (d, *J* = 3.7 Hz, 1H, H-1), 4.03 – 3.92 (m, 3H, H-5/H-5', $C\mathit{H_2}$-CF_3), 3.87 – 3.77 (m, 2H, H-3, H-3'), 3.73 (dq, *J* = 10.0, 6.2 Hz, 1H, H-5/H-5'), 3.48 (dd, *J* = 10.2, 3.7 Hz, 1H, H-2'), 3.24 – 3.13 (m, 2H, H-4, H-4’), 3.04 (dd, *J* = 10.4, 3.6 Hz, 1H, H-2), 1.40 – 1.36 (m, 6H, H-6, H-6’); ^{13}C NMR (101 MHz, $CDCl_3$) δ 134.7, 133.4, 133.3 (C_q), 128.5, 128.2, 127.8, 127.6, 126.3, 126.3, 126.2 (CH_{arom}), 99.3, 99.2 (C-1, C-1’), 78.5 (C-3’), 75.7 (C-3), 75.5 (CH_2 Nap), 69.6, 68.8 (C-4, C-4’), 67.8, 67.8 (C-5, C-5’), 65.1 (q, *J* = 35.6 Hz, *C*H_2-CF_3) 63.9 (C-2’), 61.2 (C-2), 18.8, 18.2 (C-6, C-6’); diagnostic peaks for the β-anomer: ^{1}H NMR (400 MHz, $CDCl_3$) δ 4.65 (d, *J* = 7.9 Hz, 1H, H-1’), 4.09 (dd, *J* = 10.2, 9.2 Hz, 1H), 3.59 (dq, *J* = 10.2, 6.1 Hz, 1H), 3.41 (dd, *J* = 10.2, 3.6 Hz, 1H, H-2), 3.34 (t, *J* = 9.5 Hz, 1H); ^{13}C NMR (101 MHz, $CDCl_3$) δ 101.4 (C-1’), 98.4 (C-1), 81.3, 75.9, 75.7, 71.0, 67.7, 67.0, 66.6, 66.3, 63.3, 18.4, 18.4

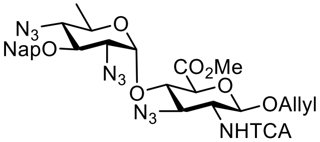
Disaccharide 3F



Pre-activation: Donor **3** (100-130 μmol, 1-1.3 eq), Ph_2SO (0.65-1.3 eq) and TTBP (2.5 eq) were coevaporated twice with toluene and dissolved in DCM (0.05 M donor). 3Å molecular sieves were added and the reaction mixture was stirred for 30-60 min at RT, before being cooled to -80 °C. Tf_2O (0.65-1.3 eq) was added and the reaction was allowed to warm to -60 °C and kept at that temperature for 1 min. before being recooled to -80 °C. Acceptor **24** (1-2 eq) was added dropwise over 30 s as a freshly prepared 0.5M solution in DCM. The reaction mixture was then allowed to warm to the specified temperature and quenched with 2 mL sat. aq. $NaHCO_3$ after 2 hr (-50 °C or - 60 °C) or 30 s (0 °C). The mixture was diluted with DCM. The solution was transferred to a separatory funnel, water was added, the layers were separated, and the water phase was extracted once more with DCM. The combined organic layers were dried over MgSO4, filtered, and concentrated in vacuo. Purification by silica gel flash column chromatography and/or sephadex LH-20 size-exclusion chromatography yielded the glycosylation product as a mixture of anomers. *In situ activation*: donor **4** (130 μmol, 1.3 eq), acceptor **24** (1 eq) and Ph_2SO (0 or 1.5 eq) twice with toluene and dissolved in DCM (0.05 M donor). 3Å molecular sieves were added and the reaction mixture was stirred for 30-60 min at RT, before being cooled to -80 °C. TMSOTf (0.2 eq) was added and the reaction mixture was slowly allowed to warm to 0 °C and quenched with 2 mL sat. aq. $NaHCO_3$. The mixture was diluted with DCM. The solution was transferred to a separatory funnel, water was added, the layers were separated, and the water phase was extracted once more with DCM. The combined organic layers were dried over MgSO4, filtered, and concentrated in vacuo. Purification by silica gel flash column chromatography and/or sephadex LH-20 size-exclusion chromatography yielded the glycosylation product as a mixture of anomers. Data for the α-anomer: ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.92 – 7.81 (m, 4H, CH_{arom}), 7.56 (dd, *J* = 8.4, 1.7 Hz, 1H, CH_{arom}), 7.51 – 7.43 (m, 3H, CH_{arom}), 6.83 (d, *J* = 9.7 Hz, 1H, NH), 5.88 (dddd, *J* = 17.1, 10.3, 6.8, 5.4 Hz, 1H, CH_2-C*H*-CH_2), 5.38 – 5.28 (m, 3H, H-1’, CH_2-CH=C*H_2*), 5.03 (d, *J* = 10.5 Hz, 1H, C*H*H Nap), 5.00 (d, *J* = 10.5 Hz, 1H, CH*H* Nap), 4.94 (d, *J* = 3.6 Hz, 1H, H-1), 4.32 – 4.16 (m, 3H, H-2, H-5, C*H*H-CH=CH_2), 4.07 (ddt, *J* = 12.8, 6.8, 1.1 Hz, 1H, CH*H*-CH=CH_2), 3.92 (t, *J* = 9.5 Hz, 1H, H-4), 3.85 – 3.78 (m, 4H, H-3, CH_3 CO_2Me), 3.77 – 3.69 (m, 1H, H-3’), 3.54 – 3.36 (m, 2H, H-2’, H-5’), 3.12 (dd, *J* = 10.1, 9.4 Hz, 1H, H-4’), 1.28 (d, *J* = 6.2 Hz, 3H, H-6’); ^{13}C NMR (101 MHz, $CDCl_3$) δ 168.4 (C-6), 162.1 (C=O), 134.6, 133.4, 133.3 (C_q), 132.3 (CH_2-*C*H=CH_2), 128.4, 128.2, 127.8, 127.6, 126.3, 126.3, 120.0 (CH_{arom}), 98.6 (C-1’), 95.4 (C-1), 78.5 (C-

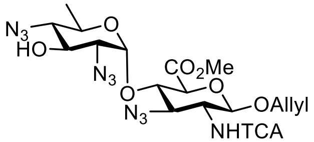
3’), 76.3 (C-4), 75.7 (CH_2 Nap), 70.9 (C-5), 69.3 (CH_2-CH=CH_2), 68.4 (C-4’), 67.7 (C-5’), 64.6 (C-3), 64.0 (C-2’), 53.4 (C-2), 53.0 (CH_3 CO_2Me), 18.3 (C-6); Diagnostic peaks for the β-anomer: ^{1}H NMR (500 MHz, $CDCl_3$) δ 4.96 (d, *J* = 3.4 Hz, 1H, H-1), 4.39 (d, *J* = 8.0 Hz, 1H, H-1’), 3.37 (dd, *J* = 9.6, 8.0 Hz, 1H, H-2’), 1.39 (d, *J* = 6.0 Hz, 3H, H-6’); ^{13}C NMR (126 MHz, $CDCl_3$) δ 101.6 (C-1’); HRMS: $[M+NH_4]^+$ calcd for $C_{29}H_{31}Cl_3N_{10}O_8NH_4$ 770.17302, found 770.17275

Disaccharide 35



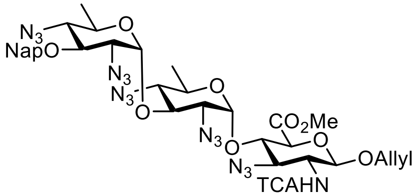
Donor **3** (2.61 g, 5.29 mmol, 1.3 eq), Ph_2SO (535 mg, 2.65 mmol, 0.65 eq) and TTBP (2.53 g, 10.2 mmol, 2.5 eq) were coevaporated twice with toluene and dissolved in 100 mL anhydrous DCM. 3Å molecular sieves were added and the reaction mixture was stirred for 30-60 min at RT, before being cooled to -80 °C. Tf_2O (0.44 mL, 2.65 mmol, 0.65 eq) was added and the reaction was allowed to warm to -60 °C and kept at that temperature for 1 min. before being recooled to -80 °C. Acceptor **35** (1.70 g, 4.07 mmol, 1 eq.) was added dropwise over 30 s as a freshly prepared 0.5M solution in DCM. The reaction mixture was then slowly allowed to warm to 0 °C and quenched with 200 mL sat. aq. $NaHCO_3$. The mixture was diluted with DCM. The solution was transferred to a separatory funnel, water was added, the layers were separated, and the water phase was extracted once more with DCM. The combined organic layers were dried over MgSO4, filtered, and concentrated in vacuo. Purification by silica gel flash column chromatography (15% acetone in pentane) yields the title compound as white foam. Yield: 2.48 g, 3.29 mmol, 81%, α:β = 10:1. $[\alpha]_D^{25}$ = 61.0° (c = 0.50, $CHCl_3$); IR (thin film): 757, 1033, 1073, 1563, 1696, 1753, 2109; ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.91 – 7.80 (m, 4H, CH_{arom}), 7.57 (dd, *J* = 8.4, 1.6 Hz, 1H, CH_{arom}), 7.50 – 7.45 (m, 2H, CH_{arom}), 7.10 (d, *J* = 7.3 Hz, 1H, NH), 5.83 (dddd, *J* = 17.0, 10.4, 6.4, 5.3 Hz, 1H, CH_2-C*H*=CH_2), 5.28 (dq, *J* = 17.1, 1.5 Hz, 1H, CH_2-CH=C*H*H), 5.25 (d, *J* = 3.6 Hz, 1H, H-1’), 5.22 (dq, *J* = 10.4, 1.3 Hz, 1H, CH_2-CH=CH*H*), 5.07 (d, *J* = 8.0 Hz, 1H, H-1), 5.02 (d, *J* = 3.5 Hz, 2H, CH_2 Nap), 4.39 (dd, *J* = 10.8, 9.0 Hz, 1H, H-3), 4.34 (ddt, *J* = 12.8, 5.2, 1.4 Hz, 1H, C*H*H-CH=CH_2), 4.07 (ddt, *J* = 12.6, 6.4, 1.2 Hz, 1H, CH*H*-CH=CH_2), 4.03 (d, *J* = 9.4 Hz, 1H, H-5), 3.88 (t, *J* = 9.2 Hz, 1H, H-4), 3.79 (s, 3H, CH_3 CO_2 Me), 3.73 (t, *J* = 9.8 Hz, 1H, H-3’), 3.50 (dd, *J* = 10.2, 3.6 Hz, 1H, H-2’), 3.45 (dq, *J* = 10.2, 6.2 Hz, 1H, H-5’), 3.35 (dt, *J* = 10.8, 7.7 Hz, 1H, H-2), 3.12 (t, *J* = 9.9 Hz, 1H, H-4’), 1.28 (d, *J* = 6.2 Hz, 3H, H-6’); ^{13}C NMR (126 MHz, $CDCl_3$) δ 167.8 (C-6), 162.5 (C=O), 134.6, 133.4, 133.3 (C_q), 133.0 (CH_2-CH=CH_2), 128.4, 128.2, 127.8, 127.7, 126.4, 126.2 (CH_{arom}), 118.9 (CH_2-CH=CH_2), 98.6 (C-1’), 97.9 (C-1), 92.1 (CCl_3) 78.7 (C-3’), 77.4 (C-4), 75.8 (CH_2 Nap), 75.4 (C-5), 70.8 (CH_2-CH=CH_2), 68.4 (C-4’), 67.8 (C-5’), 64.1 (C-2’), 63.3 (C-3), 58.1 (C-2), 53.0 (CH_3 CO_2 Me), 18.3 (C-6); HRMS: $[M+X]^+$ calcd for $C_{29}H_{31}Cl_3N_{10}O_8NH_4$ 770.17302, found 770.17284. The β-anomer was removed by silica chromatography in the next step.

Disaccharide 36



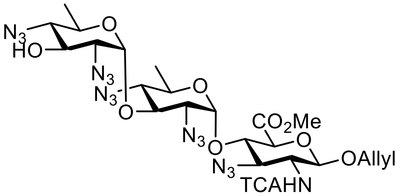
Disaccharide **35** (2.45 g, 3.25 mmol) and DDQ (1.48 g, 6.50 mmol, 2 eq) were dissolved in 100 mL 9:1 DCM/H_2O and stirred at room temperature until TLC indicated full conversion of the starting material. After which the reaction mixture was transferred to a separatory funnel and washed twice with sat. aq. $NaHCO_3$. The organic phase was dried with $MgSO_4$ and concentrated under reduced pressure. The residue was purified over silica (20% acetone) to provide the title compound as white solid. Yield: 1.77 g, 2.88 mmol, 89%. $[\alpha]_D^{25}$ = 57.2° (c = 1.28, $CHCl_3$); IR (thin film): 1036, 1070, 1530, 1694, 1750, 2109; ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.21 (d, *J* = 7.6 Hz, 1H, NH), 5.82 (dddd, *J* = 17.0, 10.4, 6.4, 5.3 Hz, 1H, CH_2-C*H*=CH_2), 5.30 – 5.25 (m, 2H, H-1', CH_2-CH=C*H*H), 5.21 (dd, *J* = 10.4, 1.4 Hz, 1H, CH_2-CH=CH*H*), 5.01 (d, *J* = 8.0 Hz, 1H, H-1), 4.38 – 4.30 (m, 2H, H-3, C*H*H-CH=CH_2), 4.12 – 4.00 (m, 2H, H-5, CH*H*-CH=CH_2), 3.91 – 3.84 (m, 2H, H-3', H-4), 3.81 (s, 3H, CH_3 CO_2Me), 3.48 – 3.37 (m, 3H, H-2, H-2', H-5'), 3.12 (d, *J* = 4.2 Hz, 1H, OH), 3.06 (t, *J* = 9.8 Hz, 1H, H-4'), 1.28 (d, *J* = 6.2 Hz, 3H, H-6'); ^{13}C NMR (126 MHz, $CDCl_3$) δ 168.1 (C-6), 162.6 (C=O), 133.0 (CH_2-*C*H=CH_2), 118.9 (CH_2-CH=*C*H_2), 98.4 (C-1'), 98.1 (C-1), 77.0 (C-4), 75.3 (C-5), 71.3 (C-3'), 70.8 (*C*H_2-CH=CH_2), 68.5 (C-4), 67.5 (C-5'), 63.9 (C-2'), 63.6 (C-3), 58.0 (C-2), 53.1 (CH_3 CO_2 Me), 18.2 (C-6'); HRMS: $[M+NH_4]^+$ calcd for $C_{16}H_{23}Cl_3N_{10}O_8NH_4$ 630.11042, found 630.11019

Trisaccharide 37



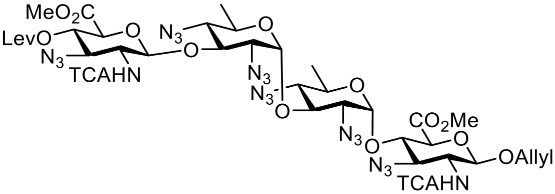
Donor **3** (64 mg, 0.13 mmol, 1.3 eq), Ph_2SO (13 mg, 0.065 mmol, 0.65 eq) and TTBP (62 mg, 0.25 mmol, 2.5 eq) were coevaporated twice with toluene and dissolved in 2.6 mL 1:1 Et_2O/DCM. 3Å molecular sieves were added and the reaction mixture was stirred for 60 min at RT, before being cooled to -80 °C. Tf_2O (130 µL of a freshly prepared 0.5M sln. in 1:1 Et_2O/DCM, 0.065 mmol, 0.65 eq) was added and the reaction was allowed to warm to -60 °C and kept at that temperature for 1 min. before being recooled to -80 °C. Acceptor **36** (1.70 g, 4.07 mmol, 1 eq.) was added dropwise over 30 s as a freshly prepared 0.05M solution in 1:1 DCM/Et_2O. The reaction mixture was then slowly allowed to warm to 0 °C and quenched with 2 mL sat. aq. $NaHCO_3$. The mixture was diluted with DCM. The solution was transferred to a separatory funnel, water was added, the layers were separated, and the water phase was extracted once more with DCM. The combined organic layers were dried over MgSO4, filtered, and concentrated in vacuo. Purification by silica gel flash column chromatography (15% acetone in pentane) yields the title compound as white foam. Yield: 77 mg, 81 µmol, 81%, α:β = 10:1. $[\alpha]_D^{25}$ = 103.0° (c = 0.52, $CHCl_3$); IR (thin film): 756, 821, 1070, 1527, 1696, 1753, 2109; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.93 – 7.81 (m, 4H, CH_{arom}), 7.58 (dd, *J* = 8.5, 1.7 Hz, 1H, CH_{arom}), 7.51 – 7.43 (m, 2H, CH_{arom}), 7.10 (d, *J* = 7.4 Hz, 1H, NH), 5.82 (dddd, *J* = 17.0, 10.4, 6.5, 5.3 Hz, 1H, CH$_2$-C*H*=CH$_2$), 5.40 (d, *J* = 3.7 Hz, 1H, H-1'), 5.37 (d, *J* = 3.7 Hz, 1H, H-1''), 5.27 (dq, *J* = 17.3, 1.5 Hz, 1H, CH$_2$-CH=C*H*H), 5.22 (dq, *J* = 10.3, 1.3 Hz, 1H, CH$_2$-CH=CH*H*), 5.04 (s, 2H, CH$_2$ Nap), 5.03 (d, *J* = 8.1 Hz, 1H, H-1), 4.39 (dd, *J* = 10.8, 9.1 Hz, 1H, H-3), 4.33 (ddt, *J* = 12.7, 5.3, 1.4 Hz, 1H, C*H*H-CH=CH$_2$), 4.10 – 4.05 (m, 1H, CH*H*-CH=CH$_2$), 4.03 (d, *J* = 9.4 Hz, 1H, H-5), 3.96 – 3.86 (m, 2H, H-4, H-5'), 3.85 – 3.77 (m, 4H, H-3'', CH$_3$ CO$_2$Me), 3.70 (dd, *J* = 10.4, 9.3 Hz, 1H, H-3'), 3.52 – 3.46 (m, 2H, H-2'', H-5''), 3.42 (dt, *J* = 10.9, 7.8 Hz, 1H, H-2), 3.22 – 3.11 (m, 3H, H-2', H-4', H-4''), 1.37 (d, *J* = 6.2 Hz, 3H, H-6'), 1.33 (d, *J* = 6.2 Hz, 3H, H-6''); ^{13}C NMR (101 MHz, CDCl$_3$) δ 167.9 (C-6), 162.5 (C=O), 134.7, 133.4, 133.3 (C$_q$), 132.9 (CH$_2$-CH=CH$_2$), 129.3, 128.4, 128.2, 127.8, 127.6, 126.3, 126.2 (CH$_{arom}$), 119.0 (CH$_2$-CH=*C*H$_2$), 98.8, 98.8 (C-1', C-1''), 97.9 (C-1), 92.0 (CCl$_3$), 78.5 (C-3''), 76.7 (C-4), 75.7 (CH$_2$ Nap), 75.2, 75.1 (C-3', C-5), 70.8 (*C*H$_2$-CH=CH$_2$), 69.3, 68.8 (C-4', C-4''), 67.9, 67.8 (C-5', C-5''), 63.9 (C-2''), 63.4 (C-3), 62.4 (C-2'), 58.2 (C-2), 53.0 (CH$_3$ CO$_2$Me), 18.7 (C-6'), 18.0 (C-6''); HRMS: [M+NH$_4$]$^+$ calcd for C$_{35}$H$_{39}$Cl$_3$N$_{16}$O$_{10}$NH$_4$ 966.24389, found 966.24377. The β-anomer was removed by silica chromatography in the next step.

Trisaccharide 38



Trisaccharide **37** (1.90 g, 2.00 mmol) and DDQ (0.91 g, 4.00 mmol, 2 eq) were dissolved in 50 mL 9:1 DCM/H$_2$O and stirred at room temperature until TLC indicated full conversion of the starting material. After which the reaction mixture was transferred to a separatory funnel and washed twice with sat. aq. NaHCO$_3$. The organic phase was dried with MgSO$_4$ and concentrated under reduced pressure. The residue was purified over silica (20% acetone) to provide the title compound as white solid. Yield: 996 mg, 1.23 mmol, 62%. $[\alpha]_D^{25}$ = 102.1° (c = 0.32, CHCl$_3$); IR (thin film): 757, 1069, 1257, 1527, 1696, 1751, 2109; ^{1}H NMR (500 MHz, CDCl$_3$) δ 7.08 (d, *J* = 7.4 Hz, 1H, NH), 5.82 (dddd, *J* = 17.0, 10.4, 6.5, 5.3 Hz, 1H, CH$_2$-C*H*=CH$_2$), 5.39 (d, *J* = 3.8 Hz, 1H, H-1'), 5.36 (d, *J* = 3.7 Hz, 1H, H-1''), 5.28 (dq, *J* = 17.2, 1.5 Hz, 1H, CH$_2$-CH=C*H*H), 5.22 (dq, *J* = 10.3, 1.3 Hz, 1H, CH$_2$-CH=CH*H*), 5.04 (d, *J* = 8.0 Hz, 1H, H-1), 4.40 (dd, *J* = 10.8, 9.1 Hz, 1H, H-3), 4.33 (ddt, *J* = 12.7, 5.3, 1.4 Hz, 1H, C*H*H-CH=CH$_2$), 4.07 (ddt, *J* = 12.7, 6.4, 1.3 Hz, 1H, CH*H*-CH=CH$_2$), 4.03 (d, *J* = 9.4 Hz, 1H, H-5), 4.00 – 3.88 (m, 3H, H-3'', H-4, H-5''), 3.82 (s, 3H, CH$_3$ CO$_2$Me), 3.71 – 3.66 (m, 1H, H-3'), 3.50 (dq, *J* = 12.4, 6.2 Hz, 1H, H-5'), 3.41 (dt, *J* = 10.2, 7.4 Hz, 1H, H-2), 3.37 (dd, *J* = 10.3, 3.8 Hz, 1H, H-2''), 3.18 (dd, *J* = 10.4, 3.7 Hz, 1H, H-2'), 3.15 – 3.07 (m, 2H, H-4', H-4''), 2.86 (d, *J* = 3.7 Hz, 1H, OH), 1.37 (d, *J* = 6.2 Hz, 3H, H-6''), 1.33 (d, *J* = 6.2 Hz, 3H, H-6'); ^{13}C NMR (126 MHz, CDCl$_3$) δ 167.9 (C-6), 162.5 (C=O), 132.9 (CH$_2$-*C*H=CH$_2$), 119.0 (CH$_2$-CH=*C*H$_2$), 98.8, 98.7 (C-1', C-1''), 97.9 (C-1), 92.0 (CCl$_3$) 76.7 (C-4), 75.2, 75.2 (C-3', C-5), 70.9 (C-3''), 70.8 (*C*H$_2$-CH=CH$_2$), 69.4, 69.0 (C-4', C-4''), 67.9 (C-5'), 67.6 (C-5''), 63.7 (C-2''), 63.4 (C-3), 62.3 (C-2'), 58.2 (C-2), 53.1 (CH$_3$ CO$_2$Me), 18.6 (C-6''), 18.0 (C-6'); HRMS: [M+NH$_4$]$^+$ calcd for C$_{24}$H$_{31}$Cl$_3$N$_{16}$O$_{10}$NH$_4$ 826.18129, found 826.18079

Tetrasaccharide 39



Donor **5** (960 mg, 1.49 mmol, 1.3 eq) and acceptor **38** (925 mg, 1.14 mmol, 1 eq) were coevaporated twice with toluene and dissolved in 30 mL DCM. 3Å molecular sieves were added and the reaction mixture was stirred for 30 min at RT, before being cooled to 0 °C. TMSOTf (2,28 mL of a freshly prepared 0.1 M solution in DCM, 0.228 mmol, 0.2 eq) was added. After TLC shows complete disappearance of acceptor **39**, the reaction mixture was quenched with 0.2 mL triethylamine, filtered over a small plug of celite and concentrated under reduced pressure. The residue was purified over silica (20%→40% acetone in pentane) to yield the title compound as pinkish foam. Yield: 855 mg, 0.67 mmol, 59%. $[\alpha]_D^{25}$ = 32.0° (c = 0.70, $CHCl_3$); IR (thin film): 757, 821, 1039, 1259, 1527, 1700, 1717, 1754, 2106; ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.26 (d, *J* = 7.4 Hz, 1H, NH), 7.15 (d, *J* = 7.4 Hz, 1H, NH), 5.82 (dddd, *J* = 17.0, 10.4, 6.4, 5.3 Hz, 1H, CH$_2$-C*H*-CH$_2$), 5.38 (d, *J* = 3.8 Hz, 1H, H-1’), 5.37 – 5.34 (m, 2H, H-1”, H-1’”), 5.27 (dq, *J* = 17.2, 1.5 Hz, 1H, CH$_2$-CH=C*H*H), 5.21 (dq, *J* = 10.4, 1.3 Hz, 1H, CH$_2$-CH=CH*H*), 5.10 (t, *J* = 9.7 Hz, 1H, H-4’”), 5.03 (d, *J* = 8.0 Hz, 1H, H-1), 4.49 (dd, *J* = 11.0, 9.7 Hz, 1H, H-3’”), 4.39 (dd, *J* = 10.8, 9.1 Hz, 1H, H-3), 4.33 (ddt, *J* = 12.8, 5.3, 1.4 Hz, 1H, C*H*H-CH=CH$_2$), 4.14 (d, *J* = 9.9 Hz, 1H, H-5’”), 4.07 (ddt, *J* = 12.8, 6.5, 1.2 Hz, 1H, CH*H*-CH=CH$_2$), 4.03 (d, *J* = 9.4 Hz, 1H, H-5), 3.98 (dd, *J* = 10.2, 9.3 Hz, 1H, H-3”), 3.93 – 3.85 (m, 2H, H-4, H-5”), 3.81 (s, 3H, CH$_3$ CO$_2$Me), 3.74 (s, 3H, CH$_3$ CO$_2$Me), 3.69 – 3.61 (m, 1H, H-3’), 3.53 – 3.36 (m, 4H, H-2, H-2”, H-2’”, H-5’), 3.17 (dd, *J* = 10.4, 3.8 Hz, 1H, H-2’), 3.13 – 3.06 (m, 2H, H-4’, H-4”), 2.85 – 2.71 (m, 2H, CH$_2$ Lev), 2.71 – 2.57 (m, 2H, CH$_2$ Lev), 2.20 (s, 3H, CH$_3$ Lev), 1.35 (d, *J* = 6.2 Hz, 3H, H-6”), 1.32 (d, *J* = 6.2 Hz, 3H, H-6’); ^{13}C NMR (126 MHz, $CDCl_3$) δ 206.1, 171.5 (C=O), 167.9, 167.0 (C-6, C-6’”), 162.6, 162.5 (C=O), 132.9 (CH$_2$-*C*H=CH$_2$), 118.9 (CH$_2$-CH=*C*H$_2$), 98.8, 98.7, 98.5 (C-1’, C-1”, C-1’”), 98.0 (C-1), 77.6 (C-3”), 76.9 (C-4), 75.6 (C-3’), 75.2 (C-5), 73.3 (C-5’”), 71.1 (C-4’”), 70.8 (CH$_2$-CH=CH$_2$), 69.0 (C-4’), 67.8 (C-5’), 67.6 (C-5”), 67.1 (C-4”), 63.3 (C-3), 63.1 (C-2”), 62.4 (C-2’), 61.1 (C-3’”), 58.1, 57.6 (CH$_3$ CO$_2$Me), 53.2, 53.0 (C-2, C-2’”), 37.8 (CH$_2$ Lev), 29.9 (CH$_3$ Lev), 27.8 (CH$_2$ Lev), 18.6 (C-6”), 18.0 (C-6’); HRMS: $[M+NH_4]^+$ calcd for $C_{38}H_{46}Cl_6N_{20}O_{17}NH_4$ 1284.17955, found 1248.1789

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7

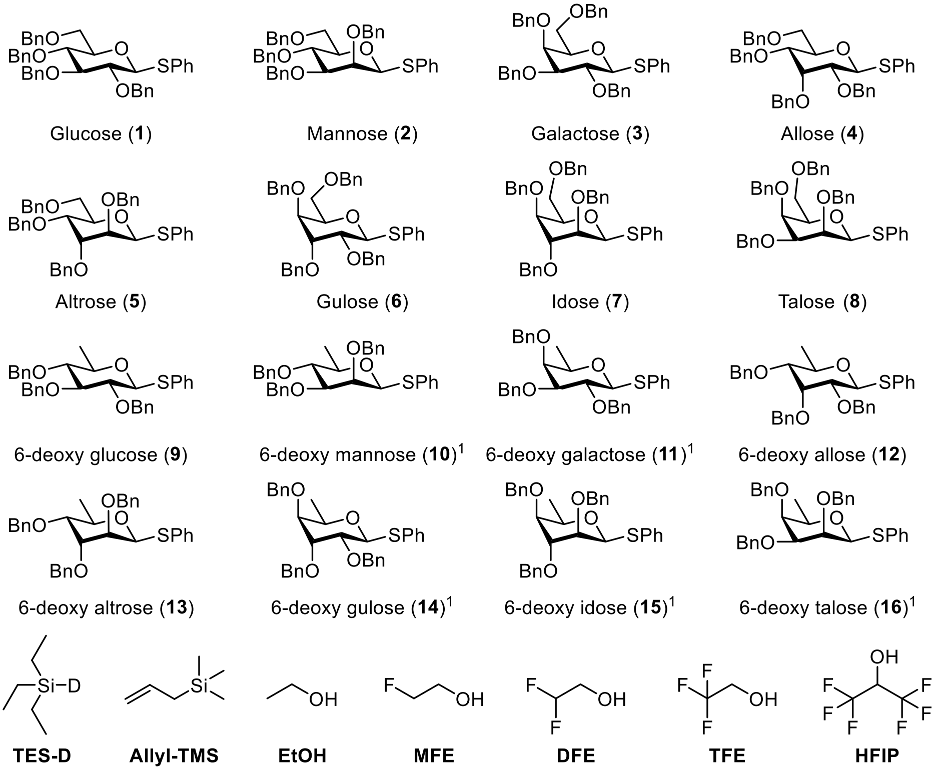
Chapter 7: summary and future prospects

Summary

One of the key challenges in synthetic carbohydrate chemistry is the formation of a glycosidic bond between two carbohydrate building blocks. The main reason that synthesis of carbohydrate oligomers is more challenging than other biomolecules, such as peptides and oligonucleotides, is that with glycosylation a new stereocenter is introduced. And where *1,2-trans* glycosidic bonds can usually be synthesised by means of neighbouring group participation, for the stereoselective and high yielding formation of *1,2-cis* glycosidic bonds no universally applicable technique exists.

In a typical glycosylation reaction, a donor is activated to form a (variety of) electrophilic species which can react with a nucleophilic acceptor, following a reaction mechanism having both S_N1 and S_N2 character. On the S_N1-side of the spectrum oxocarbenium ions partake in the mechanism while covalent intermediates act as the product forming intermediates on the S_N2-side. The result of a glycosylation reaction is influenced by the properties of both donor and acceptor and can be affected by external factors as well. Because the challenges in carbohydrate synthesis are typically solved for a specific synthetic problem, a general understanding of what effect changing a single variable has on the mechanistic pathway, and thus the (stereochemical) outcome is not available. This in turn means that synthesis of glycosidic bonds typically requires a considerable amount of optimisation at the expense of a significant amount of time and resources. The goal of this thesis is to systematically investigate how changes in stereochemistry and protecting group patterns on the donor and acceptor affect the mechanism and outcome of glycosylation reactions, to enable a more rational design of synthesis routes.

Chapter 1 presents the challenges associated with the chemical synthesis of carbohydrates and shows some solutions that have been developed for stereoselective glycosylation. Here, the S_N1/S_N2 mechanism continuum is described, as well as methods for investigating both ends of the spectrum together with some key results. Finally, the role of the reactivity of the acceptor in the outcome of the glycosylation reaction is discussed.



Glucose (**1**) Mannose (**2**) Galactose (**3**) Allose (**4**)

Altrose (**5**) Gulose (**6**) Idose (**7**) Talose (**8**)

6-deoxy glucose (**9**) 6-deoxy mannose (**10**)[1] 6-deoxy galactose (**11**)[1] 6-deoxy allose (**12**)

6-deoxy altrose (**13**) 6-deoxy gulose (**14**)[1] 6-deoxy idose (**15**)[1] 6-deoxy talose (**16**)[1]

TES-D **Allyl-TMS** **EtOH** **MFE** **DFE** **TFE** **HFIP**

Figure 1: *Donors and acceptors used in chapters* **2** *and* **3***. 1: the* D*-isomer is shown for ease of comparison, but the* L*-isomer was used in the experiments.*

Chapter 2 describes an investigation to the influence of the stereochemistry of the donor on the S_N1 mechanistic pathway of the glycosylation reaction via a combination of computational chemistry and glycosylation experiments. First, all eight diastereomeric per-*O*-benzyl pyranosyl donors, as well as their 6-deoxy analogues (**1-8** and **9-16** respectively, ***Figure 1***) were synthesised. Next, conformation energy landscape (CEL)-maps for all the corresponding oxocarbenium ions were generated to theoretically determine the conformational preference of the oxocarbenium ions, thereby predicting the expected stereochemical outcome of a glycosylation reaction which follows a S_N1 pathway. Finally, all donors were reacted with two nucleophiles which typically react following an S_N1-type mechanism, namely TES-D and allyl-TMS.
The stability of the conformers found in CEL maps can be explained by considering the "preferences" of the substituents to stabilize (or minimize destabilization of) the oxocarbenium ions. Oxocarbenium ions where the C-3 and C-4 alkoxy groups are placed in a pseudo-axial fashion are more stable compared to their pseudo-equatorial equivalents. For C-2 and C-5 a pseudo-equatorial orientation is preferred. When all 4 substituents can be placed in the preferred orientations, as is the case for gulose/6-

deoxy gulose, the ion has a strong preference for that conformation ($^4H_3$ half chair). Also, with 3 out of 4 substituents optimally orientated, the ions show a strong preference for that conformation. When only 2 substituents can be placed in the preferred orientation, the energy differences between conformations are a lot smaller. One further observation is that the preferences for 6-deoxy oxocarbenium ions are very similar to those of their 6-OBn analogues in most cases, although the absolute energy differences are different. This is also apparent in the outcome of the glycosylation reactions.

For the reactions with TES-D, the orientation of the C-2 substituent is the most important in determining the stereochemical outcome, as all of these reactions are highly *1,2-cis* selective. This in agreement with the CEL maps in most cases, except for talose and 6-deoxy glucose, where a ~1:1 mixture is predicted and for idose, where α-selectivity was predicted, but complete β-selectivity was observed.

Reactions with Allyl-TMS gave different results. When the C-2 group is equatorial, the reaction proceeds with full α-selectivity like with TES-D. When the C-2 group is placed in an axial manner however, the reaction shifts from β-selectivity for the TES-D reactions to α-selectivity with allyl-TMS. A possible explanation are the steric interactions between the substituents and the nucleophile that disfavour attack on the *cis*-side. Following a Curtin-Hammett kinetic scenario, attack can then take place on a higher energy oxocarbenium ion conformer *via* a lower energy transition state leading to the *trans*-product. Understanding the possible Curtin-Hammett scenarios occurring during the nucleophilic addition of allyl-TMS to an oxocarbenium ion is currently a topic of active research.[1]

Chapter 3 focuses on the mechanistic pathways which involve a covalent intermediate. Variable temperature (VT) NMR was used to characterise the covalent species formed upon activation of donors **1-8** (see ***Figure 1***). The observed species were either a mixture of α-triflate and α-oxosulfonium triflate, a mixture of α-triflate and α,β-oxosulfonium triflates or a mixture of α,β-oxosulfonium triflates. β-Triflates were not observed for any of the donors.

Next, the donors were coupled with five alcohol acceptors of varying nucleophilicity (EtOH-HFIP, see ***Figure 1***) to probe the influence of the nucleophilicity on the reaction path and the stereochemical outcome of the glycosylations. In the reactions with the EtOH-MFE-DFE-TFE series, the configuration of C-3 appeared to be a key determining factor in the relation between nucleophilicity and stereoselectivity. When the C-3 substituent is equatorial, a clear trend is observed where more nucleophilic acceptors give higher β-selectivity and less nucleophilic acceptors provide higher α-selectivity. When the C-3 groups are axial, α:β mixtures are obtained with no clear relation between nucleophilicity and stereoselectivity. A possible mechanistic explanation for these observations is that for the donors having an equatorially oriented

C-3 group, the most reactive acceptors can substitute the more stable covalent α-species, yielding the β-products, while less reactive acceptors can only react with the more reactive β-species to yield the α-product. When the substituent at C-3 is axial, the reactivity difference between the covalent α- and β-species is smaller because of destabilizing 1,3-diaxial interactions between the triflate and the C-3 group. The S_N2 substitution of the β-species, is also hindered by the group on C-3. These steric interactions counteract one another leading to overall poor selectivity.

The glycosylations with HFIP were all completely α-selective, regardless of the stereochemistry of C-2 or C-3. This stands in contrast to the outcome of related reactions with TES-D, the nucleophile used to benchmark S_N1 reaction pathways, where reactions are always highly *1,2-cis* selective, suggesting that the glycosylations with weak *O*-nucleophiles occurs via a different mechanism than nucleophilic addition to an oxocarbenium ion.

In **Chapter 4** a system based on the use of two conformationally restricted glucosyl donors is described to unravel the structure-reactivity relations of a set of 60 acceptors. The stereochemical outcome of the glycosylation reactions of these two donors is highly dependent on the nucleophilicity of the acceptor, as determined by glycosylations with the EtOH-HFIP model acceptors. The most nucleophilic acceptors react with full β-selectivity, while decreasing the nucleophilicity of the acceptor gradually leads to full α-selectivity.

This property was used to measure the reactivity of a large set of carbohydrate acceptors. By systematically varying the protecting group pattern on D-glucose, D-mannose, D-galactose, L-rhamnose and L-fucose acceptors and "measuring" their reactivity, it was possible to determine which structural features determine the reactivity of the acceptor. Two kinds of model acceptors were also introduced. The first kind consist of carbohydrate-like acceptors stripped to only their "essential" substituents, based on 1,2,6-trideoxy glucose and galactose with varying protecting group patterns. The second kind of model acceptors are C-2-OH glycerol acceptors with a cyclic protecting group on C-1 and C-3. These acceptors resemble carbohydrates acceptors in the sense that they are secondary alcohols next to two protected oxygen atoms. Unlike carbohydrate acceptors however, they are not chiral, so the stereochemical outcome of the glycosylation reactions is not determined by diastereomeric interactions.

Analysis of the results from the glycosylation reactions reveals that both the configuration as well as the protecting group pattern of the acceptor play a key role in determining the reactivity of the acceptor (***Figure 2***). With regard to the configuration of the acceptor, equatorial alcohols are more reactive than axial alcohols (light blue circles and blue squares vs black triangles). The orientation of the functional group next to the nucleophilic alcohol is also important, and alcohols having only equatorial neighbours are more reactive than alcohols which are next to an axial neighbour (light blue circles vs blue squares). With regard to the protecting group pattern, benzoyl protected acceptors are less reactive than their benzyl protected counterparts. The magnitude of this effect depends on which benzyl group is replaced with a benzoyl group, since the effect is much larger when an equatorial benzyl group next to the alcohol is changed for a benzoyl group than when the same is done with an axial benzyl group next to the alcohol (blue squares, red diamonds and yellow triangles).

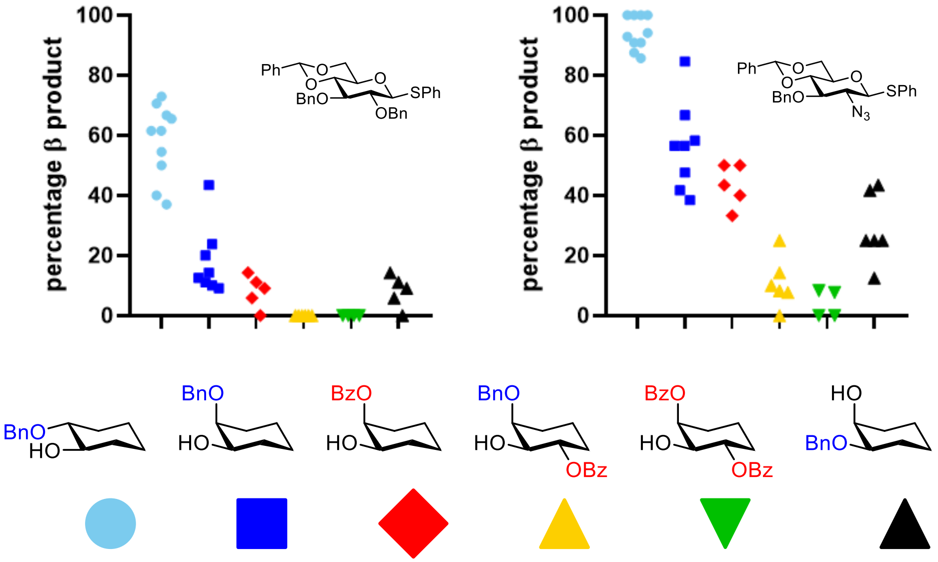


Figure 2: *Relations between the structure and the reactivity (measured as percentage β-product) of glycosyl acceptors found in chapter 4.*

Chapter 5 builds on chapter 4, by using the same methodology that was applied on benzyl/benzoyl protected acceptors to determine the influence of common *N*-protecting groups (*i.e* azide, tricholoroacetamide (TCA) and trifluoroacetamide (TFA)) on the reactivity of glycosyl acceptors. The acceptors used in this study were C-4-OH glucosamine acceptors, since the C-4-OH *N*-acetylglucosamine acceptors are notorious for their poor nucleophilicity and C-3-OH glucosamine acceptors, to investigate the effect of different protecting groups next to the nucleophilic alcohol. The C-4-OH and C-3-OH mannosamine acceptors were added in order to determine the influence of the configuration of the protected amine on the reactivity of the acceptor.

Like with benzyl/benzoyl protected acceptors, both the configuration and the nature of the protecting group are important for the reactivity of the acceptor. For both the C-4-OH glucosamine and mannosamine acceptors, the nature of the protecting group has little influence on the reactivity of the acceptors, since all glycosylations within the same acceptor series proceeded with similar stereoselectivity and high yield. With the C-3-

OH glucosamine and mannosamine acceptors, similar trends were observed as in the acceptor series in chapter 4. The first observation is that an azide has a disarming effect that is comparable to that of a *O*-benzoyl group and that acetamides have a larger disarming effect, with the trifluoroacetamides being more disarming than the trichloroacetamides. The configuration of the protected amine next to the alcohol was also found to be important for the reactivity of the acceptor. As observed for the ether protected acceptors, the C-3-OH glucosazide acceptor is more reactive than the C-3-OH mannosazide acceptor. Also, in line to the results of chapter 4, the disarming effect of the N-protecting groups on equatorial amines next to the alcohol is much more significant than the disarming effect of the N-protecting groups of the neighboring axial amines.

In **Chapter 6**, the obtained knowledge described in Chapters 2-5 is used to synthesize the repeating unit of a capsular polysaccharide found on Acinetobacter baumannii LUH 5554, a Gram-negative bacterium that has been designated by the World Health Organization as a high risk pathogen due to its high level of antibiotic resistance. This polysaccharide is built up from repeating tetramers with the structure [→4)-β-D-GlcpNAc3NAcA-(1→3)-α-D-QuipNAc4NAc-(1→3)-α-D-QuipNAc4NAc-(1→4)-β-D-GlcpNAc3NAcA-(1→] (***Figure 3***) which encompass the two rare sugars 2,4-di-*N*-acetyl-α-D-quinovose (2,4-di-*N*-acetyl bacillosamine, QuiNAc4NAc) and 2,3-di-*N*-acetyl-β-D-glucuronic acid (GlcNAc3NAcA). What makes this structure special, is that it contains *N*-acetyl groups, carboxylates and deoxy centers, but not a single hydroxyl group!

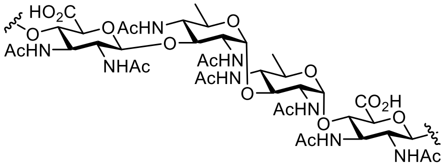


Figure 3: *Structure of the oligosaccharide from A. Baumannii LUH 5554.*

Synthetic routes for producing multi-gram quantities of the bacillosamine and 2,3-di-*N*-acetyl glucuronic acid building blocks were developed starting from D-fucose and D-glucosamine-HCl. The reactivity of the bacillosamine donors was then studied to develop methods for the construction of the 1,2-*cis* linkages. Model glycosylations with fluorinated ethanol acceptors showed that the stereoselectivity of the studied selenophenol bacillosamine donor strongly depends on the nucleophilicity of the acceptor under pre-activation conditions, with ethanol providing complete β-selectivity and 2,2,2-trifluoroethanol nearly complete α-selectivity. The azides and methyl esters on the carbohydrate acceptors should have a disarming effect on the nucleophilic alcohol based on previous studies and, as expected, glycosylation with both the 2,3-di-

N-acetyl glucuronic acid acceptors and the bacillosamine acceptors proceed with high α-selectivity.

In order to investigate the mechanism underlying this selectivity, VT-NMR was used to study the reactive intermediates formed from the bacillosamine donors. When the selenophenol donor was activated with Ph_2SO and Tf_2O, a mixture of the α-triflate, α-oxosulfonium triflate and β-oxosulfonium triflate was formed. The β-oxosulfonium triflate appeared to be the most reactive, as judged by the lowest decomposition temperature. On the other hand, activation of the corresponding PTFAI donor with TfOH, led to the formation of only the α-triflate. Based on observations in glycosylations between the selenophenol donor or imidate donor with the 2,3-di-*N*-acetyl glucuronic acid acceptors (see below) it is expected that the oxosulfonium triflates play a role in determining the selectivity of the selenophenol donor.

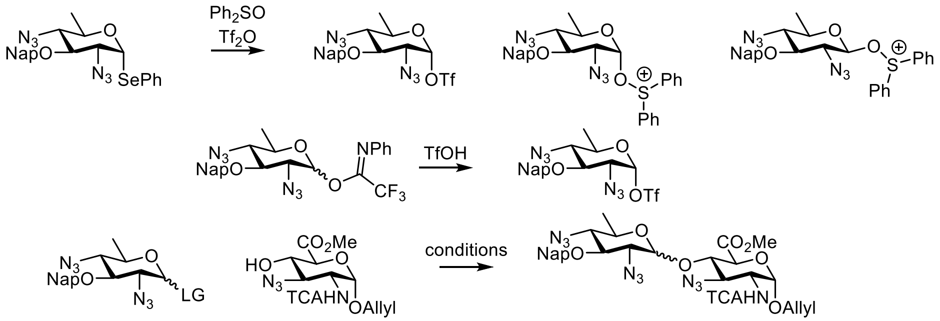
With this knowledge in hand, the tetrasaccharide could be assembled. Eventually 855 mg (670 µmol) of protected tetrasaccharide building block was obtained, which can be deprotected, or used for the synthesis of larger oligomers (see below).

Future prospects

The goal of this thesis has been to systematically map structure-reactivity relationships for both donor and acceptor building blocks and shine light on the different mechanisms of the glycosylation reaction to enable the rational design of synthetic routes towards complex oligosaccharides. The following section describes some suggestions for follow-up studies to further increase the understanding of the glycosylation reaction.

Influence of oxosulfonium species on the outcome of the glycosylation reaction

Chapter 6 shows the use of VT-NMR to characterise the reactive species that are formed when either a selenophenol or an imidate donor are activated with Ph_2SO/Tf_2O or TfOH, respectively (***Figure 4***). The selenophenol donor provided a mixture of α-triflate, α-oxosulfonium triflate and β-oxosulfonium triflate, while the imidate only delivered the α-triflate. The glycosylations with the 2,3-di-*N*-acetyl glucuronic acid acceptor suggest a prominent role for the oxosulfonium triflates in determining the stereoselectivity of the reaction. When this acceptor was reacted with the selenophenol donor under pre-activation conditions, high α-selectivity was obtained. While the reaction with the imidate donor led to a mixture of α- and β-products. The α-selectivity could be restored in the reaction with the imidate donor by adding Ph_2SO, suggesting an important role for the intermediate oxosulfonium species.



Entry	LG	Activation	α:β
1	**α-SePh**	**Ph_2SO/Tf_2O**	**10-13:1**
2	**α,β-OC(=NPh)CF_3**	**TMSOTf**	**1:1**
3	**α,β-OC(=NPh)CF_3**	**TMSOTf+Ph_2SO**	**9:1**

Figure 4*: Selected observations from chapter 6*

Figure 5 shows an example from literature where the difference in reactivity between triflates and oxosulfonium triflates was used. When Crich and Li reacted sialic acid donor **I** with a stoichiometric amount of Ph_2SO, triflate **II** was formed, followed by immediate elimination to give glycal **III**. However, when an excess of Ph_2SO was used under otherwise similar conditions, a mixture of oxosulfonium triflates IV and V was formed. These species enabled the formation of the glycosylation products with a variety of acceptors.[2]

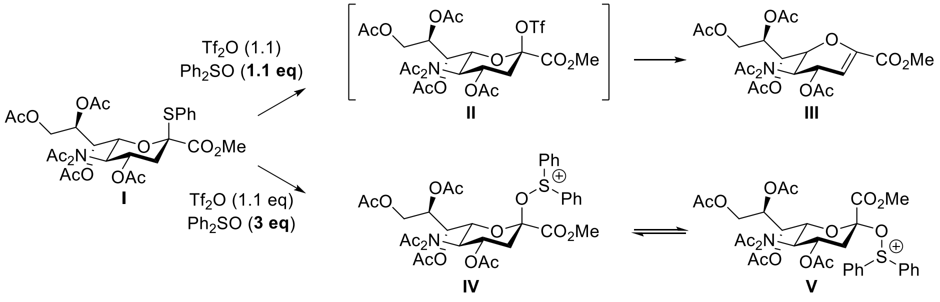


Figure 5: *A literature example which illustrates the reactivity difference between triflates and oxosulfonium triflates. When sialic acid donor I gets activated with Tf_2O and an stoichiometric amount of Ph_2SO, triflate II is formed, followed by immediate elimination to glycal III. When an excess of Ph_2SO was used, oxosulfonium triflates IV and V are formed, which can successfully react with different acceptors.*[2]

When thiophenol donors **1**-**8** (***Figure 1***) were activated with Ph_2SO and Tf_2O, oxosulfonium species were generated as determined by the VT-NMR measurements. Based on the observations described above, it is not unreasonable to expect that these oxosulfonium species play a role in shaping the stereochemical outcome of the glycosylation reactions, as reported in chapter 3. An interesting follow-up study would be to transform these thiophenol donors into the corresponding (PTFAI) imidates and use transform these into the corresponding triflates and perform glycosylations with the EtOH-HFIP acceptors to systematically investigate the role that the oxosulfonium species play in glycosylation reactions.

Relative reactivity values of acceptors with donors that react via an S_N1 or an S_N2 mechanism

In chapter 4 and chapter 5 structure-reactivity relationships for glycosyl acceptors are established based on the stereoselectivity of these acceptors in reactions with two glycosyl donors. A quantitative expression of the nucleophilicity of acceptors remains challenging nonetheless. Although multiple attempts, both computational and experimental, have been undertaken,[3] an acceptor equivalent to the widely used relative reactivity values (RRVs) used to describe the reactivity of glycosyl donors[4-6] does not yet exist. In a recent paper by Wong, Wang and coworkers the "AKa" value was proposed as a measurement of acceptor reactivity. This value can be determined by measuring the relative reaction rate between an acceptor hydroxyl group and dihydropyran under acidic conditions in a flow system.[7]

A problem in competition experiments in which two acceptors are made to compete for one donor in a "real" glycosylation reaction, is the potential occurrence of four different products, that are formed via different pathways. The relative reactivity of an acceptor may depend on the mechanistic pathway, complicating the interpretation of the obtained values. To establish how relative acceptor reactivity depends on the mechanistic pathway, acceptor competition experiments can be probed using two different kinds of donors that react via different mechanisms on opposite ends of the S_N1/ S_N2 mechanism continuum (***Figure 6***). Glycosylation of donor **D1**, a tetra-benzoyl PTFAI galactosyl donor, proceed via a displacement of a dioxolenium ion in an S_N2-type mechanism (***Figure 6A***).[8-10] While glycosylations of donor **D2**, a DTBS protected galactopyranose PTFAI donor, follow an S_N1-type mechanism to form the α-product.[11] ***Figure 6C*** shows a selection of acceptors, described in chapter 4 and 5, for a set of competition experiments (**A1**-**A11**, ***Figure 6C***).

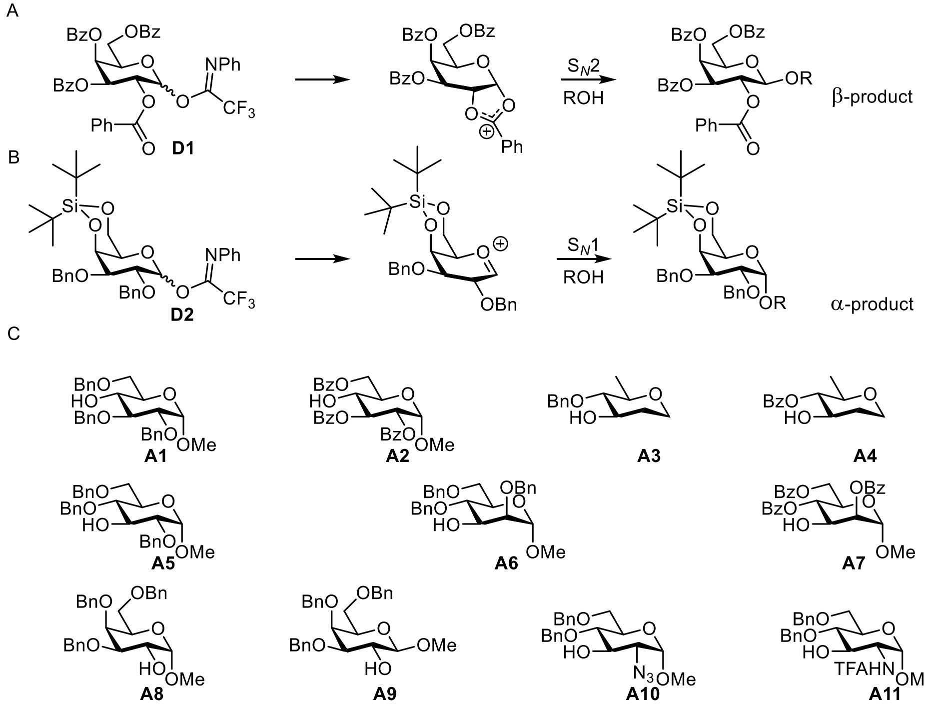


Figure 6: *A) reaction mechanism of donor D1; B) reaction mechanism of donor D2; C) acceptors tested in this work.*

For the competition experiments, a limiting amount of donor was reacted under *in situ* activation conditions with 2 equivalents of acceptor to ensure that an excess of each acceptor was always present. Due to the stereoselective nature of the reactions, only two products are formed in each reaction: product I and product II according to equation (1). The ratio between the two formed products can be used as a measure for the relative reactivity of two acceptors in a given mechanistic pathway.

$$\boldsymbol{Donor\ (1\ eq) + Acceptor\ I\ (2\ eq) + Acceptor\ II\ (2\ eq) \rightarrow product\ I + product\ II}\ (\mathbf{1})$$

The results of the competition experiments are summarised in ***Table 1***. These results show that with S$_N$2-donor **D1**, the relative reactivity of the acceptors parallels the structure-reactivity relations found in chapter 4 and chapter 5. Benzyl protected acceptors are more reactive than benzoyl protected acceptors (**A1**>**A2**; **A3**>**A4** and **A6**>**A7**), alcohols next to equatorial ethers are more reactive than alcohols next to axial ethers (**A5**>**A6** and **A9**>**A8**) and TFA groups are more disarming than azides (**A10**>**A11**).

With S_N1-donor **D2** on the other hand, benzoyl protected acceptors **A2** and **A4** appear to be more reactive than their benzylated counterparts **A1** and **A3**. Alcohols next to equatorial ethers appear to be (slightly) more reactive than alcohols next to axial ethers (**A5**>**A6**).

These results indicate that the relative nucleophilicity of the acceptors in glycosylation reactions proceeding with different mechanisms are governed by different factors. While the trend for the S_N2-substitutions seems to be correlated to the electron density on the acceptor alcohol oxygen, which decreases with increasing electron withdrawing capacity of the protecting/functional groups, the relative reactivity of the acceptors in the S_N1-substitutions correlate to the relative acidity of the alcohols, with the more acidic alcohols being more reactive in the substitution reactions. More acceptors need to be screened to shed further light on the relative acceptor reactivity under these conditions.

Table 1: *results of the competition experiments*

Entry	Donor	Acceptor I	Acceptor II	Product I:II	yield
1	**D1**	**A1**	**A2**	**>20:1**	**80%**
2	**D1**	**A3**	**A4**	**3.5:1**	**89%**
3	**D1**	**A5**	**A6**	**11:1**	**92%**
4	**D1**	**A6**	**A7**	**9:1**	**90%**
5	**D1**	**A8**	**A9**	**1:2**	**85%**
6	**D1**	**A10**	**A11**	**16:1**	**79%**
7	**D2**	**A1**	**A2**	**1:3.5**	**100%**
8	**D2**	**A3**	**A4**	**1:3.9**	**100%**
9	**D2**	**A5**	**A6**	**1.5:1**	**100%**

*Conditions: 0.05M Donor in DCM 1 eq donor, 2 eq acceptor I, 2 eq acceptor II, 0.1 eq TMSOTf **D1**: 0°C, **D2**: -40 °C to 0 °C.*

Synthesis of oligomers of the A. Baumannii LUH 5554 tetrasaccharide

Chapter 6 describes the synthesis of the tetrasaccharide repeating unit of the A. Baumannii LUH 5554 capsular polysaccharide. Since a relatively large amount of protected tetrasaccharide building block was obtained, the synthesis of oligomers is an attractive perspective. A strategy for this oligomer synthesis is depicted in ***Figure 7***. The tetrasaccharide building block is orthogonally protected at the reducing and the non-reducing end. This property can be used to generate tetramer donor and acceptor building blocks. For the synthesis of the acceptor, the levulinoyl ester can be removed selectively with H_2NNH_2-HOAc,[12] while the allyl group at the reducing end can be removed with catalytic $PdCl_2$ and turned into the imidate with conditions similar to those described in chapter 6 to generate a donor synthon. After glycosylation, the obtained octasaccharide can then be treated with H_2NNH_2-HOAc to generate an acceptor, which can react with the tetrameric donor. This process can be repeated multiple times to get the octa-, dodeca-, hexadeca- and icosasaccharides.

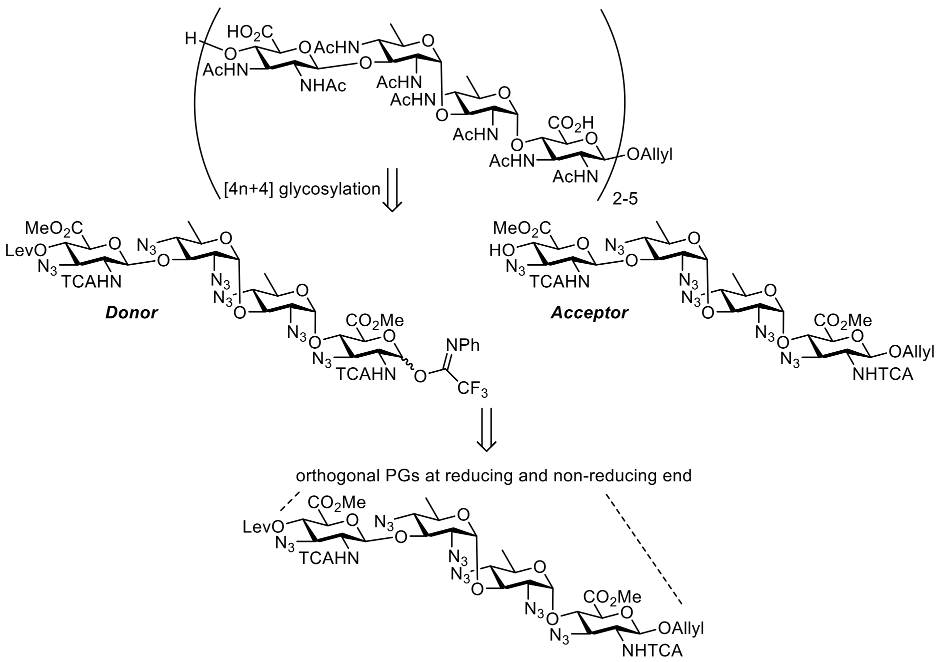


Figure 7: *Retrosynthetic analysis towards oligomers of the A. Baumannii LUH 5554 tetrasaccharide.*

With the obtained oligosaccharides the structure of the oligomers can be investigated by an approach combining NMR spectroscopy and computational chemistry. It will be of interest to see how the “lack of oxygen” substituents and the presence of all the acetamides affects the secondary structure of the saccharides. These structural studies can be followed by the immunological evaluation to investigate whether antibodies can be elicited by protein conjugates of the oligomers (the generation of which can be done exploiting the allyl group as a conjugation handle) that recognize the capsular polysaccharide, and if so, what the minimal epitope is.[13]

Experimental

General procedure I: Glycosylation with D1 or D2

Donor **D1** or **D2** (1 eq) and the acceptor (1-2 eq) were coevaporated twice with toluene and dissolved in DCM (0.05 M donor). 3A molecular sieves were added and the mixture was stirred for 30 min at RT, after which it was cooled to 0 °C and 0.1-0.2 eq of TMSOTf was added. After full conversion after the starting material, the reaction was quenched with sat. aq. $NaHCO_3$ and extracted with DCM. The organic phase was dried with $MgSO_4$ and concentrated under reduced pressure. The disaccharides were isolated by size-exclusion chromatography (Sephadex LH-20 1:1 DCM/MeOH)

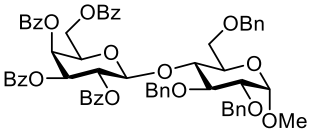
Competition experiments with D1

Donor **D1** (1 eq), acceptor I (2 eq) and acceptor II were coevaporated twice with toluene and dissolved in DCM (0.05 M donor). 3A molecular sieves were added and the mixture was stirred for 30 min at RT, after which it was cooled to 0 °C and 0.1 eq of TMSOTf was added. After full conversion after the starting material, the reaction was quenched with sat. aq. $NaHCO_3$ and extracted with DCM. The organic phase was dried with $MgSO_4$ and concentrated under reduced pressure. The mixture of disaccharide products was isolated by size-exclusion chromatography (Sephadex LH-20 1:1 DCM/MeOH). Selection of diagnostic peaks for determining the ratio of product I to product II was done by comparing the 1H-NMR spectrum of the mixture to the 1H-NMR spectra of both reference compounds.

Competition experiments with D2

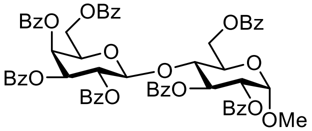
Competition experiments with **D2** were done in a procedure similar to those for **D1**. The only difference is that TMSOTf was added at -40 °C, after which the reaction mixture was allowed to warm to 0 °C.

Disaccharide D1A1



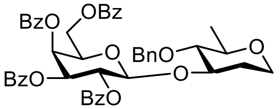
According to the general procedure **I** from D1 and A1. Yield: 88 mg, 84 μmol, 84% α:β <1:20. ^{1}H NMR (500 MHz, CDCl$_3$) δ 8.05 – 8.00 (m, 2H), 7.94 (dd, *J* = 8.3, 1.4 Hz, 2H), 7.87 – 7.83 (m, 2H), 7.79 – 7.74 (m, 2H), 7.58 – 7.52 (m, 2H), 7.52 – 7.45 (m, 5H), 7.44 – 7.34 (m, 9H), 7.33 – 7.20 (m, 9H), 7.19 – 7.14 (m, 1H), 5.86 (dd, *J* = 3.5, 1.1 Hz, 1H), 5.70 (dd, *J* = 10.4, 8.1 Hz, 1H), 5.30 (dd, *J* = 10.4, 3.5 Hz, 1H), 5.18 (d, *J* = 11.1 Hz, 1H), 4.91 (d, *J* = 11.1 Hz, 1H), 4.84 – 4.74 (m, 3H), 4.65 (d, *J* = 12.3 Hz, 1H), 4.58 (d, *J* = 3.7 Hz, 1H), 4.40 (dd, *J* = 11.2, 6.2 Hz, 1H), 4.32 (d, *J* = 12.2 Hz, 1H), 4.19 (dd, *J* = 11.2, 7.6 Hz, 1H), 4.03 (dd, *J* = 10.0, 9.0 Hz, 1H), 3.92 (td, *J* = 9.2, 8.3, 3.6 Hz, 2H), 3.70 (dd, *J* = 10.8, 2.8 Hz, 1H), 3.53 (ddd, *J* = 13.2, 10.8, 3.0 Hz, 2H), 3.44 (dd, *J* = 10.8, 1.9 Hz, 1H), 3.30 (s, 3H); ^{13}C NMR (126 MHz, CDCl$_3$) δ 165.9, 165.5, 165.5, 165.0, 139.5, 138.4, 137.9, 133.5, 133.4, 133.3, 129.9, 129.9, 129.8, 129.8, 129.7, 129.6, 129.2, 129.1, 128.9, 128.7, 128.5, 128.5, 128.4, 128.4, 128.2, 128.2, 127.9, 127.3, 127.3, 100.5, 98.6, 79.9, 78.7, 76.8, 75.3, 73.7, 73.7, 71.9, 71.0, 70.4, 69.6, 67.9, 67.6, 61.5, 55.5; HRMS: [M+NH$_4$]$^+$ calcd for $C_{62}H_{58}O_{15}NH_4$ 1060.41140, found 1060.41099

Disaccharide D1A2



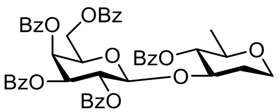
According to the general procedure **I** from D1 and A2. Yield: 75 mg, 70 µmol, 70%, α:β <1:20. ^{1}H NMR (500 MHz, CDCl$_3$) δ 8.06 – 8.03 (m, 2H), 8.01 – 7.96 (m, 8H), 7.90 – 7.87 (m, 2H), 7.76 – 7.71 (m, 2H), 7.62 (ddt, *J* = 8.8, 7.3, 1.3 Hz, 1H), 7.60 – 7.55 (m, 2H), 7.50 – 7.27 (m, 13H), 7.24 – 7.16 (m, 5H), 6.09 (dd, *J* = 10.3, 9.0 Hz, 1H), 5.78 – 5.71 (m, 2H), 5.40 (dd, *J* = 10.3, 3.4 Hz, 1H), 5.24 (dd, *J* = 10.3, 3.7 Hz, 1H), 5.13 (d, *J* = 3.8 Hz, 1H), 4.92 (d, *J* = 7.9 Hz, 1H), 4.59 (dd, *J* = 12.1, 2.0 Hz, 1H), 4.53 (dd, *J* = 12.1, 4.2 Hz, 1H), 4.22 (dd, *J* = 10.1, 9.0 Hz, 1H), 4.13 (ddd, *J* = 10.1, 4.2, 1.9 Hz, 1H), 3.94 – 3.89 (m, 1H), 3.84 (dd, *J* = 11.2, 6.3 Hz, 1H), 3.76 (dd, *J* = 11.3, 7.1 Hz, 1H), 3.38 (s, 3H); ^{13}C NMR (126 MHz, CDCl$_3$) δ 166.1, 166.0, 165.7, 165.6, 165.4, 165.4, 164.9, 133.6, 133.6, 133.5, 133.5, 133.4, 133.3, 133.2, 130.1, 130.1, 130.0, 130.0, 129.9, 129.9, 129.9, 129.8, 129.8, 129.7, 129.7, 129.7, 129.7, 129.5, 129.2, 128.9, 128.8, 128.7, 128.7, 128.6, 128.6, 128.5, 128.5, 128.4, 128.4, 128.3, 128.3, 128.2, 101.2, 97.0, 76.4, 72.0, 72.0, 71.4, 70.5, 70.0, 68.4, 67.6, 62.5, 61.2, 55.6; HRMS: [M+NH$_4$]$^+$ calcd for $C_{62}H_{52}O_{18}NH_4$ 1102.34919, found 1102.34951.

Disaccharide D1A3



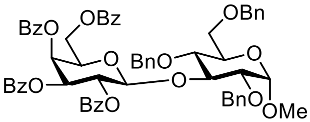
According to the general procedure **I** from D1 and A3. Yield: 80 mg, 99 µmol, 99%, α:β <1:20. ^{1}H NMR (400 MHz, CDCl$_3$) δ 8.05 – 7.94 (m, 6H), 7.83 – 7.77 (m, 2H), 7.63 – 7.48 (m, 5H), 7.47 – 7.35 (m, 7H), 7.34 – 7.28 (m, 2H), 7.28 – 7.21 (m, 4H), 6.01 (dd, *J* = 3.4, 1.1 Hz, 1H), 5.83 (dd, *J* = 10.4, 7.8 Hz, 1H), 5.63 (dd, *J* = 10.4, 3.4 Hz, 1H), 5.19 (d, *J* = 10.6 Hz, 1H), 5.02 (d, *J* = 7.9 Hz, 1H), 4.73 – 4.59 (m, 2H), 4.39 (dd, *J* = 11.0, 7.4 Hz, 1H), 4.31 (ddd, *J* = 7.2, 5.9, 1.2 Hz, 1H), 4.05 (ddd, *J* = 11.4, 8.5, 5.2 Hz, 1H), 3.80 (ddd, *J* = 11.7, 4.9, 1.7 Hz, 1H), 3.33 – 3.19 (m, 2H), 3.05 (t, *J* = 8.9 Hz, 1H), 2.03 – 1.93 (m, 1H), 1.48 (tdd, *J* = 12.8, 11.4, 4.9 Hz, 1H), 1.27 (d, *J* = 6.1 Hz, 3H); ^{13}C NMR (101 MHz, CDCl$_3$) δ 166.1, 165.7, 165.6, 165.3, 138.9, 133.6, 133.5, 133.4, 130.0, 129.9, 129.9, 129.7, 129.5, 129.2, 128.9, 128.8, 128.6, 128.6, 128.5, 128.4, 128.4, 128.3, 127.7, 98.7, 82.5, 79.9, 76.0, 75.2, 71.9, 71.3, 70.4, 68.1, 64.9, 61.8, 31.1, 18.6; HRMS: [M+NH$_4$]$^+$ calcd for $C_{47}H_{44}O_{12}NH_4$ 818.31710, found 818.31713.

Disaccharide D1A4



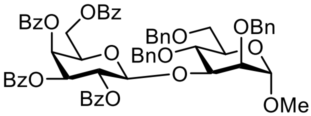
According to the general procedure **I** from D1 and A4. Yield: 81 mg, 100 µmol, 100%, α:β = 1:10. Data for the β-anomer: ^{1}H NMR (400 MHz, CDCl$_3$) δ 8.15 – 8.10 (m, 2H), 8.02 – 7.97 (m, 2H), 7.97 – 7.90 (m, 2H), 7.87 – 7.81 (m, 2H), 7.80 – 7.73 (m, 2H), 7.61 – 7.33 (m, 15H), 7.28 – 7.14 (m, 5H), 5.85 (dd, *J* = 3.4, 1.1 Hz, 1H), 5.62 (dd, *J* = 10.4, 7.7 Hz, 1H), 5.51 (dd, *J* = 10.4, 3.4 Hz, 1H), 4.96 (t, *J* = 9.2 Hz, 1H), 4.92 (d, *J* = 7.9 Hz, 1H), 4.18 (dd, *J* = 10.9, 6.0 Hz, 1H), 4.06 (dddd, *J* = 20.4, 9.1, 6.0, 2.5 Hz, 2H), 3.94 (dd, *J* = 10.9, 7.4 Hz, 1H), 3.89 (ddd, *J* = 11.9, 5.3, 2.0 Hz, 1H), 3.49 – 3.44 (m, 1H), 3.39 (td, *J* = 12.3, 2.2 Hz, 1H), 2.03 – 1.90 (m, 1H), 1.78 – 1.65 (m, 2H), 1.25 (d, *J* = 6.2 Hz, 3H); ^{13}C NMR (101 MHz, $CDCl_3$) δ 165.8, 165.6, 165.4, 164.9, 133.5, 133.4, 133.3, 133.2, 133.1, 130.3, 129.9, 129.8, 129.8, 129.7, 129.7, 129.6, 129.4, 128.9, 128.8, 128.6, 128.6, 128.6, 128.5, 128.4, 128.4, 128.3, 128.2, 128.2, 128.0, 100.3, 78.8, 75.7, 75.1, 71.8, 71.0, 70.1, 67.7, 65.2, 61.3, 31.7, 18.2; diagnostic peaks for the α-anomer: ^{1}H NMR (400 MHz, $CDCl_3$) δ 6.03 (dd, *J* = 3.4, 1.3 Hz, 1H), 5.89 (dd, *J* = 10.9, 3.4 Hz, 1H), 4.76 (t, *J* = 6.4 Hz, 1H), 4.43 (dd, *J* = 11.4, 4.7 Hz, 1H), 2.19 (dd, *J* = 12.8, 5.3 Hz, 1H), 1.13 (d, *J* = 6.2 Hz, 3H); ^{13}C NMR (101 MHz, $CDCl_3$) δ 98.3, 77.4, 76.8, 68.2, 63.0, 32.6; HRMS: $[M+NH_4]^+$ calcd for $C_{47}H_{42}O_{13}NH_4$ 832.29637, found 832.29592.

Disaccharide D1A5



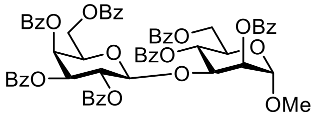
According to the general procedure **I** from D1 and A5. Yield: 104 mg, 100 μmol, 100%, α:β <1:20. ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.01 (td, *J* = 8.6, 1.4 Hz, 4H), 7.90 (dd, *J* = 8.3, 1.4 Hz, 2H), 7.81 – 7.76 (m, 2H), 7.55 – 7.46 (m, 3H), 7.43 – 7.30 (m, 10H), 7.29 – 7.19 (m, 11H), 7.10 – 7.04 (m, 2H), 6.01 (dd, *J* = 3.5, 1.1 Hz, 1H), 5.88 (dd, *J* = 10.5, 8.0 Hz, 1H), 5.69 (dd, *J* = 10.5, 3.5 Hz, 1H), 5.51 (d, *J* = 8.0 Hz, 1H), 5.29 (d, *J* = 10.5 Hz, 1H), 4.67 – 4.53 (m, 4H), 4.49 – 4.43 (m, 2H), 4.41 – 4.28 (m, 3H), 4.18 (d, *J* = 12.3 Hz, 1H), 3.73 – 3.55 (m, 4H), 3.37 (dd, *J* = 9.6, 3.5 Hz, 1H), 3.26 (s, 3H); ^{13}C NMR (101 MHz, $CDCl_3$) δ 166.0, 165.7, 165.5, 165.4, 138.7, 138.0, 138.0, 133.4, 133.4, 133.3, 133.2, 130.0, 129.9, 129.8, 129.5, 129.5, 129.1, 128.9, 128.6, 128.6, 128.5, 128.4, 128.3, 128.3, 128.1, 128.1, 128.1, 127.9, 127.8, 127.7, 101.1, 97.9, 80.9, 78.7, 75.4, 75.0, 73.9, 73.6, 71.8, 71.0, 70.7, 69.7, 68.5, 68.2, 61.6, 55.1; HRMS: $[M+NH_4]^+$ calcd for $C_{62}H_{58}O_{15}NH_4$ 1060.41140, found 1060.41118.

Disaccharide D1A6



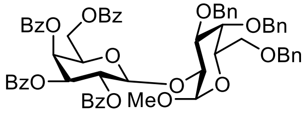
According to the general procedure **I** from D1 and A6. Yield: 96 mg, 92 μmol, 92%, α:β <1:20. ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.00 (ddd, *J* = 8.5, 3.6, 1.4 Hz, 4H), 7.92 – 7.87 (m, 2H), 7.80 – 7.74 (m, 2H), 7.60 – 7.50 (m, 2H), 7.48 – 7.13 (m, 23H), 7.03 (dd, *J* = 6.8, 2.7 Hz, 2H), 5.97 (dd, *J* = 3.5, 1.1 Hz, 1H), 5.90 (dd, *J* = 10.5, 7.9 Hz, 1H), 5.60 (dd, *J* = 10.4, 3.4 Hz, 1H), 5.12 (d, *J* = 10.9 Hz, 1H), 4.99 (d, *J* = 7.9 Hz, 1H), 4.67 (d, *J* = 2.1 Hz, 1H), 4.62 (d, *J* = 12.1 Hz, 1H), 4.56 – 4.47 (m, 3H), 4.42 – 4.28 (m, 4H), 4.25 – 4.18 (m, 1H), 4.01 – 3.91 (m, 1H), 3.77 – 3.70 (m, 4H), 3.26 (s, 3H); ^{13}C NMR (101 MHz, $CDCl_3$) δ 166.0, 165.7, 165.6, 165.2, 138.9, 138.5, 138.1, 133.6, 133.4, 133.3, 130.0, 129.9, 129.9, 129.8, 129.5, 129.3, 129.1, 128.8, 128.7, 128.5, 128.5, 128.4, 128.4, 128.3, 128.2, 128.1, 127.9, 127.8, 127.5, 127.5, 99.5, 98.8, 79.1, 75.6, 74.7, 73.7, 73.4, 72.9, 72.0, 71.9, 71.4, 70.4, 69.4, 68.1, 61.7, 54.8; HRMS: [M+NH$_4$]$^+$ calcd for C$_{62}$H$_{58}$O$_{15}$NH$_4$ 1060.41140, found 1060.41145.

Disaccharide D1A7



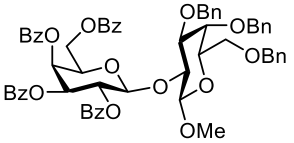
According to the general procedure **I** from D1 and A7. Yield: 86 mg, 79 µmol, 79%, α:β = 1:1. Data reported for a 1:1 mixture of anomers: ^{1}H NMR (400 MHz, CDCl$_3$) δ 8.24 – 8.21 (m, 2H), 8.19 – 8.13 (m, 3H), 8.11 – 7.97 (m, 12H), 7.75 – 7.71 (m, 2H), 7.70 – 7.67 (m, 2H), 7.66 – 7.60 (m, 6H), 7.59 – 7.50 (m, 9H), 7.48 – 7.40 (m, 12H), 7.38 – 7.29 (m, 13H), 7.22 – 7.05 (m, 13H), 6.02 (dd, *J* = 3.4, 1.4 Hz, 1H), 5.92 – 5.84 (m, 3H), 5.79 (dd, *J* = 10.1, 3.3 Hz, 1H), 5.72 (dd, *J* = 3.3, 1.8 Hz, 1H), 5.64 – 5.59 (m, 3H), 5.47 (dd, *J* = 10.3, 3.3 Hz, 1H), 5.37 (dd, *J* = 3.5, 1.9 Hz, 1H), 5.02 – 4.96 (m, 2H), 4.93 (dd, *J* = 6.9, 1.8 Hz, 2H), 4.69 – 4.61 (m, 4H), 4.60 – 4.53 (m, 2H), 4.45 (dd, *J* = 12.1, 4.7 Hz, 1H), 4.41 – 4.31 (m, 3H), 4.29 – 4.22 (m, 2H), 4.17 (ddd, *J* = 10.1, 5.2, 3.0 Hz, 1H), 3.97 (dd, *J* = 10.9, 6.9 Hz, 1H), 3.46 (s, 3H), 3.32 (s, 3H); ^{13}C NMR (101 MHz, CDCl$_3$) δ 166.3, 166.2, 166.2, 166.1, 166.0, 165.6, 165.6, 165.5, 165.4, 165.1, 164.9, 164.5, 133.6, 133.6, 133.4, 133.4, 133.3, 133.2, 133.1, 133.0, 132.8, 130.3, 130.0, 130.0, 129.9, 129.9, 129.8, 129.8, 129.8, 129.7, 129.6, 129.5, 129.5, 129.4, 129.2, 128.8, 128.8, 128.7, 128.7, 128.6, 128.5, 128.4, 128.4, 128.4, 128.3, 128.3, 128.2, 128.1, 128.0, 99.6, 98.6, 98.5, 98.3, 74.4, 74.0, 72.0, 71.8, 71.1, 70.0, 69.4, 69.4, 69.0, 68.9, 68.9, 68.4, 68.1, 68.0, 67.7, 67.5, 63.3, 63.1, 61.6, 55.6, 55.3; HRMS: [M+NH$_4$]$^+$ calcd for C$_{62}$H$_{52}$O$_{18}$NH$_4$ 1102.34919, found 1102.34904.

Disaccharide D1A8



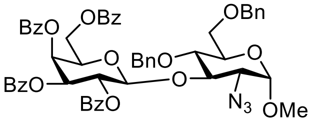
According to the general procedure **I** from D1 and A8. Yield: 90 mg, 86 µmol, 86%, α:β <1:20. ^{1}H NMR (400 MHz, CDCl$_3$) δ 8.14 – 8.09 (m, 2H), 8.02 – 7.97 (m, 2H), 7.87 – 7.82 (m, 2H), 7.81 – 7.74 (m, 2H), 7.64 – 7.57 (m, 1H), 7.54 – 7.45 (m, 3H), 7.43 – 7.35 (m, 4H), 7.34 – 7.15 (m, 21H), 7.08 – 7.03 (m, 2H), 6.04 – 5.95 (m, 2H), 5.59 (dd, *J* = 10.3, 3.5 Hz, 1H), 5.13 (d, *J* = 8.0 Hz, 1H), 5.07 (d, *J* = 3.6 Hz, 1H), 4.84 (d, *J* = 11.5 Hz, 1H), 4.61 (dd, *J* = 11.3, 6.7 Hz, 1H), 4.46 (dt, *J* = 11.6, 5.7 Hz, 4H), 4.41 – 4.32 (m, 3H), 4.28 (dd, *J* = 10.2, 3.6 Hz, 1H), 3.91 – 3.82 (m, 2H), 3.76 (dd, *J* = 3.1, 1.3 Hz, 1H), 3.51 (dd, *J* = 6.4, 1.9 Hz, 2H), 3.39 (s, 3H); ^{13}C NMR (101 MHz, CDCl$_3$) δ 166.1, 165.7, 165.7, 165.3, 138.7, 138.1, 133.7, 133.4, 133.3, 133.1, 130.2, 129.9, 129.8, 129.4, 129.4, 129.1, 128.8, 128.7, 128.6, 128.6, 128.5, 128.4, 128.4, 128.3, 128.3, 128.2, 127.8, 127.7, 127.3, 127.2, 103.3, 99.8, 80.0, 77.2, 76.0, 74.9, 73.5, 73.3, 72.2, 71.6, 69.9, 69.2, 69.1, 68.3, 62.4, 55.6; HRMS: [M+NH$_4$]$^+$ calcd for C$_{62}$H$_{58}$O$_{15}$NH$_4$ 1060.41140, found 1060.41120.

Disaccharide D1A9



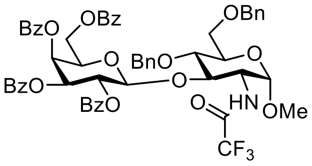
According to the general procedure **I** from D1 and A9. Yield: 94 mg, 90 µmol, 90%, α:β <1:20. ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.15 – 8.08 (m, 2H), 8.03 – 7.98 (m, 2H), 7.89 – 7.84 (m, 2H), 7.84 – 7.78 (m, 2H), 7.65 – 7.58 (m, 1H), 7.57 – 7.45 (m, 3H), 7.44 – 7.36 (m, 4H), 7.34 – 7.15 (m, 19H), 7.07 (ddd, *J* = 5.7, 2.7, 1.5 Hz, 2H), 6.03 (dd, *J* = 3.5, 1.1 Hz, 1H), 5.89 (dd, *J* = 10.4, 8.1 Hz, 1H), 5.55 (dd, *J* = 10.4, 3.4 Hz, 1H), 5.34 (d, *J* = 8.1 Hz, 1H), 4.72 (dd, *J* = 10.9, 5.9 Hz, 1H), 4.55 – 4.45 (m, 3H), 4.44 – 4.31 (m, 6H), 4.24 (d, *J* = 12.0 Hz, 1H), 4.07 (dd, *J* = 9.7, 7.6 Hz, 1H), 3.59 (d, *J* = 2.8 Hz, 1H), 3.53 (s, 4H), 3.49 – 3.40 (m, 3H); ^{13}C NMR (101 MHz, $CDCl_3$) δ 166.2, 165.7, 165.5, 138.6, 138.3, 137.9, 133.6, 133.4, 133.3, 133.0, 130.2, 129.9, 129.9, 129.8, 129.7, 129.5, 129.2, 129.0, 128.7, 128.6, 128.5, 128.4, 128.4, 128.3, 128.2, 128.1, 128.0, 127.9, 127.9, 127.6, 127.5, 104.0, 102.2, 80.7, 80.3, 73.9, 73.5, 73.4, 73.2, 72.3, 71.7, 70.9, 68.9, 68.3, 62.2, 57.3; HRMS: $[M+NH_4]^+$ calcd for $C_{62}H_{58}O_{15}NH_4$ 1060.41140, found 1060.41110.

Disaccharide D1A10



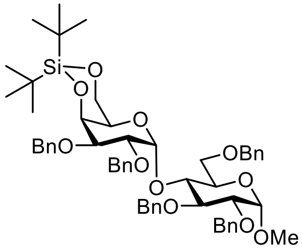
According to the general procedure **I** from D1 and A10. Yield: Yield: 88 mg, 90 µmol, 90%, α:β <1:20. ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.07 – 7.97 (m, 4H), 7.95 – 7.90 (m, 2H), 7.82 – 7.75 (m, 2H), 7.57 – 7.48 (m, 4H), 7.41 (dt, *J* = 10.1, 7.6 Hz, 6H), 7.35 – 7.27 (m, 9H), 7.26 – 7.18 (m, 6H), 5.99 (d, *J* = 3.4 Hz, 1H), 5.84 (dd, *J* = 10.4, 7.9 Hz, 1H), 5.65 (dd, *J* = 10.4, 3.4 Hz, 1H), 5.28 (d, *J* = 7.9 Hz, 1H), 5.23 (d, *J* = 10.7 Hz, 1H), 4.79 (d, *J* = 3.5 Hz, 1H), 4.60 – 4.51 (m, 3H), 4.48 (d, *J* = 12.1 Hz, 1H), 4.37 – 4.24 (m, 3H), 3.78 – 3.71 (m, 2H), 3.70 – 3.60 (m, 2H), 3.39 (s, 3H), 3.26 (dd, *J* = 10.2, 3.5 Hz, 1H); ^{13}C NMR (101 MHz, $CDCl_3$) δ 166.0, 165.6, 165.6, 165.5, 138.5, 137.9, 133.5, 133.4, 133.4, 133.3, 129.9, 129.9, 129.9, 129.5, 129.4, 129.1, 128.9, 128.7, 128.5, 128.5, 128.5, 128.4, 128.0, 127.9, 127.7, 101.1, 98.5, 78.1, 75.6, 75.1, 73.6, 71.8, 71.3, 70.4, 70.3, 68.4, 68.1, 63.6, 61.5, 55.3; HRMS: $[M+NH_4]^+$ calcd for $C_{55}H_{51}N_3O_{14}NH_4$ 995.37093, found 995.37058.

Disaccharide D1A11



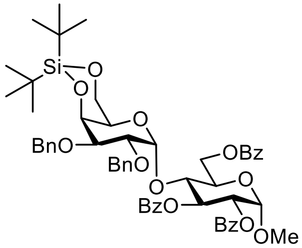
According to the general procedure **I** from D1 and A10. Yield: 80 mg, 76 µmol, 76%, α:β <1:20. ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.02 (dt, *J* = 8.4, 1.6 Hz, 2H), 7.95 – 7.87 (m, 4H), 7.77 – 7.71 (m, 2H), 7.61 – 7.25 (m, 19H), 7.23 – 7.15 (m, 5H), 6.59 – 6.48 (m, 1H), 5.98 (dd, *J* = 3.5, 1.0 Hz, 1H), 5.80 (dd, *J* = 10.4, 7.8 Hz, 1H), 5.52 (dd, *J* = 10.4, 3.4 Hz, 1H), 5.20 (d, *J* = 10.9 Hz, 1H), 5.03 (d, *J* = 7.9 Hz, 1H), 4.66 – 4.56 (m, 4H), 4.50 (d, *J* = 12.1 Hz, 1H), 4.36 – 4.22 (m, 4H), 3.78 – 3.70 (m, 3H), 3.68 – 3.63 (m, 1H), 3.32 (s, 3H); ^{13}C NMR (101 MHz, CDCl$_3$) δ 166.1, 165.8, 165.6, 165.6, 138.4, 138.0, 133.6, 133.5, 133.4, 133.4, 130.0, 130.0, 129.9, 129.9, 129.8, 129.5, 129.1, 129.0, 128.7, 128.6, 128.5, 128.5, 128.4, 128.4, 128.3, 127.9, 127.9, 127.8, 127.8, 100.8, 97.8, 77.3, 75.7, 75.0, 73.6, 71.8, 71.3, 70.8, 70.3, 68.5, 67.9, 61.4, 55.2, 53.3; HRMS: [M+NH$_4$]$^+$ calcd for C$_{57}$H$_{52}$F$_3$NO$_{15}$NH$_4$ 1065.36273, found 1065.36259.

Disaccharide D2A1



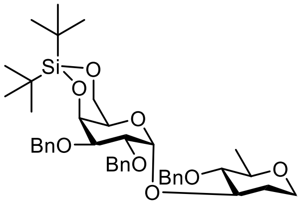
According to the general procedure **I** from D2 and A1. Yield: 95 mg, 100 μmol, 100%, α:β >20:1. ^{1}H NMR (400 MHz, CDCl$_3$) δ 7.50 – 7.15 (m, 25H), 5.75 (d, *J* = 3.9 Hz, 1H), 5.04 (d, *J* = 11.2 Hz, 1H), 4.78 (dd, *J* = 11.7, 7.9 Hz, 3H), 4.73 – 4.67 (m, 2H), 4.66 – 4.57 (m, 3H), 4.52 (d, *J* = 12.1 Hz, 1H), 4.44 (d, *J* = 12.2 Hz, 1H), 4.37 – 4.32 (m, 1H), 4.10 (dd, *J* = 9.5, 8.5 Hz, 1H), 4.04 – 3.95 (m, 2H), 3.94 – 3.87 (m, 2H), 3.78 (dd, *J* = 12.4, 2.0 Hz, 1H), 3.75 – 3.66 (m, 2H), 3.59 (ddd, *J* = 12.8, 10.1, 2.8 Hz, 2H), 3.50 (d, *J* = 5.2 Hz, 1H), 3.46 – 3.37 (m, 4H), 1.08 (s, 9H), 1.01 (s, 9H); ^{13}C NMR (101 MHz, CDCl$_3$) δ 139.0, 138.7, 138.3, 138.1, 138.0, 128.5, 128.5, 128.5, 128.5, 128.4, 128.4, 128.3, 128.3, 128.3, 128.1, 127.8, 127.8, 127.7, 127.6, 127.6, 127.3, 127.2, 97.9, 96.8, 82.2, 80.4, 77.8, 74.5, 74.0, 73.6, 73.6, 73.6, 71.1, 71.0, 70.9, 69.4, 69.2, 67.7, 66.9, 55.2, 27.7, 27.4, 23.4, 20.8; HRMS: [M+NH$_4$]$^+$ calcd for C$_{56}$H$_{70}$O$_{11}$SiNH$_4$ 964.50256, found 964.50209.

Disaccharide D2A2



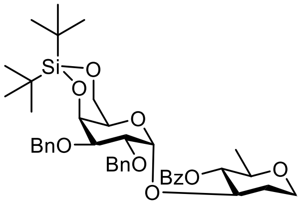
According to the general procedure **I** from D2 and A2. Yield: 99 mg, 100 μmol, 100%, α:β >20:1. ^{1}H NMR (400 MHz, CDCl$_3$) δ 8.10 – 8.05 (m, 2H), 8.00 (dt, *J* = 8.4, 1.2 Hz, 4H), 7.63 – 7.57 (m, 1H), 7.53 – 7.44 (m, 5H), 7.43 – 7.26 (m, 10H), 7.11 (s, 5H), 6.19 (dd, *J* = 10.0, 8.5 Hz, 1H), 5.22 – 5.09 (m, 3H), 4.70 – 4.58 (m, 3H), 4.51 (dd, *J* = 12.0, 3.9 Hz, 1H), 4.44 – 4.36 (m, 2H), 4.33 – 4.23 (m, 2H), 4.21 (d, *J* = 11.9 Hz, 1H), 3.92 (d, *J* = 1.8 Hz, 2H), 3.83 – 3.71 (m, 2H), 3.57 (q, *J* = 1.5 Hz, 1H), 3.41 (s, 3H), 0.97 (s, 9H), 0.78 (s, 9H); ^{13}C NMR (101 MHz, CDCl$_3$) δ 166.4, 166.2, 165.6, 139.0, 138.1, 133.5, 133.4, 133.1, 130.1, 130.0, 130.0, 130.0, 129.9, 129.8, 129.7, 129.7, 129.2, 128.7, 128.6, 128.5, 128.5, 128.5, 128.4, 128.3, 127.7, 127.5, 98.5, 96.9, 77.6, 73.2, 72.9, 72.8, 72.6, 72.5, 71.2, 71.1, 68.5, 68.4, 67.0, 63.5, 55.4, 27.7, 27.2, 23.4, 20.6; HRMS: [M+NH$_4$]$^+$ calcd for C$_{56}$H$_{64}$O$_{14}$SiNH$_4$ 1006.44036, found 1006.44041.

Disaccharide D2A3



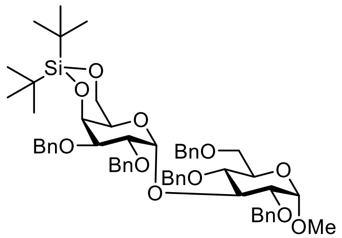
According to the general procedure **I** from D2 and A3. Yield: 71 mg, 100 µmol, 100%, α:β >20:1. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.46 – 7.39 (m, 2H), 7.34 – 7.28 (m, 2H), 7.27 – 7.22 (m, 8H), 7.21 – 7.17 (m, 3H), 5.13 (d, *J* = 11.4 Hz, 1H), 5.07 (d, *J* = 3.6 Hz, 1H), 4.79 (dd, *J* = 12.0, 5.5 Hz, 2H), 4.69 (dd, *J* = 14.4, 12.0 Hz, 2H), 4.61 – 4.54 (m, 2H), 4.23 (dd, *J* = 12.4, 2.1 Hz, 1H), 4.06 (dd, *J* = 12.4, 1.7 Hz, 1H), 3.99 (dd, *J* = 10.2, 3.6 Hz, 1H), 3.88 (dd, *J* = 10.2, 2.9 Hz, 1H), 3.82 (ddd, *J* = 11.8, 4.9, 1.6 Hz, 1H), 3.78 – 3.68 (m, 2H), 3.34 (td, *J* = 12.2, 2.0 Hz, 1H), 3.26 (dq, *J* = 9.2, 6.1 Hz, 1H), 3.03 (t, *J* = 8.9 Hz, 1H), 2.01 (ddt, *J* = 12.9, 5.3, 1.5 Hz, 1H), 1.74 – 1.62 (m, 1H), 1.22 (d, *J* = 6.1 Hz, 3H), 1.06 (s, 9H), 0.97 (s, 9H); ^{13}C NMR (101 MHz, $CDCl_3$) δ 139.0, 138.5, 128.4, 128.4, 128.3, 128.0, 127.6, 127.6, 127.6, 127.4, 100.3, 83.5, 82.0, 77.6, 76.2, 74.9, 74.0, 73.8, 71.1, 70.7, 67.8, 67.2, 65.3, 33.8, 27.8, 27.4, 23.6, 20.8, 18.7; HRMS: $[M+NH_4]^+$ calcd for $C_{41}H_{56}O_8SiNH_4$ 722.40827, found 722.40806.

Disaccharide D2A4



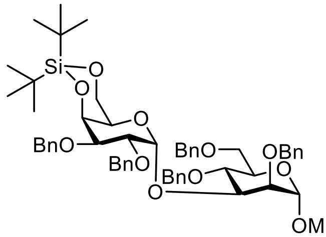
According to the general procedure **I** from D2 and A4. Yield: 72 mg, 100 µmol, 100%, α:β >20:1. ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.08 – 7.99 (m, 2H), 7.55 – 7.47 (m, 1H), 7.40 – 7.27 (m, 8H), 7.17 – 7.11 (m, 3H), 7.01 – 6.94 (m, 2H), 5.02 (t, *J* = 9.3 Hz, 1H), 4.88 (t, *J* = 1.5 Hz, 1H), 4.57 (d, *J* = 12.0 Hz, 1H), 4.53 (d, *J* = 11.9 Hz, 1H), 4.43 (t, *J* = 1.3 Hz, 1H), 4.31 (d, *J* = 12.2 Hz, 1H), 4.23 – 4.15 (m, 2H), 4.05 (dd, *J* = 12.4, 1.7 Hz, 1H), 3.99 – 3.93 (m, 1H), 3.89 (ddd, *J* = 11.3, 9.1, 5.2 Hz, 1H), 3.75 (t, *J* = 1.4 Hz, 2H), 3.70 (q, *J* = 1.6 Hz, 1H), 3.54 – 3.39 (m, 2H), 2.03 (ddt, *J* = 13.0, 4.1, 1.9 Hz, 1H), 1.86 (ddt, *J* = 12.8, 11.3, 6.3 Hz, 1H), 1.23 (d, *J* = 6.2 Hz, 3H), 1.02 (s, 9H), 0.89 (s, 9H); ^{13}C NMR (101 MHz, $CDCl_3$) δ 165.7, 139.2, 138.6, 133.0, 130.4, 129.9, 128.4, 128.3, 128.1, 128.1, 127.7, 127.4, 127.3, 99.7, 78.2, 77.8, 76.6, 75.3, 73.3, 72.8, 71.4, 71.1, 68.0, 67.2, 65.5, 33.3, 27.8, 27.3, 23.5, 20.7, 18.2; HRMS: $[M+NH_4]^+$ calcd for $C_{41}H_{54}O_9SiNH_4$ 736.38754, found 736.38728.

Disaccharide D2A5



According to the general procedure **II** from D2 and A5. Yield: 93 mg, 98 µmol, 98%, α:β >20:1. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.46 – 7.42 (m, 2H), 7.36 – 7.19 (m, 17H), 7.18 – 7.08 (m, 5H), 7.04 – 6.98 (m, 2H), 5.46 (d, *J* = 3.6 Hz, 1H), 4.93 (d, *J* = 11.6 Hz, 1H), 4.81 (d, *J* = 11.6 Hz, 1H), 4.76 – 4.71 (m, 2H), 4.65 (dd, *J* = 11.7, 4.4 Hz, 2H), 4.58 (d, *J* = 12.0 Hz, 1H), 4.52 (d, *J* = 10.8 Hz, 1H), 4.42 (d, *J* = 12.0 Hz, 1H), 4.38 (dd, *J* = 11.2, 4.2 Hz, 2H), 4.26 (dd, *J* = 9.8, 8.7 Hz, 1H), 4.22 (dd, *J* = 3.0, 1.1 Hz, 1H), 3.99 – 3.94 (m, 2H), 3.91 (dd, *J* = 12.6, 1.6 Hz, 1H), 3.86 (dd, *J* = 10.1, 2.9 Hz, 1H), 3.78 (dd, *J* = 10.0, 8.7 Hz, 1H), 3.72 – 3.68 (m, 1H), 3.65 (dd, *J* = 10.6, 3.3 Hz, 1H), 3.61 – 3.50 (m, 3H), 3.34 (s, 3H), 1.00 (s, 9H), 0.93 (s, 9H); ^{13}C NMR (101 MHz, $CDCl_3$) δ 139.1, 138.4, 138.3, 138.0, 137.9, 128.6, 128.5, 128.5, 128.5, 128.3, 128.2, 128.1, 128.0, 127.8, 127.8, 127.6, 127.5, 127.4, 127.1, 97.9, 97.5, 79.1, 79.0, 78.1, 74.5, 74.1, 73.7, 73.6, 73.5, 73.1, 70.8, 70.6, 69.9, 68.5, 67.1, 66.9, 55.1, 27.8, 27.4, 23.5, 20.7; HRMS: $[M+NH_4]^+$ calcd for $C_{56}H_{70}O_{11}SiNH_4$ 964.50256, found 964.50252.

Disaccharide D2A6



According to the general procedure **II** from D2 and A6. Yield: 87 mg, 92 µmol, 92%, α:β >20:1.^{1}H NMR (400 MHz, $CDCl_3$) δ 7.52 – 6.86 (m, 25H), 5.09 (d, *J* = 11.4 Hz, 1H), 5.05 (d, *J* = 3.5 Hz, 1H), 4.84 (d, *J* = 1.9 Hz, 1H), 4.78 – 4.68 (m, 4H), 4.66 – 4.56 (m, 2H), 4.50 (d, *J* = 12.1 Hz, 1H), 4.40 (dd, *J* = 11.9, 10.2 Hz, 2H), 4.30 (d, *J* = 2.9 Hz, 1H), 4.06 (dd, *J* = 9.2, 3.2 Hz, 1H), 3.97 – 3.89 (m, 3H), 3.88 – 3.80 (m, 2H), 3.75 (ddd, *J* = 12.9, 5.2, 2.9 Hz, 1H), 3.72 – 3.65 (m, 3H), 3.42 (s, 1H), 3.36 (s, 3H), 1.02 (s, 9H), 0.93 (s, 9H); ^{13}C NMR (101 MHz, $CDCl_3$) δ 139.1, 139.1, 138.6, 138.5, 138.4, 128.4, 128.4, 128.3, 128.2, 127.7, 127.6, 127.6, 127.5, 127.5, 127.4, 127.3, 100.4, 97.7, 79.5, 77.4, 77.4, 74.6, 74.6, 74.0, 73.5, 73.4, 71.9, 71.3, 71.0, 70.7, 69.5, 67.7, 67.2, 55.0, 27.8, 27.4, 23.5, 20.7; HRMS: $[M+NH_4]^+$ calcd for $C_{56}H_{70}O_{11}SiNH_4$ 964.50256, found 964.50245.

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Samenvatting in het Nederlands

De synthese van koolhydraten, ook wel suikers genoemd, is moeilijker dan de synthese van andere biomoleculen zoals peptiden of oligonucleotiden. Wanneer twee suikers aan elkaar gekoppeld worden, wordt er een nieuw stereocentrum geïntroduceerd. Terwijl 1,2-*trans* glycosidische bindingen betrouwbaar gesynthetiseerd kunnen worden met behulp van sturing door een ester of amide groep op de naburige koolstof in de ring, is er voor de selectieve vorming van *1,2-cis* glycosidische bindingen nog geen universeel toepasbare techniek.

Bij een typische glycosyleringsreactie wordt een donor geactiveerd om zo een (verscheidenheid aan) elektrofiele intermedairen te vormen, die kunnen reageren met een nucleofiele acceptor volgens een reactiemechanisme met zowel S_N1- als S_N2-karakter. Aan de S_N1-kant van het spectrum nemen oxocarbeniumionen deel aan het mechanisme, terwijl covalente intermedairen fungeren als glycosylerend agens aan de S_N2-kant. De uitkomst van een glycosyleringsreactie wordt beïnvloed door de eigenschappen van zowel de donor als de acceptor, en kan ook worden beïnvloed door externe factoren.

Het doel van dit proefschrift is om systematisch te onderzoeken hoe veranderingen in stereochemie en beschermende groepen op de donor en acceptor het mechanisme en de uitkomst van glycosyleringsreacties beïnvloeden. Dit onderzoek zal een meer rationeel ontwerp van oligosaccharide syntheseroutes mogelijk maken.

Hoofdstuk 1 introduceert de uitdagingen in de chemische synthese van koolhydraten en presenteert enkele oplossingen die gevonden zijn voor stereoselective glycosyleringsreacties. Het SN1/SN2-continuüm van de glycosyleringsreactiemechanisme wordt beschreven, evenals methoden om beide uiteinden van het spectrum te onderzoeken. Tenslotte wordt de rol van de reactiviteit van de acceptor in de uitkomst van de glycosyleringsreactie besproken.

In **Hoofdstuk 2** wordt de invloed van de configuratie van de donor op de stereochemische uitkomst van S_N1 reacties onderzocht door middel van een combinatie van computationele en experimentele chemie. Hiervoor zijn eerst alle acht diastereomere pyranosyl donoren, beschermd met enkel benzyl groepen gesynthetiseerd, tezamen met hun 6-deoxy analogen. Vervolgens werd de conformationele voorkeur van de oxocarbenium ionen – en daarmee de verwachte uitkomst van de S_N1 reacties – berekend door de generatie van *conformational energy landscape* (CEL) platen. Tenslotte werden de reacties van de donoren met twee nucleofielen die reageren via een S_N1 mechanisme, namelijk TES-D en allyl-TMS, bestudeerd.

De stabiliteit van de conformeren die in de CEL-platen gevonden werd, kan verklaard worden door de "voorkeuren" van de substituenten om het oxocarbenium ion het meest te stabiliseren, danwel het minst te destabiliseren. Wanneer de C-3 of C-4 alkoxy groepen op een *pseudo*-axiale manier geplaatst zijn, dan is het oxocarbenium ion stabieler dan wanneer deze groepen *pseudo*-equatoriaal geplaatst zijn. Voor C-2 en C-5 heeft een *pseudo*-equatoriale oriëntatie de voorkeur. Wanneer alle vier de substituenten in de voorkeursoriëntaties kunnen worden geplaatst, zoals het geval is voor gulose/6-deoxygulose, heeft het ion een sterke voorkeur voor een enkele goed gedefiniëerde conformatie ($^4H_3$ half-stoel). Met drie van de vier substituenten optimaal georiënteerd, vertonen de ionen ook een sterke voorkeur voor die conformatie. Wanneer slechts twee substituenten in de voorkeursoriëntatie kunnen worden geplaatst, zijn de energieverschillen tussen de verschillende conformeren een stuk kleiner en kan het oxocarbenium ion meerdere conformaties aannemen. Een andere observatie is dat de voorkeuren voor 6-deoxy oxocarbeniumionen in de meeste gevallen sterk lijken op die van hun 6-O-benzyl-evenkniën, alhoewel de absolute energieverschillen verschillen. Dit blijkt ook uit de uitkomst van de glycosyleringsreacties.

In de reacties met TES-D, is de oriëntatie van de substituent van C-2 in de donor moleculen de belangrijkste factor voor de stereochemische uitkomst van de glycosyleringsreactie gebleken. Alle reacties waren zeer *1,2-cis* selectief. Dit is in overeenstemming met de voorspelde waarden van de CEL-platen, behalve voor talose en 6-deoxyglucose, waar een 1:1 mengsel wordt voorspeld en voor idose, waar α-selectiviteit werd voorspeld, maar volledige β-selectiviteit werd waargenomen.

Reacties met allyl-TMS gaven andere resultaten. Wanneer de C-2-groep van de donorglycosiden equatoriaal is, verloopt de reactie met volledige α-selectiviteit zoals bij TES-D. Wanneer de C-2-groep echter axiaal is geplaatst, verschuift selectiviteit van de reactie om meer van het 1,2-*trans* product te geven. Een mogelijke verklaring voor deze observatie zijn de sterische interacties tussen de substituenten en het inkomende nucleofiel, die aanval op de *cis*-zijde ongunstig maken. Volgens een Curtin-Hammett kinetisch scenario kan dan een aanval plaatsvinden op een oxocarbenium ion conformeer met hogere energie omdat dit een overgangstoestand met lagere energie oplevert.

In **Hoofdstuk 3** staan de mechanismes die verlopen via een covalent tussenproduct centraal. Variabele temperatuur (VT) NMR is gebruikt om de reactieve deeltjes te karakteriseren, die gevormd worden door activatie van de donoren. De waargenomen deeltjes waren ofwel een mengsel van α-triflaat en α-oxosulfoniumtriflaat, een mengsel van α-triflaat en α,β-oxosulfoniumtriflaten of een mengsel van α,β-oxosulfoniumtriflaten. β-Triflaten werden bij geen van de donoren waargenomen.

Vervolgens werden de geactiveerde donoren gekoppeld met vijf alcohol acceptoren, die door een toenemend aantal fluor-atomen (EtOH: 0, MFE: 1, DFE: 2, TFE: 3 en HFIP: 6), steeds minder nucleofiel zijn, om de relatie tussen de nucleofiliciteit van de acceptor en het mechanisme van de reactie te onderzoeken. In de reacties met EtOH, MFE, DFE en TFE blijkt vooral de configuratie van C-3 belangrijk te zijn voor de relatie tussen de reactiviteit van de acceptor en de stereochemische uitkomst van de glycosylering. Wanneer de substituent op C-3 equatoriaal is, wordt een duidelijke trend waargenomen waarbij meer nucleofiele acceptoren een hogere β-selectiviteit geven en minder nucleofiele acceptoren een hogere α-selectiviteit. Wanneer de C-3-groepen axiaal zijn, worden α:β-mengsels verkregen zonder duidelijke relatie tussen nucleofiliciteit en stereoselectiviteit. Een mogelijke mechanistische verklaring voor deze waarnemingen is dat voor de donoren met een equatoriaal georiënteerde C-3-groep, de meest reactieve acceptoren reageren met de stabielere covalente α-deeltjes, wat de β-producten oplevert, terwijl minder reactieve acceptoren alleen kunnen reageren met de meer reactieve β-deeltjes, wat leidt tot het α-product. Wanneer de substituent op C-3 axiaal is, is het reactiviteitsverschil tussen de covalente α- en β-deeltjes kleiner vanwege destabiliserende 1,3-diaxiale interacties tussen het axiale α-triflaat- en de C-3-groep. De S_N2-substitutie van het β-deeltje wordt ook belemmerd door de groep op C-3. Deze sterische interacties werken elkaar tegen, wat leidt tot een algehele slechte selectiviteit.

De glycosyleringen met HFIP waren allemaal volledig α-selectief, ongeacht de stereochemie van C-2 of C-3. Dit staat in contrast met de uitkomst van gerelateerde reacties met TES-D, een nucleofiel dat veel gebruikt is om S_N1-reactieroutes te karakteriseren, waarin hoge *1,2-cis* selectiviteit wordt gezien. Dit suggereert dat de glycosyleringen met zwakke O-nucleofielen via een ander mechanisme plaatsvinden dan nucleofiele additie aan een oxocarbenium ion.

In **Hoofdstuk 4** wordt een systeem beschreven om de structuur-reactiviteits relaties van een set van 60 acceptoren te bepalen, dat gebaseerd is op het gebruik van twee conformationeel vastgelegde glycosyl donoren. De stereochemische uitkomst van de glycosyleringsreacties met deze twee donoren is sterk afhankelijk van de nucleofiliciteit van de acceptor, zoals bepaald door middel van glycosyleringen met de EtOH, MFE, DFE, TFE en HFIP-modelacceptoren. De meest nucleofiele acceptoren reageren met volledige β-selectiviteit, terwijl het verminderen van de nucleofiliciteit van de acceptor geleidelijk leidt tot volledige α-selectiviteit. Deze reactiviteit-stereoselectiviteit relatie werd gebruikt om de reactiviteit van een groot aantal suikeracceptoren te bepalen. Door systematisch het beschermengroep patroon op D-glucose-, D-mannose-, D-galactose-, L-rhamnose- en L-fucose-acceptoren te variëren en hun reactiviteit te "meten", was het mogelijk om te bepalen welke structurele kenmerken de reactiviteit van de acceptor bepalen. Er werden ook twee soorten modelacceptoren geïntroduceerd. De eerste soort bestaat uit suikerachtige acceptoren, gebaseerd op 1,2,6-trideoxyglucose en 1,2,6-

trideoxygalactose, die alleen de "essentiële" substituenten bevatten, met verschillende patronen van beschermgroepen. De tweede soort modelacceptoren zijn C-2-OH-glycerolacceptoren met een cyclische beschermende groep op C-1 en C-3. Deze acceptoren lijken op suikeracceptoren omdat het secundaire alcoholen zijn, die geflankeerd worden door twee beschermde hydroxyl groepen. In tegenstelling tot suikeracceptoren zijn deze alcoholen niet chiraal, dus de stereochemische uitkomst van de glycosyleringsreacties wordt niet beïnvloed door diastereomere interacties. De resultaten van de glycosyleringsreacties laten zien dat zowel de configuratie van de acceptor als het patroon van de beschermgroepen op de acceptor een sleutelrol spelen bij het bepalen van de reactiviteit van de acceptor. Met betrekking tot de configuratie van de acceptor zijn equatoriale alcoholen reactiever dan axiale alcoholen. De oriëntatie van de functionele groep naast de nucleofiele alcohol is ook belangrijk, en alcoholen met alleen equatoriale buren zijn reactiever dan alcoholen die zich naast een axiale buur bevinden. Met betrekking tot het patroon van beschermgroepen zijn benzoyl-beschermde acceptoren minder reactief dan hun benzyl-beschermde tegenhangers. De grootte van dit effect hangt af van welke benzylgroep wordt vervangen door een benzoylgroep, aangezien het effect veel groter is wanneer een equatoriale benzylgroep naast de alcohol wordt vervangen door een benzoylgroep dan wanneer hetzelfde wordt gedaan met een naburige axiale benzylgroep.

Hoofdstuk 5 bouwt voort op hoofdstuk 4, door gebruik te maken van dezelfde methodologie die werd toegepast op benzyl/benzoyl-beschermde acceptoren om de invloed van de meest gebruikte *N*-beschermengroepen (azide, trichlooracetamide (TCA) en trifluoracetamide (TFA)) op de reactiviteit van acceptor te bepalen. De acceptoren die in deze studie werden gebruikt, waren C-4-OH glucosamine-acceptoren, aangezien de C-4-OH *N*-acetylglucosamine-acceptoren berucht zijn vanwege hun slechte nucleofiliciteit en C-3-OH glucosamine-acceptoren, om het effect van verschillende beschermgroepen naast de nucleofiele alcohol te onderzoeken. De C-4-OH en C-3-OH mannosamine-acceptoren werden toegevoegd om de invloed van de configuratie van het beschermde amine op de reactiviteit van de acceptor te bepalen. Net als bij de benzyl/benzoyl-beschermde acceptoren, zijn zowel de configuratie als de aard van de beschermende groepen belangrijk voor de reactiviteit van de acceptor. Voor zowel de glucosamine C-4-OH als de mannosamine acceptoren heeft de aard van de *N*-beschermende groep weinig invloed op de reactiviteit van de acceptoren, aangezien alle glycosyleringen binnen dezelfde acceptorreeks verliepen met vergelijkbare stereoselectiviteit en hoge opbrengst. Bij de glucosamine en mannosamine C-3-OH acceptoren werden vergelijkbare trends waargenomen als bij de acceptorreeks in hoofdstuk 4. De eerste observatie is dat een azide een deactiverend effect heeft dat vergelijkbaar is met dat van een O-benzoylgroep en dat gehalogeneerde acetamides een groter deactiverend effect hebben dan de azides, waarbij de trifluoracetamides meer deactiverend zijn dan de trichlooracetamides. De configuratie van het beschermde amine naast de alcohol bleek ook belangrijk te zijn voor de reactiviteit van de acceptor. Zoals waargenomen voor de alcohol beschermde acceptoren, is de C-3-OH-glucosazide-acceptor reactiever dan de C-3-OH-mannosazide-acceptor. In lijn met de resultaten van hoofdstuk 4, is het deactiverende effect van de *N*-beschermgroepen op equatoriale amines naast de nucleofiele alcohol veel groter dan het deactiverende effect van de *N*-beschermgroepen van de naburige axiale amines.

In **Hoofdstuk 6** wordt de kennis die in de hoofdstukken 2-5 is opgedaan toegepast op de synthese van de repeterende eenheid van een *Acinetobacter Baumannii* capsulair polysaccharide . *A. Baumannii* is een Gram-negatieve bacterie die door de Wereldgezondheidsorganisatie is aangemerkt als een pathogeen met een hoog risico vanwege de hoge mate van antibioticaresistentie. Het polysacharide bestaat uit repeterende eenheden van vier suikers met de structuur [→4)-β-D-GlcpNAc3NAcA-(1→3)-α-D-QuipNAc4NAc-(1→3)-α-D-QuipNAc4NAc-(1→4)-β-D-GlcpNAc3NAcA-(1→] met de twee zeldzame suikers 2,4-di-*N*-acetyl-α-D-quinovose (2,4-di-*N*-acetyl bacillosamine, QuiNAc4NAc) en 2,3-di-*N*-acetyl-β-D-glucuronzuur (GlcNAc3NAcA). Wat de structuur van deze polysacharide bijzonder maakt, is dat deze geen enkele vrije alcohol groep bezit!

Uitgaande van D-fucose en D-glucosamine-HCl werden synthetische routes ontwikkeld om meerdere grammen van de vereiste bacillosamine en 2,3-diaminoglucuronzuur bouwstenen te produceren. De reactiviteit van de bacillosaminedonoren werd vervolgens bestudeerd om methoden te ontwikkelen voor de constructie van de *1,2-cis* bindingen. Modelglycosyleringen met gefluoreerde ethanolacceptoren toonden aan dat de stereoselectiviteit van de bestudeerde selenofenol bacillosamine donor onder pre-activeringscondities sterk afhangt van de nucleofiliteit van de acceptor, waarbij ethanol zorgt volledige β-selectiviteit laat zien en 2,2,2-trifluorethanol bijna alleen maar α-product levert. De aziden en methylesters op de koolhydraatacceptoren zouden een deactiverend effect moeten hebben op de nucleofiliciteit van het vrije alcohol moeten hebben, op basis van de eerdere studies. Inderdaad, verloopt de glycosylering met zowel de 2,3-di-*N*-acetylglucuronzuuracceptoren als de bacillosamine-acceptoren met hoge α-selectiviteit.

Om het onderliggende mechanisme van deze selectiviteit te onderzoeken werd VT-NMR gebruikt om de reactieve intermediairen gevormd uit de bacillosaminedonoren te bestuderen. Wanneer de selenofenoldonor werd geactiveerd met Ph_2SO en Tf_2O, werd een mengsel van het α-triflaat, α-oxosulfoniumtriflaat en β-oxosulfoniumtriflaat gevormd. Het β-oxosulfoniumtriflaat bleek het meest reactief te zijn, op basis van de laagste ontledingstemperatuur. De activering van de overeenkomstige PTFAI-donor met TfOH leidde tot de selectieve vorming van het α-triflaat. Op basis van de glycosyleringen van de selenofenoldonor en imidaatdonor met de 2,3-di-*N*-

acetylglucuronzuuracceptoren wordt verwacht dat de oxosulfoniumtriflaten een rol spelen bij het bepalen van de selectiviteit van de selenofenoldonor. Met deze kennis in de hand kon het tetrasaccharide worden samengesteld. Uiteindelijk werd 855 mg (670 µmol) van een beschermd tetrasaccharide-bouwsteen verkregen, welke ontschermd kan worden of kan worden gebruikt voor de synthese van grotere oligomeren.

List of Publications

Mapping the reactivity of 2,3-di-N-acetyl glucuronic acid and 2,4-di-*N*-acetyl bacillosamine building blocks in the synthesis of a highly *N*-acetylated Acinetobacter Baumannii LUH5554 tetrasaccharide
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# means equal contribution

Academic CV

Jacob van Hengst was born on 28 July 1993 in Rotterdam, the Netherlands. From 2005 to 2011 he attended the Johan de Witt Gymnasium in Dordrecht, where he obtained his secondary education degree (VWO) *cum laude* with a specialisation in science and technology (NG/NT). He competed in the National Chemistry Olympiad in 2010 and 2011, were he reached the top 20 and the 1st place respectively. In 2011 Jacob started with his bachelor Molecular Science and Technology at Leiden University and Delft University of Technology. As part of his bachelor, he worked on the PEGylation of Gd-loaded zeolite nanoparticles for MRI purposes under supervision of Wuyuan Zhang and Kristina Djanashvili at the TU Delft. In 2014 he obtained his BSc Degree *cum laude*. In that same year, he started with his master's degree in chemistry at Leiden University with a specialisation in chemical biology. During his master's Jacob worked a year in the molecular physiology group under supervision of Anthe Janssen and Mario van der Stelt. He worked on the synthesis and *in vitro* evaluation of covalent inhibitors for serine hydrolase DAGLα. A large part of this internship was the optimisation of the synthesis of a key intermediate over 10 steps. His master's degree was obtained in 2017. In the same year Jacob started with his PhD in the group of Jeroen Codée and Gijs van der Marel at Leiden University. His work focussed on mechanistic research and method development within carbohydrate chemistry. Key findings are the way that substituents on the donor influence the S_N1 and S_N2 side of the reaction, how the nucleophilicity of the acceptor influences the glycosylation mechanism, how the reactivity of the acceptor is dependent on configuration and protecting group pattern and how this acquired knowledge can be applied in the total synthesis of complex oligosaccharide. Parts of his work are published in *Angewandte Chemie, Chemical Science* and *Nature communications* and presented at the CHAINS 2021 conference. Since September 2022 Jacob works as a postdoc in the group of Frank Hollmann at the TU Delft on enzymatic oxidations using environmentally benign oxidants like oxygen or hydrogen peroxide.

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