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Chemical synthesis of fragments of galactosaminogalactan and pel polysaccharides

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Chemical Synthesis of Fragments of Galactosaminogalactan and Pel Polysaccharides

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To my family and my friends.

路漫漫其修远兮，

吾将上下而求索。

Long, long had been my road and far, far was the journey;

I would go up and down to seek my heart's desire.

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List of abbreviations

Ac	acetyl
ACN	acetonitrile
aq.	aqueous
atm	1 atmosphere = 10^5 Pa
Bn	benzyl
Boc	t-butyloxy carbonyl
bs	broad singlet
BSP	1-benzenesulfinyl piperidine
Bt	benzotriazole
Bu	butyl
t-Bu	*tert*-butyl
Bz	benzoyl
COSY	correlation spectroscopy
δ	chemical shift
d	doublet
DCM	dichloromethane
dd	doublet of doublets
DMAP	*N,N*-4-dimethylaminopyridine
DMF	dimethylformamide
DMSO	dimethyl sulfoxide
DTBMP	2,6-*di*-*tert*-butyl-4-methylpyridine
DTBS	di-tert-butylsilylidene
EA/ EtOAc	ethyl acetate
eq	equivalents
ESI	electrospray ionization
Et	ethyl
GAG	galactosaminogalactan
Gal	galactose
GalN	galactosamine
$GalN_3$	2-azido-2-deoxy galactose
GalNAc	*N*-acetyl galactosamine
Glc	glucose
GlcN	glucosamine
$GlcN_3$	2-azido-2-deoxy glucose
GlcNAc	*N*-acetyl glucosamine
h	hour
HB	hydrogen bond
HFIP	1,1,1,3,3,3-hexafluoro-2-propanol
HMBC	heteronuclear multiple-bond correlation
HPLC	high performance liquid chromatography
HRMS	high-resolution mass spectroscopy
HSQC	heteronuclear single quantum coherence
Hz	Hertz
IR	infrared
J	coupling constant
LC-MS	liquid chromatography-mass spectrometry
Lev	levulinoyl
m	multiplet
M	molar
MALDI	matrix-associated laser desorption ionization
Man	mannose
Me	methyl
min	minute
MPF	mehyl(phenyl)formamide
MS	mass spectrometry
MS	molecular sieves
Nap	2-methylnaphthyl
NBS	*N*-bromosuccinimide

NIS	*N*-iodosuccinimide
NMR	nuclear magnetic resonance
NOESY	nuclear Overhauser effect spectroscopy
Nu	nucleophile
NR	no reaction
PE	petroleum ether
Pel	pellicle polysaccharide
Ph	phenyl
Ph_2SO	diphenyl sulfoxide
Phth	phthaloyl
PMB	*para*-methoxybenzyl
ppm	parts per million
Py	pyridine
q	quartet
RT	room temperature
Rf	retention factor
s	singlet
sat.	saturated
SDS-PAGE	sodium dodecyl sulfate polyacrylamide gel electrophoresis
t	triplet
TBAB	tetra-*n*-butylammonium bromide
TBAF	tetra-*n*-butylammonium fluoride
TBAI	tetra-*n*-butylammonium iodide
TBDPS	*tert*-butyldiphenylsilyl
TBS	*tert*-butyldimethylsilyl
TCA	trichloroacetyl
TEA	triethylamine
TEMPO	2,2,6,6-tetramethyl-1-piperidinyloxy
Tf	trifluoromethanesulfonyl
TfOH	triflic acid
Tf_2O	trifluoromethanesulfonic anhydride
TFA	trifluoroacetic acid
THF	tetrahydrofuran
TIPS	triisopropylsilyl
TMS	trimethylsilyl
TLC	thin layer chromatography
Tol	*p*-tolyl
Troc	2,2,2-trichloroethoxycarbonyl
Ts	*p*-toluenesulfonyl
TTBP	2,4,6-tri-*tert*-butylpyrimidine
p-TsOH	*p*-toluenesulfonic acid
UDP	uridine 5'-diphosphate
UV	ultraviolet

Chapter 1

General Introduction

1. Introduction

Carbohydrates are one of the most structurally diverse biopolymers on earth. They play crucial roles in every corner of biology, besides as an energy source, in cell signaling, pathogen recognition, inflammation, modulation of innate immune response, etc.[1-5] To unravel the role of carbohydrates in biological processes, pure and well-defined carbohydrates are a prerequisite. However, isolation of carbohydrates from natural sources is often impractical because of the microheterogeneity and/or biological impurities. Chemical synthesis is therefore an important approach to provide these oligosaccharides. Although tremendous progress has been made in carbohydrate chemistry, the assembly of complex oligosaccharides and glycoconjugates continues to be a challenging task, requiring a huge

time and labor investment.[6-10] The stereoselective construction of glycosidic linkages is key to success in the synthesis of oligosaccharides. The glycosylation reaction, indeed a central theme of carbohydrate chemistry, usually involves the condensation of a donor with a leaving group at the anomeric position and a nucleophilic acceptor, under influence of a catalyst or promotor to yield a coupled saccharide.[11] The formation of α/β-mixtures during glycosylation often results in a time-consuming purification process, thus decreasing the efficiency of oligosaccharide assembly. While 1,2-*trans* glycosides can be reliably formed using neighboring group participation by acyl protecting groups, the construction of 1,2-*cis* linkages is more difficult. To overcome this issue, many strategies have been developed to stereoselectively introduce these glycosidic linkages, including intramolecular aglycon delivery[12-14], the use of six-membered ring containing chiral auxiliaries[15-18], conformational constrained glycosyl donors[19-26], additive controlled glycosylations[27-29], hydrogen bond-mediated aglycon delivery[30], *etc*. However, none of these methods represents a general solution to the problem, each having its distinct advantages and disadvantages.[31] In this context, the development of innovative methodologies to efficiently provide various glycoconjugates, is strongly desired.

Amino sugars, an important type of carbohydrates, are characterized by the replacement of at least one of its hydroxyl groups by a (substituted) amino group. 2-Amino-2-deoxy-glycosides, such as glucosamine (GlcN), galactosamine (GalN), *N*-acetyl-glucosamine (GlcNAc) and *N*-acetyl-galactosamine (GalNAc), are the most common D-aminosugars. Many of these aminosugars are found on cell surfaces to play a significant role as receptor ligands for macromolecules, participating in for example antibody-antigen interactions.[8, 32-35] This Chapter introduces two exopolysaccharides mainly composed of 2-amino-2-deoxy-glycosides, including *Aspergillus* galactosaminogalactan and *Pseudomonas* Pel polysaccharides. Also, it provides an overview of α-galactosaminylation and α-glucosaminylation methodologies developed to date.

2. Galactosaminogalactan (GAG)

Aspergillus fumigatus is an opportunistic fungal pathogen that causes invasive infections in immunocompromised patients.[36-37] *Aspergillus* spores are present in suspended dust all around us, both indoor and outside. Although antifungal agents are currently available, the mortality of invasive aspergillosis remains over 50%, highlighting the need for new therapies.[38] One strategy used by the mold *A. fumigatus* to establish and maintain pulmonary infection is the production of biofilms during invasive infection. Galactosaminogalactan (GAG), a cell wall component of *A. fumigatus*, has been identified as an important factor

during biofilm formation as well as infection/invasion of the host.[39-40] GAG is a linear polysaccharide composed of 1,4-linked galactose (Gal), galactosamine (GalN) and *N*-acetyl-galactosamine (GalNAc) residues that are interconnected through *cis*-glycosidic linkages (Figure 1).[37, 41-42] It hides the immunostimulatory β-glucans from the host immune system and functions as an immunomodulatory polysaccharide by inhibiting the generation of proinflammatory cytokines.[36] This feature suggests that GAG is a potential lead compound in the development of anti-inflammatory therapies.

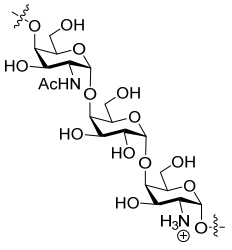


Figure 1. Structure of the GAG exopolysaccharide.

Sheppard's group provided a plausible biosynthetic pathway of GAG by comparative transcriptional analysis of *A. fumigatus* regulatory mutants deficient in the production of GAG.[37, 40, 43] The biosynthesis of GAG depends on a cluster of genes located on chromosome 3 encoding five carbohydrate-active enzymes.[44] Structural and biochemical studies indicated that GAG synthesis begins with the transformation of UDP-glucose and UDP-*N*-acetyl glucosamine into UDP-galactose and UDP-*N*-acetyl-galactosamine through the activation of epimerase Uge3 (Figure 2). Polymerization of the monosaccharides and transport across the membrane is supposed to be mediated by the glycosyl transferase Gtb3. Then GalNAc moieties within the newly secreted polymer are partially de-acetylated by the secreted protein Agd3. It has been found that the agd3-deficient mutant produces normal amounts of GAG, but this strain is impaired in its ability of biofilm formation and lacks cell wall decoration. The agd3-deficient strains also exhibit markedly lower virulence in a murine model of *A. fumigatus* infection compared to the wild-type strain, indicating Agd3 as a virulence factor.[45] After de-*N*-acetylation, the emerging polymer is thought to be cleaved by two glycoside hydrolases: an endo-α-1,4-*N*-acetylgalactosaminidase Sph3 and an endo-α-1,4-galactosaminidase Ega3. Recent studies have shown that these two hydrolases can degrade GAG, disrupt *A. fumigatus* biofilms, and attenuate fungal virulence in mice, suggesting that targeting these hydrolases holds promise for therapeutic applications in the treatment of *Aspergillus* infections.[46-47]

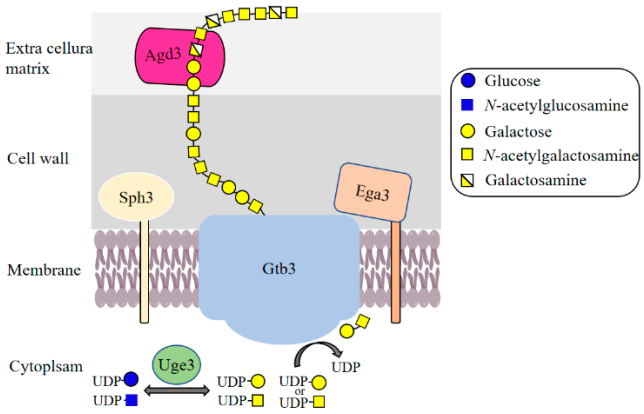
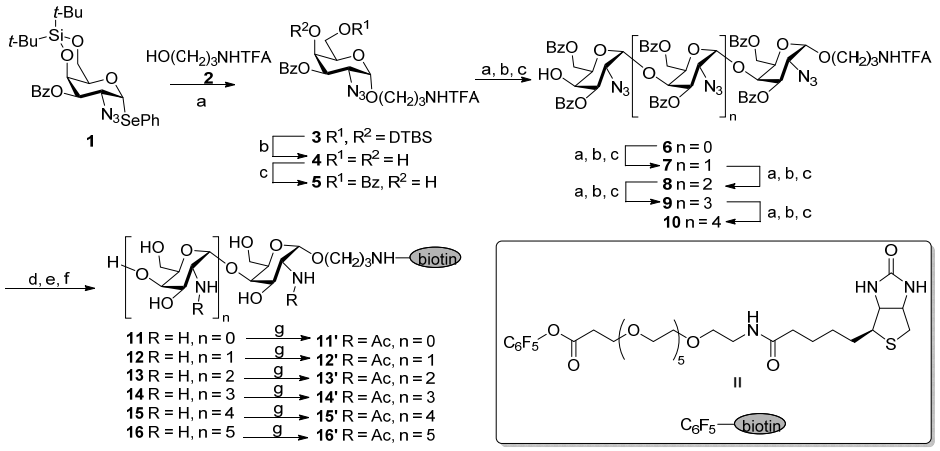


Figure 2. Biosynthetic pathway of GAG polysaccharide

The chemical synthesis of GAG homo-oligomers of GalN and GalNAc was first reported by Nifantiev's group, which is presented in Scheme 1.[48] The key to the assembly of GAG oligosaccharides is the stereoselective glycosylation of the axial 4-OH groups in the galactosamine acceptors, which have relatively low reactivity. The DTBS-protected 2-azido-2-deoxy-galactoside **1** was used as glycosyl donor, as it precludes the formation of β-glycosylation products owing to the steric hindrance effect of DTBS group (*vide infra*). First, selenoglycoside **1** was coupled with the linker *N*-(3-trifluoroacetyl)-propanol **2** under the promotion of the dimethyldisulfide-methyl triflate (Me_2S_2-MeOTf) system, giving the desired α-linked product **3**. Removal of the DTBS group with HF afforded the diol **4**, which was regioselectively benzoylated to furnish the desired 4-OH acceptor **5**. Glycosylation of **5** with donor **1**, removal of the DTBS group, and 6-*O*-benzoylation then afforded disaccharide acceptor **6**. To elongate the chains, the three-step cycle was continued: 1) coupling reaction with donor **1**; 2) DTBS removal with HF/pyridine; and 3) selective 6-O-benzoylation. After repeating the three-step cycle several times, hexasaccharide **10** was generated. Deprotection of the synthesized oligomers was accomplished by $Pd(OH)_2$/C catalyzed reduction of the N_3 groups with H_2, in the presence of Boc_2O and Et_3N, and subsequent removal of benzoyl and trifluoroacetyl groups by a double base treatment. The free amine groups in the spacer of the generated *N*-Boc protected intermediates were biotinylated and the Boc groups were cleaved using acidic conditions, generating the biotinylated oligo-α-(1→4)-D-galactosamines **11**-**16**. Then these products were *N*-acetylated to provide GalNAc-containing conjugates **11'**-**16'** comprising from two to six monosaccharide units. Besides these synthesized GAG homo-oligomers, longer chains of GAG homo-oligomers and hetero-oligomers are still needed to elucidate their interaction with the host immune system as well as fungal biosynthesis enzymes.



Scheme 1. Chemical synthesis of oligo-α-(1→4)-galactosamine conjugates. a) **2**, Me_2S_2, MeOTf, MS 4Å, DCM, for **3**: 81%; **1**, Me_2S_2, MeOTf, MS 4Å, DCM, for **6-10**; b) 40% aq HF, pyridine; for **4**: 80%; c) BzCl, pyridine, 0 ºC, for **5**: 94%; for **6**: 71%; for **7**: 72%; for **8**: 72%; for **9**: 60%; for **10**: 55%; d) $Pd(OH)_2/C$, Et_3N, Boc_2O, EtOAc, atm. H_2; e) 1M NaOMe, DCM-MeOH (1:3), then 1 M NaOH; f) C_6F_5-biotin, Et_3N, DMF, then CF_3COOH, for **11**: 71%; for **12**: 62%; for **13**: 53%; for **14**: 48%; for **15**: 72%; for **16**: 53%; g) Ac_2O, Et_3N, MeOH, for **11'**: 90%; for **12'**: 97%; for **13'**: 95%; for **14'**: 88%; for **15'**: 80%; for **16'**: 87%.

3. Pellicle (Pel) polysaccharide

Pseudomonas aeruginosa is a widespread, opportunistic, biofilm-forming Gram-negative bacterium, which is well known for the chronic infections it causes in individuals with the genetic disease, cystic fibrosis (CF).[49-50] It can cause both acute and chronic infections in immunocompromised patients and can become resistant to antibiotics due to its ability to form a biofilm which complicates the treatment of *pseudomonas* infections. In biofilm formation, this bacterium is capable of synthesizing three distinct exopolysaccharides: alginate, the polysaccharide synthesis locus (Psl), and pellicle (Pel) polysaccharides.[51-52] Alginates are linear polysaccharides composed of β-1,4 linked D-mannuronic and L-guluronic acids, which contribute to increase the bacteria's resistance to antibiotics and evade the host defense mechanisms.[53] Psl is a neutral polysaccharide composed of a pentasaccharide repeating unit containing D-glucose, L-rhamnose and D-mannose, which is an essential matrix component required for biofilm formation.[54] Pel is a cationic linear polysaccharide composed of 1,4-linked α-GlcNAc and α-GalNAc residues, of which some of the residues have been de-acetylated to generate positively charged GlcN and GalN moieties (Figure 3).[55] The Pel polysaccharide plays an important role in maintaining cell-cell and cell-surface interactions in biofilms and affords biofilm protection by enhancing

resistance to aminoglycoside antibiotics.[56] It has been reported that deletion of genes responsible for Pel polysaccharide synthesis in *P. aeruginosa* can abolish biofilm formation and/or significantly compromise bacterial virulence.[52, 57] Understanding the production and mode of action of Pel polysaccharides will pave the way for the development of new therapeutics to combat *Pseudomonas* infections.

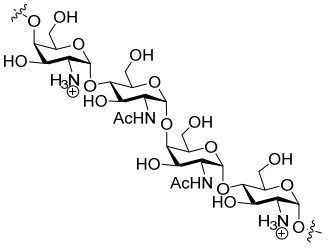


Figure 3. Putative structure of Pel polysaccharides.

Although the exact composition of the Pel polysaccharide remains to be definitively established, its biosynthesis machinery has been described as shown in Figure 4.[51, 56-58] The essential proteins involved in Pel biosynthesis are encoded by seven genes, *pelA* to *pelG*. Pel polymerization is proposed to begin with the predicted glycosyltransferase PelF, which is regulated by the binding of secondary messenger c-di-GMP to the cytoplasmic domain of the inner membrane protein PelD. After polymerization, Pel is predicted to be transported across the inner membrane by PelD in conjunction with the inner membrane proteins PelE and/or PelG. Once being shipped across the inner membrane, Pel is partially deacetylated by the periplasmic deacetylase PelA. After de-acetylation, the resulting polymer is exported across the outer membrane by the outer membrane proteins PelB and PelC. To date, the details of the Pel synthesis remain largely unknown, such as the characteristics and functions of the enzymes involved in Pel polymerization and transport across the inner and outer membranes. Accordingly, chemical synthesis of well-defined Pel polysaccharides is highly needed to study their biosynthesis and unravel their role in biofilm formation.

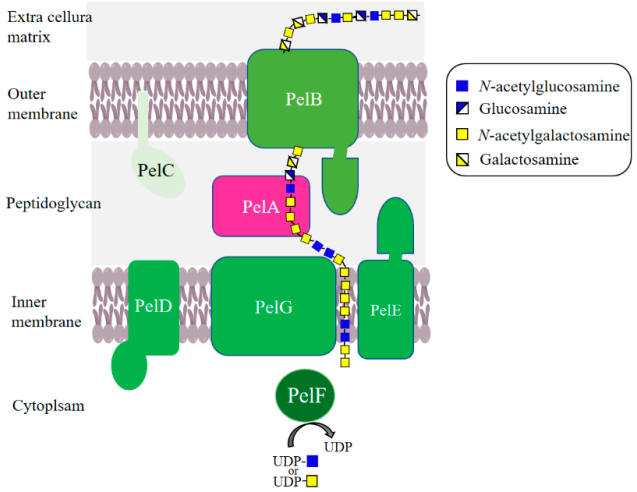
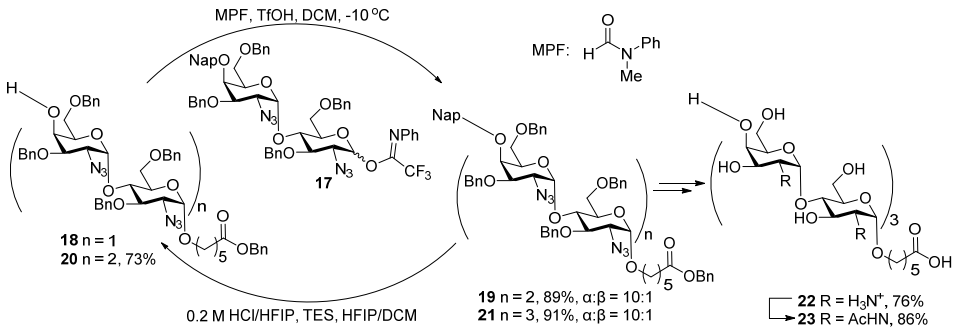


Figure 4. Plausible biosynthetic pathway of Pel polysaccharide.

Recently, Wang *et al.* reported the synthesis of the (GalN-GlcN)$_3$ Pel fragments **22** and **23** (Scheme 2).[59] The key challenge in the generation of these hexasaccharides is the stereoselective construction of two kinds of *cis*-glycosidic linkages, namely the α-GlcN-(1→4)-GalN and α-GalN-(1→4)-GlcN connections. The α-GalN$_3$ linkages can be introduced with DTBS-directed α-galactosylation methodology, while the α-GlcN$_3$ linkages were stereoselectively constructed using a new additive, methyl(phenyl)formamide (MPF), controlled glycosylation method. A [2 + 2 + 2] strategy was developed for the assembly of the hexasaccharides. The [2+2] glycosylation using MPF as additive at −10 °C at a 0.2 M concentration afforded the tetrasaccharide **19** in 89% yield with 10:1 α/β ratio. Next, the Nap ether was cleaved using HCl and triethylsilane in DCM/HFIP to give the tetrasaccharide acceptor **20**, which was coupled with donor **17** under modulation by MPF to generate hexasaccharide **21** in high yield and α-selectivity. Reduction of the azides and removal of the benzyl ester and ethers were achieved in a one-step reduction to provide compound **22**, of which the amino groups were acetylated to afford the Pel structure **23**.



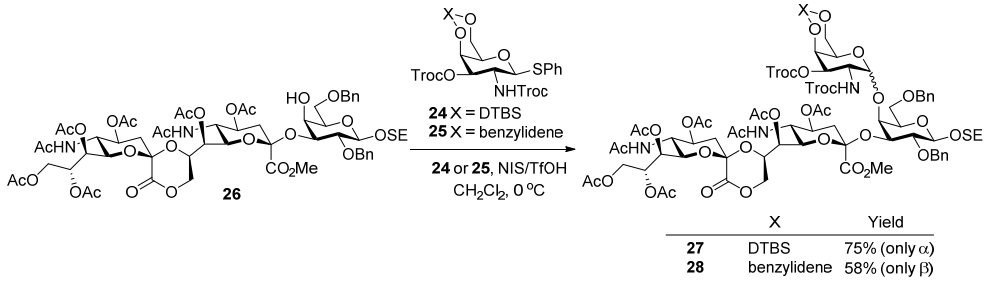
Scheme 2. Chemical synthesis of well-defined Pel oligosaccharides.

4. Stereoselective synthesis of α-galactosamines

The 1,2-*cis*-selective formation of 2-amino-2-deoxy-glycosides remains a considerable challenge, because of the requirement for a non-participating amino protecting group and the lower reactivity of glycosamine donors. To improve the stereoselectivity of glycosylation reactions, many strategies have been developed in recent years. Below some methods are presented that can be used for the formation of 1,2-*cis*-galactosamine linkages, including the previously introduced di-*tert*-butylsilylene (DTBS)-directed α-galactosylation methodology[24, 48], reagent controlled glycosylations[27, 60], the use of 2,3-oxazolidinone protected glycosyl donors[61-62] and glycosylations based on Nickel-catalyzed reactions of C(2)-*N*-substituted benzylidene galactosamine donors[32].

4.1 DTBS-directed α-glycosylation

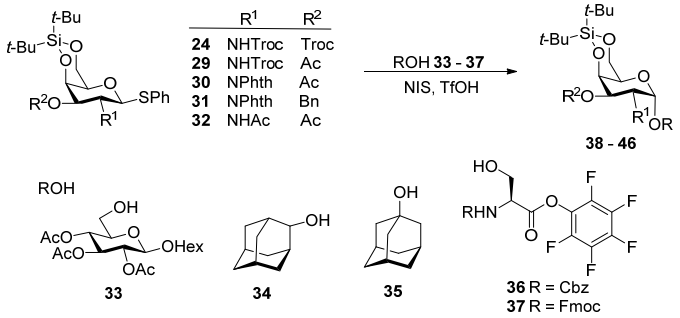
The unusual α-galactosylation using DTBS-protected galactosides as donors was discovered by chance in Kiso's group during a synthetic study towards b-series gangliosides (Scheme 3).[24] In the study, the 4,6-*O*-DTBS protected donor **24** exhibited excellent α-selectivity in the coupling reaction with trisaccharide acceptor **26**, affording tetrasaccharide **27** in 75% yield. In contrast, the corresponding 4,6-*O*-benzylidene protected donor **25** afforded β-product **28** exclusively. This indicates that 4,6-*O*-DTBS-protection predominantly leads to α-galactosylation.



Scheme 3. First encounter of 4,6-*O*-DTBS controlled α-galactosylation.

Notably, the α-directing capacity of this galactosylation method is independent of the reaction temperature, solvent and protecting groups even in the presence of participating acyl groups, such as NHTroc, NPhth and NHAc groups at C2 (Table 1).[24, 63-64] What's more, the DTBS-directed approach is tolerant to different types of acceptors. The α-selectivity is almost completely independent of the nucleophilicity of the acceptor hydroxyl, which can be a primary, secondary or tertiary alcohol. Besides employment in the stereoselective synthesis of α-galactosides[24, 63-69], the DTBS-group has been used to direct the stereoselectivity on the construction of different biologically relevant glycans, including β-arabinofuranosides[25, 70-72], α-galactofuranosides[73-74], α/β-glucosides[75-76], β-mannosides[21], β-glucuronides[77], α-sialosides[78] and α-kdo glycosides[79].

Table 1: α-Selective glycosylations of GalN donors with various acceptors.



Entry	Donor	Acceptor	Solvent	*T* (°C)	Product	Yield (α:β) (%)
1	**24**	**33**	CH_2Cl_2	0	**38**	96:3
2	**24**	**33**	*n*-hexane	RT	**38**	58:3
3	**24**	**33**	Toluene	0	**38**	91:7
4	**24**	**33**	$MeNO_2$	0	**38**	93:6
5	**24**	**33**	MeCN	0→40	**38**	23:0
6	**24**	**34**	CH_2Cl_2	0	**39**	91:7
7	**24**	**35**	CH_2Cl_2	0	**40**	90:0

8	**24**	**36**	CH_2Cl_2	0	**41**	78:0
9	**24**	**37**	CH_2Cl_2	0	**42**	90:5
10	**29**	**33**	CH_2Cl_2	0	**43**	96:0
11	**30**	**33**	CH_2Cl_2	0	**44**	90:5
12	**31**	**33**	CH_2Cl_2	0	**45**	94:0
13	**32**	**33**	CH_2Cl_2	0	**46**	50:0

The reaction mechanism for the DTBS-directed α-galactosylation has been elucidated by a combination of experimental and computational studies, and is shown in Figure 5.[26] Upon activation of the glycosyl donor **47**, the intermediate oxocarbenium **48** is formed, of which the conformation of the sugar ring is restricted to the half-chair $^4H_3$ conformer. The fused ring system formed by the DTBS group hampers the other conformers. Subsequently, the $^4H_3$ conformer can undergo nucleophilic attack by the alcohol acceptor, either from the *exo* side (α-face) or the *endo* side (β-face). With the *endo* attack on the β-face being blocked by the substantial steric hindrance of the *tert*-butyl group, nucleophilic attack predominantly takes place from the *exo* side (α-face). *Endo*- and *exo* attack take place through different transition states. To maximize orbital overlap between the incoming alcohol acceptor and the developing lone pair on oxygen, the transition state of the former attack features a twist-boat-like conformation **49** while the transition state of the latter proceeds with a more favorable chair-like conformation **50**. Thus, the twist-boat-like conformer **49** is kinetically disfavored and suffers from an unfavorable steric clash between the approaching acceptor and the *tert*-butyl group. Therefore, nucleophilic attack predominantly occurs via *exo* attack through the more stable chair-like conformer **50** giving the α-product **52**.

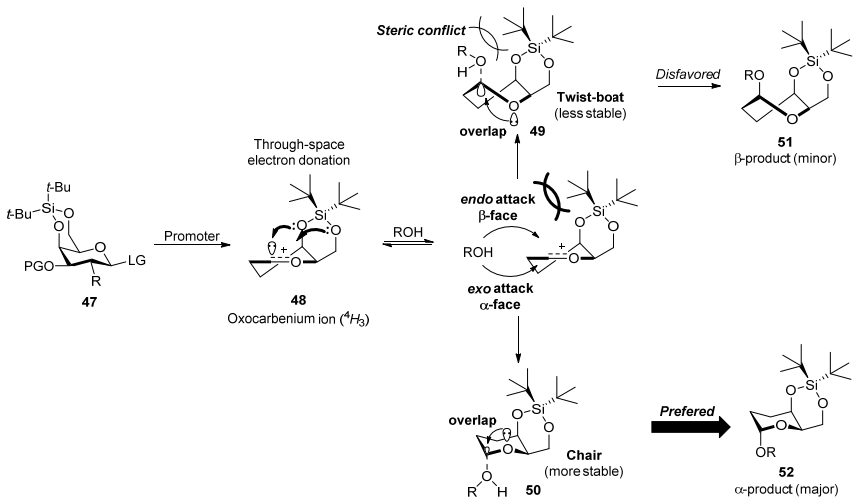
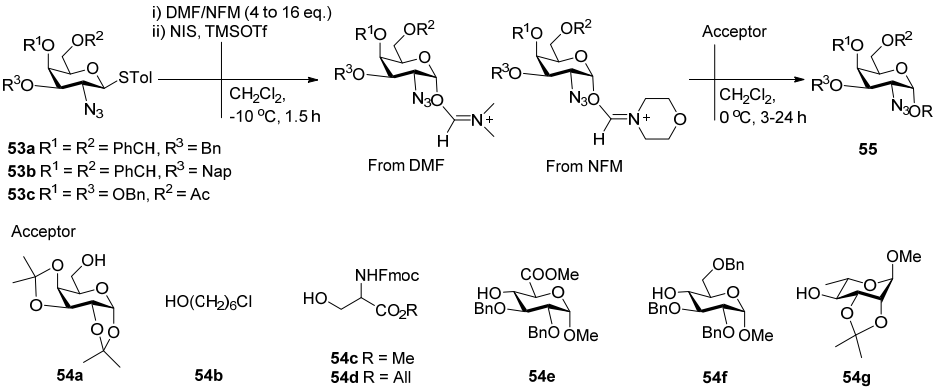


Figure 5. Proposed mechanism of DTBS-directed α-galactosylation.

4.2 Reagent controlled synthesis of α-galactosamine

Reagent controlled glycosylation methodology is an effective approach for stereoselective construction of *cis*-glycosidic bonds. In 2011, Mong's group first reported the DMF-modulated glycosylation strategy for α-galactosaminylation using 2-azido-2-deoxy thioglycosyl donors (Table 2).[27] Following a preactivation glycosylation procedure, the 2-azido-2-deoxy galactoside donors **53a** and **53c** were activated with NIS and TMSOTf in the presence of 6 equiv of DMF, followed by addition of primary acceptors **54a**-**54c**, affording the products in excellent selectivity (7:1 to α only, Table 2, entries 1, 2 and 3). However, further studies showed that glycosylations of 2-azido-2-deoxy-glycosyl donors with secondary glycosyl acceptors were impractically slow.[60] In formamide modulated glycosylations, the formation of a glycosyl imidinium ions is the key step. To modulate the reactivities of these adducts, *N*-formyl morpholine (NFM), *N*,*N*-diisopropyl formamide (DIPF), *N*-formyl piperidine (NFP), tetramethylurea (TMU), dimethylacetamide (DMA), as well as other additives, such as diphenyl sulfoxide (DPSO) and triphenylphosphine oxide (TPP) were used as nucleophilic additives. In these evaluation studies, NFM was found to be an effective modulator for glycosylations of 2-azido-2-deoxy-glycosyl donors **53a** and **53b** with primary and less reactive secondary acceptors **54d**-**54g**, providing the disaccharides in 13:1 to α-exclusive α/β ratios (Table 2, entries 4-7). Similar to this methodology, the MPF-modulated glycosylation has been successfully applied for the assembly of Pel fragments as described above (see Scheme 2).

Table 2. DMF/NFM-modulated glycosylation with 2-azido-2-deoxy thiogalactosyl donors.

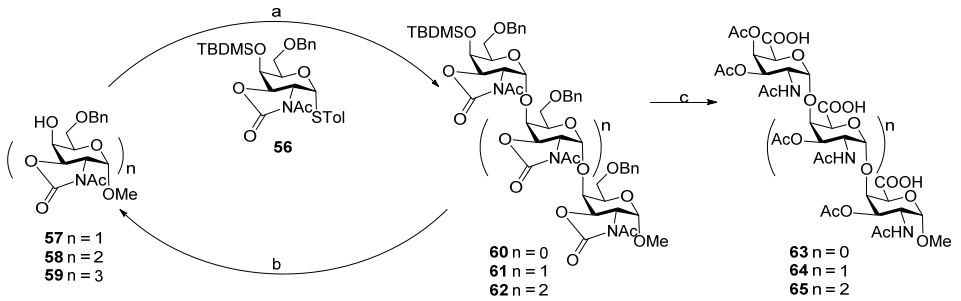


Entry	donor/acceptor	Additive (equiv.)	Yield	α:β
1	**53a**/**54a**	DMF (6)	66%	10:1
2	**53a**/**54b**	DMF (6)	65%	α only

3	**53c**/**54c**	DMF (6)	80%	7:1
4	**53a**/**54d**	NFM (16)	90%	α only
5	**53a**/**54e**	NFM (16)	89%	α only
6	**53b**/**54f**	NFM (16)	83%	13:1
7	**53b**/**54g**	NFM (4)	82%	32:1

4.3 2,3-Oxazolidinone-protected galactosamine donors

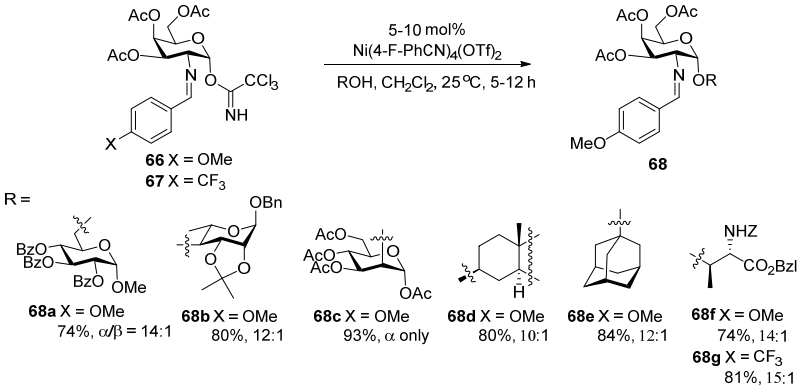
Oxazolidinone-protected glucosamine as an α-selective glycosyl donor was first reported in 2001 by the group of Kerns[80], and subsequent investigation of its *N*-acetyl or *N*-benzyl analogues confirmed that the ring-fused oxazolidinone moiety is an effective nonparticipating group for the stereoselective construction of α-glucosamine linkages.[20, 61, 81] This methodology has been successfully used to introduce the α-galactosamine moiety in the synthesis of fragments of the Vi antigen from *Salmonella typhi* (Scheme 4).[62] The Vi polysaccharide is a linear homopolymer of 1,4-linked *N*-acetyl-α-galactosaminuronic acid with *O*-acetylation at C3. The key feature of the synthesis of Vi antigen depicted in Scheme 4 is the two-step chain elongation cycle, consisting of 1) glycosylation reaction with the *N*-acetyl-2,3-oxazolidinone glycosyl donor; and 2) removal of the TBDMS group. A pre-activation strategy, comprising the use of a combination of diphenyl sulfoxide (Ph_2SO), triflic anhydride (Tf_2O) and the hindered base TTBP, was used to activate the donor. The selectivity of all glycosylation reactions was excellent, while the yields of isolated α-products decreased (72% for the dimer, 61% for the trimer; 53% for the tetramer) as the reactivity of 4-OH group decreased with the elongation of the chain. To form the final products, the oxazolidinone group was hydrolyzed in a NaOH solution, and at the same time the TBDMS group was cleaved. Subsequent acetylation and a tandem hydrogenolysis and oxidation furnished the uronic acid in moderate to good yields.



Scheme 4. Synthesis of oligosaccharide fragment of the Vi antigen. a) Ph_2SO, Tf_2O, CH_2Cl_2, -72 °C to RT, 3 h, yields for **60**: 72%; **61**: 61%; **62**: 53%. b) TBAF/THF, RT, 10 min, yields for **58**: 90%; **59**: 90%. c) i) NaOH (aqueous)/1,4-dioxane (1:1), 40 °C, 2-5 h; ii) Ac_2O, DMAP, pyridine, 0 °C to RT, 2–10 h; iii) H_2, Pd/C, THF/AcOH/H_2O (4:2:1), 2-5 h; iv) $NaIO_4$, $RuCl_3 \cdot xH_2O$, $CCl_4/CH_3CN/H_2O$ (2:2:3), overnight, yields for **63**: 67%; **64**: 53%; **65**: 47%.

4.4 Nickel-catalyzed glycosylations of C(2)-*N*-benzylidene galactosamine donors

Ni-catalyzed stereoselective glycosylation with C(2)-*N*-benzylidene galactosamine trichloroacetimidates for the formation of α-galactosamine was first reported by Nguyen's group.[32] Coupling of α-galactosamine trichloroacetimidates **66** and **67** with primary, secondary, and tertiary acceptors in the presence of 5-10 mol % of $Ni(4\text{-F-PhCN})_4(OTf)_2$ at 25 °C provided the desired products in high yields (74-93%) and with excellent α-selectivity (10:1 to α-only, Scheme 5). The α-selectivity of the nickel method relies on the nature of the nickel-complex, while the reactivity of the nucleophiles and protecting groups on acceptors have little effect on the stereoselectivity. This methodology has also been applied for the synthesis of α-glucosamines, which will be discussed in the next section.



Scheme 5. α-Selective coupling with *N*-substituted benzylidene galactosamine imidates.

Two plausible mechanisms for the nickel-catalyzed α-selective glycosylation are described in Figure 6.[32] In pathway I, the seven-membered ring complex **A** is first formed through the reversible coordination of $L_nNi(OTf)_2$ to both the trichloroacetimidate nitrogen and benzylidene protected nitrogen in donor **69**. Ionization of **A** leads to the corresponding complex **B**, facilitated by the hydrogen bonding between the incoming hydroxy nucleophile and the trichloroacetamide. Next, ligand exchange and dissociation of trichloroacetamide gives the ion pair **C**, which recombines to afford the favorable five-membered ring

intermediate **D**. Dissociation of the nickel species from **D** provides α-glucosamine/galactosamine **70**. In pathway II, the Lewis acid $L_nNi(OTf)_2$ coordinates to the trichloroacetimidate nitrogen of **69** to form the complex **E**, which is transformed into the oxocarbenium intermediate **F** after ionization. Ligand exchange followed by coordination of nickel to the benzylidene nitrogen of **F** furnishes the ion pair **C**, which finally yields the 1,2-*cis*-2-amino glycoside **70**. It has been verified that the α-orientation of the trichloroacetimidate leaving group and the presence of the external alcohol nucleophile are essential for the ionization of glycosyl imidate donors. Furthermore, the substituted benzylidene group at the C(2) amino position in the glycosyl donors is pivotal for the high α-selectivity.

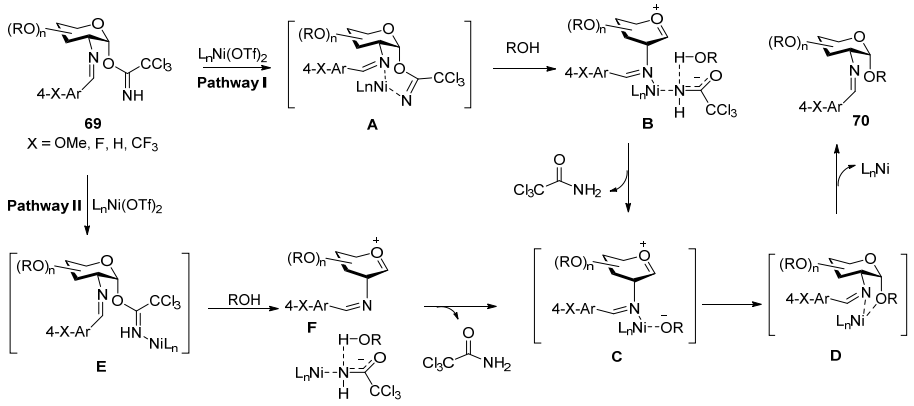


Figure 6. Plausible mechanism of nickel-catalyzed α-selective glycosylation.

5. Stereoselective synthesis of α-glucosamines

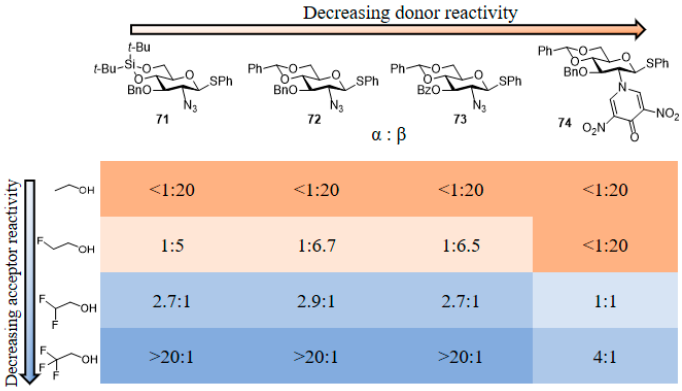
Glucosamine is a key component in various natural polysaccharides and glycoconjugates. While β-glucosamines can be facilely synthesized, no general solution exists for the stereoselective construction of α-glucosamines. Here some strategies are presented that can be used for the α-selective formation of glucosamine linkages.

5.1 4,6-Tethered glucosazide donors

To stereoselectively construct α-glucosamines, a C2-azido group is most commonly used in glucosamine donors as a non-participating group. In 2017, van der Vorm *et al.*[82] systematically evaluated a set of glycosylation reactions between a series of 4,6-tethered glucosazide donors and a panel of acceptors with decreasing nucleophilicity (Table 3). The DTBS-protected donor **71** was found to be more reactive than benzylidene-protected donors **72** and **73**, while donor **74**, carrying the strongly electron-withdrawing dinitropyridone

(DNPY) group proved to be the least reactive. The nucleophilicity of the acceptors, used in this study, gradually decreased from ethanol to monofluoroethanol (MFE), difluoroethanol (DFE) to trifluoroethanol (TFE). The glycosylation reactions, which were undertaken using the Ph_2SO/Tf_2O preactivation procedure, present two major trends. First, with the decreasing reactivity of the donors, the glycosylations provided a larger proportion of the β-products, with the least reactive donor **74** being the most β-selective of the donors listed above. Secondly, decreasing acceptor nucleophilicity corresponds to an increase in the α/β ratio. This trend is apparent for all donors, with the most reactive acceptor, ethanol, offering least α-linked product while the least reactive acceptor, TFE, provided most α-linked product.

Table 3. Glycosylations of 4,6-tethered glucosazide donors with (partially) fluorinated ethanols



The reactive intermediates and plausible reaction pathways for 4,6-tethered glucosazide donors are indicated in Figure 7. The following kinetic scenario emerges. The relatively stable α-triflate, which can be observed by low-temperature NMR spectroscopy, is in equilibrium with the more reactive β-counterpart and if the acceptor is nucleophilic enough, the triflate can be directly displaced. For instance, the glucosazide donors react with ethanol and MFE in an S_N2-like substitution reaction pathway, forming the products with a high β : α-ratio. The stronger electron-withdrawing DNPY group in donor **74** can lead to a more stable covalent α-triflate and favors an associative displacement mechanism, giving a further increase in β-selectivity. For the weaker nucleophiles, such as DFE and TFE, the glycosylation is less likely to proceed in the S_N2-like pathway. The high α-selectivity for these acceptors can be explained by the involvement of more electrophilic intermediates such as the glycosyl oxocarbenium ion-like species. Conformationally restricted by the benzylidene and silylidene protecting groups, the intermediate oxocarbenium ion preferentially adopts a $^4H_3/^4E$-like conformation. A $B_{2,5}$-like structure such as **77** is

significantly less favorable because this puts the C-2-azide in a flagpole position. The $^4H_3/^4E$-conformer is attacked from the bottom face to generate the α-products through a chair-like transition state. The more reactive donors more readily dissociate to form an oxocarbenium ion-like species, which accounts for the increased α-selectivity for those donors.

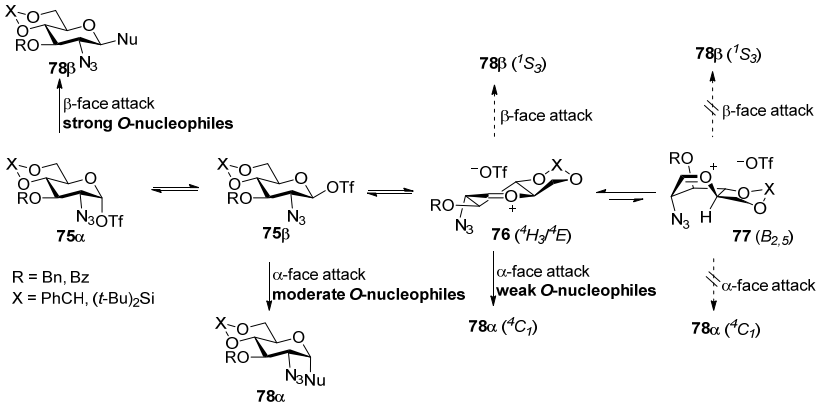
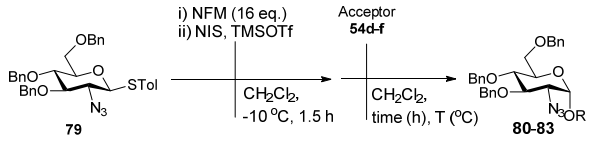


Figure 7. Reactive intermediates and reaction pathways for 4,6-tethered glucosazide donors.

5.2 Reagent controlled α-glucosaminylation methodology

As described above, the reactivity of both the donor and acceptor has a great influence on the stereoselectivity of a glycosylation reaction. Therefore, additive controlled glycosylation methodology, in which donor reactivity can be modulated to match the reactivity of the acceptor alcohols, is attractive and gaining increasing interest for the stereoselective construction of 1,2-*cis*-glycosidic linkages.[83-84] Different additives have been investigated to accommodate the reactivity difference between different donors and acceptors.[85-90] DMF-modulated glycosylations were first developed and these have been applied for the synthesis of various oligosaccharides, such as a branched α-glucan with an α-(1,4)-linked backbone from *Mycobacterium tuberculosis* and α-(1,3)-glucans from *Aspergillus fumigatus*.[29] Mong and co-workers found that glycosylations mediated by DMF didn't proceed with satisfactory stereoselectivity for the construction of 1,2-*cis*-glucosamine and galactosamine linkages.[60] They introduced NFM to modulate the reactivity of $GalN_3$ (*vide supra*, section 4 and Table 2) and $GlcN_3$ donors, showing better stereoselectivity compared to DMF (Table 4). With the strong electron-withdrawing azide group in the C2-azido donors, their reactivity is lower in comparison to their 2-*O*-benzyl counterparts. This lower reactivity can be counterbalanced by the use an additive, that is less capable of supporting the positive charge at the imidinium ion, resulting in a better leaving group, thereby explaining why NFM outperforms DMF in these glycosylations.

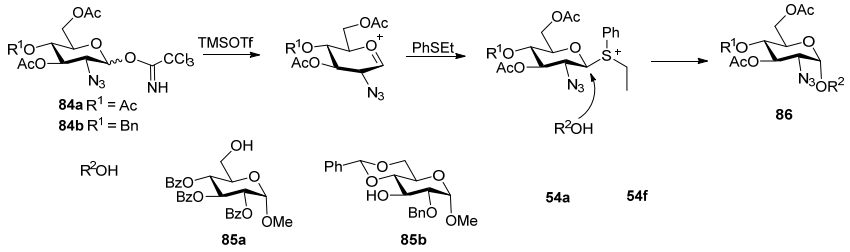
Table 4. NFM-modulated glycosylation with 2-azido-2-deoxythioglucosyl donor



Entry	Acceptor	Time (h), T (°C)	Product	Yield (%), α:β
1	**54d**	12, -5	**80**	81, 11:1
2	**54e**	12, -5	**81**	75, 16:1
3	**54f**	18, -5	**82**	70, 19:1
4	**54g**	12, -10	**83**	84, 19:1

Besides the formamide additives, thioethers, such as PhSEt, and thiophene were explored as additives for stereoselective glycosylation of 2-azido-2-deoxy-glucosides by Boons's group.[91] Glycosylations of $GlcN_3$-trichloroacetimidates **84a** and **84b** provide excellent α-selectivity, promoted with TMSOTf at a relatively high temperature (0 °C) in the presence of PhSEt or thiophene (10 equiv, Table 5). Mechanistic studies indicated that a β-anomeric sulfonium ion is formed after activation of the imidate donor in the presence of PhSEt. Subsequent displacement of the β-anomeric sulfonium ion by an acceptor alcohol then affords an α-linked product.

Table 5. α-Selective glucosylations in the presence of PhSEt or thiophene.



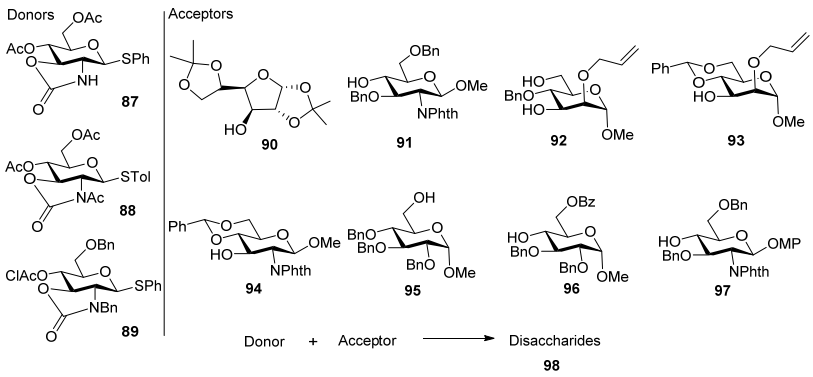
Donor	Acceptor	T (°C)	thioether	Yield (%), α:β
84a	**85a**	-78	none	91, 2:1
84a	**85a**	-78	PhSEt	83, 5:1
84a	**85a**	0	none	92, 8/1
84a	**85a**	0	PhSEt	94, 20/1
84a	**85a**	0	thiophene	91, α-only
84a	**85b**	0	thiophene	60, 15:1
84a	**54a**	0	PhSEt	92, 5:1

84a	**54a**	0	thiophene	95, 14:1
84a	**54f**	0	thiophene	43, α-only
84b	**85a**	0	thiophene	93, 20:1
84b	**85b**	0	thiophene	50, 15:1
84b	**54a**	0	thiophene	96, 15:1
84b	**54f**	0	thiophene	37, α-only

5.3 Oxazolidinone-containing glucosamine donor

The non-*N*-acetylated oxazolidinone protected 2-amino-2-deoxy-glucose **87** was first employed as a donor for the formation of α-linked glycosides by the group of Kerns.[80] The oxazolidinone **87** glycosylated primary and secondary glycosyl acceptors under the promotion of phenylsulfenyl triflate (PST) at -78 °C to give disaccharides in high yields and with excellent α-selectivity (Table 6). Nevertheless, the use of non-*N*-acetylated oxazolidinone-protected donors has several limitations: 1) some thioglycoside donors are difficult to activate, requiring at least 2 equiv of PST, as 1 equiv is lost to *N*-sulfenylation, and 2) *N*-glycosylation has been observed in oligosaccharide synthesis. To avoid the side-reactions, the *N*-acetylated donor **88** and *N*-benzylated donor **89** were prepared.[20, 92] With oxazolidinone **88** as the donor and BSP-Tf_2O as mild promotor, a selectivity-reactivity relationship was observed for the stereoselectivity of the glycosylations of various acceptors. Acceptors of low nucleophilicity gave mainly the α-products, while acceptors with intermediate reactivity led to α/β mixture, and the β-products were obtained with reactive acceptors. Afterwards, Ito and co-workers reported *N*-benzyl-2,3-oxazolidinone **89** as donor and PhSOTf or *N*-(phenylthio)-ϵ-caprolactam as promotor, furnishing disaccharides with high α-selectivity. Furthermore, Ye[93-94] and Oscarson[81] found that the stereoselectivity of *N*-acetylated-2,3-oxazolidinone-protected donors towards glycosylations can be significantly influenced by additives. Thiophene and AgOTf were found to be the best α-directing additives. It has been described that the stereoselectivity can also be controlled by the use of (Lewis) acidic reaction conditions, as the glycosylated β-products can isomerize to the corresponding α-products. The ring strain imposed on the system by the *trans*-fused oxozolidinone can lead to rapid ring opening upon protonation of the glucosamine endocyclic *O*-atom. Rotation around the C1-C2 bond and subsequent ring closure provides the thermodynamically more stable α-linked products.[81]

Table 6. Glycosylation reactions with ring-fused oxazolidinone of glucosamine



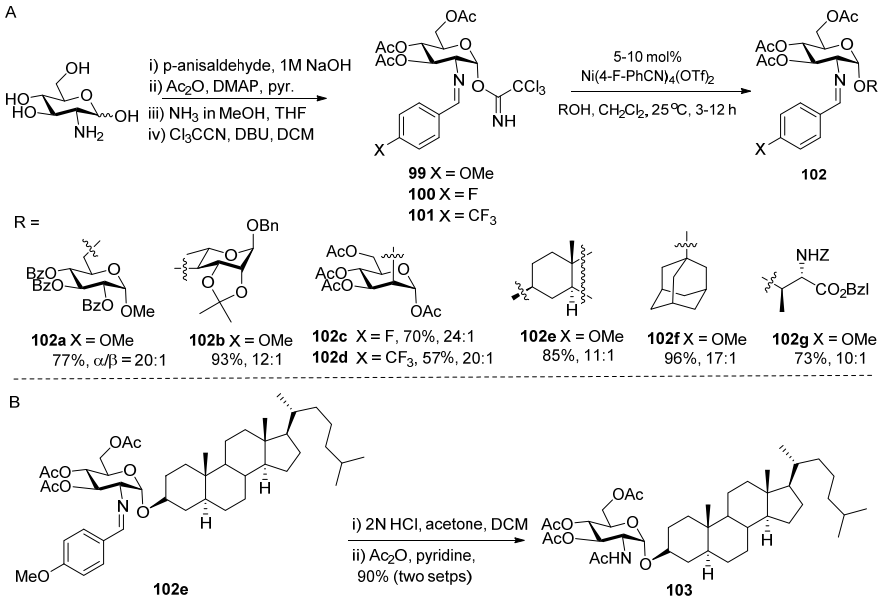
Entry	Donor	Acceptor	Condition	Product (%)	α:β
1	**87**	**90**	A	**98a** (97%)	α-only
2	**87**	**91**	A	**98b** (75%)	α-only
3	**87**	**92**	A	**98c** (90%)	α-only
4	**87**	**93**	A	**98d** (95%)	α-only
5	**88**	**90**	B	**98e** (95%)	β-only
6	**88**	**94**	B	**98f** (75%)	1:4.5
7	**88**	**91**	B	**98g** (81%)	α-only
8	**89**	**95**	C	**98h** (88%)	10:1
9	**89**	**96**	D	**98i** (52%)	α-only
10	**89**	**97**	D	**98g** (54%)	α-only

Conditions: A) PST, CH_2Cl_2, -78 °C. B) BSP, Tf_2O, TTBP, CH_2Cl_2, -60 °C. C) AgOTf, PhSCl, DTBMP, toluene/1,4-dioxane (3:1), 0 °C to rt. (D) *N*-(phenylthio)-ϵ-caprolactam, Tf_2O, CH_2Cl_2, rt.

5.4 Nickel-catalyzed stereoselective glycosylations of *N*-benzylidene protected donors

Similar to the nickel-catalyzed stereoselective α-galactosaminylation (*vide supra*), C2-*N*-substituted benzylidene glucosamine donors **99-101** were developed and found to be viable donors for the synthesis of α-linked glucosamines (Scheme 6).[32] Preparation of the trichloroacetimidate **99** was achieved by treatment of commercially available D-glucosamine with *p*-anisaldehyde under basic condition, followed by acetylation, selective deacetylation and coupling with Cl_3CCN (Scheme 6A). Condensation reactions with a variety of primary, secondary and tertiary alcohols with the trichloroacetimidate donor furnished disaccharides **102a**-**102g** with excellent α-selectivity (10:1 to 20:1). This method has been employed for the synthesis of a number of trisaccharides and tetrasaccharides with satisfactory α-selectivity using relatively unreactive disaccharide donors and acceptors. Removal of the benzylidene groups can be achieved under acidic condition (5 N HCl), after which *N*-acetyl or other

desired functionalities can be readily installed at the liberated nitrogen. For acid-sensitive oligosaccharides and glycoconjugates, the benzylidene groups can be cleaved with 1.1 equivalents HCl at 25 ºC for 5 minutes. For instance, treatment of **102e** with 2 N HCl, followed by acetylation of the generated amine afforded the glycoconjugate **103** in 90% yield.



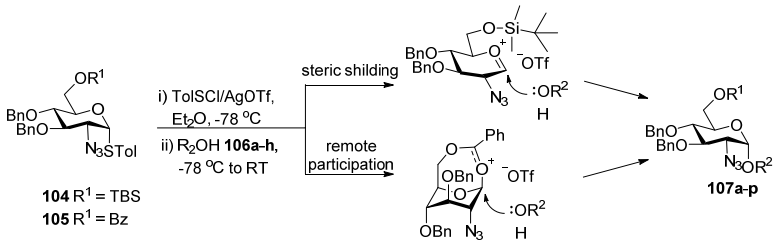
Scheme 6. A) α-Selective glycosylation with *N*-substituted benzylidene glucosamine donors. B) Removal of *N*-substituted benzylidene group

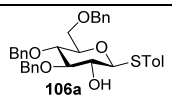
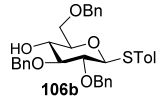
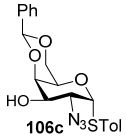
5.5 Remote participation in α-selective glucosaminylation reactions

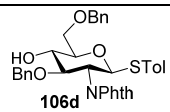
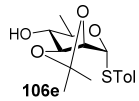
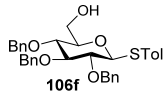
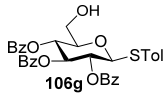
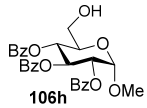
It has been reported that acyl groups located at more distant positions than *O*-2 or *N*-2 in glycosyl donors can affect the stereoselectivity of glycosylation reactions via remote participation.[95-101] This long range effect is heavily debated[102] and in general, glycosylations with donors bearing remote participating groups are not as stereoselective as donors bearing C-2-neighboring participating groups and the degree of the remote stereo-directing effect varies with the type of donor and the position of the remote participating group. For instance, 3,6-*O*-acyl groups in glucosyl donors have been reported to favor α-glycosylation with modest to good selectivity.[96, 99] Moreover, glucosyl donors with bulky substituents at the 6-*O*-position, such as tert-butyl diphenylsilyl (TBDPS) and trityl groups, also favor α-glycosylation owing to the steric shielding influence on the β-face.[100, 103]

Recently Gao *et al.* reported an efficient strategy to achieve α-selective glucosaminylation based on the combined α-directing effects of the TolSCl/AgOTf promotion system and the protecting groups at the 6-*O*-position in donors.[104] Table 7 presents the glycosylation of 6-*O*-TBS-2-deoxy-2-azido-thioglucoside **104** and 6-*O*-Bz $GlcN_3$ donor **105** with various primary and secondary alcohols. All of the glycosylation reactions were executed using a pre-activation protocol. The donor was activated with 1.0 equiv of TolSCl/AgOTf in diethyl ether at -78 °C, after which the acceptor was added to the reaction mixture and the mixture was slowly warmed to room temperature. The authors argued that the participating Bz group or the bulky TBS group at the *O*-6-position would block the β-attack of the glycosyl acceptor through either remote group participation or steric hindrance, thus facilitating the formation of the α-products. Glycosylation of $GlcN_3$-donors **104** and **105** with secondary acceptors **106a-e** afforded the desired disaccharides in good yields (78-86%) and with excellent α-selectivity (15:1 to α-only, Table 7, entries 1-5). However, coupling of these donors with reactive primary acceptor **106f** generated the products in 5:1 and 3:1 α/β ratio (Table 7, entry 6). The less reactive Bz-protected acceptors **106g** and **106h** gave better results in terms of α-glycosylation selectivity (16:1 to 19:1, Table 7, entries 7 and 8).

Table 7. Glycosylation of 6-O-TBS and Bz protected $GlcN_3$ donors



Entry	Acceptors	Products	Yield	α:β
1	 **106a**	**107a** R^1 = TBS	80%	α-only
		107b R^1 = Bz	81%	α-only
2	 **106b**	**107c** R^1 = TBS	81%	>19:1
		107d R^1 = Bz	83%	15:1
3	 **106c**	**107e** R^1 = TBS	86%	α-only
		107f R^1 = Bz	83%	α-only

4	 106d	**107g** R^1 = TBS	78%	>19:1
		107h R^1 = Bz	84%	α-only
5	 106e	**107i** R^1 = TBS	81%	α-only
		107j R^1 = Bz	85%	>19:1
6	 106f	**107k** R^1 = TBS	80%	5:1
		107l R^1 = Bz	84%	3:1
7	 106g	**107m** R^1 = TBS	87%	>19:1
		107n R^1 = Bz	85%	>19:1
8	 106h	**107o** R^1 = TBS	87%	>19:1
		107p R^1 = Bz	88%	16:1

6. Outline of the thesis

This Thesis reports the assembly of a library of GAG fragments from *Aspergillus fumigatus* and a library of Pel oligomers of *Pseudomonas aeruginosa*, using DTBS-directed α-glycosylation methodology. In the introductory **Chapter 1** a concise overview is presented on the recent progress of the stereoselective introduction of α-galactosamine and α-glucosamine glycosidic linkages. Information is given on the structure, occurrence, properties and (bio)synthesis of both GAG exopolysaccharides and Pel polysaccharides. **Chapter 2** describes the synthesis of homopolymers of Gal, GalN and GalNAc. Two nonasaccharides composed of Gal or GalN moieties as well as a dodecasaccharide containing GalNAc moieties were constructed with high yields and complete α-selectivity. **Chapter 3** shows the assembly of heteropolymers of Gal, GalN and/or GalNAc moieties. A DTBS-trichloroacetamide donor was used, alongside a DTBS-protected galactosazide donor to introduce the α-GalNAc linkages, overcoming the neighboring group participation effect, and effectively discriminating the two nitrogen functionalities. **Chapter 4** deals with the successful synthesis of a GAG-heptasaccharide with an 2-azido group on the galactose sugar ring of the non-reducing end. The azido group was introduced to provide the heptasaccharide with a biorthogonal conjugation handle, which will benefit the study of the biosynthesis pathway of GAG. **Chapter 5** describes the optimization of glycosylation reactions towards the stereoselective introduction of α-GlcN linkages. With the aid of the optimized condition, a library of Pel heptasaccharides was assembled. **Chapter 6** provides a summary of the obtained results described in the foregoing chapters and an outlook for future research.

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Chapter 2

Synthesis of α-galactose, α-galactosamine and α-*N*-acetyl galactosamine galactosaminogalactan homo-oligomers from *Aspergillus fumigatus*

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Introduction

Aspergillus fumigatus is an opportunistic pathogenic fungus that causes invasive infections in immunocompromised patients, with a mortality rate of 60-80%.[1-4] Galactosaminogalactan (GAG), a prominent cell wall component of *A. fumigatus*, has been identified as an important factor during invasion and infection of the host.[5-10] It hides the immunostimulatory β-glucans from the host immune system and functions as an immunomodulatory polysaccharide by inhibiting the generation of proinflammatory cytokines.[7] The GAG polysaccharide is composed of galactose (Gal), galactosamine (GalN) and *N*-acetylgalactosamine (GalNAc) residues that are interconnected through 1,4-*cis*-glycosidic linkages and are distributed in a seemingly random order[9-11] (Figure 1A). To

unravel the mode of action of enzymes involved in GAG-biosynthesis, well-defined GAG-fragments are indispensable tools.[12-13] Pure GAG-oligosaccharide fragments can also be employed to study their interaction with components of the host immune system and map interactions with antibodies at the molecular level. This can inspire the development of anti-fungal vaccines and diagnostics. The random distribution of the Gal, GalN- and GalNAc monosaccharides in the GAG chains impedes the isolation of pure and well-defined specimens from natural sources and therefore the synthesis of a set of structurally well-defined GAG homopolymers was undertaken (See Figure 1B). Recently, Nifantiev and co-workers[14] reported on the assembly of a small set of GAG homo-oligomers up to the hexamer level, containing either GalN or GalNAc residues. Because enzymes involved in GAG biosynthesis may require longer oligosaccharides, structures up to the dodecasaccharide level were assembled here.

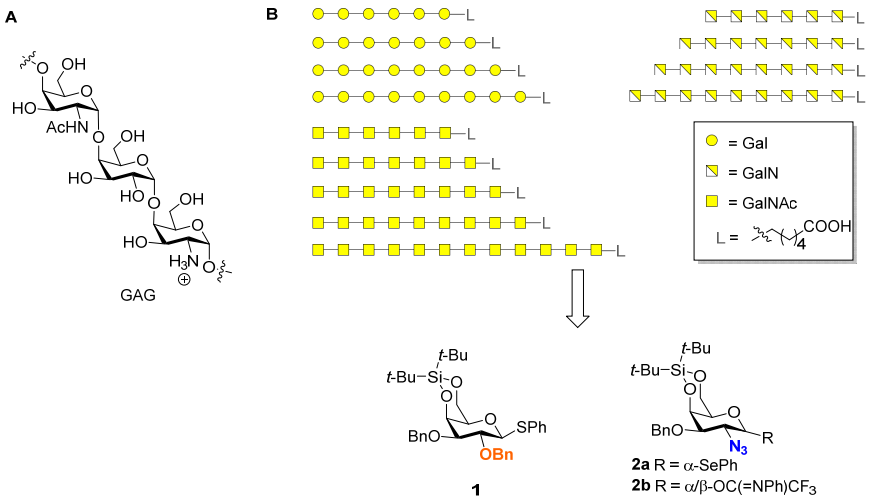


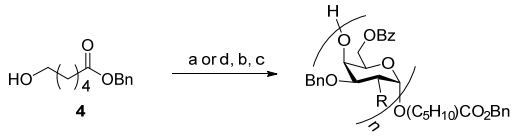
Figure 1. A) Structure of GAG. B) The designed GAG homo-oligomers and building blocks utilized in the here-presented studies to prepare the GAG homopolymers.

To be able to generate various GAG structures, Kiso's di-*tert*-butylsilylidene (DTBS) galactosylation methodology should be especially suited, as this approach gives unusual high α-stereoselectivity even when a C2 group is present, that is capable of neighboring group participation.[15-20] Therefore donors **1** and **2** were designed to assemble a library of GAG homo-oligomers, as depicted in Figure 1B. A hexanoic acid spacer was incorporated at the reducing end of the fragments for future conjugation purposes. The $GalN_3$ donor **2** will serve as precursor for GalN and GalNAc residues in the homo-oligomers.

Results and discussion

The building blocks **1**, **2a**, **b** and **4**, needed for the assembly the projected Gal- and $GalN_3$ homo-oligomers, were prepared using published procedures.[21-23] Application of Kiso's galactosylation methodology is bound to a stepwise elongation procedure that consists of the following three reactions; 1) glycosylation; 2) DTBS-removal and 3) regioselective benzoylation of the primary alcohol group. For the latter transformation benzoyl-hydroxybenzotriazole (BzOBt), a mild acylating agent proved to be suited.[24] Table 1 summarizes the result of each reaction *en route* to the fully protected Gal- and $GalN_3$ homo-oligomers.

Table 1. Synthesis of homo-oligomers of Gal and $GalN_3$.



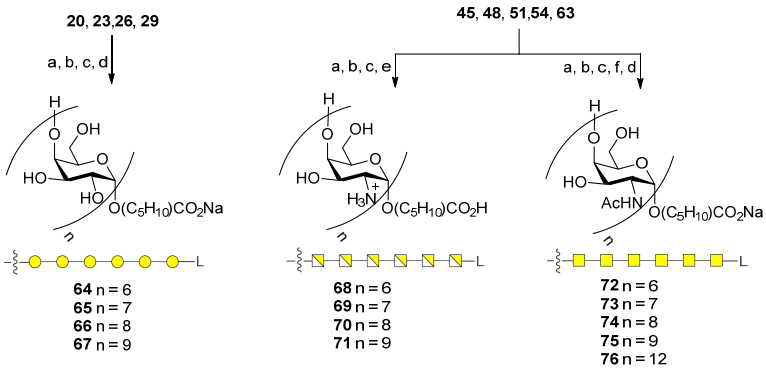
n	R	Glycosylation[a]	Desilylation[b]	Benzoylation[c]
1	OBn	**5** (86%)	**6** (92%)	**7** (94%)
2	OBn	**8** (91%)	**9** (96%)	**10** (95%)
3	OBn	**11** (84%)	**12** (94%)	**13** (95%)
4	OBn	**14** (80%)	**15** (93%)	**16** (92%)
5	OBn	**17** (80%)	**18** (92%)	**19** (90%)
6	OBn	**20** (72%)	**21** (93%)	**22** (95%)
7	OBn	**23** (76%)	**24** (95%)	**25** (94%)
8	OBn	**26** (81%)	**27** (93%)	**28** (95%)
9	OBn	**29** (65%)	-	-
1	N_3	**30** (83%) (64%)[d]	**31** (94%)	**32** (93%)
2	N_3	**33** (91%) (67%)[d]	**34** (95%)	**35** (92%)
3	N_3	**36** (84%) (60%)[d]	**37** (92%)	**38** (94%)
4	N_3	**39** (82%)	**40** (91%)	**41** (92%)
5	N_3	**42** (90%)	**43** (93%)	**44** (90%)
6	N_3	**45** (89%)	**46** (92%)	**47** (90%)
7	N_3	**48** (88%)	**49** (94%)	**50** (92%)
8	N_3	**51** (87%)	**52** (91%)	**53** (94%)
9	N_3	**54** (89%)	**55** (94%)	**56** (90%)
10	N_3	**57** (65%)	**58** (96%)	**59** (94%)
11	N_3	**60** (73%)	**61** (84%)	**62** (93%)
12	N_3	**63** (79%)	-	-

[a] **1**, NIS, TfOH, 4Å MS, DCM, 0 °C; or **2b**, TfOH, 4Å MS, DCM, 0 °C. [b] HF/pyridine, THF, rt. [c] BzOBt, Et_3N, DCM, rt. [d] **2a**, NIS, TfOH, 4Å MS, DCM, 0 °C.

As can be seen from the Table, all glycosylations using the Gal-donor **1** proceeded efficiently providing the oligomers (n = 1-9, R = OBn) with excellent stereoselectivity. Removal of the silylidene ketals and subsequent regioselective protection of the liberated C6-hydroxyl groups also proceeded uneventfully and the efficiency of all reaction steps did not diminish with growing chain length. For the assembly of the GalN/GalNAc homo-oligomers the use of selenophenyl donor **2a** was explored first. The relatively moderate yield of the glycosylation for the mono-, di- and trimer ($R = N_3$, 64% for **30**, 67% for **33** and 60% for **36**), was an incentive to switch to the use of *N*-phenyltrifluoroacetimidate donor **2b**. As can be seen in Table 1, this donor performed well and all glycosylation reactions proceeded effectively up to the dodecasaccharide level. Similar to the chemistry developed for the Gal-oligomers, the protecting group manipulations posed no problems in the $GalN_3$ series and the desilylation and regioselective benzoylation reactions proceeded in excellent yields (84%-96% and 90%-94%, respectively) also with the longer oligomers.

With all protected fragments in hand deprotection conditions were developed to complete the assembly of the GAG homo-oligomers (Scheme 1). First the set of Gal-oligomers was brought to the end stage by removing the silylidene ketal, followed by saponification of the benzoates and benzyl ester, hydrogenolysis of all benzyl ethers and an ion exchange procedure to furnish the sodium salts of the target compounds. Following this sequence of events, hexasaccharide **64** and heptasaccharide **65** were obtained in 69% and 75% yield, respectively. The octasaccharide **66** and nonasaccharide **67** on the other hand were obtained in significantly lower yields (25% and 29% respectively), because their solubility in water - quite surprisingly- turned out to be relatively poor.

Next $GalN_3$ oligomers **45**, **48**, **51**, **54** and **63** were transformed into the set of GalN- and GalNAc-target compounds **68**-**71** and **72**-**76**. Similar to the Gal-series, removal of the silylidene groups from these substrates was followed by saponification and reduction of the benzyl esters and azide moieties. An anion ion exchange reaction (to change the acetate counterions for chlorides) delivered the GalN-oligomers **68**-**71**, all in good yield. No solubility issues were encountered in this series. The free amines generated could also be chemoselectively acetylated to provide the GalNAc-oligosaccharides **72**-**76**. Also, these oligomers proved to be well soluble in water and were obtained as their sodium salts in 39%-62% yield (over 5 steps).



Scheme 1. Deprotection of synthesized oligosaccharides. a) HF/pyridine (70%), THF, 0 ºC to rt; b) 1M NaOH, THF, MeOH; c) $Pd(OH)_2/C$, THF/H_2O/*t*-BuOH, H_2; d) Dowex-Na^+, **64**: 69%; **65**: 75%; **66**: 25%; **67**: 29%; **72**: 44%; **73**: 47%; **74**: 46%; **75**: 62%; **76**: 39%. e) Amberlite Cl^- form, **68**: 67%; **69**: 56%; **70**: 66%; **71**: 55%. f) Ac_2O, $NaHCO_3$, H_2O/THF, g) 2M NaOH, THF, MeOH.

To investigate the conformation and spatial presentation of the synthetic GAGs, the conformational and dynamic properties of these molecules were studied by a combination of NMR and computational methods.[25-31] These have revealed that the glycosidic linkages of these GAGs show a conformational equilibrium between two major conformers. Interestingly, the dynamic equilibrium provides an overall extended shape that does not substantially change between the two Ψ+ and Ψ- geometries. All molecules display elongated, almost straight, geometries, in which the only inter-residue contacts occur between directly linked residues (Figure 2). In both canonical structures, the hydroxymethyl groups and those at C2 (OH/NHAc/NH_2) are presented towards the bulk solvent with an almost perpendicular orientation to the oligosaccharide main chain axis, properly oriented to interact with binding partners, such as biomachinery enzymes or antibodies. DFT calculations indicated a series of inter-residue hydrogen bonds stabilizing both conformations, amongst which a *non-conventional* C-H···O HB between H5 of residue (i+1) and the O3 of residue (i), which was revealed by a significant downfield chemical shift for the non-reducing-end H5 protons in the NMR spectra. This is the first time that this type of *non-conventional* C-H···O HB is reported for linear oligosaccharide structures.

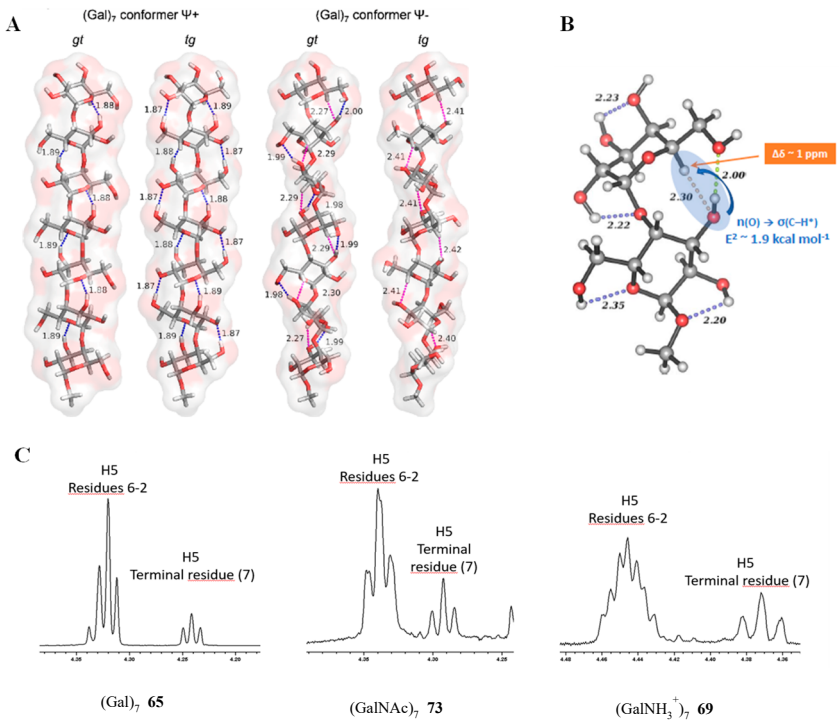


Figure 2. A) Quantum mechanically (QM)-optimized structures for the Gal heptamer in the typically dominant *gt* and *tg* hydroxymethyl group conformations. van der Waals surfaces are shown with 80% transparency. B) View of the **Ψ**-conformer for the disaccharide unit with the theoretical HBs. The non-conventional C5-H5(i+1)···O3(i). HB is highlighted, along with the energy value (ca. 2 kcal/mol) estimated from the NBO calculations and the expected deshielding for H5 (Δδ ca. 1 ppm). C) The shape of the ^{1}H NMR signals observed for H5 protons (except for the reducing end) for the heptamers of Gal, GalNAc and $GalNH_3^+$. There is a slight difference in the chemical shift of those of the $GalNH_3^+$moieties while those of the Gal and GalNAc analogues are identical.

Conclusion

Synthetic methodology enabling the assembly of GAG homo-oligomers has been developed. Key features of the synthetic strategy include the use of di-*tert*-butylsilylidene directed α-galactosylation methodology and regioselective benzoylation reactions using Bz-OBt. With the use of silylidene protected Gal or $GalNH_2$ donors, the required *cis*-Gal/$GalNH_2$ linkages were installed in a highly stereoselective manner. Structural analysis of the Gal, GalN and GalNAc oligomers by a combination of NMR and MD approaches revealed that the oligomers adopt an elongated, almost straight structure, stabilized by inter-residue H-bonds, one of which is a non-conventional C-H···O hydrogen bond between H5 of the residue (i+1) and O3 of the residue (i). The structures position the C2 substituents almost perpendicular to the oligosaccharide main chain axis, pointing outward to the environment and available for interactions with antibodies or other binding partners. The generated oligosaccharides and established structures can find application in future binding studies to establish GAG-epitopes, that may be used in anti-fungal conjugate vaccine modalities.

Experimental section

General procedure for glycosylation with thiodonor 1 (procedure A)

DCM, washed with saturated $NaHCO_3$ and brine. The organic phase was dried with anhydrous $MgSO_4$. The donor (1.5 – 3.0 eq) and the acceptor (1.0 eq) were co-evaporated with toluene (three times). The residue was dissolved in dry DCM (0.1 M acceptor in DCM) under nitrogen and stirred over fresh flame-dried molecular sieves 3Å. The solution was cooled to 0 ºC, after which NIS (2.0 – 6.0 eq) and TfOH (0.1 – 0.3 eq) were added. The reaction was stirred at 0 ºC until TLC-analysis showed complete conversion of the acceptor. The reaction was quenched with saturated $Na_2S_2O_3$, diluted with filtered and concentrated *in vacuo*. The products were purified by silica gel column chromatography (See experimental description below for eluent system).

General procedure for glycosylation with imidate donor 2b (procedure B)

The donor (1.5 – 3.0 eq) and acceptor (1.0 eq) were co-evaporated with toluene (three times). The residue was dissolved in dry DCM (0.1 M acceptor in DCM) under nitrogen and stirred over fresh flame-dried molecular sieves 4Å. The solution was cooled to 0 ºC, after which TfOH (0.1 – 0.3 eq) was added. The reaction was stirred at 0 ºC until TLC-analysis showed complete conversion of the acceptor. The reaction was quenched with Et_3N, diluted with DCM, washed with saturated $NaHCO_3$ and brine. The organic phase was dried with anhydrous $MgSO_4$, filtered and concentrated *in vacuo*. The products were purified by silica gel column chromatography (See experimental description below for eluent system).

General procedure for the deprotection of di-*tert*-butyl silylidene group (general procedure C)

HF/pyridine (16 eq) solution was added to a solution of starting material in THF at 0 ºC. The reaction was warmed to room temperature and stirred until TLC-analysis indicated full consumption of the starting material (± 1h). Then the mixture was diluted with DCM and washed with saturated $NaHCO_3$ and brine, dried with anhydrous $MgSO_4$, filtered and concentrated *in vacuo*. The product was purified by silica gel column chromatography (See experimental description below for eluent system).

General procedure for selective benzoylation of primary alcohol (general procedure D)

PhCOOBt (4.5 eq) and Et_3N (5.0 eq) were added to the solution of starting material in DCM (0.05 M). The reaction was allowed to stirred overnight at room temperature. Then the mixture was diluted with DCM and washed with saturated $NaHCO_3$ and brine, dried with anhydrous $MgSO_4$, filtered and concentrated *in vacuo*. The product was purified by silica gel column chromatography (See experimental description below for eluent system).

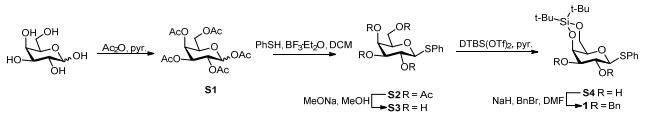
General procedure for saponification and hydrogenation of the oligosaccharides (general procedure E)

1 M NaOH solution was added to the mixture of the starting material in THF/MeOH (2 ml/0.9 ml) at 0 ºC. The solution was warmed to room temperature slowly and stirred overnight. The reaction was cooled to 0 ºC and

neutralized by Amberlite IR120 (H+) resin. After filtration, the filtrate was concentrated *in vacuo*. The residue was dissolved in THF/H_2O/*tert*-BuOH (2 ml/2 ml/0.8 ml) before a catalytic amount of $Pd(OH)_2/C$ was added. The reaction mixture was stirred for 3 days under a H_2 atmosphere, filtered and concentrated *in vacuo*. A white powder was obtained, which was purified by gel filtration (HW-40, 0.15M NH_4OAc in H_2O). The products were transformed into the sodium salts over a short Dowex Na^+ column or chloride salts in the mixture of Amberlite (Cl form) and water, after which the compounds were lyophilized.

Experimental Procedures and Characterization Data of Products

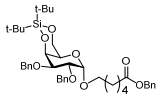
2,3-di-*O*-benzyl-4,6-di-*tert*-butylsilylidene-1-thio-β-D-galactopyranoside 1



Galactose (100 g) was suspended in pyridine (448 ml), which was cooled in ice-bath. Then Ac_2O (526 ml) was added to the reaction solution, which was allowed to warm to room temperature and stirred for overnight. MeOH was added to quench the reaction and the solution was concentrated to form the crude product **S1**. The crude **S1** (50 g) was dissolved in DCM (100 ml) and cooled in ice-bath. Then PhSH and $BF_3{\cdot}Et_2O$ were added to the solution and the reaction solution was allowed to warm to room temperature and stirred for overnight. Then the solution was washed with water, sat. $NaHCO_3$ solution and sat. NaCl solution subsequently. The organic layer was dried over $MgSO_4$, filtered and concentrated. The crude was purified by silica gel column chromatography (pentane:Et_2O = 3:1- 2:1) to give **S2** in 88% yield. **S2** (50 g) was suspended in MeOH (150 ml) and cooled in ice-bath. MeONa was added to the solution and the reaction solution was allowed to warm to room temperature and stirred for overnight. The solution was neutralized with Dowex ion-exchange resin, filtered and concentrated. The crude product **S3** was used directly to the next step. **S3** (5.26 g, 19.3 mmol) was dissolved in pyridine (100 ml) and cooled to -30 °C. $DTBS(OTf)_2$ (6.3 ml, 19.3 mmol) was added to the reaction solution, which was allowed to warm to room temperature and stirred for 2h. MeOH (3 ml) was added to the solution and concentrated *in vacuo*. The crude was washed with 1M HCl, sat. $NaHCO_3$ solution and sat. NaCl solution subsequently. The organic layer was dried over $MgSO_4$, filtered and concentrated. The crude was purified by silica gel column chromatography (pentane:EtOAc = 5:1- 3:1) to give **S4** in 87% yield. S4 (4.5g, 11 mmol) was dissolved in DMF (60 ml) and cooled in ice-bath. Then BnBr (5.3 ml, 44 mmol) and NaH (1.06g, 26.4 mmol) were added subsequently to the reaction mixture, which was allowed to stir in ice-bath for 3h. MeOH was added to quench the reaction, and the solution was diluted in Et_2O and washed with water and sat. NaCl solution subsequently. The organic layer was dried over $MgSO_4$, filtered and concentrated. The crude was purified by silica gel column chromatography (pentane:Et_2O = 10:1-8:1) to give compound **1** in 82% yield. ^1H NMR (400 MHz, $CDCl_3$) δ 7.64 – 7.58 (m, 2H), 7.50 (ddd, *J* = 9.8, 7.7, 2.1 Hz, 4H), 7.45 – 7.28 (m, 9H), 4.98 (d, *J* = 2.0 Hz, 2H), 4.90 – 4.70 (m, 3H), 4.56 (d, *J* = 2.9 Hz, 1H), 4.33 – 4.19 (m, 2H), 3.93 (td, *J* = 9.5, 2.3 Hz, 1H), 3.55 (dt, *J* = 9.0, 2.5 Hz, 1H), 3.34 (d, *J* = 2.0 Hz, 1H), 1.27 – 1.12 (m, 18H). ^{13}C NMR

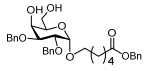
(101 MHz, $CDCl_3$) δ 138.44, 138.42, 134.92, 132.14, 128.85, 128.56, 128.54, 128.41, 127.92, 127.84, 127.37, 88.76, 82.90, 77.31, 76.05, 74.82, 71.11, 70.06, 67.48, 27.80, 27.76, 23.54, 20.84.

6-(Benzyl hexanoyl) 2,3-di-*O*-benzyl-4,6-di-*tert*-butylsilylidene-α-D-galactopyranoside (5)



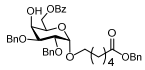
The reaction was carried out according to the general procedure A. The donor **1**[21] (3.5 g, 5.9 mmol) and the acceptor **4**[22] (1.44 g, 6.5 mmol) were co-evaporated with toluene (three times). The residue was dissolved in 65 ml dry DCM under nitrogen and stirred over fresh flame-dried molecular sieves 3Å. The solution was cooled to 0 ºC, after which NIS (2.65 g, 11.8 mmol) and TfOH (105 µl, 1.18 mmol) were added. The reaction was stirred at 0 ºC for 1 h. Then the reaction was quenched with saturated $Na_2S_2O_3$, diluted with DCM, washed with saturated $NaHCO_3$ and brine. The organic phase was dried with anhydrous $MgSO_4$, filtered and concentrated *in vacuo*. The product was purified by silica gel column chromatography (pentane:Et_2O = 10:1- 5:1). Compound **5** (3.57 g, 86% yield, pentane:EtOAc = 10:1, R*f* = 0.25-0.35) was obtained as yellow syrup. $[\alpha]_D^{25}$ -13.6 (c=1, $CHCl_3$). IR (neat, cm^{-1}) ν 1096, 1264, 1455, 1473, 1734, 2859, 2932. ^{1}H-NMR ($CDCl_3$, 400 MHz) δ 7.46 – 7.41 (m, 2H, *aromatic* H), 7.38 – 7.22 (m, 13H, *aromatic* H), 5.10 (s, 2H, *PhC*H_{2C}*OO*), 4.86 (d, *J* = 11.9 Hz, 1H, *PhC*H_2), 4.73 (s, 2H, *PhC*H_2), 4.70 (d, *J* = 3.7 Hz, 1H, H-1), 4.65 (d, *J* = 12.0 Hz, 1H, *PhC*H_2), 4.51 (d, *J* = 2.8 Hz, 1H, H-4), 4.20 (dd, *J* = 12.5, 2.1 Hz, 1H, H-6), 4.08 (dd, *J* = 12.4, 1.7 Hz, 1H, H-6), 3.97 (dd, *J* = 10.0, 3.6 Hz, 1H, H-2), 3.82 (dd, *J* = 10.0, 3.0 Hz, 1H, H-3), 3.62 – 3.54 (m, 2H, H-5, H-7), 3.47 – 3.36 (m, 1H, H-7), 2.33 (t, *J* = 7.5 Hz, 2H, H-11), 1.70 – 1.55 (m, 4H, H-8, H-10), 1.44 – 1.29 (m, 2H, H-9), 1.06 (s, 9H, *C*H_3), 1.00 (s, 9H, *C*H_3). ^{13}C NMR (100 MHz, $CDCl_3$) δ 173.4 (C=O), 139.1, 138.7, 136.1, 128.6, 128.3, 128.2, 127.6, 127.5 (*aromatic* C/*CH*), 98.0 (C-1), 77.7 (C-3), 74.4 (C-2), 73.6 (CH_2*Ph*), 71.2 (C-4), 71.1 (CH_2*Ph*), 67.9 (C-7), 67.3 (C-6), 67.2 (C-5), 66.1 (*C*=*O*CH_2*Ph*), 34.2 (C-11), 29.1 (C-8), 27.7 (CH_3), 27.4 (CH_3), 25.7 (C-9), 24.7 (C-10), 23.5 (C-*Si*), 20.7 (C-*Si*). ^{13C}-HMBC ($CDCl_3$, 100 MHz): 98.0 ($J_{C1,H1}$ = 168 Hz). HR-MS: Calculated for $C_{41}H_{56}O_8Si$ $[M+Na]^+$: 727.3642, found: 727.3637.

6-(Benzyl hexanoyl) 2,3-di-*O*-benzyl-α-D-galactopyranoside (6)



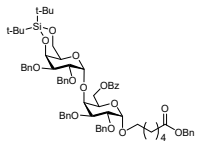
The reaction was carried out according to the general procedure C using compound **3** (3.26 g, 4.62 mmol) and HF/pyridine (70%, 960 µl). The product was purified by column chromatography (pentane:EtOAc = 1:1). Compound **6** (2.4 g, 92% yield, pentane:EtOAc = 1:2, R*f* = 0.35-0.45) was obtained as yellow syrup. $[\alpha]_D^{25}$ +97.4 (c=1, $CHCl_3$). IR (neat, cm^{-1}) ν 967, 1027, 1045, 1076, 1093, 1149, 1212, 1453, 1731, 2869, 2925, 3463. ^{1}H-NMR ($CDCl_3$, 400 MHz) δ 7.40 – 7.24 (m, 15H, *aromatic* H), 5.11 (s, 2H, *PhC*H_{2C}=*O*), 4.85 – 4.76 (m, 3H, *C*H_2*Ph*, H-1), 4.69 (d, *J* = 11.4 Hz, 1H, *C*H_2*Ph*), 4.64 (d, *J* = 12.1 Hz, 1H, *C*H_2*Ph*), 4.08 (d, *J* = 2.9 Hz, 1H, H-4), 3.95 – 3.73 (m, 5H, H-2, 3, 5, 6), 3.68 – 3.59 (m, 1H, H-7), 3.47 – 3.37 (m, 1H, H-7), 2.41 (bs, 2H, *O*H), 2.36 (t, *J* = 7.5 Hz, 3H, H-11), 1.73 – 1.56 (m, 4H, H-8, H-10), 1.45 – 1.33 (m, 2H, H-9). ^{13}C NMR (100 MHz, $CDCl_3$) δ 173.7 (C=O), 138.6, 138.3, 136.2, 128.8, 128.7, 128.6, 128.4, 128.1, 128.0 (*aromatic* C/*CH*), 97.5 (C-1), 77.6, 76.0, 73.5 (CH_2*Ph*), 73.1 (CH_2*Ph*), 69.2, 68.1 (C-7), 66.4 (*C*=*O*CH_2*Ph*), 63.2 (C-6), 34.4 (C-11), 29.2 (C-8), 25.9 (C-9), 24.8 (C-10). HR-MS: Calculated for $C_{33}H_{40}O_8$ $[M+Na]^+$: 587.2621, found: 587.2615.

6-(Benzyl hexanoyl) 6-*O*-benzoyl-2,3-di-*O*-benzyl-α-D-galactopyranoside (7)



The reaction was carried out according to the general procedure D using compound **6** (1.87 g, 3.33 mmol), PhCOOBt (3.18 g, 13.3 mmol) and Et_3N (2 ml, 14.7 mmol). The product was purified by column chromatography (pentane:EtOAc = 4:1). Compound **7** (2.1 g, 94% yield, pentane:EtOAc = 3:1, R*f* = 0.35-0.45) was obtained as yellow syrup. $[\alpha]_D^{25}$ +37.8 (c=1, $CHCl_3$). IR (neat, cm^{-1}) ν 1027, 1040, 1095, 1153, 1270, 1452, 1720, 2868, 2927, 3463. ^{1}H-NMR ($CDCl_3$, 400 MHz) δ 8.05 – 7.98 (m, 2H), 7.58 – 7.51 (m, 1H), 7.47 – 7.26 (m, 17H, *aromatic* H), 5.09 (s, 2H, *Ph*CH_{2C}=*O*), 4.86 – 4.77 (m, 3H, *C*H_2*Ph*, H-1), 4.70 (d, *J* = 11.5 Hz, 1H, *C*H_2*Ph*), 4.64 (d, *J* = 12.1 Hz, 1H, *C*H_2*Ph*), 4.56 (dd, *J* = 11.5, 4.8 Hz, 1H, H-6), 4.48 (dd, *J* = 11.5, 7.6 Hz, 1H, H-6), 4.14 – 4.05 (m, 2H, H-4, H-5), 3.91 (dd, *J* = 9.8, 3.2 Hz, 1H, H-2), 3.84 (dd, *J* = 9.8, 3.6 Hz, 1H, H-3), 3.64 – 3.56 (m, 1H, H-7), 3.44 – 3.36 (m, 1H, H-7), 2.51 (bs, 1H, *O*H), 2.28 (t, *J* = 7.5 Hz, 2H, H-11), 1.65 – 1.56 (m, 4H, H-8, H-10), 1.35 – 1.23 (m, 2H, H-9). ^{13}C NMR (100 MHz, $CDCl_3$) δ 173.3 (C=O), 166.3 (C*OPh*), 138.4, 138.1, 136.1, 133.1, 129.9, 129.6, 128.6, 128.5, 128.4, 128.2, 127.9, 127.8 (*aromatic* C/*CH*), 97.2 (C-1), 77.6 (C-2), 75.8 (C-3), 73.3 (CH_2*Ph*), 73.0 (CH_2*Ph*), 68.0 (C-7), 67.9 (C-4), 67.7 (C-5), 66.1 (*C*=*O*CH_2*Ph*), 64.2 (C-6), 34.1 (C-11), 29.0 (C-8), 25.7 (C-9), 24.6 (C-10). HR-MS: Calculated for $C_{40}H_{44}O_9$ $[M+Na]^+$: 691.2883, found: 691.2878.

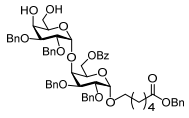
6-(Benzyl hexanoyl) pentyl 2,3-di-*O*-benzyl-4,6-di-*tert*-butylsilylidene-α-D-galactopyranosyl-(1→4)-6-*O*-benzoyl-2,3-di-*O*-benzyl-α-D-galactopyranoside (8)



The reaction was carried out according to the general procedure A. The donor **1** (2.00 g, 3.37 mmol) and the acceptor **7** (1.50 g, 2.24 mmol) were co-evaporated with toluene (three times). The residue was dissolved in 22 ml dry DCM under nitrogen and stirred over fresh flame-dried molecular sieves 3Å. The solution was cooled to 0 ºC, after which NIS (1.51 g, 6.72 mmol) and TfOH (60 µl, 0.67 mmol) were added. The reaction was stirred at 0 ºC for 1 h. Then the reaction was quenched with saturated $Na_2S_2O_3$, diluted with DCM, washed with saturated $NaHCO_3$ and brine. The organic phase was dried with anhydrous $MgSO_4$, filtered and concentrated *in vacuo*. The product was purified by silica gel column chromatography (pentane:EtOAc = 7:1). Compound **8** (2.40 g, 91% yield, pentane:EtOAc = 3:1, R*f* = 0.65-0.75) was obtained as colorless syrup. $[\alpha]_D^{25}$ +57.4 (c=1, $CHCl_3$). IR (neat, cm^{-1}) ν 444, 651, 737, 797, 826, 977, 1009, 1027, 1046, 1092, 1131, 1274, 1453, 1724, 2858, 2932. ^{1}H-NMR ($CDCl_3$, 400 MHz) δ 8.03 – 7.95 (m, 2H, *aromatic* H), 7.60 – 7.52 (m, 1H, *aromatic* H), 7.50 – 7.11 (m, 27H, *aromatic* H), 5.08 (s, 2H, *Ph*CH_2C=*O*), 4.93 – 4.86 (m, 2H, *C*H_2*Ph*, H-1^A), 4.84 (d, *J* = 3.6 Hz, 1H, H-1^B), 4.78 – 4.61 (m, 8H, *C*H_2*Ph*, H-6^A), 4.55 (dd, *J* = 11.1, 6.2 Hz, 1H, H-6^A), 4.45 (d, *J* = 2.4 Hz, 1H, H-4^B), 4.07 (d, *J* = 2.6 Hz, 1H, H-4^A), 4.05 – 3.98 (m, 2H, H-2^B, H-5^A), 3.96 (q, *J* = 1.6 Hz, 1H, H-5^B), 3.91 – 3.81 (m, 3H, H-3A, H-3^B, H-2^A), 3.73 – 3.69 (m, 2H, H-6^B), 3.64 – 3.56 (m, 1H, H-7), 3.46 – 3.38 (m, 1H, H-7), 2.28 (t, *J* = 7.6 Hz, 2H, H-11), 1.64 – 1.53 (m, 4H, H-10, H-8), 1.34 – 1.22 (m, 2H, H-9), 1.01 (s, 9H, *C*H_3), 0.94 (s, 9H, *C*H_3). ^{13}C NMR (100 MHz, $CDCl_3$) δ 173.6 (C=O), 166.2 (C*OPh*), 139.3, 138.7, 138.5, 136.3, 133.3, 130.1, 129.8, 129.1, 128.8, 128.5, 128.4, 128.2, 127.9, 127.8, 127.6, 127.5 (*aromatic* C/*CH*), 100.4 (C-1^B), 97.2 (C-1^A), 78.2 (C-2^A), 77.3 (C-3^A), 75.8 (C-3^B), 75.5 (C-4^A), 74.4 (CH_2*Ph*), 73.6 (C-5^A),

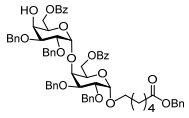
73.1 (C*H*$_2$*Ph*), 73.0 (C*H*$_2$*Ph*), 70.9 (C-4^B), 70.5 (C*H*$_2$*Ph*), 68.8 (C-2^B), 68.1 (C-7), 67.8 (C-5^B), 67.2 (C-6^B), 66.3 (*C*=O*C*H$_2$*Ph*), 63.1 (C-6^A), 34.3 (C-11), 29.2 (C-8), 27.9 (C*H*$_3$), 27.5 (C*H*$_3$), 25.9 (C-9), 24.8 (C-10), 23.6 (C-*Si*), 20.9 (C-*Si*). HR-MS: Calculated for $C_{68}H_{82}O_{14}Si$ [M+Na]$^+$: 1173.5372, found: 1173.5366.

6-(Benzyl hexanoyl) 2,3-di-*O*-benzyl-α-D-galactopyranosyl-(1→4)-6-*O*-benzoyl-2,3-di-*O*-benzyl-α-D-galactopyranoside (9)



The reaction was carried out according to the general procedure C using compound **8** (2.39 g, 2.08 mmol) and HF/pyridine (70%, 860 µl, 33.3 mmol). The product was purified by column chromatography (pentane:EtOAc = 2:1 - 1:1). Compound **9** (2.0 g, 96% yield, pentane:EtOAc = 1:1, R*f* = 0.25-0.35) was obtained as yellow syrup. $[\alpha]_D^{25}$ +58.1 (c=1, $CHCl_3$). IR (neat, cm^{-1}) ν 737, 1027, 1046, 1093, 1155, 1274, 1453, 1720, 2868, 2924, 3492. ^{1}H-NMR ($CDCl_3$, 400 MHz) δ 8.05 – 7.97 (m, 2H, *aromatic* H), 7.62 – 7.54 (m, 1H, *aromatic* H), 7.51 – 7.16 (m, 27H, *aromatic* H), 5.10 (s, 2H, *Ph*CH_2C=*O*), 4.98 (d, *J* = 2.3 Hz, 1H, H-1^B), 4.88 (s, 1H, H-1^A), 4.85 – 4.63 (m, 9H, CH_2*Ph*, H-6^A), 4.58 (dd, *J* = 11.2, 6.1 Hz, 1H, CH_2*Ph*, H-6^A), 4.13 – 3.99 (m, 4H, H-4, H-5), 3.91 – 3.85 (m, 4H, H-3, H-2), 3.65 – 3.56 (m, 2H, H-6^B, H-7), 3.55 – 3.40 (m, 2H, H-6^B, H-7), 2.61 (bs, 2H, *O*H), 2.30 (t, *J* = 7.6 Hz, 2H, H-11), 1.67 – 1.55 (m, 4H, H-10, H-8), 1.33 – 1.24 (m, 2H, H-9). ^{13}C NMR (100 MHz, $CDCl_3$) δ 173.5 (C=O), 166.1 (C*OPh*), 138.6, 138.4, 138.1, 136.1, 133.3, 129.9 (*aromatic* C), 129.7, 128.6, 128.6, 128.5, 128.4, 128.3, 128.2, 128.0, 127.9, 127.9, 127.8 (*aromatic* C*H*), 100.6 (C-1^B), 97.3 (C-1^A), 78.2 (C-2^A), 77.8 (C-5^B), 77.4 (C-2^B), 75.4 (C-3^A, C-3^B), 74.2 (C*H*$_2$*Ph*), 73.4 (C*H*$_2$*Ph*), 73.0 (C*H*$_2$*Ph*), 72.4 (C*H*$_2$*Ph*), 69.8 (C-4^B), 69.2 (C-4^A), 68.7 (C-5^A), 68.1 (C-7), 66.2 (*C*=O*C*H$_2$*Ph*), 63.1 (C-6), 34.2 (C-11), 29.1 (C-8), 25.8 (C-9), 24.7 (C-10). HR-MS: Calculated for $C_{60}H_{66}O_{14}$ [M+Na]$^+$: 1033.4350, found: 1033.4345.

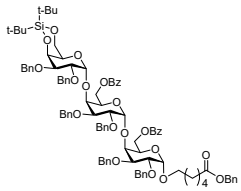
6-(Benzyl hexanoyl) 6-*O*-benzoyl-2,3-di-*O*-benzyl-α-D-galactopyranosyl-(1→4)-6-*O*-benzoyl-2,3-di-*O*-benzyl-α-D-galactopyranoside (10)



The reaction was carried out according to the general procedure D using compound **9** (2.01 g, 1.99 mmol), PhCOOBt (2.14 g, 8.96 mmol) and Et_3N (1.4 ml, 9.95 mmol). The product was purified by column chromatography (pentane:EtOAc = 5:1 - 3:1). Compound **10** (2.1 g, 94% yield, pentane:EtOAc = 3:1, R*f* = 0.40-0.50) was obtained as yellow syrup. $[\alpha]_D^{25}$ +42.4 (c=1, $CHCl_3$). IR (neat, cm^{-1}) ν 738, 1047, 1098, 1275, 1452, 1720, 2869, 2916, 2496. ^{1}H-NMR ($CDCl_3$, 400 MHz) δ 8.02 – 7.91 (m, 4H, *aromatic* H), 7.62 – 7.09 (m, 31H, *aromatic* H), 5.08 (s, 2H, *Ph*CH_2C=*O*), 5.01 (s, 1H, H-1^B), 4.87 – 4.60 (m, 10H, H-1^A, CH_2*Ph*, H-6^A), 4.57 – 4.44 (m, 3H, H-6^A, H-4^A, H-5^B), 4.16 – 4.03 (m, 3H, H-3^A, H-4^B, H-6^B), 4.01 (t, *J* = 6.7 Hz, 1H, H-5^A), 3.95 – 3.83 (m, 4H, H-2^A, 2^B, 3^B, 6^B), 3.62 – 3.53 (m, 1H, H-7), 3.45 – 3.37 (m, 1H, H-7), 2.27 (t, *J* = 7.6 Hz, 2H, H-11), 1.64 – 1.52 (m, 4H, H-10, H-8), 1.30 – 1.21 (m, 2H, H-9). ^{13}C NMR (100 MHz, $CDCl_3$) δ 173.6 (C=O), 166.2 (C*OPh*), 138.8, 138.2, 136.3, 133.7, 133.4, 133.2, 130.3, 130.0, 129.9, 128.8, 128.6, 128.5, 128.4, 127.9, 127.7 (*aromatic* C*H*/C), 100.3 (C-1^B), 97.5 (C-1^A), 78.3 (C-2^B), 77.3 (C-3^B), 77.1 (C-3^A), 75.7 (C-5^B), 75.6 (C-2^A), 74.5 (C*H*$_2$*Ph*), 73.3 (C*H*$_2$*Ph*), 73.2 (C*H*$_2$*Ph*), 72.7 (C*H*$_2$*Ph*), 68.8 (C-5^A), 68.2 (C-7), 68.1 (C-4^A), 67.1

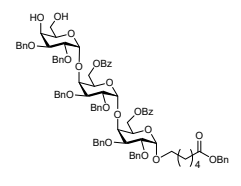
(C-4^{B}), 66.3 (*C*=O*C*H_2*Ph*), 63.1 (C-6^{A}), 62.7 (C-6^{B}), 34.3 (C-11), 29.2 (C-8), 25.9 (C-9), 24.8 (C-10). HR-MS: Calculated for $C_{67}H_{70}O_{15}$ $[M+Na]^+$: 1137.4612, found: 1137.4607.

6-(Benzyl hexanoyl) 2,3-di-*O*-benzyl-4,6-di-*tert*-butylsilylidene-α-D-galactopyranosyl-(1→4)-6-*O*-benzoyl-2,3-di-*O*-benzyl-α-D-galactopyranosyl-(1→4)-6-*O*-benzoyl-2,3-di-*O*-benzyl-α-D-galactopyranoside (11)



The reaction was carried out according to the general procedure A. The donor **1** (1.82 g, 3.07 mmol) and the acceptor **10** (1.90 g, 1.71 mmol) were co-evaporated with toluene (three times). The residue was dissolved in 17 ml dry DCM under nitrogen and stirred over fresh flame-dried molecular sieves 3Å. The solution was cooled to 0 ºC, after which NIS (1.38 g, 6.14 mmol) and TfOH (54 µl, 0.61 mmol) were added. The reaction was stirred at 0 ºC for 1 h. Then the reaction was quenched with saturated $Na_2S_2O_3$, diluted with DCM, washed with saturated $NaHCO_3$ and brine. The organic phase was dried with anhydrous $MgSO_4$, filtered and concentrated *in vacuo*. The product was purified by silica gel column chromatography (pentane:EtOAc = 5:1). Compound **11** (2.28 g, 84% yield, pentane:EtOAc = 5:2, R*f* = 0.40-0.50) was obtained as colorless syrup. $[\alpha]_D^{25}$ +47.5 (c=1, $CHCl_3$). IR (neat, cm^{-1}) ν 444, 475, 650, 734, 795, 824, 914, 937, 977, 1005, 1025, 1044, 1063, 1090, 1270, 1452, 1724, 2859, 2932. ^{1}H-NMR ($CDCl_3$, 400 MHz) δ 8.02 – 7.96 (m, 2H, *aromatic* H, Bz), 7.95 – 7.90 (m, 2H, *aromatic* H, Bz), 7.61 – 7.03 (m, 44H, *aromatic* H), 5.09 (d, *J* = 3.3 Hz, 1H, H-1C), 5.07 (s, 2H, *Ph*CH_2C=*O*), 4.97 – 4.89 (m, 2H, *C*H_2*Ph*, H-1^{B}), 4.86 – 4.50 (m, 16H, H-1^{A}, *C*H_2*Ph*, H-6^{B}, 6^{A}), 4.49 – 4.42 (m, 2H, H-4^{B}, H-4^{C}), 4.15 (d, *J* = 2.6 Hz, 1H, H-4^{A}), 4.04 – 3.92 (m, 5H, H-2^{B}, 2^{C}, 5^{A}, 5^{B}, 5^{C}), 3.90 – 3.77 (m, 4H, H-2^{A}, 3^{A}, 3^{B}, 3^{C}), 3.75 – 3.64 (m, 2H, H-6^{C}), 3.61 – 3.51 (m, 1H, H-7), 3.46 – 3.37 (m, 1H, H-7), 2.27 (t, *J* = 7.6 Hz, 2H, H-11), 1.58 (p, *J* = 7.5 Hz, 4H, H-10, H-8), 1.31 – 1.21 (m, 2H, H-9), 1.02 (s, 9H, *C*H_3), 0.91 (s, 9H, *C*H_3). ^{13}C NMR (100 MHz, $CDCl_3$) δ 173.4 (C=O), 165.9 (C*OPh*), 165.4 (C*OPh*), 139.1, 138.4, 136.1, 133.2, 129.6, 128.9, 128.5, 128.4, 127.9, 127.5, 127.1 (*aromatic* C/C*H*), 99.94 (C-1^{C}), 99.89 (C-1^{B}), 97.3 (C-1^{A}), 78.1, 77.6 (C-2^{A}), 77.2, 76.4, 75.4, 75.0, 74.5 (C-4^{A}), 74.0 (C*H*$_2$*Ph*), 73.5 (C*H*$_2$*Ph*), 73.0 (C*H*$_2$*Ph*), 72.9 (C*H*$_2$*Ph*), 72.6 (C*H*$_2$*Ph*), 70.6 (C-4^{B}), 70.1 (C*H*$_2$*Ph*), 69.0 (C-4^{C}), 68.6, 67.9 (C-7), 67.4 (C-5^{C}), 67.1 (C-6^{C}), 66.0 (*C*=O*C*H_2*Ph*), 62.8 (C-6^{A}), 61.3 (C-6^{B}), 34.1 (C-11), 29.0 (C-8), 27.7 (C*H*$_3$), 27.2 (C*H*$_3$), 25.6 (C-9), 24.6 (C-10), 23.4 (C-*Si*), 20.6 (C-*Si*). HR-MS: Calculated for $C_{95}H_{108}O_{20}Si$ $[M+H]^+$: 1597.7281, found: 1597.7276.

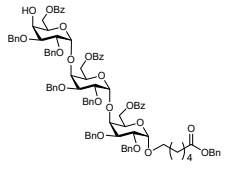
6-(Benzyl hexanoyl) 2,3-di-*O*-benzyl-α-D-galactopyranosyl-(1→4)-6-*O*-benzoyl-2,3-di-*O*-benzyl-α-D-galactopyranosyl-(1→4)-6-*O*-benzoyl-2,3-di-*O*-benzyl-α-D-galactopyranoside (12)



The reaction was carried out according to the general procedure C using compound **11** (2.03 g, 1.27 mmol) and HF/pyridine (70%, 530 µl, 33.3 mmol). The product was purified by column chromatography (pentane:EtOAc = 3:2). Compound **12** (1.74 g, 94% yield, pentane:EtOAc = 2:1, R*f* = 0.25-0.35) was obtained as yellow syrup. $[\alpha]_D^{25}$ +42.5 (c=1, $CHCl_3$). IR (neat, cm^{-1}) ν 736, 1005, 1027, 1046, 1092, 1272, 1315, 1452, 1720, 2870, 2923, 3454. ^{1}H-NMR ($CDCl_3$, 400 MHz) δ 8.04 – 7.99 (m, 2H, m, 2H, *aromatic* H, Bz), 7.97 – 7.91

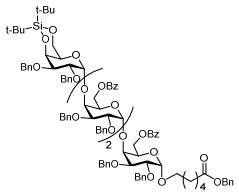
(m, 2H, m, 2H, *aromatic* H, Bz), 7.61 – 7.05 (m, *aromatic* H), 5.09 – 5.05 (m, 3H, *Ph*CH_2C=*O*, H-1^C), 5.04 (d, *J* = 3.3 Hz, 1H, H-1^B), 4.95 – 4.53 (m, 16H, H-1A, *Ph*CH_2, 6^A, 6^B), 4.51 – 4.39 (m, 2H, H-4^B, 6^B), 4.17 – 4.03 (m, 4H, H-3^B, 4^A, 4^C, 5^C), 4.01 (t, *J* = 6.7 Hz, 1H, H-5^A), 3.98 – 3.77 (m, 6H, H-2, H-3^A, H-3^C, H-5^B), 3.65 – 3.36 (m, 4H, H-6C, H-7), 2.80 (bs, 1H, *O*H), 2.47 (bs, 1H, *O*H), 2.27 (t, *J* = 7.5 Hz, 2H, H-11), 1.65 – 1.51 (m, 4H, H-10, H-8), 1.33 – 1.21 (m, 2H, H-9). ^{13}C NMR (100 MHz, $CDCl_3$) δ 173.3 (C-12), 165.9 (C*OPh*), 165.4 (C*OPh*), 138.7, 138.5, 138.2, 137.8, 136.0, 133.1, 129.8, 129.6, 128.5, 128.4, 128.2, 127.9, 127.3 (aromatic C/C*H*), 100.2 (C-1^C), 99.8 (H-1^B), 97.2 (H-1^A), 78.0 (C-2^B), 77.6 (C-5^B), 76.9 (C-5^C), 76.6 (C-3), 76.3 (C-3^B), 75.6 (C-2^A), 74.7 (C-3), 74.5 (C-2^C), 74.0 (CH_2*Ph*), 73.3 (CH_2*Ph*), 72.93 (CH_2*Ph*), 72.91 (CH_2*Ph*), 72.9 (CH_2*Ph*), 72.0 (CH_2*Ph*), 69.09 (C-4), 69.06 (C-4), 69.01 (C-4), 68.5 (C-5^A), 67.9 (C-7), 66.0 (*C*=O*C*H_2*Ph*), 62.85 (C-6^A), 62.80 (C-6^C), 61.3 (C-6^B), 34.1 (C-11), 28.9 (C-8), 25.6 (C-9), 24.6 (C-10). HR-MS: Calculated for $C_{87}H_{92}O_{20}$ $[M+NH_4]^+$: 1474.6526, found: 1474.6520.

6-(Benzyl hexanoyl) 6-*O*-benzoyl-2,3-di-*O*-benzyl-α-D-galactopyranosyl-(1→4)-6-*O*-benzoyl-2,3-di-*O*-benzyl-α-D-galactopyranosyl-(1→4)-6-*O*-benzoyl-2,3-di-*O*-benzyl-α-D-galactopyranoside (13)



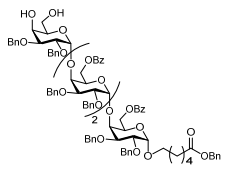
The reaction was carried out according to the general procedure D using compound **12** (1.45 g, 1.0 mmol), PhCOOBt (1.07 g, 4.49 mmol) and Et_3N (700 µl, 5.0 mmol). The product was purified by column chromatography (pentane:EtOAc = 5:2). Compound **13** (1.48 g, 95% yield, pentane:EtOAc = 2:1, R*f* = 0.35-0.45) was obtained as yellow syrup. $[\alpha]_D^{25}$ +31.4 (c=1, $CHCl_3$). IR (neat, cm^{-1}) ν 464, 734, 964, 1003, 1026, 1046, 1070, 1091, 1156, 1271, 1315, 1452, 1497, 1720, 2869, 2925, 3497. ^{1}H-NMR ($CDCl_3$, 400 MHz) δ 8.05 – 7.88 (m, 6H, *aromatic* H, Bz), 7.66 – 7.01 (m, 44H, *aromatic* H), 5.12 – 5.04 (m, 3H, *C*H_2*Ph*, H-1^C), 5.01 (d, *J* = 3.2 Hz, 1H, H-1^B), 4.93 – 4.38 (m, 20H, *C*H_2*Ph*, H-1^A, H-4, H-6^A, 6^B), 4.12 (s, 2H), 4.05 – 3.76 (m, 9H), 3.62 – 3.51 (m, 1H, H-7), 3.47 – 3.35 (m, 1H, H-7), 2.53 (bs, 1H, *O*H), 2.27 (t, *J* = 7.6 Hz, 2H, H-11), 1.64 – 1.50 (m, 4H, H-10, 8), 1.33 – 1.22 (m, 2H, H-9). ^{13}C NMR (100 MHz, $CDCl_3$) δ 173.4 (C-12), 166.0 (C*OPh*), 165.9 (C*OPh*), 165.4 (C*OPh*), 138.81, 138.59, 138.32, 138.30, 138.14, 137.89, 136.07, 133.22, 133.18, 133.02, 130.01, 129.97, 129.87, 129.85, 129.65, 129.60, 128.55, 128.52, 128.50, 128.48, 128.34, 128.31, 128.25, 128.18, 128.17, 127.93, 127.87, 127.75, 127.72, 127.62, 127.53, 127.46, 127.41, 127.35 (*aromatic* C/C*H*), 100.1 (C-1^B), 100.0 (C-1^C), 97.3 (C-1^A), 78.2, 77.7, 76.4, 76.3, 75.7, 75.1, 74.4, 74.2 (CH_2*Ph*), 73.6 (CH_2*Ph*), 73.1 (CH_2*Ph*), 73.0 (CH_2*Ph*), 72.9 (CH_2*Ph*), 72.3 (CH_2*Ph*), 69.0, 68.6, 68.0 (C-7), 67.7, 66.6, 66.1 (CH_2*Ph*), 62.9 (C-6^A), 62.3 (C-6^C), 61.3 (C-6^B), 34.1 (C-11), 29.0 (C-8), 25.7 (C-9), 24.6 (C-10). HR-MS: Calculated for $C_{94}H_{96}O_{21}$ $[M+H]^+$: 1561.6522, found: 1561.6517.

6-(Benzyl hexanoyl) 2,3-di-*O*-benzyl-4,6-di-*tert*-butylsilylidene-α-D-galactopyranosyl-(1→4)-6-*O*-benzoyl-2,3-di-*O*-benzyl-α-D-galactopyranosyl-(1→4)-6-*O*-benzoyl-2,3-di-*O*-benzyl-α-D-galactopyranosyl-(1→4)-6-*O*-benzoyl-2,3-di-*O*-benzyl-α-D-galactopyranoside (14)



The reaction was carried out according to the general procedure A. The donor **1** (1.65 g, 2.79 mmol) and the acceptor **13** (1.45 g, 0.93 mmol) were co-evaporated with toluene (three times). The residue was dissolved in 28 ml dry DCM under nitrogen and stirred over fresh flame-dried molecular sieves 3Å. The solution was cooled to 0 ºC, after which NIS (1.26 g, 5.58 mmol) and TfOH (50 µl, 0.56 mmol) were added. The reaction was stirred at 0 ºC for 1 h. Then the reaction was quenched with saturated $Na_2S_2O_3$, diluted with DCM, washed with saturated $NaHCO_3$ and brine. The organic phase was dried with anhydrous $MgSO_4$, filtered and concentrated *in vacuo*. The product was purified by silica gel column chromatography (pentane:EtOAc:DCM = 20:3:1). Compound **14** (2.28 g, 84% yield, pentane:EtOAc = 5:2, R*f* = 0.40-0.50) was obtained as colorless syrup. $[\alpha]_D^{25}$ +36.7 (c=1, $CHCl_3$). IR (neat, cm^{-1}) ν 444, 469, 474, 650, 732, 797, 824, 977, 1003, 1026, 1045, 1090, 1269, 1452, 1725, 2859, 2932. ^{1}H-NMR ($CDCl_3$, 400 MHz) δ 8.06 – 7.87 (m, 6H, *aromatic* H, Bz), 7.67 – 6.99 (m, 54H, *aromatic* H), 5.11 (d, *J* = 3.5 Hz, 1H, H-1^D), 5.07 (s, 2H, *C*H$_2$*Ph*), 5.02 (d, *J* = 2.2 Hz, 1H, H-1^C), 4.94 (d, *J* = 3.6 Hz, 1H, H-1^B), 4.93 – 4.33 (m, 26H), 4.17 (d, *J* = 2.6 Hz, 1H), 4.14 – 3.88 (m, 8H), 3.86 – 3.71 (m, 4H), 3.71 – 3.53 (m, 3H, H-6^D, H-7), 3.47 – 3.35 (m, 1H, H-7), 2.27 (t, *J* = 7.5 Hz, 2H, H-11), 1.64 – 1.51 (m, 4H, H-10, H-8), 1.33 – 1.22 (m, 2H, H-9), 1.01 (s, 9H, *C*H$_3$), 0.89 (s, 9H, *C*H$_3$). ^{13}C NMR (100 MHz, $CDCl_3$) δ 173.4 (C-12), 166.0 (C*OPh*), 165.4 (2 C*OPh*), 139.05, 138.74, 138.67, 138.47, 138.35, 138.33, 138.03, 138.00, 136.00, 133.11, 133.00, 129.85, 129.81, 129.78, 129.56, 129.53, 128.95, 128.91, 128.56, 128.50, 128.46, 128.42, 128.39, 128.37, 128.19, 128.15, 128.09, 128.08, 127.85, 127.81, 127.57, 127.54, 127.51, 127.46, 127.39, 127.28, 127.25, 127.23, 126.86 (aromatic C/C*H*), 100.1 (H-1^C), 100.0 (H-1^B), 99.9 (H-1^D), 97.3 (H-1^A), 78.2, 77.9, 76.9, 76.7, 76.4, 75.9, 74.7, 74.5, 74.1 (C*H$_2$Ph*), 73.5 (C*H$_2$Ph*), 73.4 (C*H$_2$Ph*), 73.2 (C*H$_2$Ph*), 72.9 (C*H$_2$Ph*), 72.4 (C*H$_2$Ph*), 70.6, 70.1 (C*H$_2$Ph*), 68.94, 68.85, 68.6, 67.9 (C-7), 67.4, 67.1 (C-6), 66.1 (C*H$_2$Ph*), 62.9 (C-6), 61.3 (C-6), 61.2 (C-6), 34.1 (C-11), 29.0 (C-8), 27.7 (C*H$_3$*), 27.2 (C*H$_3$*), 25.7 (C-9), 24.6 (C-10), 23.4 (C-*Si*), 20.6 (C-*Si*). HR-MS: Calculated for $C_{122}H_{134}O_{26}$ $[M+NH_4]^+$: 2060.9276, found: 2060.9271.

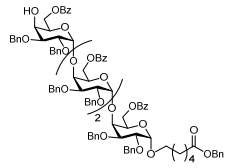
6-(Benzyl hexanoyl) 2,3-di-*O*-benzyl-α-D-galactopyranosyl-(1→4)-6-*O*-benzoyl-2,3-di-*O*-benzyl-α-D-galactopyranosyl-(1→4)-6-*O*-benzoyl-2,3-di-*O*-benzyl-α-D-galactopyranosyl-(1→4)-6-*O*-benzoyl-2,3-di-*O*-benzyl-α-D-galactopyranoside (15)



The reaction was carried out according to the general procedure C using compound **14** (1.30 g, 0.64 mmol) and HF/pyridine (70%, 266 µl, 10.2 mmol). The product was purified by column chromatography (pentane:EtOAc = 3:2-1:1). Compound **15** (1.13 g, 93% yield, pentane:EtOAc = 1:1, R*f* = 0.25-0.35) was obtained as yellow syrup. $[\alpha]_D^{25}$ +38.3 (c=1, $CHCl_3$). IR (neat, cm^{-1}) ν 734, 1003, 1026, 1045, 1092, 1271, 1315, 1452, 1497, 1720, 2870, 2925, 3473. ^{1}H-NMR ($CDCl_3$, 400 MHz) δ 8.18 – 8.02 (m, 6H, *aromatic* H, Bz), 7.74 – 7.14 (m, 55H, *aromatic* H), 5.20 (d, *J* = 3.2 Hz, 1H, H-1^D), 5.19 – 5.13 (m, 4H, *C*H$_2$*Ph*, H-1^C, H-1^B), 5.07 – 4.67 (m, 21H), 4.67 – 4.51 (m, 4H), 4.30 – 4.10 (m, 6H), 4.09 – 4.01 (m, 3H), 4.01 – 3.93 (m, 4H), 3.86 (dd, *J* = 10.0, 3.1 Hz, 1H, H-3), 3.77 – 3.65 (m, 1H, H-7), 3.63 – 3.47 (m, 3H, H-6, H-7), 2.99 (s, 1H, *O*H), 2.61 (s, 1H, *O*H), 2.38 (t, *J* = 7.5

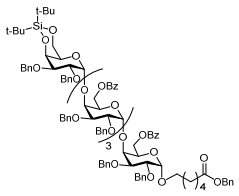
Hz, 2H, H-11), 1.76 – 1.62 (m, 4H, H-10, H-8), 1.46 – 1.36 (m, 2H, H-9). ^{13C} NMR (100 MHz, $CDCl_3$) δ 173.3 (C-12), 165.9 (C*OPh*), 165.4 (C*OPh*), 165.3 (C*OPh*), 138.7, 138.6, 138.5, 138.3, 138.1, 138.0, 137.8, 136.0, 133.2, 133.1, 129.9, 129.8, 129.7, 129.6, 129.5, 128.6, 128.54, 128.53, 128.52, 128.43, 128.42, 128.34, 128.32, 128.24, 128.22, 128.21, 128.14, 128.13, 128.11, 127.84, 127.82, 127.81, 127.64, 127.63, 127.62, 127.60, 127.5, 127.44, 127.42, 127.41, 127.33, 127.31, 127.2 (aromatic C/*CH*), 100.2 (C-1^C), 99.9 (C-1^B), 99.8 (C-1^D), 97.2 (C-1^A), 78.0, 77.8, 76.8, 76.6, 76.4, 76.3, 75.8, 74.8, 74.7, 74.0 (CH_2*Ph*), 73.9, 73.5, 73.2, 73.0, 72.84, 72.83, 72.7, 71.9(6xCH_2*Ph*), 69.1, 69.0, 68.6, 67.9 (C-7), 66.0 (CH_2*Ph*), 62.9, 62.8, 61.3, 61.1 (4xC-6), 34.0 (C-11), 28.9 (C-8), 25.6 (C-9), 24.5 (C-10). HR-MS: Calculated for $C_{114}H_{118}O_{26}$ $[M+H]^+$: 1903.7990, found: 1903.7984.

6-(Benzyl hexanoyl) 6-*O*-benzoyl-2,3-di-*O*-benzyl-α-D-galactopyranosyl-(1→4)-6-*O*-benzoyl-2,3-di-*O*-benzyl-α-D-galactopyranosyl-(1→4)-6-*O*-benzoyl-2,3-di-*O*-benzyl-α-D-galactopyranosyl-(1→4)-6-*O*-benzoyl-2,3-di-*O*-benzyl-α-D-galacto-pyranoside (16)



The reaction was carried out according to the general procedure D using compound **15** (1.12 g, 0.59 mmol), PhCOOBt (633 mg, 2.65 mmol) and Et_3N (410 µl, 2.94 mmol). The product was purified by column chromatography (pentane:EtOAc = 2:1). Compound **16** (1.09 g, 92% yield, pentane:EtOAc = 3:2, R*f* = 0.30-0.40) was obtained as yellow syrup. $[\alpha]_D^{25}$ +29.2 (c=1, $CHCl_3$). IR (neat, cm^{-1}) ν 736, 1005, 1026, 1046, 1070, 1092, 1156, 1271, 1315, 1452, 1720, 2869, 2926, 3500. ^{1}H-NMR ($CDCl_3$, 400 MHz) 8.05 – 7.87 (m, 8H, *aromatic* H, Bz), 7.66 – 6.97 (m, 57H, *aromatic* H), 5.07 (s, 2H, *C*H_2*Ph*), 5.06 (d, *J* = 3.5 Hz, 1H, H-1^D), 5.04 – 5.00 (m, 2H, H-1^C, H-1^B), 4.89 – 4.33 (m, 26), 4.20 – 3.74 (m, 14H), 3.60 – 3.51 (m, 1H, H-7), 3.44 – 3.34 (m, 1H, H-7), 2.26 (t, *J* = 7.6 Hz, 2H, H-11), 1.63 – 1.50 (m, 4H, H-10, H-8), 1.30 – 1.21 (m, 2H, H-9). ^{13}C NMR (100 MHz, $CDCl_3$) δ 173.4 (C-12), 166.0 (C=*O*, Bz), 165.9 (C=*O*, Bz), 165.5 (C=*O*, Bz), 165.3 (C=*O*, Bz), 138.8, 138.7, 138.6, 138.34, 138.32, 138.2, 138.1, 137.8, 136.1, 133.3, 133.2, 133.0, 130.1, 130.0, 129.9, 129.8, 129.7, 129.64, 129.63, 128.62, 128.61, 128.60, 128.54, 128.52, 128.43, 128.41, 128.33, 128.31, 128.30, 128.23, 128.22, 128.21, 128.19, 127.93, 127.91, 127.73, 127.71, 127.70, 127.6, 127.53, 127.51, 127.4, 127.32, 127.30 (*aromatic* C/*CH*), 100.2 (C-1^C), 100.0 (C-1^B, C-1^D), 97.3 (C-1^A), 78.2, 78.1, 76.9, 76.7, 76.5, 76.4, 76.0, 75.9, 75.0, 74.3 (CH_2*Ph*), 73.8, 73.7, 73.4, 73.1, 72.9, 72.7, 72.2 (6xCH_2*Ph*), 69.1, 68.9, 68.6, 67.9 (C-7), 67.6, 66.4, 66.1 (CH_2*Ph*), 62.9, 62.1, 61.3, 61.1 (4xC-6), 34.1 (C-11), 29.0 (C-8), 25.7 (C-9), 24.6 (C-10). HR-MS: Calculated for $C_{94}H_{96}O_{21}$ $[M+NH_4]^+$: 2024.8517, found: 2024.8512.

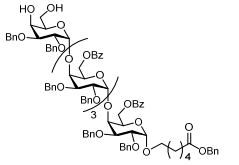
6-(Benzyl hexanoyl) 2,3-di-*O*-benzyl-4,6-di-*tert*-butylsilylidene-α-D-galactopyranosyl-(1→4)-6-*O*-benzoyl-2,3-di-*O*-benzyl-α-D-galactopyranosyl-(1→4)-6-*O*-benzoyl-2,3-di-*O*-benzyl-α-D-galactopyranosyl-(1→4)-6-*O*-benzoyl-2,3-di-*O*-benzyl-α-D-galactopyranosyl-(1→4)-6-*O*-benzoyl-2,3-di-*O*-benzyl-α-D-galactopyranoside (17)



The reaction was carried out according to the general procedure A. The donor **1** (1.26 g, 2.13 mmol) and the acceptor **16** (1.07 g, 0.53 mmol) were co-evaporated with toluene (three times). The residue was dissolved in 5.3 ml dry DCM under nitrogen and stirred over fresh flame-dried molecular sieves 3Å. The solution was cooled to 0 ºC, after which NIS (719 mg, 3.20 mmol) and TfOH (5 µl, 0.05 mmol) were added. The reaction was stirred at 0 ºC for 2 h. Then the reaction was quenched with saturated $Na_2S_2O_3$, diluted with DCM, washed with saturated $NaHCO_3$ and brine. The organic phase was dried with anhydrous $MgSO_4$, filtered and concentrated *in vacuo*. The product was purified by silica gel column chromatography (pentane:EtOAc = 4:1). Compound **17** (1.06 g, 84% yield, pentane:EtOAc = 5:2, R*f* = 0.45-0.55) was obtained as colorless syrup. $[\alpha]_D^{25}$ +38.7 (c=1, $CHCl_3$). IR (neat, cm^{-1}) ν 737, 1005, 1027, 1047, 1095, 1271, 1315, 1362, 1452, 1725, 2859, 2931. ^{1}H-NMR ($CDCl_3$, 500 MHz) δ 8.05 – 7.96 (m, 6H, C*H*, Bz), 7.95 – 7.90 (m, 2H, C*H*, Bz), 7.63 – 6.98 (m, 72H, *aromatic* H), 5.12 (d, *J* = 3.4 Hz, 1H, H-1^E), 5.06 (d, *J* = 4.3 Hz, 4H, *C*H$_2$*Ph*, H-1^D, H-1^C), 4.93 (d, *J* = 3.5 Hz, 1H, H-1^B), 4.91 – 4.70 (m, 17H), 4.68 – 4.33 (m, 16H), 4.21 – 4.10 (m, 3H), 4.06 (s, 1H, H-5), 4.03 – 3.81 (m, 10H), 3.80 – 3.71 (m, 2H, H-3), 3.69 – 3.54 (m, 3H, H-6^E, H-7), 3.46 – 3.36 (m, 1H, H-7), 2.27 (t, *J* = 7.5 Hz, 2H, H-11), 1.58 (p, *J* = 7.7 Hz, 4H, H-10, 8), 1.31 – 1.25 (m, 2H, H-9), 1.01 (s, 9H, *C*H$_3$), 0.89 (s, 9H, *C*H$_3$). ^{13}C NMR (125 MHz, $CDCl_3$) δ 173.3 (C-12), 166.0 (C=*O*, Bz), 165.5 (C=*O*, Bz), 165.3 (C=*O*, Bz), 139.1, 138.8, 138.7, 138.64, 138.61, 138.4, 138.33, 138.32, 138.13, 138.12, 136.10, 133.24, 133.23, 133.1, 133.01, 130.00, 129.92, 129.91, 129.63, 129.62, 129.61, 129.0, 128.7, 128.6, 128.52, 128.51, 128.44, 128.42, 128.3, 128.22, 128.20, 128.13, 128.11, 128.0, 127.9, 127.63, 127.62, 127.60, 127.53, 127.51, 127.42, 127.41, 127.34, 127.32, 126.9 (aromatic C/C*H*), 100.1 (C-1^D), 100.0 (C-1^C, C-1^B), 99.9 (C-1^E), 97.3 (C-1^A), 78.1, 77.9, 77.4, 77.2, 76.9, 76.6, 76.5, 76.2, 75.8, 75.3, 74.4, 74.34, 74.31, 74.0, 73.8, 73.44, 73.41, 73.1, 72.9 (6 C*H*$_2$*Ph*), 72.83, 72.81, 72.6, 72.3 (3 C*H*$_2$*Ph*), 70.6, 70.1 (C*H*$_2$*Ph*), 69.1, 68.94 68.91, 68.7, 67.9(C-7), 67.4, 67.0 (C-6^E), 66.0 (C*H*$_2$*Ph*), 63.0 (C-6^A), 61.4 (C-6^D), 61.1 (C-6^C, 6^B), 34.1 (C-11), 29.0 (C-8), 27.7 (3xC*H*$_3$), 27.2 (3xC*H*$_3$), 25.7 (C-9), 24.6 (C-10), 23.4 (C-*Si*), 20.6 (C-*Si*). MALDI-MS: Calculated for $C_{149}H_{160}O_{32}Si$ $[M+Na]^+$: 2512.0560, found: 2512.0364.

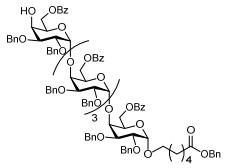
6-(Benzyl hexanoyl) 2,3-di-*O*-benzyl-α-D-galactopyranosyl-(1→4)-6-*O*-benzoyl-2,3-di-*O*-benzyl-α-D-galactopyranosyl-(1→4)-6-*O*-benzoyl-2,3-di-*O*-benzyl-α-D-galactopyranosyl-(1→4)-6-*O*-benzoyl-2,3-di-*O*-benzyl-α-D-galactopyranosyl-(1→4)-6-*O*-benzoyl-2,3-di-*O*-benzyl-α-D-galactopyranoside (18)

The reaction was carried out according to the general procedure C using compound **17** (1.04 g, 0.42 mmol) and HF/pyridine (70%, 170 µl, 6.67 mmol). The product was purified by column chromatography (pentane:EtOAc = 3:2-1:1). Compound **18** (916 mg, 92% yield, pentane:EtOAc = 1:1, R*f* = 0.25-0.35) was obtained as yellow syrup. $[\alpha]_D^{25}$ +40.2 (c=1, $CHCl_3$). IR (neat, cm^{-1}) ν 734, 1000, 1026, 1045, 1090, 1269, 1315, 1360, 1452, 1720, 2925, 3030, 3486. ^{1}H-NMR ($CDCl_3$, 500 MHz) δ 8.04 – 7.91 (m, 8H, C*H*, Bz), 7.64 – 6.97 (m, 67H, aromatic H), 5.11 – 5.03 (m, 5H, *C*H$_2$*Ph*, H-1^E, 1^D, 1^C), 5.01 (d, *J* = 3.4 Hz, 1H, H-1^B), 4.95 – 4.54 (m, 25H), 4.52 – 4.28 (m, 6H), 4.19 – 4.10 (m, 3H), 4.09 – 4.03 (m, 2H), 4.02 – 3.96 (m, 2H, H-5^A, 5^E), 3.94 – 3.86 (m, 5H), 3.86 – 3.77 (m, 4H), 3.73 (dd, *J* =



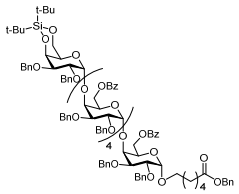
10.0, 3.1 Hz, 1H, H-3^{B}), 3.62 – 3.52 (m, 1H, H-7), 3.47 – 3.33 (m, 3H, H-7, H-6^{E}), 2.26 (t, *J* = 7.5 Hz, 2H, H-11), 1.62 – 1.52 (m, 4H, H-10, 8), 1.35 – 1.21 (m, 2H, H-9). ^{13}C NMR (125 MHz, $CDCl_3$) δ 173.4 (C-12), 166.0 (C=O, Bz), 165.5 (C=O, Bz), 165.4 (C=O, Bz), 165.3 (C=O, Bz), 138.8, 138.7, 138.62, 138.59, 138.33, 138.32, 138.30, 138.1, 138.0, 137.9, 136.1, 133.23, 133.21, 129.92, 129.91, 129.90, 129.7, 129.62, 129.60, 129.1, 128.9, 128.73, 128.71, 128.6, 128.53, 128.52, 128.50, 128.42, 128.40, 128.33, 128.31, 128.24, 128.23, 128.22, 128.21, 128.19, 128.0, 127.94, 127.92, 127.8, 127.72, 127.71, 127.64, 127.62, 127.51, 127.50, 127.43, 127.41, 127.3, 126.6, 126.3 (aromatic C/*CH*), 100.2 (C-1^{D}, 1^{B}), 100.1 (C-1^{C}), 99.9 (C-1^{E}), 97.3 (C-1^{A}), 78.1, 77.9, 77.2, 76.63, 76.61, 76.2, 76.1, 75.9, 75.4, 74.7, 74.5, 74.1, 73.8, 73.5, 73.3, 73.1, 72.9, 72.8, 72.7, 72.1 (9 C*H*$_2$*Ph*), 69.23, 69.21, 69.1, 68.7, 67.9 (C-7), 66.1 (C*H*$_2$*Ph*), 63.1, 62.9, 61.5, 61.3, 61.1 (5 C-6), 34.1 (C-11), 29.0 (C-8), 25.7 (C-9), 24.6 (C-10). HR-MS: Calculated for $C_{141}H_{144}O_{32}$ $[M+NH_4]^+$: 2366.9984, found: 2366.9979.

6-(Benzyl hexanoyl) 6-*O*-benzoyl-2,3-di-*O*-benzyl-α-D-galactopyranosyl-(1→4)-6-*O*-benzoyl-2,3-di-*O*-benzyl-α-D-galactopyranosyl-(1→4)-6-*O*-benzoyl-2,3-di-*O*-benzyl-α-D-galactopyranosyl-(1→4)-6-*O*-benzoyl-2,3-di-*O*-benzyl-α-D-galacto-pyranosyl-(1→4)-6-*O*-benzoyl-2,3-di-*O*-benzyl-α-D-galactopyranoside (19)



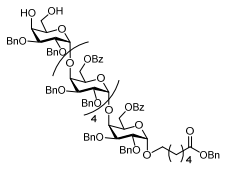
The reaction was carried out according to the general procedure D using compound **18** (897 mg, 0.38 mmol), PhCOOBt (411 mg, 1.72 mmol) and Et_3N (266 µl, 1.91 mmol). The product was purified by column chromatography (pentane:EtOAc:DCM = 7:2:1). Compound **19** (1.09 g, 92% yield, pentane:EtOAc = 3:2, R*f* = 0.30-0.40) was obtained as yellow syrup. $[\alpha]_D^{25}$ +22.2 (c=1, $CHCl_3$). IR (neat, cm^{-1}) ν 414, 417, 452, 468, 734, 1000, 1026, 1046, 1070, 1092, 1156, 1269, 1315, 1452, 1720, 2870, 2923, 3509. ^{1}H-NMR ($CDCl_3$, 500 MHz) δ 8.04 – 7.91 (m, 10H, C*H*, Bz), 7.63 – 6.97 (m, 70H, aromatic H), 5.11 – 5.03 (m, 6H, *C*H$_2$*Ph*, H-1^{E}, 1^{D}, 1^{C}, 1^{B}), 4.95 – 4.38 (m, 34H), 4.34-4.31 (m, 1H, H-6), 4.21 – 4.05 (m, 5H), 4.04 – 3.83 (m, 11H), 3.80 (dd, *J* = 10.0, 3.1 Hz, 1H, H-3^{B}), 3.58 (dt, *J* = 10.0, 7.0 Hz, 1H, H-7), 3.41 (dt, *J* = 10.0, 6.6 Hz, 1H, H-7), 2.27 (t, *J* = 7.5 Hz, 2H, H-11), 1.58 (p, *J* = 7.7 Hz, 4H, H-10, 8), 1.32 – 1.24 (m, 2H, H-9). ^{13}C NMR (125 MHz, $CDCl_3$) δ 173.3 (C-12), 166.0, 165.8, 165.5, 165.4, 165.3 (5 C=O, Bz), 138.74, 138.72, 138.64, 138.61, 138.33, 138.31, 138.23, 138.21, 138.1, 137.8, 136.1, 133.1, 132.9, 130.0, 129.93, 129.92, 129.90, 129.63, 129.61, 129.52, 129.51, 128.64, 128.61, 128.53, 128.51, 128.43, 128.42, 128.33, 128.31, 128.24, 128.22, 128.11, 128.10, 127.83, 127.81, 127.7, 127.61, 127.60, 127.5, 127.4, 127.32, 127.31, 127.2 (*aromatic* C/C*H*), 100.2 (C-1), 100.1 (C-1), 99.9 (2xC-1), 97.3 (C-1^{A}), 78.14, 78.11, 77.2, 76.8, 76.6, 76.5, 76.3, 76.1, 75.9, 75.3, 75.0, 74.5, 74.2, 73.7, 73.5, 73.4, 73.1, 72.84, 72.82, 72.7, 72.6, 72.2 (10 *CH*$_2$*Ph*), 69.1, 69.0, 68.9, 68.7, 67.9 (C-7), 67.6, 66.5, 66.0 (*CH*$_2$*Ph*), 63.0, 62.1, 61.5, 61.2, 61.1 (5 C-6), 34.1 (C-11), 28.9 (C-8), 25.6 (C-9), 24.6 (C-10). MALDI-MS: Calculated for $C_{148}H_{148}O_{33}$ $[M+Na]^+$: 2475.9801, found: 2475.9603.

6-(Benzyl hexanoyl) 2,3-di-*O*-benzyl-4,6-di-*tert*-butylsilylidene-α-D-galactopyranosyl-(1→4)-6-*O*-benzoyl-2,3-di-*O*-benzyl-α-D-galactopyranosyl-(1→4)-6-*O*-benzoyl-2,3-di-*O*-benzyl-α-D-galactopyranosyl-(1→4)-6-*O*-benzoyl-2,3-di-*O*-benzyl-α-D-galactopyranosyl-(1→4)-6-*O*-benzoyl-2,3-di-*O*-benzyl-α-D-galactopyranosyl-(1→4)-6-*O*-benzoyl-2,3-di-*O*-benzyl-α-D-galactopyranoside (20)



The reaction was carried out according to the general procedure A. The donor **1** (995 mg, 1.68 mmol) and the acceptor **19** (916 mg, 0.37 mmol) were co-evaporated with toluene (three times). The residue was dissolved in 3.7 ml dry DCM under nitrogen and stirred over fresh flame-dried molecular sieves 3Å. The solution was cooled to 0 ºC, after which NIS (545 mg, 2.42 mmol) and TfOH (4 µl, 0.04 mmol) were added. The reaction was stirred at 0 ºC for 2 h. Then the reaction was quenched with saturated $Na_2S_2O_3$, diluted with DCM, washed with saturated $NaHCO_3$ and brine. The organic phase was dried with anhydrous $MgSO_4$, filtered and concentrated *in vacuo*. The product was purified by silica gel column chromatography (pentane:EtOAc:DCM = 40:9:2). Compound **20** (790 mg, 72% yield, pentane:EtOAc = 5:2, R*f* = 0.45-0.55) was obtained as colorless syrup. $[\alpha]_D^{25}$ +35.2 (c=1, $CHCl_3$). IR (neat, cm^{-1}) ν 445, 474, 651, 734, 797, 824, 1003, 1026, 1046, 1062, 1092, 1269, 1315, 1452, 1721, 2860, 2931. ^{1}H-NMR ($CDCl_3$, 500 MHz) δ 8.04 – 7.88 (m, 8H, *C*H, Bz), 7.93 – 7.88 (m, 2H, *C*H, Bz), 7.64 – 6.92 (m, 80H, aromatic H), 5.11 – 4.99 (m, 6H, *C*H_2*Ph*, H-1^F, 1^E, 1^D, 1^C), 4.95 – 4.33 (m, 41H), 4.24 (s, 1H, H-5), 4.17 – 4.08 (m, 4H), 4.05 (s, 1H), 4.01 – 3.78 (m, 12H), 3.76 – 3.68 (m, 2H, H-3^F, 3^B), 3.67 – 3.50 (m, 3H, H-6^F, 7), 3.45 – 3.35 (m, 1H, H-7), 2.27 (t, *J* = 7.5 Hz, 2H, H-11), 1.64 – 1.51 (m, 4H, H-10, 8), 1.31 – 1.20 (m, 2H, H-9), 1.00 (s, 9H, 3x*C*H_3), 0.87 (s, 9H, 3x*C*H_3). ^{13}C NMR (125 MHz, $CDCl_3$) δ 173.4 (C-12), 166.0, 165.5, 165.4, 165.3, 165.3 (5 C=O, Bz), 139.2, 138.8, 138.74, 138.71, 138.6, 138.4, 138.3, 138.2, 138.13, 138.11, 136.10, 133.2, 133.1, 130.03, 130.01, 129.9, 129.7, 129.64, 129.62, 129.61, 129.0, 128.7, 128.63, 128.62, 128.60, 128.54, 128.52, 128.51, 128.4, 128.35, 128.32, 128.26, 128.23, 128.21, 127.9, 127.7, 127.68, 127.63, 127.61, 127.53, 127.51, 127.45, 127.42, 127.3, 127.2, 126.9 (*aromatic* C), 100.2 (C-1), 100.0 (3xC-1), 99.9 (C-1^F), 97.3 (C-1^A), 78.1, 77.9, 77.4, 77.3, 77.2, 76.9, 76.7, 76.5, 76.3, 76.1, 75.9, 75.3, 74.9, 74.3, 74.2, 74.0, 73.8, 73.7, 73.5, 73.4, 73.2, 72.9 (7 CH_2*Ph*), 72.84, 72.81, 72.6, 72.4 (3 CH_2*Ph*), 70.6, 70.1 (CH_2*Ph*), 69.2, 69.0, 68.9, 68.7, 68.0 (C-7), 67.4, 67.1 (C-6^F), 66.1 (CH_2*Ph*), 63.0, 61.5, 61.3, 61.14, 61.05 (5 C-6), 34.2 (C-11), 29.0 (C-8), 27.7 (3xCH_3), 27.2 (3xCH_3), 25.7 (C-9), 24.7 (C-10), 23.4 (C-*Si*), 20.6 (C-*Si*). MALDI-MS: Calculated for $C_{176}H_{186}O_{38}Si$ $[M+Na]^+$: 2958.2289, found: 2958.2033.

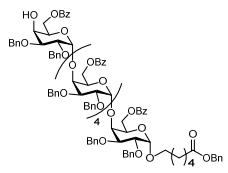
6-(Benzyl hexanoyl) 2,3-di-*O*-benzyl-α-D-galactopyranosyl-(1→4)-6-*O*-benzoyl-2,3-di-*O*-benzyl-α-D-galactopyranosyl -(1→4)-6-*O*-benzoyl-2,3-di-*O*-benzyl-α-D-galactopyranosyl-(1→4)-6-*O*-benzoyl-2,3-di-*O*-benzyl-α-D-galactopyranosyl-(1→4)-6-*O*-benzoyl-2,3-di-*O*-benzyl-α-D-galacto-pyranosyl-(1→4)-6-*O*-benzoyl-2,3-di-*O*-benzyl-α-D-galactopyranoside (21)



The reaction was carried out according to the general procedure C using compound **20** (768 mg, 0.26 mmol) and HF/pyridine (70%, 110 µl, 4.19 mmol). The product was purified by column chromatography (pentane:EtOAc = 3:2). Compound **21** (664 mg, 91% yield, pentane:EtOAc = 1:1, R*f* = 0.25-0.35) was obtained as yellow syrup. $[\alpha]_D^{25}$ +36.4 (c=1, $CHCl_3$). IR (neat, cm^{-1}) ν 464, 734, 1000, 1026, 1045, 1090, 1156, 1269, 1315, 1452, 1720, 2869, 2925, 3461. ^{1}H-NMR ($CDCl_3$, 500 MHz) δ 8.04 – 7.95 (m, 8H, *C*H, Bz), 7.95 – 7.90 (m, 2H, *C*H, Bz), 7.62 – 6.94 (m, 80H, *aromatic* H), 5.10 – 5.03 (m, 6H, *C*H_2*Ph*, H-1^F, 1^E, 1^D, 1^C), 5.00 (d, *J* = 3.5 Hz,

1H, H-1^{B}), 4.92 – 4.54 (m, 32H), 4.51 – 4.35 (m, 6H), 4.32 – 4.23 (m, 2H), 4.19 – 4.09 (m, 4H), 4.08 – 3.75 (m, 15H), 3.71 (dd, *J* = 10.0, 3.1 Hz, 1H, H-3^{B}), 3.57 (dt, *J* = 10.0, 7.0 Hz, 1H, H-7), 3.47 – 3.33 (m, 3H, H-7, 6^{F}), 2.26 (t, *J* = 7.5 Hz, 2H, H-11), 1.57 (p, *J* = 7.4 Hz, 4H, H-10, 8), 1.30 – 1.25 (m, 2H, H-9). ^{13}C NMR (125 MHz, $CDCl_3$) δ 173.3 (C-12), 166.0, 165.5 , 165.4, 165.34, 165.31 (5 C=O, Bz), 138.7, 138.63, 138.61, 138.3, 138.24, 138.21, 138.1, 138.0, 137.8, 136.1, 133.2, 133.14, 133.11, 129.95, 129.93, 129.91, 129.63, 129.61, 129.60, 129.5, 128.7, 128.6, 128.54, 128.52, 128.51, 128.50, 128.4, 128.34, 128.32, 128.24, 128.22, 128.21, 128.11, 128.10, 127.9, 127.8, 127.7, 127.64, 127.62, 127.52, 127.51, 127.50, 127.4, 127.34, 127.32, 127.31, 127.2, 127.1 (*aromatic* C/C*H*), 100.2 (2xC-1), 100.1 (C-1^{B}), 99.9 (C-1), 99.8 (C-1^{F}), 97.3 (C-1^{A}), 78.0, 77.8, 77.4, 77.2, 76.63, 76.61, 76.2, 76.1, 75.9, 75.3, 74.9, 74.7, 74.4, 74.04 (CH_2*Ph*), 74.01, 73.8, 73.7, 73.5, 73.2, 73.1, 72.8, 72.7, 72.64, 72.62, 72.0 (10 CH_2*Ph*), 69.2, 69.1, 69.0, 68.7, 67.9 (C-7), 66.0 (CH_2*Ph*), 63.0, 62.8, 61.5, 61.3, 61.2, 61.1 (6 C-6), 34.1 (C-11), 29.0 (C-8), 25.7 (C-9), 24.6 (C-10). MALDI-MS: Calculated for $C_{168}H_{170}O_{38}$ $[M+Na]^+$: 2818.1268, found: 2818.1032.

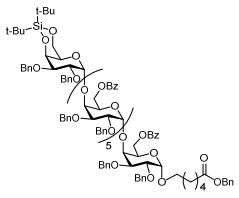
6-(Benzyl hexanoyl) 6-*O*-benzoyl-2,3-di-*O*-benzyl-α-D-galactopyranosyl-(1→4)-6-*O*-benzoyl-2,3-di-*O*-benzyl-α-D-galactopyranosyl-(1→4)-6-*O*-benzoyl-2,3-di-*O*-benzyl-α-D-galactopyranosyl-(1→4)-6-*O*-benzoyl-2,3-di-*O*-benzyl-α-D-galacto-pyranosyl-(1→4)-6-*O*-benzoyl-2,3-di-*O*-benzyl-α-D-galactopyranoside (22)



The reaction was carried out according to the general procedure D using compound **21** (614 mg, 0.22 mmol), PhCOOBt (289 mg, 1.21 mmol) and Et_3N (183 µl, 1.31 mmol). The product was purified by column chromatography (pentane:EtOAc:DCM = 7:2:1). Compound **22**(620 mg, 95% yield, pentane:EtOAc = 3:2, R*f* = 0.30-0.40) was obtained as yellow syrup. $[\alpha]_D^{25}$ +37.4 (c=1, $CHCl_3$). IR (neat, cm^{-1}) ν 419, 1005, 1027, 1047, 1070, 1096, 1272, 1315, 1723, 2872, 2923, 3480. ^{1}H-NMR ($CDCl_3$, 500 MHz) δ 8.02 – 7.91 (m, 12H, *C*H, Bz), 7.63 – 6.94 (m, 83H, *aromatic* H), 5.11 – 5.03 (m, 6H, *C*H_2*Ph*, H-1^{F}, 1^{E}, 1^{D}, 1^{C}), 5.02 (d, *J* = 3.5 Hz, 1H, H-1^{B}), 4.92 – 4.22 (m, 42H), 4.18 – 4.03 (m, 6H), 3.99 (t, *J* = 6.8 Hz, 1H, H-5^{A}), 3.96 – 3.79 (m, 12H), 3.77 (dd, *J* = 10.0, 3.1 Hz, 1H, H-3), 3.57 (dt, *J* = 9.9, 7.0 Hz, 1H, H-7), 3.41 (dt, *J* = 9.9, 6.6 Hz, 1H, H-3), 2.58 (bs, 1H, *O*H), 2.26 (t, *J* = 7.6 Hz, 2H, H-11), 1.61 – 1.52 (m, 4H, H-10, 8), 1.29 – 1.24 (m, 2H, H-9). ^{13}C NMR (125 MHz, $CDCl_3$) δ 173.4 (C-12), 166.0, 165.9, 165.5, 165.4, 165.4, 165.3 (6 C=O, Bz), 138.8, 138.7, 138.6, 138.4, 138.33, 138.31, 138.25, 138.21, 138.1, 137.9, 136.1, 133.2, 133.2, 133.0, 130.1, 130.04, 130.01, 129.9, 129.7, 129.5, 129.4, 129.3, 128.7, 128.64, 128.62, 128.61, 128.56, 128.53, 128.42, 128.41, 128.33, 128.31, 128.24, 128.22, 128.21, 128.0, 127.9, 127.8, 127.74, 127.72, 127.63, 127.61, 127.5, 127.42, 127.40, 127.36, 127.33, 127.31, 127.22, 127.21 (aromatic C/C*H*), 100.2 (C-1), 100.1 (C-1), 99.9 (3xC-1), 97.3 (C-1^{A}), 78.2, 77.3, 77.2, 76.7, 76.6, 76.2, 76.1, 76.0, 75.9, 75.8, 75.4, 75.0, 74.9, 74.5, 74.2, 73.8 (2 CH_2*Ph*), 73.73, 73.71, 73.6, 73.4, 73.2, 72.9, 72.7, 72.64, 72.61, 72.2 (9 CH_2*Ph*), 69.2, 69.0, 68.9, 68.7, 68.0 (C-7), 67.6, 66.5, 66.1 (CH_2*Ph*), 63.1, 62.1, 61.5, 61.3, 61.2, 61.1 (6 C-6), 34.2 (C-11), 29.0 (C-8), 25.7 (C-9), 24.6 (C-10). MALDI-MS: Calculated for $C_{175}H_{174}O_{39}$ $[M+Na]^+$: 2922.1530, found: 2922.1282.

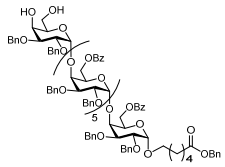
6-(Benzyl hexanoyl) 2,3-di-*O*-benzyl-4,6-di-*tert*-butylsilylidene-α-D-galactopyranosyl-(1→4)-6-*O*-benzoyl-2,3-di-*O*-benzyl-α-D-galactopyranosyl-(1→4)-6-*O*-benzoyl-2,3-di-*O*-benzyl-α-D-galactopyranosyl-(1→4)-6-

_O_-benzoyl-2,3-di-_O_-benzyl-α-D-galactopyranosyl-(1→4)-6-_O_-benzoyl-2,3-di-_O_-benzyl-α-D-galactopyranosyl-(1→4)-6-_O_-benzoyl-2,3-di-_O_-benzyl-α-D-galactopyranosyl-(1→4)-6-_O_-benzoyl-2,3-di-_O_-benzyl-α-D-galactopyranoside (23)



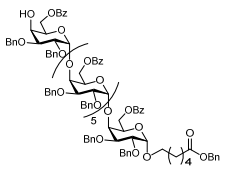
The reaction was carried out according to the general procedure A. The donor **1** (610 mg, 1.04 mmol) and the acceptor **22** (604 mg, 0.21 mmol) were co-evaporated with toluene (three times). The residue was dissolved in 3.7 ml dry DCM under nitrogen and stirred over fresh flame-dried molecular sieves 3Å. The solution was cooled to 0 ºC, after which NIS (304 mg, 1.35 mmol) and TfOH (2 µl, 0.02 mmol) were added. The reaction was stirred at 0 ºC for 2 h. Then the reaction was quenched with saturated $Na_2S_2O_3$, diluted with DCM, washed with saturated $NaHCO_3$ and brine. The organic phase was dried with anhydrous $MgSO_4$, filtered and concentrated *in vacuo*. The product was purified by silica gel column chromatography (pentane:EtOAc:DCM = 40:9:2). Compound **23** (531 mg, 76% yield, pentane:EtOAc = 2:1, R*f* = 0.55-0.55) was obtained as colorless syrup. $[\alpha]_D^{25}$ +34.4 (c=1, $CHCl_3$). IR (neat, cm^{-1}) ν 736, 1005, 1027, 1046, 1063, 1093, 1271, 1452, 1723, 2859, 2929. ^{1}H-NMR ($CDCl_3$, 400 MHz) δ 8.05 – 7.84 (m, 12H, *C*H, Bz), 7.69 – 6.88 (m, 93H, *aromatic* H), 5.12 – 5.01 (m, 6H, *C*H_2*Ph*, H-1^G, 1^F, 1^E, 1^D), 4.99 (d, *J* = 3.3 Hz, 1H, H-1^C), 4.92 – 4.08 (m, 57H), 4.05 – 3.75 (m, 16H), 3.70 (dd, *J* = 10.2, 2.7 Hz, 2H, H-3), 3.66 – 3.50 (m, 3H, H-7, 6^G), 3.40 (dt, *J* = 9.9, 6.6 Hz, 1H, H-7), 2.26 (t, *J* = 7.5 Hz, 2H, H-11), 1.56 (q, *J* = 7.4 Hz, 4H, H-10, 8), 1.32 – 1.21 (m, 2H, H-9), 0.99 (s, 9H, 3x*C*H_3), 0.86 (s, 9H, 3x*C*H_3). ^{13}C NMR (125 MHz, $CDCl_3$) δ 173.3 (C-12), 166.0, 165.5, 165.4 (3 C=O, Bz), 165.3 (2xC=O, Bz), 165.2 (C=O, Bz), 139.1, 138.7, 138.7, 138.6, 138.6, 138.6, 138.4, 138.3, 138.3, 138.2, 138.2, 138.1, 138.1, 136.1, 133.1, 133.0, 130.0, 129.9, 129.9, 129.6, 129.6, 129.6, 128.9, 128.7, 128.6, 128.5, 128.5, 128.5, 128.4, 128.4, 128.3, 128.2, 128.2, 128.1, 128.1, 127.8, 127.6, 127.6, 127.5, 127.5, 127.4, 127.4, 127.3, 127.3, 127.2, 127.1, 127.1, 126.9 (aromatic C/*CH*), 100.1 (C-1), 100.0 (3xC-1), 99.8 (C-1), 97.3 (C-1^A), 78.1, 77.8, 77.4, 77.2, 76.6, 76.5, 76.2, 76.1, 75.9, 75.3, 74.8, 74.3, 74.1, 73.9, 73.7, 73.6, 73.44, 73.41, 73.1, 72.9 (7 CH_2*Ph*), 72.8, 72.7, 72.63, 72.61, 72.4 (4 CH_2*Ph*), 70.6, 70.1 (CH_2*Ph*), 69.1, 68.9, 68.7, 67.9 (C-7), 67.4, 67.0 (C-6^G), 66.0 (CH_2*Ph*), 63.0, 61.5, 61.3, 61.2, 61.1, 61.1 (6 C-6), 34.1 (C-11), 29.0 (C-8), 27.7 (3xCH_3), 27.2 (3xCH_3), 25.7 (C-9), 24.6 (C-10), 23.3 (C-*Si*), 20.6 (C-*Si*). MALDI-MS: Calculated for $C_{203}H_{212}O_{44}Si$ $[M+Na]^+$: 3404.4018, found: 3404.3707.

6-(Benzyl hexanoyl) 2,3-di-_O_-benzyl-α-D-galactopyranosyl-(1→4)-6-_O_-benzoyl-2,3-di-_O_-benzyl-α-D-galactopyranosyl-(1→4)-6-_O_-benzoyl-2,3-di-_O_-benzyl-α-D-galactopyranosyl-(1→4)-6-_O_-benzoyl-2,3-di-_O_-benzyl-α-D-galactopyranosyl-(1→4)-6-_O_-benzoyl-2,3-di-_O_-benzyl-α-D-galactopyranosyl-(1→4)-6-_O_-benzoyl-2,3-di-_O_-benzyl-α-D-galactopyranoside (24)



The reaction was carried out according to the general procedure C using compound **23** (508 mg, 0.15 mmol) and HF/pyridine (70%, 62 µl, 2.40 mmol). The product was purified by column chromatography (pentane:EtOAc:DCM = 12:5:1). Compound **24** (463 mg, 95% yield, pentane:EtOAc = 1:1, R*f* = 0.25-0.35) was obtained as yellow syrup. $[\alpha]_D^{25}$ +32.5 (c=1, $CHCl_3$). IR (neat, cm^{-1}) ν 734, 803, 1003, 1026, 1046, 1093, 1269, 1315, 1360, 1723, 2869, 2925, 3416. ^{1}H-NMR ($CDCl_3$, 400 MHz) δ 8.05 – 7.88 (m, 12H, *C*H, Bz), 7.61 – 6.91 (m, 93H), 5.13 – 5.00 (m, 7H, *CH*$_2$*Ph*, H-1^G, 1^F, 1^E, 1^D, 1^C), 4.99 (d, *J* = 3.5 Hz, 1H, H-1^B), 4.90 – 4.52 (m, 33^H), 4.50 – 3.73 (m, 30H), 3.69 (dd, *J* = 10.0, 3.1 Hz, 1H, H-3^B), 3.57 (dt, *J* = 10.0, 7.0 Hz, 1H, H-7), 3.47 – 3.28 (m, 3H, H-7, 6^G), 2.72 (bs, 1H, *O*H), 2.32 (bs, 1H, *O*H), 2.27 (t, *J* = 7.5 Hz, 2H, H-11), 1.66 – 1.51 (m, 4H, H-10, 8), 1.31 – 1.25 (m, 2H, H-9). ^{13}C NMR (125 MHz, $CDCl_3$) δ 173.1 (C-12), 165.8, 165.3, 165.2, 165.17, 165.12 (6 C=O, Bz), 138.6, 138.5, 138.4, 138.3, 138.2, 138.1, 138.0, 137.9, 137.8, 137.7, 135.9, 133.0, 129.8, 129.7, 129.6, 129.5, 129.4, 129.3, 128.6, 128.5, 128.43, 128.41, 128.35, 128.31, 128.2, 128.1, 128.04, 128.02, 128.01, 127.7, 127.5, 127.4, 127.3, 127.23, 127.21, 127.1, 127.0, 126.9 (aromatic C/C*H*), 100.0 (C-1), 99.9 (C-1), 99.8 (C-1), 99.7 (C-1), 97.2 (C-1^A), 77.9, 77.7, 77.4, 77.1, 76.8, 76.5, 76.4, 76.0, 75.7, 75.1, 74.6, 74.2, 73.9 (C*H*$_2$*Ph*), 73.8, 73.6, 73.5, 73.4, 73.1, 72.9, 72.7, 72.6, 72.5, 72.5, 71.9 (10 C*H*$_2$*Ph*), 69.0, 68.9, 68.5, 67.8 (C-7), 65.8 (C*H*$_2$*Ph*), 62.9, 62.7, 61.3, 61.2, 61.1, 61.0 (7 C-6), 33.9 (C-11), 28.8 (C-8), 25.5 (C-9), 24.4 (C-10). MALDI-MS: Calculated for $C_{195}H_{196}O_{44}$ $[M+Na]^+$: 3264.2997, found: 3264.2726.

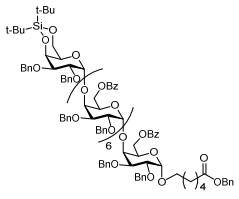
6-(Benzyl hexanoyl) 6-*O*-benzoyl-2,3-di-*O*-benzyl-α-D-galactopyranosyl-(1→4)-6-*O*-benzoyl-2,3-di-*O*-benzyl-α-D-galactopyranosyl-(1→4)-6-*O*-benzoyl-2,3-di-*O*-benzyl-α-D-galactopyranosyl-(1→4)-6-*O*-benzoyl-2,3-di-*O*-benzyl-α-D-galacto-pyranosyl-(1→4)-6-*O*-benzoyl-2,3-di-*O*-benzyl-α-D-galactopyranosyl-(1→4)-6-*O*-benzoyl-2,3-di-*O*-benzyl-α-D-galactopyranosyl-(1→4)-6-*O*-benzoyl-2,3-di-*O*-benzyl-α-D-galactopyranoside (25)



The reaction was carried out according to the general procedure D using compound **24** (393 mg, 0.12 mmol), PhCOOBt (174 mg, 0.73 mmol) and Et_3N (110 µl, 0.79 mmol). The product was purified by column chromatography (pentane:EtOAc:DCM = 12:4:1). Compound **25** (402 mg, 94% yield, pentane:EtOAc = 3:2, R*f* = 0.30-0.40) was obtained as yellow syrup. $[\alpha]_D^{25}$ +24.6 (c=1, $CHCl_3$). IR (neat, cm^{-1}) ν 734, 1003, 1026, 1046, 1070, 1093, 1157, 1269, 1315, 1452, 1721, 2872, 2925. ^{1}H-NMR ($CDCl_3$, 400 MHz) δ 8.11 – 7.94 (m, 14H, *C*H, Bz), 7.68 – 6.99 (m, 96H, *aromatic* H), 5.14 (s, 2H, *CH*$_2$*Ph*), 5.13 – 5.06 (m, 5H, H-1^G, 1^F, 1^E, 1^D, 1^C), 5.05 (d, *J* = 3.4 Hz, 1H, H-1^B), 4.97 – 4.36 (m, 46H), 4.35 – 4.08 (m, 10H), 4.04 (t, *J* = 6.8 Hz, 1H, H-5^A), 4.00 – 3.76 (m, 15H), 3.63 (dt, *J* = 10.2, 7.1 Hz, 1H, H-7), 3.47 (dt, *J* = 10.1, 6.7 Hz, 1H, H-7), 2.58 (bs, 1H, H-*O*H), 2.33 (t, *J* = 7.5 Hz, 2H, H-11), 1.73 – 1.54 (m, 4H, H-10, 8), 1.38 – 1.29 (m, 2H, H-9). ^{13}C NMR (125 MHz, $CDCl_3$) δ 173.4 (C-12), 166.0, 165.8, 165.5, 165.4, 165.34, 165.32, 165.2 (7 C=O, Bz), 138.8, 138.64, 138.62, 138.5, 138.3, 138.23, 138.21, 138.1, 137.9, 136.1, 133.2, 133.2, 133.1, 130.04, 130.01, 129.94, 129.92, 129.8, 129.7, 129.64, 129.61, 129.5, 128.7, 128.64, 128.62, 128.6,1 128.53, 128.51, 128.4, 128.34, 128.32, 128.31, 128.24, 128.22, 128.21,

128.20, 128.1, 127.9, 127.8, 127.74, 127.72, 127.64, 127.62, 127.61, 127.5, 127.4, 127.34, 127.32, 127.31, 127.23, 127.21, 127.15, 127.13 (aromatic C/C*H*), 100.2, 100.03, 99.98, 99.95 (4 C-1), 99.94 (2xC-1), 97.3 (C-1^A), 78.2, 77.3, 77.0, 76.6, 76.5, 76.1, 75.9, 75.8, 75.3, 75.0, 74.8, 74.7, 74.3, 74.2, 73.8, 73.74, 73.72, 73.6, 73.4, 73.1, 72.9, 72.8, 72.73, 72.71, 72.63, 72.61, 72.2 (14 CH_2Ph), 69.1, 69.0, 68.7, 67.9 (C-7), 67.6, 66.4, 66.1 (CH_2Ph), 63.0, 62.0, 61.5, 61.3, 61.2, 61.1, 61.0 (7 C-6), 34.1 (C-11), 29.0 (C-8), 25.7 (C-9), 24.6 (C-10). MALDI-MS: Calculated for $C_{202}H_{200}O_{45}$ $[M+Na]^+$: 3368.3259, found: 3368.2962.

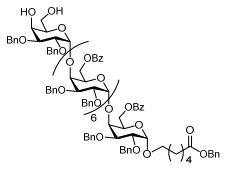
6-(Benzyl hexanoyl) 2,3-di-*O*-benzyl-4,6-di-*tert*-butylsilylidene-α-D-galactopyranosyl-(1→4)-6-*O*-benzoyl-2,3-di-*O*-benzyl-α-D-galactopyranosyl-(1→4)-6-*O*-benzoyl-2,3-di-*O*-benzyl-α-D-galactopyranosyl-(1→4)-6-*O*-benzoyl-2,3-di-*O*-benzyl-α-D-galactopyranosyl-(1→4)-6-*O*-benzoyl-2,3-di-*O*-benzyl-α-D-galactopyranosyl-(1→4)-6-*O*-benzoyl-2,3-di-*O*-benzyl-α-D-galactopyranosyl-(1→4)-6-*O*-benzoyl-2,3-di-*O*-benzyl-α-D-galacto-pyranoside (26)



The reaction was carried out according to the general procedure A. The donor **1** (337 mg, 0.57 mmol) and the acceptor **25** (381 mg, 0.11 mmol) were co-evaporated with toluene (three times). The residue was dissolved in 1.5 ml dry DCM under nitrogen and stirred over fresh flame-dried molecular sieves 3Å. The solution was cooled to 0 ºC, after which NIS (167 mg, 0.74 mmol) and TfOH (1 µl, 0.01 mmol) were added. The reaction was stirred at 0 ºC for 2 h. Then the reaction was quenched with saturated $Na_2S_2O_3$, diluted with DCM, washed with saturated $NaHCO_3$ and brine. The organic phase was dried with anhydrous $MgSO_4$, filtered and concentrated *in vacuo*. The product was purified by silica gel column chromatography (pentane:EtOAc:DCM = 16:4:1). Compound **26** (352 mg, 81% yield, pentane:EtOAc = 2:1, R*f* = 0.55-0.55) was obtained as colorless syrup. $[\alpha]_D^{25}$ +31.4 (c=1, $CHCl_3$). IR (neat, cm^{-1}) ν 736, 1005, 1027, 1046, 1062, 1095, 1271, 1315, 1362, 1724, 2859, 2931. ^{1}H-NMR ($CDCl_3$, 500 MHz) δ 8.04 – 7.93 (m, 12H, *C*H, Bz), 7.93 – 7.87 (m, 2H, *C*H, Bz), 7.61 – 6.89 (m, 106H*, aromatic* H), 5.11 – 5.00 (m, 7H, *C*H_2Ph, H-1^h, 1^G, 1^F, 1^E, 1^D), 4.97 (d, *J* = 3.4 Hz, 1H, H-1^C), 4.92 – 3.67 (m, 80H), 3.66 – 3.52 (m, 3H, H-7, 6h), 3.43 – 3.39 (m, H-7), 2.27 (t, *J* = 7.5 Hz, 2H, H-11), 1.64 – 1.51 (m, 4H, H-10, 8), 1.32 – 1.20 (m, 2H, H-9), 0.99 (s, 9H, *C*H_3), 0.87 (s, 9H, *C*H_3). ^{13}C NMR (125 MHz, $CDCl_3$) δ 173.3 (C-12), 165.9, 165.4, 165.3, 165.27, 165.26, 165.2, 165.1 (7 C=O, Bz), 139.1, 138.7, 138.6, 138.58, 138.55, 138.51, 138.4, 138.3, 138.26, 138.22, 138.17, 138.12, 138.07, 138.01, 136.0, 133.1, 133.0, 132.99, 129.93, 129.88, 129.85, 129.61, 129.57, 129.55, 129.52, 128.9, 128.6, 128.55, 128.52, 128.50, 128.47, 128.44, 128.41, 128.38, 128.28, 128.20, 128.17, 128.13, 128.11, 128.08, 128.06, 127.8, 127.6, 127.53, 127.51, 127.48, 127.43, 127.41, 127.31, 127.28, 127.24, 127.21, 127.19, 127.11, 127.0, 126.9 (aromatic C/C*H*), 100.07 (C-1), 99.9 (C-1), 99.9 (C-1), 97.3 (C-1^A), 78.0, 77.7, 77.28, 77.21, 76.8, 76.6, 76.5, 76.2, 76.1, 75.8, 75.7, 75.6, 75.22, 74.7, 74.6, 74.3, 74.2, 74.0, 73.9, 73.72, 73.7, 73.64, 73.60, 73.4, 73.1, 72.8 (8 CH_2Ph), 72.7, 72.6, 72.55, 72.53, 72.3 (4 CH_2Ph), 70.5, 70.0 (CH_2Ph), 69.1, 68.98, 68.93, 68.88, 68.84, 68.83, 68.6, 67.9 (C-7), 67.4, 67.0 (C-6h), 66.01 (CH_2Ph), 62.9, 61.4, 61.2, 61.14, 61.12, 61.06, 60.9 (7 C-6), 34.1 (C-11), 28.9 (C-8), 27.6 (3xCH_3), 27.2 (3xCH_3), 25.6 (C-9),

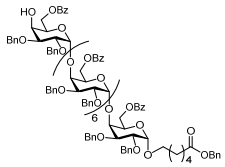
24.6 (C-10), 23.3 (C-*Si*), 20.6 (C-*Si*). MALDI-MS: Calculated for $C_{230}H_{238}O_{50}Si$ $[M+Na]^+$: 3850.5748, found: 3850.5363.

6-(Benzyl hexanoyl) 2,3-di-*O*-benzyl-α-D-galactopyranosyl-(1→4)-6-*O*-benzoyl-2,3-di-*O*-benzyl-α-D-galactopyranosyl-(1→4)-6-*O*-benzoyl-2,3-di-*O*-benzyl-α-D-galactopyranosyl-(1→4)-6-*O*-benzoyl-2,3-di-*O*-benzyl-α-D-galactopyranosyl-(1→4)-6-*O*-benzoyl-2,3-di-*O*-benzyl-α-D-galactopyranosyl-(1→4)-6-*O*-benzoyl-2,3-di-*O*-benzyl-α-D-galactopyranosyl-(1→4)-6-*O*-benzoyl-2,3-di-*O*-benzyl-α-D-galactopyranoside (27)



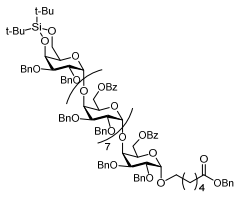
The reaction was carried out according to the general procedure C using compound **26** (330 mg, 86 µmol) and HF/pyridine (70%, 25 µl, 1.38 mmol). The product was purified by column chromatography (pentane:EtOAc:DCM = 6:4:1). Compound **27** (296 mg, 93% yield, pentane:EtOAc = 1:1, R*f* = 0.25-0.35) was obtained as yellow syrup. $[\alpha]_D^{25}$ +34.1 (c=1, $CHCl_3$). IR (neat, cm^{-1}) ν 738, 1003, 1027, 1047, 1095, 1271, 1452, 1723, 2873, 2925, 3506. ^{1}H-NMR ($CDCl_3$, 500 MHz) δ 8.06 – 7.87 (m, 14H, *C*H, Bz), 7.63 – 6.90 (m, 106H, *aromatic* H), 5.07 (s, 2H, *CH*$_2$*Ph*), 5.06 – 4.99 (m, 6H, H-1), 4.98 (d, *J* = 3.5 Hz, 1H, H-1^B), 4.92 – 3.71 (m, 80H), 3.68 (dd, *J* = 10.0, 3.1 Hz, 1H, H-3^B), 3.56 (dt, *J* = 10.2, 7.1 Hz, 1H, H-7), 3.45 – 3.27 (m, 3H, H-7, 6^H), 2.71 (bs, 1H, *O*H), 2.26 (t, *J* = 7.6 Hz, 2H, H-11), 1.64 – 1.47 (m, 4H, H-10, 8), 1.31 – 1.21 (m, 4H, H-9). ^{13}C NMR (125 MHz, $CDCl_3$) δ 173.4 (C-12), 166.0, 165.5, 165.4, 165.43, 165.35, 165.32, 165.30 (7 C=O, Bz), 138.8, 138.7, 138.66, 138.64, 138.61, 138.4, 138.34, 138.32, 138.31, 138.23, 138.22, 138.1, 138.0, 137.9, 136.1, 133.24, 133.21, 130.0, 129.94, 129.92, 129.7, 129.6, 129.5, 129.4, 128.7, 128.64, 128.62, 128.61, 128.53, 128.51, 128.42, 128.41, 128.33, 128.31, 128.23, 128.21, 128.20, 128.19, 128.14, 128.0, 127.9, 127.8, 127.73, 127.71, 127.70, 127.64, 127.62, 127.61, 127.5, 127.42, 127.41, 127.33, 127.32, 127.31, 127.30, 127.2, 127.09, 127.06 (aromatic C/C*H*), 100.2 (C-1), 100.1 (C-1), 100.0 (C-1), 99.8 (C-1), 97.3 (C-1^A), 78.0, 77.9, 77.3, 77.0, 76.7, 76.6, 76.1, 76.0, 75.9, 75.7, 75.3, 74.8, 74.7, 74.6, 74.3, 74.0 (C*H*$_2$*Ph*), 73.9, 73.8, 73.74, 73.72, 73.71, 73.5, 73.23, 73.21, 72.9, 72.7, 72.68, 72.63, 72.1 (12 C*H*$_2$*Ph*), 69.4, 69.2, 69.0, 68.7, 68.0 (C-7), 66.1 (C*H*$_2$*Ph*), 63.1, 62.9, 61.5, 61.3, 61.21, 61.19, 61.17, 61.08 (8 C-6), 34.2 (C-11), 29.0 (C-8), 25.7 (C-9), 24.7 (C-10). MALDI-MS: Calculated for $C_{222}H_{222}O_{50}$ $[M+Na]^+$: 3710.4727, found: 3710.4379.

6-(Benzyl hexanoyl) 6-*O*-benzoyl-2,3-di-*O*-benzyl-α-D-galactopyranosyl-(1→4)-6-*O*-benzoyl-2,3-di-*O*-benzyl-α-D-galactopyranosyl-(1→4)-6-*O*-benzoyl-2,3-di-*O*-benzyl-α-D-galactopyranosyl-(1→4)-6-*O*-benzoyl-2,3-di-*O*-benzyl-α-D-galacto-pyranosyl-(1→4)-6-*O*-benzoyl-2,3-di-*O*-benzyl-α-D-galacto-pyranosyl-(1→4)-6-*O*-benzoyl-2,3-di-*O*-benzyl-α-D-galactopyrano-syl-(1→4)-6-*O*-benzoyl-2,3-di-*O*-benzyl-α-D-galactopyranosyl-(1→4)-6-*O*-benzoyl-2,3-di-*O*-benzyl-α-D-galactopyranoside (28)



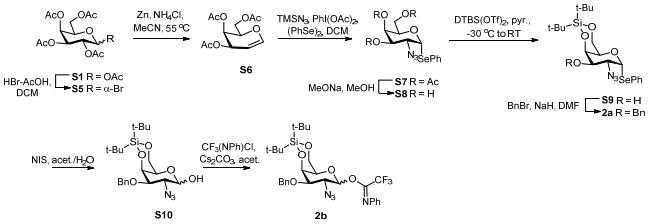
The reaction was carried out according to the general procedure D using compound **27** (179 mg, 49 µmol), PhCOOBt (70 mg, 0.29 mmol) and Et_3N (44 µl, 0.32 mmol). The product was purified by column chromatography (pentane:EtOAc:DCM = 12:4:1). Compound **28** (175 mg, 95% yield, pentane:EtOAc = 3:2, R*f* = 0.30-0.40) was obtained as yellow syrup. $[\alpha]_D^{25}$ +26.7 (c=1, $CHCl_3$). IR (neat, cm^{-1}) ν 1027, 1047, 1096, 1272, 1452, 1724, 2870, 2926, 3489. ^{1}H-NMR ($CDCl_3$, 400 MHz) δ 8.03 – 7.84 (m, 16H, *C*H, Bz), 7.65 – 6.87 (m, 109H, *aromatic* H), 5.07 (s, 2H, *C*H_2*Ph*), 5.04 – 4.92 (m, 6H), 4.90 – 3.66 (m, 80H), 3.59 – 3.49 (m, 1H, H-7), 3.45 – 3.33 (m, 1H, H-7), 2.46 (s, 1H, *O*H), 2.26 (t, *J* = 7.6 Hz, 2H, H-11), 1.62 – 1.47 (m, 4H, H-10, 8), 1.32 – 1.24 (m, 2H, H-9). ^{13}C NMR (125 MHz, $CDCl_3$) δ 173.42 (C-12), 166.05, 165.87, 165.53, 165.45, 165.37, 165.33, 165.28 (C=O, Bz), 138.81, 138.67, 138.63, 138.59, 138.38, 138.28, 138.23, 138.20, 137.90, 136.15, 133.20, 133.01, 130.08, 129.97, 129.94, 129.71, 129.67, 129.64, 129.61, 129.57, 128.70, 128.64, 128.59, 128.53, 128.50, 128.46, 128.37, 128.33, 128.28, 128.24, 128.21, 128.17, 127.91, 127.87, 127.73, 127.69, 127.64, 127.60, 127.50, 127.42, 127.38, 127.35, 127.28, 127.24, 127.20, 127.11 (aromatic C/C*H*), 100.20 (C-1), 100.03 (C-1), 100.00 (C-1), 97.37 (C-1), 78.19, 77.31, 76.98, 76.68, 76.60, 76.15, 75.93, 75.81, 75.34, 75.01, 74.73, 74.36, 74.25, 73.81, 73.74, 73.70, 73.57, 73.44, 73.19, 72.90, 72.73, 72.63, 72.24, 69.20, 69.00, 68.75, 67.98 (C-7), 67.62, 66.49, 66.11 (CH_2*Ph*), 63.09, 62.07, 61.54, 61.35, 61.23, 61.08 (C-6), 34.19 (C-11), 29.03 (C-8), 25.73 (C-9), 24.69 (C-10). MALDI-MS: Calculated for $C_{229}H_{226}O_{51}$ $[M+Na]^+$: 3814.4989, found: 3814.4630.

6-(Benzyl hexanoyl) 2,3-di-*O*-benzyl-4,6-di-*tert*-butylsilylidene-α-D-galactopyranosyl-(1→4)-6-*O*-benzoyl-2,3-di-*O*-benzyl-α-D-galactopyranosyl-(1→4)-6-*O*-benzoyl-2,3-di-*O*-benzyl-α-D-galactopyranosyl-(1→4)-6-*O*-benzoyl-2,3-di-*O*-benzyl-α-D-galactopyranosyl-(1→4)-6-*O*-benzoyl-2,3-di-*O*-benzyl-α-D-galactopyranosyl-(1→4)-6-*O*-benzoyl-2,3-di-*O*-benzyl-α-D-galactopyranosyl-(1→4)-6-*O*-benzoyl-2,3-di-*O*-benzyl-α-D-galactopyranosyl-(1→4)-6-*O*-benzoyl-2,3-di-*O*-benzyl-α-D-galactopyranoside (29)



The reaction was carried out according to the general procedure A. The donor **1** (117 mg, 0.20 mmol) and the acceptor **28** (150 mg, 40 µmol) were co-evaporated with toluene (three times). The residue was dissolved in 1 ml dry DCM under nitrogen and stirred over fresh flame-dried molecular sieves 3Å. The solution was cooled to 0 °C, after which NIS (58 mg, 0.26 mmol) and TfOH (1 µl, 4 µmol) were added. The reaction was stirred at 0 °C for 2 h. Then the reaction was quenched with saturated $Na_2S_2O_3$, diluted with DCM, washed with saturated $NaHCO_3$ and brine. The organic phase was dried with anhydrous $MgSO_4$, filtered and concentrated *in vacuo*. The product was purified by silica gel column chromatography (pentane:EtOAc:DCM = 16:4:1). Compound **29** (110 mg, 65% yield, pentane:EtOAc = 2:1, R*f* = 0.55-0.55) was obtained as colorless syrup. $[\alpha]_D^{25}$ +35.3 (c=1, $CHCl_3$). IR (neat, cm^{-1}) ν 731, 1027, 1045, 1062, 1315, 1725, 2932, 3062. ^{1}H-NMR ($CDCl_3$, 500 MHz) 8.07 – 7.91 (m, 16H, *C*H, Bz), 7.64 – 6.92 (m, 119H, *aromatic* H), 5.12 (s, 2H, *C*H_2*Ph*), 5.10 – 5.02 (m, 6H, H-1), 5.00 (d, *J* = 3.3 Hz, 1H, H-1^C), 4.95 – 4.05 (m, 72H), 4.04 – 3.55 (m, 25H), 3.47

– 3.40 (m, 1H, H-7), 2.31 (t, *J* = 7.6 Hz, 2H, H-11), 1.67 – 1.55 (m, 4H, H-10, 8), 1.33 – 1.27 (m, 2H, H-9), 1.03 (s, 9H, CH_3), 0.90 (s, 9H, CH_3). ^{13}C NMR (125 MHz, $CDCl_3$) δ 173.4 (C-12), 166.1, 165.55, 165.47, 165.37, 165.34, 165.30 (6 CH_2Ph), 139.2, 138.8, 138.7, 138.6, 138.5, 138.4, 138.4, 138.3, 138.2, 138.1, 136.2, 133.1, 130.1, 130.0, 129.7, 129.6, 129.0, 128.8, 128.7, 128.6, 128.5, 128.4, 128.3, 128.3, 128.2, 127.9, 127.7, 127.6, 127.5, 127.4, 127.3, 127.2, 127.1, 127.0 (aromatic C/C*H*), 100.0 (C-1), 99.9 (C-1), 97.4 (C-1^A), 78.2, 77.9, 77.4, 77.3, 77.0, 76.7, 76.6, 76.3, 76.2, 76.0, 75.8, 75.4, 74.83, 74.81, 74.74, 74.72, 74.42, 74.40, 74.2, 74.0, 73.83, 73.81, 73.7, 73.4, 73.2, 72.93 (7 CH_2Ph), 72.91, 72.8, 72.7, 72.6, 72.4 (4 CH_2Ph), 70.6, 70.1 (CH_2Ph), 69.2, 69.0, 68.8, 68.0 (C-7), 67.5, 67.1 (C-6i), 66.1 (CH_2Ph), 63.1, 61.6, 61.4, 61.33, 61.31, 61.24, 61.21, 61.1 (8 C-6), 34.2 (C-11), 29.1 (C-8), 27.7 (3xCH_3), 27.3 (3xCH_3), 25.8 (C-9), 24.7 (C-10), 23.4 (C-*Si*), 20.7 (C-*Si*). ^{13}C-HMBC ($CDCl_3$, 125 MHz): 97.4 ($J_{C1A,H1A}$ = 167 Hz), 100.0 ($J_{C1,H1}$ = 167 Hz, 170 Hz, 169 Hz, 171 Hz). MALDI-MS: Calculated for $C_{257}H_{264}O_{56}Si$ $[M+Na]^+$: 4296.7477, found: 4296.7031.



Phenyl 3,4,6-tri-*O*--acetyl-2-azido-2-deoxy-1-seleno-α-D-galactopyranoside (S7)

Compound **S1** (75.6 g, 193.8 mmol) was dissolved in DCM (500 ml) and cooled in ice-bath, then HBr-AcOH (67 ml, 387.6 mmol) was added slowly to the solution, which was allowed to warm to room temperature and stirred for 4h. The solution was poured into ice-water and washed with water, sat. $NaHCO_3$ solution, sat. NaCl solution subsequently. The organic layer was dried with anhydrous $MgSO_4$, filtered and concentrated *in vacuo*. The crude product was dissolved in MeCN (500 ml), then zinc (95g, 1.45 mol) and NH_4Cl (77.75 g, 1.45 mol) were added to the solution. The reaction mixture was warmed to 55 ºC and allowed to stir for overnight. The solid was filtered and the filtrate was concentrated *in vacuo*. The product **S6** was purified by silica gel column chromatography (pentane:EtOAc = 4:1) to give the target in 75% yield. S6 (33.2 g, 122 mmol) was dissolved in DCM (600 ml) and cooled to -30 ºC, then $(PhSe)_2$ (38g, 122 mmol), $PhI(OAc)_2$ (39.3 g, 122 mmol) and $TMSN_3$ (34.4 ml, 244 mmol) were added to the solution. The reaction mixture was allowed to warm to 0 ºC slowly and stirred at 0 ºC for overnight. The solution was washed with sat. $NaHCO_3$ solution, sat. NaCl solution subsequently. The organic layer was dried with anhydrous $MgSO_4$, filtered and concentrated *in vacuo*. The crude was recrystallized with pentane and Et_2O to afford **S7** in 71% yield as white solid. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.63 – 7.57 (m, 2H), 7.35 – 7.25 (m, 4H), 6.00 (d, *J* = 5.4 Hz, 1H), 5.47 (dd, *J* = 3.3, 1.3 Hz, 1H), 5.11 (dd, *J* = 10.9, 3.2 Hz, 1H), 4.67 (ddd, *J* = 7.1, 5.7, 1.3 Hz, 1H), 4.26 (dd, *J* = 10.8, 5.4 Hz, 1H), 4.12 – 3.98 (m, 2H), 2.15 (s, 3H), 2.06 (s, 3H), 1.97 (s, 3H).

Phenyl 2-azido-2-deoxy-1-seleno-4,6-*tert*-butylsilylidene-α-D-galactopyranoside (2a)[23]

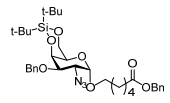
S7 (22 g, 47 mmol) was suspended in MeOH (150 ml) and cooled in ice-bath, then MeONa (508 mg, 9.4 mmol) was added to the mixture, which allowed to warm to room temperature and stirred for overnight. The solution was neutralized with Dowex ion-exchange resin, filtered and concentrated in vacuo. The crude was dissolved in pyridene (150 ml) and cooled to -30 ºC. $DTBS(OTf)_2$ (16 ml, 49.5 mmol) was added to the reaction solution, which was allowed to warm to room temperature and stirred for 2h. MeOH (5 ml) was added to the solution and concentrated *in vacuo*. The crude was washed with 1M HCl, sat. $NaHCO_3$ solution and sat. NaCl solution subsequently. The organic layer was dried over $MgSO_4$, filtered and concentrated. The crude was purified by silica gel column chromatography (pentane:EtOAc = 20:1) to give **S9** in 88% yield. **S9** (7.6 g, 15.7 mmol) was dissolved in DMF (120 ml) and cooled in ice-bath. Then BnBr (2.1 ml, 17.2 mmol) and NaH (815 mg, 20.4 mmol) were added subsequently to the reaction mixture, which was allowed to stir in ice-bath for 3h. MeOH was added to quench the reaction, and the solution was diluted in Et_2O and washed with water and sat. NaCl solution subsequently. The organic layer was dried over $MgSO_4$, filtered and concentrated. The crude was purified by silica gel column chromatography (pentane:Et_2O = 40:1) to give compound **2a** in 86% yield. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.57 – 7.53 (m, 2H), 7.46 – 7.24 (m, 10H), 5.94 (d, *J* = 5.2 Hz, 1H), 4.77 (d, *J* = 11.6 Hz, 1H), 4.69 (d, *J* = 11.6 Hz, 1H), 4.59 (dd, *J* = 3.1, 1.1 Hz, 1H), 4.35 – 4.28 (m, 1H), 4.24 (dd, *J* = 12.5, 2.2 Hz, 1H), 4.04 (d, *J* = 2.3 Hz, 1H), 4.00 (dd, *J* = 12.5, 1.7 Hz, 1H), 3.64 (dd, *J* = 10.2, 3.0 Hz, 1H), 1.05 (d, *J* = 13.2 Hz, 18H).

2-azido-3-*O*-benzyl-2-deoxy-4,6-*O*-*tert*-butylsilylidene-1-*O*-(*N*-phenyl-trifluoroacetimidoyl)-α/β-D-galactopyranoside (2b)

NIS (9.15 g, 40.68 mmol) was added to the solution of compound **2a**[23] (18 g, 31.3 mmol) in Acetone/H_2O (210 ml/72ml) at 0 ºC. The reaction was slowly warmed to room temperature and stirred until TLC-analysis indicated full consumption of the starting material (± 1H). Then the mixture was diluted with DCM and washed with saturated $Na_2S_2O_3$ and brine, dried with anhydrous $MgSO_4$, filtered and concentrated *in vacuo*. The product **S10** was purified by silica gel column chromatography (pentane:EtOAc = 4:1). Cs_2CO_3 was added to the solution of compound **S10** (10.59g, 24.33 mmol) in 140 ml acetone. The mixture was stirred at 0 ºC for 15 minutes. Then CF_{3C}(=NPh)Cl (6.06 g, 29.2 mmol) was added to the solution. which was slowly warmed to room temperature and stirred overnight. The reaction was quenched with Et_3N and concentrated *in vacuo*. The product **2b** was purified by silica gel column chromatography (pentane:Et_2O = 30:1 – 10:1). Compound **2b** (13.3 g, α/β = 2:1, 90% yield, pentane: Et_2O = 10:1, R*f* = 0.45-0.55) was obtained as white solid. α isomer: ^{1}H-NMR ($CDCl_3$, 400 MHz) δ 7.50 – 7.24 (m, 7H, aromatic H), 7.15 – 7.05 (m, 1H, aromatic H), 6.84 (d, *J* = 7.7 Hz, 2H, aromatic H), 6.47 (bs, 1H, H-1), 4.78 (d, *J* = 11.4 Hz, 1H, *C*H_2*Ph*), 4.69 (d, *J* = 11.4 Hz, 1H, *C*H_2*Ph*), 4.63 (s, 1H, H-4), 4.22 (q, *J* = 12.8 Hz, 2H. H-6), 4.10 (t, *J* = 6.3 Hz, 1H, H-2), 3.89 (d, *J* = 9.5 Hz, 1H, H-3), 3.76 (s, 1H, H-5), 1.09-1.02 (m, 18H, *C*H_3). ^{13}C NMR (100 MHz, $CDCl_3$) δ 143.29, 137.45, 128.74, 128.56, 128.01, 127.91, 124.40, 119.35 (aromatic C/*C*H), 94.73 (C-1), 76.04 (C-3), 70.71 (*C*H_2*Ph*), 69.89 (C-5), 69.16 (C-4), 66.76 (C-6), 57.71 (C-2), 27.59 (*C*H_3), 27.23 (*C*H_3), 23.38 (C-*Si*), 20.73 (C-*Si*). *β* isomer: ^{1}H-NMR ($CDCl_3$, 400 MHz) δ 7.48 – 7.25 (m, 7H, aromatic H), 7.14 – 7.04 (m, 1H, aromatic H), 6.85 (d, *J* = 7.7 Hz, 2H, aromatic H), 5.50 (bs, 1H, H-1), 4.77 (d, *J* = 11.9 Hz, 1H, *C*H_2*Ph*), 4.66 (d, *J* = 11.9 Hz,

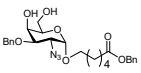
1H, *C*H$_2$*Ph*), 4.43 (s, 1H, H-5), 4.19 (s, 2H, H-6), 4.02 (s, 1H, H-4), 3.30 (s, 2H, H-2, 3), 1.15 – 1.00 (m, 18H, *C*H$_3$). ^{13}C NMR (100 MHz, CDCl$_3$) δ 143.45, 137.54, 128.83, 128.71, 128.17, 127.97, 124.48, 119.42 (aromatic C/*CH*), 95.82 (C-1), 79.55 (C-3), 72.18 (C-2), 70.99 (C*H$_2$Ph*), 68.57 (C-5), 66.84 (C-6), 60.79 (C-4), 27.72 (C*H$_3$*), 27.42 (C*H$_3$*), 23.55 (C-*Si*), 20.89 (C-*Si*). HR-MS: Calculated for $C_{29}H_{37}F_3N_4O_5Si$ [M+Na]$^+$: 629.2383, found: 629.2376.

6-(Benzyl hexanoyl) 2-azido-3-*O*-benzyl-2-deoxy-4,6-di-*tert*-butylsilylidene-α-D-galactopyranoside (30)



The reaction was carried out according to the general procedure B. The donor **2b** (1.5 g, 2.47 mmol) and acceptor **4** (1.1 g, 4.95 mmol) were co-evaporated with toluene (three times). The residue was dissolved in dry 25 ml DCM under nitrogen and stirred over fresh flame-dried molecular sieves 4Å. The solution was cooled to 0 ºC, after which TfOH (22 µl, 0.25 mmol) was added. The reaction was stirred at 0 ºC for 1 h. Then the reaction was quenched with Et$_3$N, diluted with DCM, washed with saturated NaHCO$_3$ and brine. The organic phase was dried with anhydrous MgSO$_4$, filtered and concentrated *in vacuo*. The product was purified by silica gel column chromatography (pentane:Et$_2$O = 20:1 - 6:1). Compound **30** (1.31 g, 83% yield, pentane: Et$_2$O = 10:1, R*f* = 0.25-0.35) was obtained as yellow syrup. $[\alpha]_D^{25}$ +68.6 (c=1, CHCl$_3$). IR (neat, cm^{-1}) ν 442, 651, 797, 826, 962, 980, 1006, 1043, 1067, 1080, 1100, 1141, 1171, 1455, 1474, 1736, 2109, 2859, 2933. ^{1}H-NMR (CDCl$_3$, 400 MHz) δ 7.47 – 7.27 (m, 10H, aromatic H), 5.13 (s, 2H, *C*H$_2$*Ph*), 4.93 (d, *J* = 3.5 Hz, 1H, H-1), 4.77 (d, *J* = 11.5 Hz, 1H, *C*H$_2$*Ph*), 4.67 (d, *J* = 11.5 Hz, 1H, *C*H$_2$*Ph*), 4.61 (dd, *J* = 2.9, 1.1 Hz, 1H, H-4), 4.27 (dd, *J* = 12.5, 2.1 Hz, 1H, H-6), 4.16 (dd, *J* = 12.5, 1.7 Hz, 1H, H-6), 3.89 (dd, *J* = 10.6, 2.9 Hz, 1H, H-3), 3.79 (dd, *J* = 10.6, 3.5 Hz, 1H, H-2), 3.71 – 3.61 (m, 2H, H-5, 7), 3.47 (dt, *J* = 9.8, 6.4 Hz, 1H, H-7), 2.38 (t, *J* = 7.5 Hz, 2H, H-11), 1.77 – 1.57 (m, 4H, H-10, 8), 1.47 – 1.34 (m, 2H, H-9), 1.14 – 1.01 (m, 18H, *C*H$_3$). ^{13}C NMR (100 MHz, CDCl$_3$) δ 173.46 (C-12), 137.94, 136.12, 128.63, 128.58, 128.28, 128.25, 127.99, 127.92 (aromatic C/*CH*), 98.43 (C-1), 75.50 (C-3), 70.48 (C*H$_2$Ph*), 69.87 (C-4), 68.17 (C-6), 67.47 (C-5), 67.28 (C-7), 66.20 (C*H$_2$Ph*), 58.33 (C-2), 34.21 (C-11), 29.12 (C-8), 27.74 (3xCH$_3$), 27.41 (3xCH$_3$), 25.72 (C-9), 24.70 (C-10), 23.51 (C-*Si*), 20.80 (C-*Si*). HR-MS: Calculated for $C_{34}H_{49}N_3O_7Si$ [M+Na]$^+$: 662.3237, found: 662.3232.

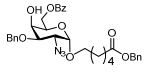
6-(Benzyl hexanoyl) 2-azido-3-*O*-benzyl-2-deoxy-α-D-galactopyranoside (31)



The reaction was carried out according to the general procedure C using compound **30** (1.14 g, 1.78 mmol) and HF/pyridine (70%, 740 µl, 28.5 mmol). The product was purified by column chromatography (pentane:EtOAc = 1:1). Compound **31** (831 mg, 94% yield, pentane:EtOAc = 1:2, R*f* = 0.35-0.45) was obtained as yellow syrup. $[\alpha]_D^{25}$ +73.8 (c=1, CHCl$_3$). IR (neat, cm^{-1}) ν 966, 736, 966, 1027, 1143, 1213, 1232, 1731, 2106, 2858, 2925, 3460. ^{1}H-NMR (CDCl$_3$, 400 MHz) δ 7.43 – 7.27 (m, 10H, aromatic H), 5.11 (s, 2H, *C*H$_2$*Ph*), 4.88 (d, *J* = 1.2 Hz, 1H, H-1), 4.78 (d, *J* = 11.7 Hz, 1H, *C*H$_2$*Ph*), 4.61 (d, *J* = 11.7 Hz, 1H, *C*H$_2$*Ph*), 4.07 (s, 1H, H-5), 3.92 (dd, *J* = 11.6, 6.6 Hz, 1H, H-6), 3.86 – 3.77 (m, 3H, H-2, 3, 6), 3.75 – 3.68 (m, 1H, H-4), 3.68 – 3.62 (m, 1H, H-7), 3.39 (dt, *J* = 9.7, 6.3 Hz, 1H, H-7), 3.05 (bs, 1H, *O*H), 2.36 (t, *J* = 7.4 Hz, 2H, H-11), 1.72 – 1.60 (m, 2H, H-10), 1.60 – 1.50 (m, 2H, H-8), 1.41 – 1.29 (m, 2H, H-9). ^{13}C NMR (100 MHz, CDCl$_3$) δ 173.55 (C-12), 137.44, 136.04, 128.64, 128.60, 128.32, 128.25, 128.02, 127.64 (aromatic C/*CH*), 98.56 (C-1), 72.96

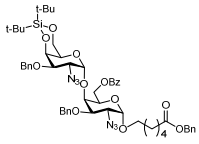
(C-3), 70.68 (C-4), 70.21 (CH_2Ph), 67.72 (C-7), 67.31 (C-5), 66.27 (CH_2Ph), 62.72 (C-6), 60.72 (C-2), 34.18 (C-11), 28.99 (C-8), 25.73 (C-9), 24.63 (C-10). HR-MS: Calculated for $C_{26}H_{33}N_3O_7$ $[M+H]^+$: 500.2397, found: 500.2391.

6-(Benzyl hexanoyl) 2-azido-6-O-benzoyl-3-*O*-benzyl-2-deoxy-α-D-galactopyranoside (32)



The reaction was carried out according to the general procedure D using compound **31** (831 mg, 1.66 mmol), PhCOOBt (1.79 g, 7.49 mmol) and Et_3N (1.2 ml, 8.3 mmol). The product was purified by column chromatography (pentane:EtOAc = 4:1). Compound **32** (931 mg, 93% yield, pentane:EtOAc = 3:1, R*f* = 0.35-0.45) was obtained as yellow syrup. $[\alpha]_D^{25}$ +42.9 (c=1, $CHCl_3$). IR (neat, cm^{-1}) ν 989, 1027, 1042, 1096, 1115, 1151, 1269, 1315, 1452, 1717, 2106, 2870, 2933, 3484. ^{1}H-NMR ($CDCl_3$, 400 MHz) δ 8.15 – 8.08 (m, 2H, *aromatic* H), 7.64 – 7.55 (m, 1H, *aromatic* H), 7.53 – 7.27 (m, 11H, *aromatic* H), 7.25 – 7.18 (m, 1H, *aromatic* H), 5.15 (s, 2H, CH_2Ph), 4.98 (d, *J* = 3.6 Hz, 1H, H-1), 4.76 (s, 2H, CH_2Ph), 4.71 – 4.58 (m, 2H, H-6), 4.23 – 4.14 (m, 2H, H-4, 5), 4.01 (dd, *J* = 10.5, 3.0 Hz, 1H, H-3), 3.79 (dd, *J* = 10.4, 3.6 Hz, 1H, H-2), 3.72 (dt, *J* = 9.8, 6.7 Hz, 1H, H-7), 3.49 (dt, *J* = 9.8, 6.5 Hz, 1H, H-7), 3.13 (bs, 1H, *O*H), 2.36 (t, *J* = 7.5 Hz, 2H, H-11), 1.74 – 1.59 (m, 4H, H-10, 8), 1.46 – 1.32 (m, 2H, H-9). ^{13}C NMR (100 MHz, $CDCl_3$) δ 173.15 (C-12), 166.09 (C=O, Bz), 137.09, 135.87, 133.08, 132.98, 129.85, 129.66, 129.42, 128.83, 128.41, 128.41, 128.33, 128.23, 128.17, 128.03, 127.97, 127.94, 127.89, 127.78, 125.11 (aromatic C/C*H*), 97.69 (C-1), 75.82 (C-3), 71.69 (CH_2Ph), 67.95 (C-5), 67.83 (C-7), 66.15 (C-4), 65.86 (CH_2Ph), 63.99 (C-6), 58.76 (C-2), 33.86 (C-11), 28.76 (C-8), 25.42 (C-9), 24.33 (C-10). HR-MS: Calculated for $C_{33}H_{37}N_3O_8$ $[M+H]^+$: 604.2659, found: 604.2653.

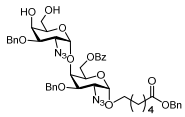
6-(Benzyl hexanoyl) 2-azido-3-*O*-benzyl-2-deoxy-4,6-di-*tert*-butylsilylidene-α-D-galactopyranosyl-(1→4)-2-azido-6-*O*-benzoyl-3-*O*-benzyl-2-deoxy-α-D-galactopyranoside (33)



The reaction was carried out according to the general procedure B. The donor **2b** (3.24 g, 5.34 mmol) and the acceptor **32** (2.15 g, 3.56 mmol) were co-evaporated with toluene (three times). The residue was dissolved in 50 ml dry DCM under nitrogen and stirred over fresh flame-dried molecular sieves 4Å. The solution was cooled to 0 ºC, after which TfOH (60 µl, 0.67 mmol) was added. The reaction was stirred at 0 ºC for 1 h. Then the reaction was quenched with Et_3N, diluted with DCM, washed with saturated $NaHCO_3$ and brine. The organic phase was dried with anhydrous $MgSO_4$, filtered and concentrated *in vacuo*. The product was purified by silica gel column chromatography (pentane:EtOAc = 10:1 – 6:1). Compound **33** (3.29 g, 91% yield, pentane: EtOAc = 6:1, R*f* = 0.25-0.35) was obtained as yellow syrup. $[\alpha]_D^{25}$ +111.5 (c=1, $CHCl_3$). IR (neat, cm^{-1}) ν 738, 796, 826, 1010, 1027, 1045, 1139, 1270, 1454, 1472, 1727, 2109, 2859, 2933. ^{1}H-NMR ($CDCl_3$, 400 MHz) δ 8.08 – 8.00 (m, 2H, aromatic H), 7.60 – 7.53 (m, 1H, aromatic H), 7.48 – 7.40 (m, 4H, aromatic H), 7.39 – 7.24 (m, 13H, aromatic H), 5.11 (d, *J* = 2.9 Hz, 1H, H-1^B), 5.07 (s, 2H, CH_2Ph), 5.00 (d, *J* = 3.5 Hz, 1H, H-1^A), 4.80 – 4.62 (m, 5H, CH_2Ph, H-6^A), 4.56 (dd, *J* = 11.1, 6.3 Hz, 1H, H-6^A), 4.51 – 4.47 (m, 1H, H-5^B), 4.30 (d, *J* = 2.8 Hz, 1H, H-4^A), 4.16 – 4.08 (m, 1H, H-3^B), 4.07 – 4.03 (m, 1H, H-5^A), 3.96 – 3.85 (m, 3H, H-3^A, 2^B, 4^B), 3.76 (dd, *J* = 12.9, 1.5 Hz, 1H, H-6^B), 3.72 – 3.58 (m, 3H, H-2^A, 6^B, 7), 3.46 (dt,

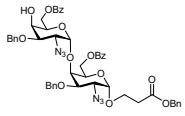
J = 9.8, 6.4 Hz, 1H, H-7), 2.31 (t, *J* = 7.5 Hz, 2H, H-11), 1.67 – 1.54 (m, 4H, H-10, 8), 1.39 – 1.26 (m, 2H, H-9), 1.06 – 0.95 (m, 18H, *C*H$_3$). ^{13}C NMR (100 MHz, CDCl$_3$) δ 173.36 (C-12), 165.98 (C=O, Bz), 137.73, 137.14, 136.08, 133.40, 129.70, 129.60, 128.59, 128.57, 128.56, 128.53, 128.21, 128.17, 127.98, 127.96, 127.92, 127.20 (aromatic C/C*H*), 98.96 (C-1^B), 97.93 (C-1^A), 75.72 (C-3^A), 75.30 (C-4^B), 72.40 (C-4^A), 72.16 (C*H$_2$Ph*), 70.37 (C*H$_2$Ph*), 69.50 (C-5^B), 68.63 (C-3^B), 68.16 (C-7), 67.76 (C-5^A), 66.92 (C-6^B), 66.11 (C*H$_2$Ph*), 62.65 (C-6^A), 59.70 (C-2^A), 58.60 (C-2^B), 34.11 (C-11), 28.99 (C-8), 27.62 (C*H$_3$*), 27.34 (C*H$_3$*), 25.66 (C-9), 24.57 (C-10), 23.35 (C-*Si*), 20.73 (C-*Si*). HR-MS: Calculated for $C_{54}H_{68}N_6O_{12}Si$ [M+H]$^+$: 1021.4743, found: 1021.4737.

6-(Benzyl hexanoyl) 2-azido-3-*O*-benzyl-2-deoxy-α-D-galactopyranosyl-(1→4)-2-azido-6-*O*-benzoyl-3-*O*-benzyl-2-deoxy-α-D-galactopyranoside (34)



The reaction was carried out according to the general procedure C using compound **33** (3.29 g, 3.22 mmol) and HF/pyridine (70%, 1.2 ml, 51.5 mmol). The product was purified by column chromatography (pentane:EtOAc = 2:1 - 1:1). Compound **34** (2.62 g, 92% yield, pentane:EtOAc = 1:1, R*f* = 0.25-0.35) was obtained as yellow syrup. $[\alpha]_D^{25}$ +85.4 (c=1, CHCl$_3$). IR (neat, cm^{-1}) ν 1271, 1725, 2107, 2858, 2935, 3460. ^{1}H-NMR (CDCl$_3$, 400 MHz) δ 8.06 – 7.98 (m, 2H, *C*H, Bz), 7.61 – 7.52 (m, 1H, aromatic H), 7.48 – 7.24 (m, 17H, aromatic H), 5.06 (s, 2H, *C*H$_2$*Ph*), 5.04 (d, *J* = 3.5 Hz, 1H, H-1^B), 4.98 (d, *J* = 3.6 Hz, 1H, H-1^A), 4.80 (d, *J* = 11.7 Hz, 1H, *C*H$_2$*Ph*), 4.73 – 4.57 (m, 5H, *C*H$_2$*Ph*, H-6^A), 4.22 (d, *J* = 2.7 Hz, 1H, H-4^A), 4.15 – 4.05 (m, 3H, H-5^A, 4^B, 5^B), 3.97 – 3.88 (m, 2H, H-3^A, 3^B), 3.84 (dd, *J* = 10.5, 3.4 Hz, 1H, H-2^B), 3.72 – 3.60 (m, 2H, H-2^A, 7), 3.55 – 3.38 (m, 3H, H-6^B, 7), 3.07 (bs, 1H, *O*H), 2.30 (t, *J* = 7.5 Hz, 2H, H-11), 1.67 – 1.51 (m, 4H, H-10, 8), 1.37 – 1.27 (m, 2H, H-9). ^{13}C NMR (100 MHz, CDCl$_3$) δ 173.20 (C-12), 165.83 (C=O, Bz), 137.04, 136.86, 135.84, 133.19, 129.46, 129.37, 128.45, 128.44, 128.36, 128.04, 128.00, 127.95, 127.94, 127.84, 127.37 (aromatic C/C*H*), 99.08 (H-1^B), 97.75 (H-1^A), 76.01 (H-3^B), 75.45 (H-3^A), 73.76 (H-4^A), 72.15 (C*H$_2$Ph*), 71.55 (C*H$_2$Ph*), 69.41 (H-5^B), 68.51 (H-5^A), 67.97 (H-7), 67.23 (H-4^B), 65.91 (C*H$_2$Ph*), 62.52 (H-6^A), 62.46 (H-6^B), 59.56 (C-2), 59.55 (C-2), 33.89 (H-11), 28.75 (C-8), 25.42 (C-9), 24.34 (C-10). HR-MS: Calculated for $C_{46}H_{52}N_6O_{12}$ [M+H]$^+$: 881.3721, found: 881.3716.

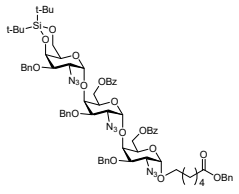
6-(Benzyl hexanoyl) 2-azido-6-*O*-benzoyl-3-*O*-benzyl-2-deoxy-α-D-galactopyranosyl-(1→4)-2-azido-6-*O*-benzoyl-3-*O*-benzyl-2-deoxy-α-D-galactopyranoside (35)



The reaction was carried out according to the general procedure D using compound **34** (2.61 g, 2.97 mmol), PhCOOBt (2.84 g, 11.87 mmol) and Et$_3$N (1.9 ml, 13.37 mmol). The product was purified by column chromatography (pentane:EtOAc = 5:1 - 4:1). Compound **35** (2.88 g, 92% yield, pentane:EtOAc = 3:1, R*f* = 0.40-0.50) was obtained as yellow syrup. $[\alpha]_D^{25}$ +85.6 (c=1, CHCl$_3$). IR (neat, cm^{-1}) ν 1002, 1027, 1047, 1113, 1156, 1272, 1316, 1452, 1720, 2108, 2870, 2928, 3496. ^{1}H-NMR (CDCl$_3$, 400 MHz) δ 8.08 – 8.00 (m, 2H, *C*H, Bz), 7.94 – 7.85 (m, 2H, *C*H, Bz), 7.60 – 7.48 (m, 2H, aromatic H), 7.46 – 7.24 (m, 16H, aromatic H), 7.22 – 7.15 (m, 2H, aromatic H), 7.11 – 7.04 (m, 1H, aromatic H), 5.09 (d, *J* = 3.6 Hz, 1H, H-1^B), 5.07 (s, 2H, *C*H$_2$*Ph*), 5.00 (d, *J* = 3.6 Hz, 1H, H-1^A), 4.81 (d, *J* = 11.9 Hz, 1H, *C*H$_2$*Ph*), 4.76 – 4.63 (m,

4H, *CH*$_2$*Ph*, H-6^A), 4.60 (dd, *J* = 11.2, 6.5 Hz, 1H, H-6^A), 4.53 – 4.41 (m, 2H, H-5^B, 6^B), 4.27 (d, *J* = 2.8 Hz, 1H, H-4^A), 4.13 (t, *J* = 6.7 Hz, 1H, H-5^A), 4.10 – 3.99 (m, 4H, H-5^A, 3^B, 4^B, 6^B), 3.93 (dd, *J* = 10.8, 2.8 Hz, 1H, H-3^A), 3.87 (dd, *J* = 10.4, 3.5 Hz, 1H, H-2^B), 3.74 – 3.62 (m, 2H, H-2^A, 7), 3.45 (dt, *J* = 9.8, 6.4 Hz, 1H, H-7), 2.72 (bs, 1H, *O*H), 2.30 (t, *J* = 7.5 Hz, 2H, H-11), 1.67 – 1.52 (m, 4H, H-10, 8), 1.37 – 1.25 (m, 2H, H-9). ^{13}C NMR (100 MHz, $CDCl_3$) δ 173.31 (C-12), 165.91 (C=O, Bz), 137.13, 136.99, 136.00, 133.33, 133.01, 129.70, 129.65, 129.59, 129.51, 128.58, 128.50, 128.42, 128.24, 128.16, 128.14, 128.10, 127.99, 127.83, 127.32 (aromatic C/*CH*), 98.93 (C-1B), 97.97 (C-1^A), 76.06 (C-3^B), 75.30 (C-3^A), 73.45 (C-4^A), 72.28 (*CH*$_2$*Ph*), 71.96 (*CH*$_2$*Ph*), 68.56 (C-5^A), 68.12 (C-7), 68.07 (C-5^B), 66.04 (*CH*$_2$*Ph*), 65.41 (C-4^B), 62.55 (C-6^A), 62.33 (C-6^B), 59.52 (C-2^A), 59.48 (C-2^B), 34.03 (C-11), 28.90 (C-8), 25.56 (C-9), 24.48 (C-10). HR-MS: Calculated for $C_{53}H_{56}N_6O_{13}$ $[M+H]^+$: 985.3984, found: 985.3978.

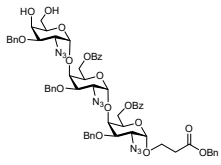
6-(Benzyl hexanoyl) 2-azido-3-*O*-benzyl-2-deoxy-4,6-di-*tert*-butylsilylidene-α-D-galactopyranosyl-(1→4)-2-azido-6-*O*-benzoyl-3-*O*-benzyl-2-deoxy-α-D-galactopyranosyl-(1→4)-2-azido-6-*O*-benzoyl-3-*O*-benzyl-2-deoxy-α-D-galactopyranoside (36)



The reaction was carried out according to the general procedure B. The donor **2b** (3.54 g, 5.85 mmol) and the acceptor **35** (2.88 g, 2.92 mmol) were co-evaporated with toluene (three times). The residue was dissolved in 29 ml dry DCM under nitrogen and stirred over fresh flame-dried molecular sieves 4Å. The solution was cooled to 0 ºC, after which TfOH (26 µl, 0.29 mmol) was added. The reaction was stirred at 0 ºC for 1 h. Then the reaction was quenched with Et_3N, diluted with DCM, washed with saturated $NaHCO_3$ and brine. The organic phase was dried with anhydrous $MgSO_4$, filtered and concentrated *in vacuo*. The product was purified by silica gel column chromatography (pentane:EtOAc = 8:1 – 5:1). Compound **36** (3.42 g, 84% yield, pentane: EtOAc = 4:1, R*f* = 0.40-0.50) was obtained as yellow syrup. $[\alpha]_D^{25}$ +142.8 (c=1, $CHCl_3$). IR (neat, cm^{-1}) ν 651, 737, 796, 826, 979, 1006, 1027, 1045, 1063, 1098, 1268, 1315, 1454, 1724, 2108, 2859, 2932. ^{1}H-NMR ($CDCl_3$, 400 MHz) δ 8.06 – 8.00 (m, 2H, *CH*, Bz), 7.95 – 7.88 (m, 2H, *CH*, Bz), 7.62 – 7.53 (m, 2H, aromatic H), 7.50 – 7.26 (m, 22H, aromatic H), 7.22 – 7.17 (m, 1H, aromatic H), 7.13 – 7.05 (m, 1H, aromatic H), 5.17 (d, *J* = 3.5 Hz, 1H, H-1^C), 5.08 (s, 2H, *CH*$_2$*Ph*), 5.05 (d, *J* = 3.5 Hz, 1H, H-1^B), 4.96 (d, *J* = 3.6 Hz, 1H, H-1^A), 4.88 – 4.61 (m, 7H, *CH*$_2$*Ph*, H-6^A), 4.59 – 4.45 (m, 3H, H-6^A, 6^B, 4^B), 4.43 – 4.37 (m, 2H, H-3^C, 4^B), 4.28 (dd, *J* = 9.6, 2.7 Hz, 2H, H-4^A, 4^C), 4.10 (t, 1H, H-5^A), 4.03 – 3.96 (m, 2H, H-5^B, 5^C), 3.94 – 3.84 (m, 2H, H-3^A, 3^B), 3.83 – 3.77 (m, 2H, H-2^B, 2^C), 3.72 (dd, *J* = 12.8, 1.6 Hz, 1H, H-6^C), 3.68 – 3.61 (m, 2H, H-2^A, 7), 3.58 (dd, *J* = 12.7, 2.1 Hz, 1H, H-6^C), 3.44 (dt, *J* = 9.8, 6.4 Hz, 1H, H-7), 2.30 (t, *J* = 7.5 Hz, 2H, H-11), 1.66 – 1.52 (m, 4H, H-10, 8), 1.36 – 1.25 (m, 2H, H-9), 1.00 – 0.91 (m, 18H, *CH*$_3$). ^{13}C NMR (100 MHz, $CDCl_3$) δ 173.40 (C-12), 166.01 (C=O, Bz), 165.40 (C=O, Bz), 137.78, 137.12, 137.04, 136.10, 133.47, 133.28, 129.71, 129.70, 129.59, 129.58, 128.61, 128.57, 128.55, 128.50, 128.26, 128.22, 127.98, 127.93, 127.51, 127.21 (aromatic C/*CH*), 98.92 (C-1^B), 98.77 (C-1^C), 98.00 (C-1^A), 75.58 (C-3^C), 75.34 (C-3^B), 74.97 (C-3^A), 73.35 (C-4^A), 72.39 (*CH*$_2$*Ph*), 72.09 (*CH*$_2$*Ph*), 71.68 (C-4^C), 70.36 (*CH*$_2$*Ph*), 69.56 (C-4^B), 68.82 (C-5^C), 68.62 (C-5^A), 68.21 (C-7), 67.75 (C-5^B), 66.90 (C-6^C), 66.16 (*CH*$_2$*Ph*), 62.63 (C-6^A), 61.28 (C-6^B), 60.38 (C-2^C), 59.73 (C-2^A), 58.64 (C-2^B), 34.15 (C-11), 29.00 (C-8), 27.63 (CH_3), 27.30 (CH_3),

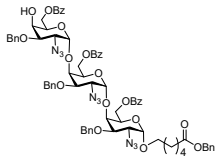
25.68 (C-9), 24.60 (C-10), 23.36 (C-*Si*), 20.71 (C-*Si*). HR-MS: Calculated for $C_{74}H_{87}N_9O_{17}Si$ $[M+H]^+$: 1402.6067, found: 1402.6062.

6-(Benzyl hexanoyl) 2-azido-3-*O*-benzyl-2-deoxy-α-D-galactopyranosyl-(1→4)-2-azido-6-*O*-benzoyl-3-*O*-benzyl-2-deoxy-α-D-galactopyranosyl-(1→4)-2-azido-6-*O*-benzoyl-3-*O*-benzyl-2-deoxy-α-D-galactopyranoside (37)



The reaction was carried out according to the general procedure C using compound **36** (3.42 g, 2.44 mmol) and HF/pyridine (70%, 1.0 ml, 39 mmol). The product was purified by column chromatography (pentane:EtOAc = 2:1 - 3:2). Compound **37** (2.90 g, 92% yield, pentane:EtOAc = 1:1, R*f* = 0.30-0.40) was obtained as yellow syrup. $[\alpha]_D^{25}$ +117.8 (c=1, $CHCl_3$). IR (neat, cm^{-1}) ν 737, 1009, 1027, 1045, 1110, 1055, 1110, 1155, 1269, 1315, 1452, 1720, 2106, 2873, 2928, 3470. ^{1}H-NMR ($CDCl_3$, 500 MHz) δ 8.07 – 8.00 (m, 2H, *C*H, Bz), 7.92 – 7.86 (m, 2H, *C*H, Bz), 7.62 – 7.55 (m, 2H), 7.48 – 7.27 (m, 21H), 7.18 (t, *J* = 7.7 Hz, 2H), 7.05 – 6.98 (m, 1H, aromatic H), 5.15 (d, *J* = 3.5 Hz, 1H, H-1^B), 5.07 (s, 2H, *C*H$_2$*Ph*), 4.98 (d, *J* = 3.6 Hz, 1H, H-1^A), 4.93 (d, *J* = 3.6 Hz, 1H, H-1^C), 4.84 (dd, *J* = 18.0, 11.7 Hz, 2H, *C*H$_2$*Ph*), 4.76 – 4.62 (m, 5H, *C*H$_2$*Ph*, H-6^A), 4.61 – 4.50 (m, 2H, H-6^A, 6^B), 4.47 (dd, *J* = 9.6, 5.2 Hz, 1H, H-5^B), 4.28 (d, *J* = 2.8 Hz, 1H, H-4^A), 4.18 (d, *J* = 2.5 Hz, 1H, H-4^B), 4.16 – 4.08 (m, 3H, H-5^A, 6^B, 4^C), 4.06 – 3.99 (m, 2H, H-3^B, 5^C), 3.92 (dd, *J* = 10.8, 2.7 Hz, 1H, H-3^A), 3.87 (dd, *J* = 10.4, 3.0 Hz, 1H, H-3^C), 3.79 (dd, *J* = 10.9, 3.5 Hz, 1H, H-2^B), 3.75 (dd, *J* = 10.4, 3.5 Hz, 1H, H-2^C), 3.70 – 3.62 (m, 2H, H-2^A, 7), 3.50 – 3.38 (m, 3H, H-6^C, 7), 2.83 (bs, 1H, *O*H), 2.30 (t, *J* = 7.5 Hz, 2H, H-11), 2.14 (bs, 1H, *O*H), 1.65 – 1.53 (m, 4H, H-10, 8), 1.36 – 1.27 (m, 2H, H-9). ^{13}C NMR (125 MHz, $CDCl_3$) δ 173.39 (C-12), 165.98 (C=O, Bz), 165.40 (C=O, Bz), 137.09, 137.05, 137.01, 136.05, 133.45, 133.24, 129.68, 129.65, 129.56, 129.54, 128.66, 128.59, 128.57, 128.52, 128.47, 128.25, 128.22, 128.19, 128.17, 128.02, 127.92, 127.60, 127.27 (aromatic C/C*H*), 99.46 (C-1^C), 98.80 (C-1^B), 97.98 (C-1^A), 76.32 (C-3^C), 75.52 (C-3^B), 75.26 (C-3^A), 73.61 (C-4^B), 73.30 (C-4^A), 72.49, 72.35, 71.85 (3 C*H*$_2$*Ph*), 69.61 (C-5^C), 68.89 (C-5^B), 68.60 (C-5^A), 68.20 (C-7), 67.51 (C-4C), 66.12 (C*H*$_2$*Ph*), 62.65 (C-6^C), 62.58 (C-6^A), 61.30 (C-6^B), 60.17 (C-2^B), 59.75 (C-2^A), 59.63 (C-2^C), 34.11 (C-11), 28.97 (C-8), 25.64 (C-9), 24.56 (C-10). HR-MS: Calculated for $C_{66}H_{71}N_9O_{17}$ $[M+H]^+$: 1262.5046, found: 1262.5041.

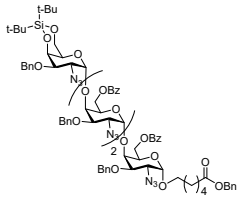
6-(Benzyl hexanoyl) 2-azido-6-*O*-benzoyl-3-*O*-benzyl-2-deoxy-α-D-galactopyranosyl-(1→4)-2-azido-6-*O*-benzoyl-3-*O*-benzyl-2-deoxy-α-D-galactopyranosyl-(1→4)-2-azido-6-*O*-benzoyl-3-*O*-benzyl-2-deoxy-α-D-galactopyranoside (38)



The reaction was carried out according to the general procedure D using compound **37** (2.92 g, 2.31 mmol), PhCOOBt (2.49 g, 10.4 mmol) and Et_3N (1.6 ml, 11.6 mmol). The product was purified by column chromatography (pentane:EtOAc = 4:1). Compound **38** (3.24 g, 94% yield, pentane:EtOAc = 3:1, R*f* = 0.35-0.45) was obtained as yellow syrup. $[\alpha]_D^{25}$ +113.0 (c=1, $CHCl_3$). IR (neat, cm^{-1}) ν 737, 1005, 1027, 1046, 1098, 1112, 1156, 1268, 1315, 1452, 1717, 2106, 2872, 2929, 2490. ^{1}H-NMR ($CDCl_3$, 400 MHz) δ 8.07 – 8.00 (m, 2H, *C*H, Bz), 7.94

– 7.85 (m, 4H, *C*H, Bz), 7.61 – 6.98 (m, 29H, aromatic H), 5.16 (d, *J* = 3.5 Hz, 1H, H-1), 5.07 (s, 2H, *C*H$_2$*Ph*), 5.02 – 4.94 (m, 2H, H-1^A, 1^C), 4.91 – 4.78 (m, 2H, *C*H$_2$*Ph*), 4.78 – 4.63 (m, 5H, *C*H$_2$*Ph*, H-6^A), 4.58 (dd, *J* = 11.1, 6.5 Hz, 1H, H-6^A), 4.54 – 4.45 (m, 2H, H-5^B, 6^B), 4.44 – 4.36 (m, 2H, H-5^A, 6^C), 4.29 (d, *J* = 2.7 Hz, 1H, H-4^A), 4.24-4.19 (m, 2H, H-4^B, 6^B), 4.12 (t, *J* = 6.7 Hz, 1H, H-5^C), 4.06 – 3.89 (m, 5H, H-3^A, 3^C, 3^B, 3^C, 6^C), 3.85 (dd, *J* = 10.8, 3.5 Hz, 1H, H-2^B), 3.77 (dd, *J* = 10.4, 3.5 Hz, 1H, H-2^C), 3.71 – 3.60 (m, 2H, H-2^A, 7), 3.45 (dt, *J* = 9.7, 6.4 Hz, 1H, H-7), 2.57 (bs, 1H, *O*H), 2.30 (t, *J* = 7.5 Hz, 2H, H-11), 1.67 – 1.51 (m, 4H, H-10, 8), 1.37 – 1.25 (m, 2H, H-9). ^{13}C NMR (100 MHz, $CDCl_3$) δ 173.35 (C-12), 165.95 (2xC=O), 165.32 (C=O), 137.15, 136.98, 136.86, 136.03, 133.43, 133.22, 133.07, 129.75, 129.68, 129.65, 129.60, 129.51, 128.61, 128.56, 128.54, 128.49, 128.44, 128.37, 128.30, 128.19, 128.14, 128.00, 127.93, 127.89, 127.45, 127.25 (aromatic C/C*H*), 99.03 (C-1^C), 98.78 (C-1^B), 97.94 (C-1^A), 76.18 (C-3^C), 75.22 (C-3^B), 75.17 (C-3^A), 73.18 (C-4^B), 73.08 (C-4^A), 72.40, 72.34, 72.04 (3 C*H*$_2$*Ph*), 68.83 (C-5^B), 68.59 (C-5^C), 68.16 (C-7), 68.08 (C-5^A), 66.09 (C*H*$_2$*Ph*), 65.45 (C-4^C), 62.58 (C-6^A), 62.32 (C-6^C), 61.21 (C-6^B), 60.16 (C-2^B), 59.71 (C-2^A), 59.57 (C-2^C), 34.08 (C-11), 28.94 (C-8), 25.61 (C-9), 24.52 (C-10). HR-MS: Calculated for $C_{73}H_{75}N_9O_{18}$ $[M+H]^+$: 1366.5308, found: 1366.5303.

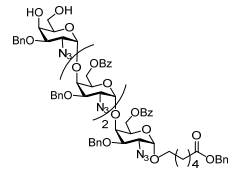
6-(Benzyl hexanoyl) 2-azido-3-*O*-benzyl-2-deoxy-4,6-di-*tert*-butylsilylidene-α-D-galactopyranosyl-(1→4)-2-azido-6-*O*-benzoyl-3-*O*-benzyl-2-deoxy-α-D-galactopyranosyl-(1→4)-2-azido-6-*O*-benzoyl-3-*O*-benzyl-2-deoxy-α-D-galactopyranosyl-(1→4)-2-azido-6-*O*-benzoyl-3-*O*-benzyl-2-deoxy-α-D-galactopyranoside (39)



The reaction was carried out according to the general procedure B. The donor **2b** (2.66 g, 4.39 mmol) and the acceptor **38** (3.0 g, 2.2 mmol) were co-evaporated with toluene (three times). The residue was dissolved in 22 ml dry DCM under nitrogen and stirred over fresh flame-dried molecular sieves 4Å. The solution was cooled to 0 ºC, after which TfOH (19 µl, 0.22 mmol) was added. The reaction was stirred at 0 ºC for 1 h. Then the reaction was quenched with Et_3N, diluted with DCM, washed with saturated $NaHCO_3$ and brine. The organic phase was dried with anhydrous $MgSO_4$, filtered and concentrated *in vacuo*. The product was purified by silica gel column chromatography (pentane:EtOAc = 5:1). Compound **39** (3.68 g, 92% yield, pentane: EtOAc = 4:1, R*f* = 0.35-0.45) was obtained as yellow syrup. $[\alpha]_D^{25}$ +188.6 (c=1, $CHCl_3$). IR (neat, cm^{-1}) ν 444, 475, 651, 736, 826, 1005, 1027, 1045, 1063, 1098, 1266, 1315, 1452, 1721, 2108, 2859, 2932. ^{1}H-NMR ($CDCl_3$, 400 MHz) δ 8.07 – 8.00 (m, 2H, *C*H, Bz), 7.95 – 7.87 (m, 4H, *C*H, Bz), 7.64 – 7.03 (m, 34H, aromatic H), 5.16 – 5.11 (m, 1H, H-1), 5.07 (d, *J* = 6.8 Hz, 3H, *C*H$_2$*Ph*, H-1), 5.02 – 4.94 (m, 2H, 2xH-1), 4.89 (d, *J* = 11.9 Hz, 1H, *C*H$_2$*Ph*), 4.85 – 4.14 (m, 20H), 4.10 (t, *J* = 7.2 Hz, 1H), 4.04 – 3.61 (m, 12H), 3.57 (d, *J* = 12.7 Hz, 1H), 3.50 – 3.41 (m, 1H, H-7), 2.31 (t, *J* = 7.4 Hz, 2H, H-11), 1.59 (h, *J* = 7.3 Hz, 4H, H-10, 8), 1.31 (p, *J* = 8.9, 8.2 Hz, 2H, H-9), 1.00 – 0.91 (m, 18H, *C*H$_3$). ^{13}C NMR (100 MHz, $CDCl_3$) δ 173.36 (C-12), 165.97, 165.42, 165.36 (3 C=O, Bz), 137.76, 137.04, 136.92, 136.07, 133.44, 133.31, 133.23, 129.68, 129.66, 129.62, 129.55, 128.59, 128.55, 128.52, 128.48, 128.23, 128.18, 128.00, 127.93, 127.85, 127.55, 127.24, 127.21 (aromatic C/C*H*), 98.89 (C-1), 98.85 (C-1), 98.76 (C-1), 97.96 (C-1^A), 75.61, 75.46, 75.31, 74.92, 73.20, 72.88, 72.47, 72.34, 72.06 (3 C*H*$_2$*Ph*), 71.85, 70.33 (C*H*$_2$*Ph*), 69.50, 68.82, 68.62, 68.20 (C-7), 67.70, 66.86 (C-6^D), 66.12 (C*H*$_2$*Ph*), 62.61 (C-6^A), 61.30 (C-6^B, 6^C),

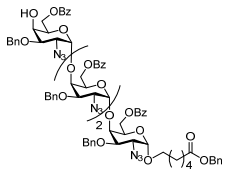
60.41, 60.31, 59.78, 58.67 (4 C-2), 34.12 (C-11), 28.98 (C-8), 27.60 (3xC*H*$_3$), 27.28 (3xC*H*$_3$), 25.65 (C-9), 24.57 (C-10), 23.32 (C-*Si*), 20.67 (C-*Si*). HR-MS: Calculated for $C_{94}H_{106}N_{12}O_{22}Si$ $[M+NH_4]^+$: 1800.7658, found: 1800.7652.

6-(Benzyl hexanoyl) 2-azido-3-*O*-benzyl-2-deoxy-α-D-galactopyranosyl-(1→4)-2-azido-6-*O*-benzoyl-3-*O*-benzyl-2-deoxy-α-D-galactopyranosyl-(1→4)-2-azido-6-*O*-benzoyl-3-*O*-benzyl-2-deoxy-α-D-galactopyranosyl-(1→4)-2-azido-6-*O*-benzoyl-3-*O*-benzyl-2-deoxy-α-D-galactopyranoside (40)



The reaction was carried out according to the general procedure C using compound **39** (3.68 g, 2.06 mmol) and HF/pyridine (70%, 860 µl, 33.0 mmol). The product was purified by column chromatography (pentane:EtOAc = 3:2-1:1). Compound **40** (3.27 g, 91% yield, pentane:EtOAc = 1:1, R*f* = 0.25-0.35) was obtained as yellow syrup. $[\alpha]_D^{25}$ +126.7 (c=1, $CHCl_3$). IR (neat, cm^{-1}) ν 737, 1005, 1027, 1046, 1112, 1155, 1269, 1316, 1452, 1721, 2108, 2872, 2929, 3463. ^{1}H-NMR ($CDCl_3$, 500 MHz) δ 8.06 – 8.00 (m, 2H, *C*H, Bz), 7.94 – 7.86 (m, 4H, *C*H, Bz), 7.64 – 6.98 (m, 34H, aromatic H), 5.14 (d, *J* = 3.6 Hz, 1H, H-1^B), 5.07 (s, 2H, *C*H$_2$*Ph*), 5.03 (d, *J* = 3.6 Hz, 1H, H-1^C), 4.97 (d, *J* = 3.5 Hz, 1H, H-1^A), 4.90 – 4.85 (m, 2H, *C*H$_2$*Ph*, H-1^D), 4.82 (dd, *J* = 11.8, 7.1 Hz, 2H), 4.76 (d, *J* = 11.8 Hz, 1H), 4.74 – 4.60 (m, 5H), 4.60 – 4.44 (m, 4H), 4.41 (dd, *J* = 9.6, 5.4 Hz, 1H), 4.28 (d, *J* = 2.8 Hz, 1H, H-4^A), 4.25 (d, *J* = 2.6 Hz, 1H, H-4^B), 4.18 – 4.09 (m, 3H), 4.08 – 3.89 (m, 6H), 3.85 – 3.78 (m, 2H), 3.75 – 3.63 (m, 4H, 3xH-2, H-7), 3.49 – 3.37 (m, 3H, H-6^D, 7), 2.30 (t, *J* = 7.5 Hz, 2H, H-11), 1.65 – 1.53 (m, 4H, H-10, 8), 1.36 – 1.27 (m, 2H, H-9). ^{13}C NMR (125 MHz, $CDCl_3$) δ 173.35 (C-12), 165.96, 165.37, 165.34 (3 C=O, Bz), 137.08, 137.03, 137.01, 136.83, 136.05, 133.42, 133.29, 133.19, 129.67, 129.65, 129.61, 129.53, 129.51, 128.62, 128.60, 128.56, 128.55, 128.51, 128.48, 128.44, 128.19, 128.14, 127.98, 127.94, 127.88, 127.64, 127.29, 127.20 (aromatic C/C*H*), 99.47 (C-1^D), 98.86 (C-1^C), 98.76 (C-1^B), 97.95 (C-1^A), 76.35, 75.49, 75.34, 75.16, 73.78, 73.25, 72.75, 72.49, 72.41, 72.33, 71.80 (4 C*H*$_2$*Ph*), 69.59, 68.90, 68.80, 68.60, 68.19 (C-7), 67.49 (C-4^D), 66.09 (C*H*$_2$*Ph*), 62.63 (C-6C, 6D), 62.58 (C-6A), 61.28 (C-6B), 60.35, 60.19, 59.76, 59.65 (4 C-2), 34.09 (C-11), 28.95 (C-8), 25.62 (C-9), 24.54 (C-10). HR-MS: Calculated for $C_{86}H_{90}N_{12}O_{22}$ $[M+H]^+$: 1643.6371, found: 1643.6365.

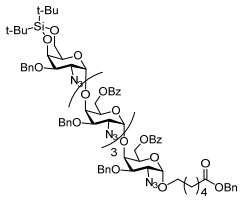
6-(Benzyl hexanoyl) 2-azido-6-*O*-benzoyl-3-*O*-benzyl-2-deoxy-α-D-galactopyranosyl-(1→4)-2-azido-6-*O*-benzoyl-3-*O*-benzyl-2-deoxy-α-D-galactopyranosyl-(1→4)-2-azido-6-*O*-benzoyl-3-*O*-benzyl-2-deoxy-α-D-galactopyranosyl-(1→4)-2-azido-6-*O*-benzoyl-3-*O*-benzyl-2-deoxy-α-D-galactopyranoside (41)



The reaction was carried out according to the general procedure D using compound **40** (3.24 g, 1.97 mmol), PhCOOBt (2.12 g, 8.88 mmol) and Et_3N (1.4 ml, 9.85 mmol). The product was purified by column chromatography (pentane:EtOAc = 4:1 – 3:1). Compound **41** (3.37 g, 92% yield, pentane:EtOAc = 2:1, R*f* = 0.30-0.40) was obtained as yellow syrup. $[\alpha]_D^{25}$ +115.6 (c=1, $CHCl_3$). IR (neat, cm^{-1}) ν 737, 1005, 1027, 1046, 1063, 1098, 1110, 1156, 1268, 1315, 1452, 1720, 2106, 2872, 2929, 3477. ^{1}H-NMR ($CDCl_3$, 400 MHz) δ 8.07 – 8.00 (m, 2H, *C*H, Bz), 7.95 – 7.84 (m, 6H, *C*H, 3xBz), 7.62 – 6.96 (m, 37H, aromatic H), 5.15 (d, *J* = 3.6 Hz, 1H,

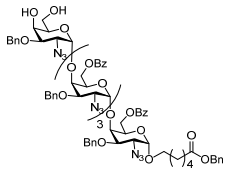
H-1^{B}), 5.06 (s, 2H, *C*H$_2$*Ph*), 5.04 (d, *J* = 3.6 Hz, 1H, H-1^{C}), 4.98 (d, *J* = 3.6 Hz, 1H, H-1^{A}), 4.92 (d, *J* = 3.6 Hz, 1H, H-1^{D}), 4.90 – 4.54 (m, 10H), 4.53 – 4.33 (m, 6H), 4.28-4.25 (m, 2H, H-4^{A}, 4^{B}), 4.20 – 4.05 (m, 4H), 4.04 – 3.87 (m, 6H), 3.84 – 3.73 (m, 3H, 3xH-2), 3.71 – 3.62 (m, 2H, H-2, 7), 3.45 (dt, *J* = 9.8, 6.4 Hz, 1H, H-7), 2.55 (bs, 1H, *O*H), 2.30 (t, *J* = 7.5 Hz, 2H, H-11), 1.68 – 1.52 (m, 4H, H-10, 8), 1.37 – 1.27 (m, 2H, H-9). ^{13}C NMR (100 MHz, $CDCl_3$) δ 173.32 (C-12), 165.93, 165.88, 165.34, 165.25 (4 C=O, Bz), 137.12, 136.98, 136.85, 136.80, 136.01, 133.40, 133.28, 133.18, 133.02, 129.74, 129.65, 129.63, 129.56, 129.53, 129.48, 129.46, 128.55, 128.54, 128.52, 128.49, 128.46, 128.44, 128.42, 128.33, 128.26, 128.17, 128.12, 127.96, 127.90, 127.89, 127.85, 127.47, 127.23, 127.15 (aromatic C/*CH*), 99.11 (C-1^{D}), 98.86 (C-1^{C}), 98.72 (C-1^{B}), 97.91 (C-1^{A}), 76.26, 75.30, 75.16, 75.08, 73.34, 73.19, 72.62, 72.42 (C*H$_2$Ph*), 72.31 (C*H$_2$Ph*), 71.99 (C*H$_2$Ph*), 68.82, 68.75, 68.56, 68.14 (C-7), 68.02, 66.06 (C*H$_2$Ph*), 65.35 (C-4^{D}), 62.56, 62.18, 61.24, 61.18 (4 C-6), 60.32, 60.16, 59.71, 59.58 (4 C-2), 34.05 (C-11), 28.92 (C-8), 25.59 (C-9), 24.50 (C-10). HR-MS: Calculated for $C_{93}H_{94}N_{12}O_{23}$ $[M+H]^+$: 1747.6633, found: 1747.6628.

Pentasaccharide 42



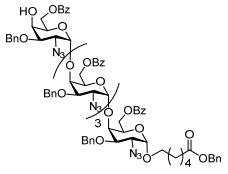
The reaction was carried out according to the general procedure B. The donor **2b** (2.90 g, 4.78 mmol) and the acceptor **41** (3.34 g, 1.91 mmol) were co-evaporated with toluene (three times). The residue was dissolved in 19 ml dry DCM under nitrogen and stirred over fresh flame-dried molecular sieves 4Å. The solution was cooled to 0 °C, after which TfOH (17 µl, 0.19 mmol) was added. The reaction was stirred at 0 °C for 1 h. Then the reaction was quenched with Et_3N, diluted with DCM, washed with saturated $NaHCO_3$ and brine. The organic phase was dried with anhydrous $MgSO_4$, filtered and concentrated *in vacuo*. The product was purified by silica gel column chromatography (pentane:EtOAc = 5:1). Compound **42** (3.72 g, 90% yield, pentane: EtOAc = 4:1, R*f* = 0.35-0.45) was obtained as yellow syrup. $[\alpha]_D^{25}$ +151.3 (c=1, $CHCl_3$). IR (neat, cm^{-1}) ν 1003, 1027, 1045, 1063, 1096, 1156, 1266, 1315, 1452, 1721, 2108, 2859, 2933. ^{1}H-NMR ($CDCl_3$, 400 MHz) δ 8.08 – 8.00 (m, 2H, *C*H, Bz), 7.95 – 7.86 (m, 6H, *C*H, Bz), 7.64 – 6.97 (m, 42H, aromatic H), 5.13 (d, *J* = 3.5 Hz, 1H, H-1^{B}), 5.07 (s, 2H, *C*H$_2$*Ph*), 5.04 – 4.95 (m, 4H, 4xH-1), 4.91 – 4.54 (m, 13H), 4.51 – 4.33 (m, 8H), 4.31 – 3.84 (m, 14H), 3.82 – 3.74 (m, 3H), 3.74 – 3.60 (m, 5H), 3.54 (dd, *J* = 12.8, 2.1 Hz, 1H, H-6^{D}), 3.46 (dt, *J* = 9.8, 6.4 Hz, 1H, H-7), 2.31 (t, *J* = 7.4 Hz, 2H, H-11), 1.67 – 1.53 (m, 4H, H-10, 8), 1.37 – 1.28 (m, 2H, H-9), 1.00 – 0.89 (m, 18H, *C*H$_3$). ^{13}C NMR (100 MHz, $CDCl_3$) δ 173.36 (C-12), 165.98 (C=O, Bz), 165.36 (C=O, Bz), 165.30 (C=O, Bz), 137.75, 137.03, 137.01, 136.92, 136.87, 136.07, 133.45, 133.30, 133.20, 129.68, 129.65, 129.62, 129.57, 129.54, 129.52, 128.60, 128.58, 128.52, 128.49, 128.46, 128.44, 128.22, 128.18, 127.95, 127.92, 127.87, 127.84, 127.57, 127.23, 127.18 (aromatic C/*CH*), 98.92 (C-1), 98.85 (2xC-1), 98.78 (C-1), 97.97 (C-1^{A}), 75.60, 75.49, 75.31, 75.23, 74.87, 73.27, 73.09, 72.62, 72.47, 72.39, 72.32, 72.00 (4 C*H$_2$Ph*), 71.78, 70.32 (C*H$_2$Ph*), 69.48, 68.82, 68.78, 68.61, 68.20 (C-7), 67.67, 66.83 (C-6^{E}), 66.12 (C*H$_2$Ph*), 62.57 (C-6^{A}), 61.27 (C-6), 61.17 (C-6), 60.43, 60.38, 60.30, 59.76, 58.68 (5 C-2), 34.11 (C-11), 28.98 (C-8), 27.59 (C*H$_3$*), 27.26 (C*H$_3$*), 25.65 (C-9), 24.56 (C-10), 23.30 (C-*Si*), 20.66 (C-*Si*). HR-MS: Calculated for $C_{114}H_{125}N_{15}O_{27}Si$ $[M+NH_4]^+$: 2181.89823, found: 2181.89769.

Pentasaccharide 43



The reaction was carried out according to the general procedure C using compound **42** (3.4 g, 1.57 mmol) and HF/pyridine (70%, 460 µl, 25.1 mmol). The product was purified by column chromatography (pentane:EtOAc = 3:2-1:1). Compound **43** (3.16 g, 93% yield, pentane:EtOAc = 1:1, R*f* = 0.25-0.35) was obtained as yellow syrup. $[\alpha]_D^{25}$ +141.0 (c=1, $CHCl_3$). IR (neat, cm^{-1}) ν 736, 1004, 1027, 1045, 1063, 1098, 1110, 1156, 1268, 1315, 1452, 1720, 2108, 2875, 2926, 3504. ^{1}H-NMR ($CDCl_3$, 500 MHz) δ 8.03 (d, *J* = 7.7 Hz, 2H, *C*H, Bz), 7.95 – 7.84 (m, 6H, *C*H, Bz), 7.66 – 6.98 (m, 42H, aromatic H), 5.14 (s, 1H, H-1^B), 5.07 (s, 2H, *C*H$_2$*Ph*), 5.03 (d, *J* = 3.5 Hz, 1H, H-1^C), 4.98-4.96 (m, 2H, H-1), 4.90 – 4.32 (m, 19H), 4.28 - 4.24 (m, 2H, H-4^A, 4^B), 4.21 – 3.87 (m, 12H), 3.84 – 3.76 (m, 2H), 3.75 – 3.61 (m, 5H), 3.50 – 3.32 (m, 3H, H-6^D, 7), 2.78 (bs, 1H, *O*H), 2.30 (t, *J* = 7.5 Hz, 2H, H-11), 2.10 (bs, 1H, *O*H), 1.65 – 1.52 (m, 4H, H-10, 8), 1.37 – 1.29 (m, 2H, H-9). ^{13}C NMR (125 MHz, $CDCl_3$) δ 173.33 (C-12), 165.95, 165.36, 165.30, 165.28 (C=O, Bz), 137.03, 137.01, 136.83, 136.04, 133.41, 133.28, 133.15, 129.64, 129.59, 129.54, 129.51, 129.49, 128.58, 128.56, 128.54, 128.48, 128.46, 128.42, 128.18, 128.17, 128.13, 128.10, 127.96, 127.90, 127.87, 127.60, 127.29, 127.21, 127.18 (aromatic H), 99.42 (C-1^E), 98.92 (C-1^D), 98.84 (C-1^C), 98.75 (C-1^B), 97.95 (C-1^A), 76.36, 75.47, 75.29, 75.24, 75.12, 73.69, 73.28, 72.94, 72.70, 72.46, 72.40, 72.38, 72.25, 71.79 (5 C*H*$_2$*Ph*), 69.54, 68.84, 68.79, 68.59, 68.18 (C-7), 67.49, 66.08 (C*H*$_2$*Ph*), 62.62 (C-6), 62.56 (C-6), 61.24 (C-6), 61.16 (C-6), 60.36, 60.34, 60.20, 59.74, 59.64 (5 C-2), 34.08 (C-11), 28.93 (C-8), 25.61 (C-9), 24.52 (C-10). HR-MS: Calculated for $C_{106}H_{109}N_{15}O_{27}$ $[M+NH_4]^+$: 2041.79611, found: 2041.79556.

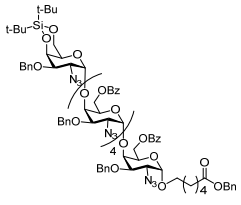
Pentasaccharide 44



The reaction was carried out according to the general procedure D using compound **43** (3.12 g, 1.54 mmol), PhCOOBt (1.66 g, 6.93 mmol) and Et_3N (1.1 ml, 7.7 mmol). The product was purified by column chromatography (pentane:EtOAc = 5:2). Compound **44** (1.09 g, 92% yield, pentane:EtOAc = 2:1, R*f* = 0.25-0.30) was obtained as yellow syrup. $[\alpha]_D^{25}$ +128.1 (c=1, $CHCl_3$). IR (neat, cm^{-1}) ν 736, 1003, 1027, 1046, 1063, 1096, 1110, 1156, 1176, 1266, 1315, 1452, 1720, 2106, 2873, 2929, 3504. ^{1}H-NMR ($CDCl_3$, 400 MHz) δ 8.09 (d, *J* = 7.7 Hz, 2H, *C*H, Bz), 7.95 (dd, *J* = 16.7, 7.7 Hz, 8H, *C*H, Bz), 7.69 – 7.04 (m, 45H, aromatic H), 5.20 (d, *J* = 3.6 Hz, 1H, H-1^B), 5.13 (s, 2H, *C*H$_2$*Ph*), 5.09 (d, *J* = 3.6 Hz, 1H, H-1C), 5.05 – 5.00 (m, 2H, H-1D, 1A), 4.99 – 4.60 (m, 14H), 4.57 – 4.37 (m, 8H), 4.34-4.31 (m, 2H, H-4^A, 4^B), 4.26 – 3.91 (m, 14H), 3.89 – 3.67 (m, 6H), 3.51 (dt, *J* = 9.9, 6.4 Hz, 1H, H-7), 2.54 (bs, 1H, *O*H), 2.36 (t, *J* = 7.5 Hz, 2H, H-11), 1.65 (h, *J* = 7.9 Hz, 4H, H-10, 8), 1.43 – 1.32 (m, 2H, H-9). ^{13}C NMR (125 MHz, $CDCl_3$) δ 173.34 (C-12), 165.96, 165.90, 165.38, 165.33, 165.24 (C=O, Bz), 137.16, 137.03, 136.86, 136.84, 136.06, 133.42, 133.28, 133.18, 133.03, 129.79, 129.67, 129.66, 129.58, 129.57, 129.56, 129.54, 129.52, 128.59, 128.57, 128.55, 128.50, 128.48, 128.43, 128.39, 128.28, 128.20, 128.17, 128.15, 127.99, 127.91, 127.89, 127.52, 127.31, 127.23 (aromatic C/C*H*), 99.12 (C-1^E), 98.94 (C-1^D), 98.85 (C-1^C), 98.77 (C-1^B), 97.97 (C-1^A), 76.32, 75.30, 75.26, 75.18, 75.08, 73.34, 73.29, 72.86, 72.72, 72.47, 72.40, 72.35, 72.30, 72.05 (5 C*H*$_2$*Ph*), 68.83, 68.61, 68.19 (C-7), 68.03, 66.10 (C*H*$_2$*Ph*), 65.41, 62.58 (C-6), 62.19 (C-6), 61.27 (C-6), 61.13

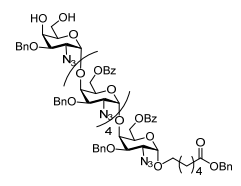
(C-6), 60.38 (C-2), 60.24 (C-2), 59.76 (C-2), 59.64 (C-2), 34.10 (C-11), 28.95 (C-8), 25.63 (C-9), 24.54 (C-10). HR-MS: Calculated for $C_{113}H_{113}N_{15}O_{28}$ $[M+NH_4]^+$: 2145.82232, found: 2145.82117.

Hexasaccharide 45



The reaction was carried out according to the general procedure B. The donor **2b** (2.20 g, 3.62 mmol) and the acceptor **44** (3.08 g, 1.45 mmol) were co-evaporated with toluene (three times). The residue was dissolved in 15 ml dry DCM under nitrogen and stirred over fresh flame-dried molecular sieves 4Å. The solution was cooled to 0 ºC, after which TfOH (13 µl, 0.14 mmol) was added. The reaction was stirred at 0 ºC for 1 h. Then the reaction was quenched with Et_3N, diluted with DCM, washed with saturated $NaHCO_3$ and brine. The organic phase was dried with anhydrous $MgSO_4$, filtered and concentrated *in vacuo*. The product was purified by silica gel column chromatography (pentane:EtOAc = 5:1). Compound **45** (3.30 g, 89% yield, pentane: EtOAc = 2:1, R*f* = 0.55-0.65) was obtained as yellow syrup. $[\alpha]_D^{25}$ +134.6 (c=1, $CHCl_3$). IR (neat, cm^{-1}) ν 651, 736, 797, 824, 1003, 1027, 1045, 1063, 1098, 1109, 1156, 1266, 1315, 1452, 1721, 2108, 2859, 2932. ^{1}H-NMR ($CDCl_3$, 500 MHz) δ 8.07 – 8.00 (m, 2H, *C*H, Bz), 7.95 – 7.86 (m, 8H, *C*H, Bz), 7.62 – 6.99 (m, 50H, aromatic H), 5.14 (d, *J* = 3.6 Hz, 1H, H-1^B), 5.07 (s, 2H, *C*H$_2$*Ph*), 5.02 (d, *J* = 3.6 Hz, 1H, H-1^C), 5.00 – 4.93 (m, 4H, H-1^A, 1^D, 1^E, 1^F), 4.90 – 4.55 (m, 14H), 4.51 – 4.32 (m, 9H), 4.29 – 4.22 (m, 3H), 4.20 – 3.97 (m, 9H), 3.96 – 3.84 (m, 5H), 3.82 – 3.75 (m, 3H), 3.73 – 3.62 (m, 6H), 3.55 (dd, *J* = 12.9, 2.1 Hz, 1H, H-6^F), 3.46 (dt, *J* = 9.8, 6.4 Hz, 1H, H-7), 2.30 (t, *J* = 7.5 Hz, 2H, H-11), 1.66 – 1.52 (m, 4H, H-10, 8), 1.37 – 1.27 (m, 2H, H-9), 1.00 – 0.89 (m, 18H, *C*H$_3$). ^{13}C NMR (125 MHz, $CDCl_3$) δ 173.29 (C-12), 165.93, 165.36, 165.30, 165.26 (C=O, Bz), 137.75, 137.03, 137.00, 136.86, 136.08, 133.41, 133.28, 133.23, 133.15, 129.65, 129.61, 129.59, 129.57, 129.55, 129.53, 128.56, 128.55, 128.50, 128.48, 128.45, 128.43, 128.41, 128.19, 128.14, 127.91, 127.88, 127.85, 127.80, 127.58, 127.27, 127.25, 127.23, 127.19 (aromatic C/C*H*), 98.86 (2xC-1), 98.84 (C-1), 98.76 (C-1), 97.98 (C-1^A), 75.58, 75.45, 75.31, 75.21, 75.18, 74.80, 73.28, 73.01, 72.81, 72.74, 72.49, 72.39, 72.36, 72.25, 72.00 (5 C*H$_2$Ph*), 71.81, 70.29 (C*H$_2$Ph*), 69.49, 68.83, 68.77, 68.62, 68.19 (C-7), 67.67, 66.82 (C-6^F), 66.08 (C*H$_2$Ph*), 62.57 (C-6), 61.28 (C-6), 61.18 (C-6), 60.45, 60.40, 60.38, 60.33, 59.77, 58.69 (6 C-2), 34.09 (C-11), 28.95 (C-8), 27.57 (C*H$_3$*), 27.25 (C*H$_3$*), 25.63 (C-9), 24.54 (C-10), 23.27 (C-*Si*), 20.64 (C-*Si*). MALDI-MS: Calculated for $C_{134}H_{144}N_{18}O_{32}Si$ $[M+Na]^+$: 2567.9861, found: 2567.9677.

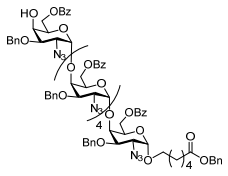
Hexasaccharide 46



The reaction was carried out according to the general procedure C using compound **45** (2.97 g, 1.17 mmol) and HF/pyridine (70%, 490 µl, 18.7 mmol). The product was purified by column chromatography (pentane:EtOAc = 3:2). Compound **46** (2.90 g, 92% yield, pentane:EtOAc = 1:1, R*f* = 0.25-0.35) was obtained as yellow syrup. $[\alpha]_D^{25}$ +132.5 (c=1, $CHCl_3$). IR (neat, cm^{-1}) ν 736, 1003, 1027, 1045, 1063, 1096, 1110, 1156, 1267, 1315, 1452, 1720, 2106, 2873, 2926, 3473. ^{1}H-NMR ($CDCl_3$, 500 MHz) δ 8.03 (d, *J* = 7.7 Hz, 2H, *C*H, Bz),

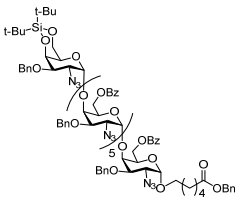
7.95 – 7.83 (m, 8H, *C*H, Bz), 7.64 – 6.95 (m, 50H, aromatic H), 5.13 (d, *J* = 3.5 Hz, 1H, H-1^{B}), 5.07 (s, 2H, *C*H$_2$*Ph*), 5.01 (d, *J* = 3.6 Hz, 1H, H-1^{C}), 4.99 – 4.91 (m, 3H, H-1^{A}, 1^{D}, 1^{E}), 4.90 – 4.54 (m, 15H, H-1^{F}), 4.53 – 4.31 (m, 8H), 4.30 – 4.21 (m, 2H), 4.21 – 3.84 (m, 15H), 3.84 – 3.76 (m, 2H), 3.74 – 3.61 (m, 6H), 3.45 (dt, *J* = 9.8, 6.4 Hz, 1H, H-7), 3.42 – 3.34 (m, 2H, H-6^{F}), 2.71 (bs, 1H, *O*H), 2.30 (t, *J* = 7.5 Hz, 2H, H-11), 1.66 – 1.53 (m, 4H, H-10, 8), 1.35 – 1.27 (m, 2H, H-9). ^{13}C NMR (125 MHz, $CDCl_3$) δ 173.34 (C-12), 165.95, 165.37, 165.32, 165.27 (C=O, Bz), 137.04, 137.02, 136.85, 136.78, 136.06, 133.42, 133.29, 133.26, 133.15, 129.65, 129.59, 129.56, 129.54, 129.51, 128.60, 128.57, 128.55, 128.50, 128.48, 128.45, 128.42, 128.19, 128.15, 128.10, 127.98, 127.91, 127.89, 127.88, 127.61, 127.30, 127.23, 127.22 (aromatic C/*CH*), 99.43 (C-1^{F}), 98.91 (C-1^{E}, 1^{D}), 98.86 (C-1^{C}), 98.77 (C-1^{B}), 97.96 (C-1^{A}), 76.37, 75.52, 75.31, 75.24, 75.22, 75.10, 73.71, 73.29, 72.90, 72.78, 72.48, 72.40, 72.33, 72.28, 71.82 (5 C*H*$_2$*Ph*), 69.54, 68.82, 68.61, 68.19 (C-7), 67.53, 66.10 (C*H*$_2$*Ph*), 62.65 (C-6), 62.57 (C-6), 61.25 (C-6), 61.14 (C-6), 60.38, 60.23, 59.76, 59.65 (C-2), 34.09 (C-11), 28.95 (C-8), 25.63 (C-9), 24.54 (C-10). HR-MS: Calculated for $C_{126}H_{128}N_{18}O_{32}$ $[M+NH_4]^+$: 2422.92858, found: 2422.92803.

Hexasaccharide 47



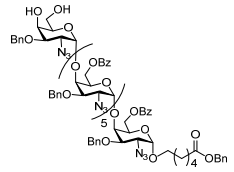
The reaction was carried out according to the general procedure D using compound **46** (2.90 g, 1.20 mmol), PhCOOBt (1.59 g, 6.6 mmol) and Et_3N (1.0 ml, 7.20 mmol). The product was purified by column chromatography (pentane:EtOAc = 2:1). Compound **47** (2.77 mg, 90% yield, pentane:EtOAc = 3:2, R*f* = 0.30-0.40) was obtained as yellow syrup. $[\alpha]_D^{25}$ +130.6 (c=1, $CHCl_3$). IR (neat, cm^{-1}) 1027, 1047, 1065, 1112, 1271, 1723, 2109, 2879, 2929, 3509. ^{1}H-NMR ($CDCl_3$, 500 MHz) δ 8.03 (d, *J* = 7.8 Hz, 2H, *C*H, Bz), 7.96 – 7.82 (m, 10H, *C*H, Bz), 7.61 – 6.95 (m, 53H), 5.14 (d, *J* = 3.7 Hz, 1H, H-1^{B}), 5.07 (s, 2H, *C*H$_2$*Ph*), 5.02 (d, *J* = 3.7 Hz, 1H, H-1^{C}), 4.99 – 4.92 (m, 3H, H-1^{A}, 1^{D}, 1^{E}), 4.92 – 4.53 (m, 15H, H-1^{F}), 4.52 – 4.30 (m, 10H), 4.29 – 4.21 (m, 2H, H-4^{A}, 4^{B}), 4.18 – 3.83 (m, 16H), 3.82 – 3.61 (m, 7H), 3.45 (dt, *J* = 10.6, 6.5 Hz, 1H, H-7), 2.44 (bs, 1H, *O*H), 2.30 (t, *J* = 7.5 Hz, 2H, H-11), 1.60 (dt, *J* = 16.0, 7.9 Hz, 4H, H-10, 8), 1.37 – 1.28 (m, 2H, H-9). ^{13}C NMR (125 MHz, $CDCl_3$) δ 173.34 (C-12), 165.97, 165.91, 165.38, 165.34, 165.29, 165.24 (6 C=O, Bz), 137.16, 137.03, 136.87, 136.85, 136.80, 136.07, 133.43, 133.30, 133.27, 133.18, 133.03, 129.80, 129.68, 129.66, 129.59, 129.56, 129.52, 128.59, 128.56, 128.51, 128.49, 128.46, 128.43, 128.39, 128.29, 128.21, 128.18, 128.16, 128.00, 127.93, 127.90, 127.88, 127.53, 127.31, 127.25, 127.23 (aromatic C/*CH*), 99.12 (C-1^{F}), 98.92 (C-1^{E}, 1^{D}), 98.87 (C-1^{C}), 98.78 (C-1^{B}), 97.98 (C-1^{A}), 76.33, 75.33, 75.25, 75.22, 75.06, 73.36, 73.30, 72.91, 72.80, 72.78, 72.50, 72.40, 72.32, 72.29, 72.07 (5 C*H*$_2$*Ph*), 68.83, 68.62, 68.21 (C-7), 68.02, 66.11 (C*H*$_2$*Ph*), 65.42 (C-4^{F}), 62.59, 62.18, 61.27, 61.17, 61.11 (C-6), 60.42, 60.39, 60.26, 59.77, 59.65 (C-2), 34.11 (C-11), 28.97 (C-8), 25.64 (C-9), 24.56 (C-10). MALDI-MS: Calculated for $C_{133}H_{132}N_{18}O_{33}$ $[M+Na]^+$: 2531.9102, found: 2531.8920.

Heptasaccharide 48



The reaction was carried out according to the general procedure B. The donor **2b** (1.66 g, 2.73 mmol) and the acceptor **47** (2.74 g, 1.09 mmol) were co-evaporated with toluene (three times). The residue was dissolved in 11 ml dry DCM under nitrogen and stirred over fresh flame-dried molecular sieves 4Å. The solution was cooled to 0 °C, after which TfOH (10 µl, 0.11 mmol) was added. The reaction was stirred at 0 °C for 1 h. Then the reaction was quenched with Et_3N, diluted with DCM, washed with saturated $NaHCO_3$ and brine. The organic phase was dried with anhydrous $MgSO_4$, filtered and concentrated *in vacuo*. The product was purified by silica gel column chromatography (pentane:EtOAc = 4:1). Compound **48** (2.83 g, 88% yield, pentane: EtOAc = 2:1, R*f* = 0.55-0.65) was obtained as yellow syrup. $[\alpha]_D^{25}$ +152.4 (c=1, $CHCl_3$). IR (neat, cm^{-1}) ν 651, 736, 824, 1003, 1027, 1045, 1063, 1098, 1109, 1156, 1266, 1315, 1452, 1721, 2108, 2860, 2932. ^{1}H-NMR ($CDCl_3$, 500 MHz) δ 8.06 – 8.00 (m, 2H, *C*H, Bz), 7.95 – 7.85 (m, 10H, *C*H, Bz), 7.62 – 6.97 (m, 58H, aromatic H), 5.14 (s, 1H, H-1B), 5.07 (s, 2H, *C*H_2*Ph*), 5.02 (d, *J* = 3.3 Hz, 1H, H-1^C), 4.99 – 4.91 (m, 5H, 5xH-1), 4.90 – 4.62 (m, 14H), 4.62 – 4.55 (m, 2H), 4.51 – 3.82 (m, 31H), 3.79 (d, *J* = 2.8 Hz, 3H), 3.72 – 3.61 (m, 7H), 3.58-3.53 (m, 1H, H-6^G), 3.50 – 3.41 (m, 1H, H-7), 2.31 (t, *J* = 7.4 Hz, 2H, H-11), 1.67 – 1.53 (m, 4H, H-10, 8), 1.37 – 1.27 (m, 2H, H-9), 1.00 – 0.89 (m, 18H, *C*H_3). ^{13}C NMR (125 MHz, $CDCl_3$) δ 173.31 (C-12), 165.96, 165.38, 165.33, 165.30, 165.28 (C=O, Bz), 137.77, 137.04, 137.01, 136.87, 136.83, 136.09, 133.43, 133.30, 133.23, 133.16, 129.67, 129.62, 129.58, 129.56, 129.54, 128.58, 128.56, 128.52, 128.50, 128.45, 128.42, 128.20, 128.16, 127.94, 127.90, 127.86, 127.81, 127.59, 127.27, 127.24, 127.21 (aromatic C/*CH*), 98.92 (C-1), 98.86 (4xC-1), 98.78 (C-1), 97.99 (C-1^A), 75.59, 75.48, 75.33, 75.23, 75.20, 75.17, 74.84, 73.31, 73.02, 72.93, 72.76, 72.51, 72.42, 72.38, 72.32, 72.26, 72.01 (6 CH_2*Ph*), 71.83, 70.30 (CH_2*Ph*), 69.50, 68.81, 68.63, 68.21 (C-7), 67.68, 66.83 (C-6^G), 66.10 (CH_2*Ph*), 62.59, 61.28, 61.17 (C-6), 60.46, 60.43, 60.40, 60.35, 59.79, 58.70 (C-2), 34.11 (C-11), 28.97 (C-8), 27.58 (CH_3), 27.26 (CH_3), 25.65 (C-9), 24.56 (C-10), 23.29 (C-*Si*), 20.65 (C-*Si*). ^{13}C-HMBC ($CDCl_3$, 125 MHz): 98.92 ($J_{C1,H1}$ = 172 Hz), 98.86 ($J_{C1,H1}$ = 172 Hz), 98.78 ($J_{C1,H1}$ = 173 Hz), 97.99 ($J_{C1,H1}$ = 172 Hz). MALDI-MS: Calculated for $C_{154}H_{163}N_{21}O_{37}Si$ $[M+Na]^+$: 2949.1186, found: 2949.0945.

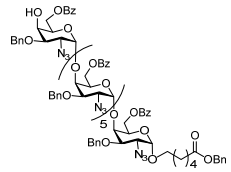
Heptasaccharide 49



The reaction was carried out according to the general procedure C using compound **48** (2.40 g, 0.82 mmol) and HF/pyridine (70%, 340 µl, 13.1 mmol). The product was purified by column chromatography (pentane:EtOAc = 3:2-1:1). Compound **49** (2.20 g, 94% yield, pentane:EtOAc = 1:1, R*f* = 0.25-0.35) was obtained as yellow syrup. $[\alpha]_D^{25}$ +137.7 (c=1, $CHCl_3$). IR (neat, cm^{-1}) ν 1003, 1027, 1046, 1063, 1098, 1112, 1156, 1268, 1315, 1452, 1720, 2108, 2872, 2926, 3484. ^{1}H-NMR ($CDCl_3$, 500 MHz) δ 8.05 – 8.00 (m, 2H, *C*H, Bz), 7.94 – 7.83 (m, 10H, *C*H, Bz), 7.62 – 6.95 (m, 58H, aromatic H), 5.13 (d, *J* = 3.6 Hz, 1H, H-1B), 5.07 (s, 2H, *C*H_2*Ph*), 5.01 (d, *J* = 3.6 Hz, 1H, H-1^C), 4.97 (d, *J* = 3.6 Hz, 1H, H-1^A), 4.96 – 4.90 (m, 3H, 3xH-1), 4.90 – 4.55 (m, 17H, H-1), 4.52 – 4.30 (m, 10H), 4.26 (dd, *J* = 15.3, 2.7 Hz, 2H), 4.19 – 3.84 (m, 18H), 3.84 – 3.75 (m, 2H), 3.74 – 3.60 (m, 7H), 3.49 -3.42 (m, 1H, H-7), 3.40 – 3.32 (m, 2H, H-6^G), 2.30 (t, *J* = 7.5 Hz, 2H, H-11), 1.67 – 1.53 (m, 4H, H-10,

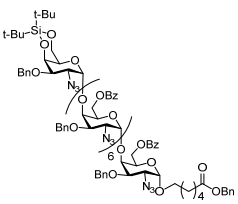
8), 1.36 – 1.25 (m, 2H, H-9). ^{13}C NMR (125 MHz, $CDCl_3$) δ 173.35 (C-12), 165.96, 165.37, 165.32, 165.28, 165.25 (C=O, Bz), 137.04, 137.01, 136.85, 136.80, 136.78, 136.05, 133.43, 133.30, 133.26, 133.15, 129.66, 129.64, 129.59, 129.55, 129.53, 129.50, 128.60, 128.57, 128.56, 128.51, 128.49, 128.47, 128.44, 128.42, 128.20, 128.19, 128.15, 128.10, 127.98, 127.91, 127.89, 127.87, 127.83, 127.60, 127.28, 127.23, 127.21, 127.19 (aromatic C/C*H*), 99.43 (C-1^G), 98.93 (C-1^F), 98.90 (3xC-1), 98.78 (C-1B), 97.96 (C-1^A), 76.39, 75.53, 75.32, 75.23, 75.13, 73.70, 73.29, 72.96, 72.91, 72.83, 72.76, 72.48, 72.40, 72.38, 72.33, 72.27, 71.83 (6 CH_2*Ph*), 69.52, 68.81, 68.60, 68.20 (C-7), 67.54 (C-4^G), 66.10 (CH_2*Ph*), 62.66, 62.56, 61.24, 61.22, 61.12 (C-6), 60.39, 60.36, 60.23, 59.76, 59.65 (C-2), 34.10 (C-11), 28.96 (C-8), 25.63 (C-9), 24.55 (C-10). MALDI-MS: Calculated for $C_{146}H_{147}N_{21}O_{37}$ $[M+Na]^+$: 2809.0164, found: 2808.9943.

Heptasaccharide 50



The reaction was carried out according to the general procedure D using compound **49** (2.04 g, 0.73 mmol), PhCOOBt (963 mg, 4.03 mmol) and Et_3N (610 µl, 4.38 mmol). The product was purified by column chromatography (pentane:EtOAc = 2:1). Compound **50** (2.10 g, 92% yield, pentane:EtOAc = 3:2, R*f* = 0.30-0.40) was obtained as yellow syrup. $[\alpha]_D^{25}$ +108.6 (c=1, $CHCl_3$). IR (neat, cm^{-1}) ν 1005, 1027, 1047, 1063, 1112, 1269, 1315, 1721, 2109, 2873, 2926, 3473. ^{1}H-NMR ($CDCl_3$, 400 MHz) δ 8.07 – 8.00 (m, 2H, *C*H, Bz), 7.96 – 7.82 (m, 12H, *C*H, Bz), 7.64 – 6.95 (m, 61H), 5.14 (d, *J* = 3.6 Hz, 1H, H-1^B), 5.07 (s, 2H, *C*H$_2$*Ph*), 5.01 (d, *J* = 3.6 Hz, 1H, H-1^C), 4.98 (d, *J* = 3.6 Hz, 1H, H-1^A), 4.96 – 4.55 (m, 20H, 4xH-1), 4.54 – 4.23 (m, 14H), 4.20 – 3.61 (m, 27H), 3.45 (dt, *J* = 9.8, 6.4 Hz, 1H, H-7), 2.50 (bs, 1H, *O*H), 2.30 (t, *J* = 7.4 Hz, 2H, H-11), 1.69 – 1.50 (m, 4H, H-10, 8), 1.39 – 1.23 (m, 2H, H-9). ^{13}C NMR (100 MHz, $CDCl_3$) δ 173.34 (C-12), 165.94, 165.87, 165.35, 165.30, 165.25, 165.19 (C=O, Bz), 137.12, 136.99, 136.83, 136.81, 136.78, 136.75, 136.02, 133.42, 133.29, 133.25, 133.16, 133.02, 130.01, 129.74, 129.64, 129.62, 129.55, 129.51, 129.49, 129.46, 128.56, 128.54, 128.49, 128.47, 128.45, 128.42, 128.40, 128.36, 128.26, 128.19, 128.14, 127.97, 127.89, 127.86, 127.83, 127.81, 127.46, 127.23, 127.18, 127.16 (aromatic C/C*H*), 99.09 (C-1), 98.88 (C-1), 98.76 (C-1), 97.93 (C-1^A), 76.32, 75.29, 75.21, 75.06, 73.31, 73.25, 72.92, 72.79, 72.75, 72.72, 72.44, 72.37, 72.34, 72.26, 72.01 (5 CH_2*Ph*), 68.76, 68.57, 68.16 (C-7), 67.97, 66.08 (CH_2*Ph*), 65.32 (C-4^g), 62.54, 62.11, 61.20, 61.07 (C-6), 60.37, 60.33, 60.20, 59.72, 59.60 (C-2), 34.07 (C-11), 28.93 (C-8), 25.61 (C-9), 24.52 (C-10). MALDI-MS: Calculated for $C_{153}H_{151}N_{21}O_{38}$ $[M+Na]^+$: 2913.0427, found: 2913.0199.

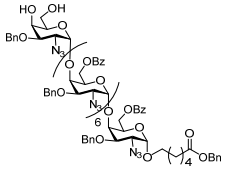
Octasaccharide 51



The reaction was carried out according to the general procedure B. The donor **2b** (1.08 g, 1.77 mmol) and the acceptor **50** (2.05 g, 0.71 mmol) were co-evaporated with toluene (three times). The residue was dissolved in 7 ml dry DCM under nitrogen and stirred over fresh flame-dried molecular sieves 4Å. The solution was cooled to 0 ºC, after which TfOH (6 µl, 0.07 mmol) was added. The reaction was stirred at 0 ºC for

1 h. Then the reaction was quenched with Et_3N, diluted with DCM, washed with saturated $NaHCO_3$ and brine. The organic phase was dried with anhydrous $MgSO_4$, filtered and concentrated *in vacuo*. The product was purified by silica gel column chromatography (pentane:EtOAc = 3:1). Compound **51** (2.07 g, 87% yield, pentane: EtOAc = 2:1, R*f* = 0.55-0.65) was obtained as yellow syrup. $[\alpha]_D^{25}$ +140.2 (c=1, $CHCl_3$). IR (neat, cm^{-1}) ν 442, 469, 651, 1003, 1026, 1045, 1063, 1096, 1109, 1156, 1266, 1315, 1452, 1720, 2109, 2862, 2932. ^{1}H-NMR ($CDCl_3$, 400 MHz) δ 8.08 – 8.00 (m, 2H, *C*H, Bz), 7.96 – 7.83 (m, 12H, *C*H, Bz), 7.61 – 6.95 (m, 66H, aromatic H), 5.14 (d, *J* = 3.5 Hz, 1H, H-1^B), 5.07 (s, 2H, *C*H$_2$*Ph*), 5.01 (d, *J* = 3.6 Hz, 1H, H-1^C), 4.98 (d, *J* = 3.5 Hz, 1H, H-1^A), 4.96 – 4.53 (m, 24H, 5xH-1), 4.53 – 3.76 (m, 40H), 3.74 – 3.60 (m, 8H), 3.59 – 3.40 (m, 2H, H-6^H, 7), 2.30 (t, *J* = 7.5 Hz, 2H, H-11), 1.68 – 1.52 (m, 4H, H-10, 8), 1.39 – 1.23 (m, 2H, H-9), 1.02 – 0.85 (m, 18H, *C*H$_3$). ^{13}C NMR (100 MHz, $CDCl_3$) δ 173.30 (C-12), 165.93, 165.33, 165.28, 165.24, 165.21 (C=O, Bz), 137.72, 136.99, 136.97, 136.82, 136.78, 136.03, 133.42, 133.29, 133.22, 133.14, 129.64, 129.62, 129.59, 129.52, 129.50, 129.47, 128.56, 128.54, 128.49, 128.47, 128.42, 128.40, 128.19, 128.14, 127.87, 127.81, 127.79, 127.52, 127.18, 127.13 (aromatic C/C*H*), 98.84 (C-1), 98.79 (C-1), 97.94 (C-1^A), 75.58, 75.46, 75.29, 75.19, 74.81, 73.25, 72.98, 72.91, 72.82, 72.71, 72.46, 72.36, 72.27, 72.20, 71.95 (5 C*H$_2$Ph*), 71.74, 70.27 (C*H$_2$Ph*), 69.44, 68.74, 68.56, 68.17 (C-7), 67.62, 66.78 (C-6^H), 66.07 (C*H$_2$Ph*), 62.52, 61.20, 61.09 (C-6), 60.34, 59.73, 58.65 (C-2), 34.07 (C-11), 28.94 (C-8), 27.55 (C*H$_3$*), 27.23 (C*H$_3$*), 25.61 (C-9), 24.52 (C-10), 23.26 (C-*Si*), 20.61 (C-*Si*). ^{13}C-HMBC ($CDCl_3$, 125 MHz): 98.84 ($J_{C1,H1}$ = 171 Hz), 98.79 ($J_{C1,H1}$ = 173 Hz), 97.94 ($J_{C1,H1}$ = 171 Hz). MALDI-MS: Calculated for $C_{174}H_{182}N_{24}O_{42}Si$ $[M+Na]^+$: 3330.2510, found: 3330.2209.

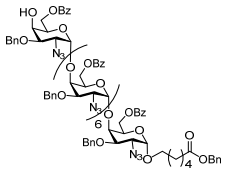
Octasaccharide 52



The reaction was carried out according to the general procedure C using compound **51** (2.0 g, 0.60 mmol) and HF/pyridine (70%, 250 µl, 9.68 mmol). The product was purified by column chromatography (pentane:EtOAc = 3:2-1:1). Compound **52** (1.80 g, 91% yield, pentane:EtOAc = 1:1, R*f* = 0.25-0.35) was obtained as yellow syrup. $[\alpha]_D^{25}$ +127.7 (c=1, $CHCl_3$). IR (neat, cm^{-1}) ν 1003, 1027, 1046, 1063, 1112, 1269, 1723, 2109, 2872, 2926, 3457. ^{1}H-NMR ($CDCl_3$, 500 MHz) δ 8.14 – 8.08 (m, 2H, *C*H, Bz), 8.03 – 7.90 (m, 12H, *C*H, Bz), 7.68 – 7.02 (m, 66H, aromatic H), 5.22 (d, *J* = 3.5 Hz, 1H, H-1^B), 5.14 (s, 2H, *C*H$_2$*Ph*), 5.10 (d, *J* = 3.7 Hz, 1H, H-1^C), 5.07 – 4.99 (m, 5H, H-1^A, 1^D, 1^E, 1^F, 1^G), 4.98 – 3.68 (m, 65H, H-1H), 3.58 – 3.41 (m, 3H, H-6^H, 7), 2.90 (bs, 1H, *O*H), 2.37 (t, *J* = 7.4 Hz, 2H, H-11), 1.73 – 1.59 (m, 4H, H-10, 8), 1.47 – 1.32 (m, 2H, H-9). ^{13}C NMR (125 MHz, $CDCl_3$) δ 173.10 (C-12), 165.87, 165.30, 165.25, 165.20, 165.18 (C=O, Bz), 136.97, 136.95, 136.78, 136.73, 136.70, 135.98, 133.34, 133.21, 133.17, 133.07, 129.57, 129.55, 129.50, 129.46, 129.43, 128.49, 128.46, 128.43, 128.41, 128.38, 128.36, 128.34, 128.10, 128.05, 128.01, 127.87, 127.84, 127.80, 127.77, 127.56, 127.23, 127.17, 127.15 (aromatic C/C*H*), 99.35 (C-1), 98.89 (C-1), 98.80 (C-1), 98.69 (C-1), 97.89 (C-1^A), 76.25, 75.36, 75.25, 75.14, 75.08, 75.02, 73.62, 73.22, 72.87, 72.79, 72.75, 72.69, 72.40, 72.32, 72.30, 72.24, 72.18, 72.15, 72.09, 72.01, 71.64 (6 C*H$_2$Ph*), 69.50, 68.77, 68.73, 68.54, 67.96 (C-7), 67.24 (C-4^H), 65.85 (C*H$_2$Ph*), 62.40, 62.37, 61.05, 60.94,

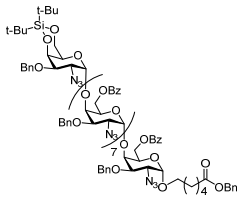
60.91 (C-6), 60.18, 60.00, 59.54, 59.43 (C-2), 33.86 (C-11), 28.72 (C-8), 25.40 (C-9), 24.31 (C-10). MALDI-MS: Calculated for $C_{166}H_{166}N_{24}O_{42}$ $[M+Na]^+$: 3190.1489, found: 3190.1224.

Octasaccharide 53



The reaction was carried out according to the general procedure D using compound **52** (1.49 g, 0.46 mmol), PhCOOBt (601 mg, 2.50 mmol) and Et_3N (380 µl, 2.74 mmol). The product was purified by column chromatography (pentane:EtOAc:DCM = 10:3:2). Compound **53** (1.62 g, 94% yield, pentane:EtOAc:DCM = 5:2:1, R*f* = 0.30-0.40) was obtained as yellow syrup. $[\alpha]_D^{25}$ +118.6 (c=1, $CHCl_3$). IR (neat, cm^{-1}) ν 1003, 1027, 1046, 1063, 1096, 1110, 1156, 1176, 1266, 1315, 1452, 1720, 2106, 2875, 2928. ^{1}H-NMR ($CDCl_3$, 400 MHz) δ 8.06 – 8.00 (m, 2H, *C*H, Bz), 7.95 – 7.82 (m, 14H, *C*H, Bz), 7.60 – 6.94 (m, 69H, aromatic H), 5.15 (d, *J* = 3.6 Hz, 1H, H-1^B), 5.06 (s, 2H, *C*H$_2$*Ph*), 5.03 (d, *J* = 3.6 Hz, 1H, H-1^C), 4.98 (d, *J* = 3.5 Hz, 1H, H-1^A), 4.97 – 4.92 (m, 4H, 4xH-1), 4.91 – 4.55 (m, 19H, H-1H), 4.53 – 4.31 (m, 14H), 4.30 – 4.24 (m, 2H, H-4^A, 4^B), 4.21 – 3.84 (m, 22H), 3.80 (dd, *J* = 10.7, 3.4 Hz, 1H), 3.76 – 3.62 (m, 8H), 3.45 (dt, *J* = 9.9, 6.4 Hz, 1H, H-7), 2.51 (bs, 1H, *O*H), 2.30 (t, *J* = 7.4 Hz, 2H, H-11), 1.66 – 1.52 (m, 4H, H-10, 8), 1.38 – 1.25 (m, 2H, H-9). ^{13}C NMR (125 MHz, $CDCl_3$) δ 173.26 (C-12), 165.90, 165.84, 165.32, 165.27, 165.23, 165.18 (C=O, Bz), 137.12, 136.98, 136.81, 136.78, 136.76, 136.74, 136.02, 133.37, 133.23, 133.19, 133.11, 132.97, 129.74, 129.60, 129.58, 129.52, 129.50, 129.47, 128.51, 128.49, 128.46, 128.44, 128.42, 128.39, 128.37, 128.31, 128.22, 128.13, 128.09, 127.93, 127.87, 127.83, 127.81, 127.79, 127.48, 127.27, 127.21, 127.19, 127.17 (aromatic C/C*H*), 99.04 (C-1), 98.83 (C-1), 98.72 (C-1), 97.92 (C-1^A), 76.24, 75.28, 75.17, 75.11, 75.00, 73.26, 72.90, 72.84, 72.78, 72.73, 72.43, 72.36, 72.34, 72.27, 72.23, 71.96 (6 C*H*$_2$*Ph*), 68.77, 68.58, 68.14 (C-7), 68.00, 66.03 (C*H*$_2$*Ph*), 65.37 (C-4^H), 62.55, 62.18, 61.23, 61.10 (C-6), 60.38, 60.34, 60.20, 59.72, 59.60 (C-2), 34.04 (C-11), 28.90 (C-8), 25.58 (C-9), 24.49 (C-10). MALDI-MS: Calculated for $C_{173}H_{170}N_{24}O_{43}$ $[M+Na]^+$: 3294.1751, found: 3294.1474.

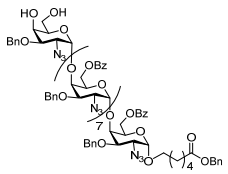
Nonasaccharide 54



The reaction was carried out according to the general procedure B. The donor **2b** (1.08 g, 1.77 mmol) and the acceptor **53** (732 mg, 1.21 mmol) were co-evaporated with toluene (three times). The residue was dissolved in 5 ml dry DCM under nitrogen and stirred over fresh flame-dried molecular sieves 4Å. The solution was cooled to 0 ºC, after which TfOH (4 µl, 0.05 mmol) was added. The reaction was stirred at 0 ºC for 1 h. Then the reaction was quenched with Et_3N, diluted with DCM, washed with saturated $NaHCO_3$ and brine. The organic phase was dried with anhydrous $MgSO_4$, filtered and concentrated *in vacuo*. The product was purified by silica gel column chromatography (pentane:EtOAc:DCM = 6:1:1). Compound **54** (1.58 g, 89% yield, pentane:EtOAc:DCM = 21:5:5, R*f* = 0.35-0.45) was obtained as yellow syrup. $[\alpha]_D^{25}$ +137.3 (c=1, $CHCl_3$). IR (neat, cm^{-1}) ν 824, 1003, 1027, 1046, 1063, 1098, 1109, 1156, 1266, 1315, 1452, 1721, 2108, 2862, 2932. ^{1}H-NMR ($CDCl_3$, 500 MHz) δ 8.07 – 8.00 (m, 2H), 7.95 – 7.85 (m, 15H), 7.61 – 7.51 (m, 9H), 7.49 – 7.09

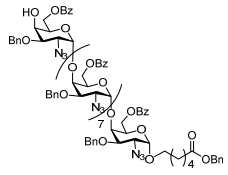
(m, 66H), 7.08 – 6.95 (m, 8H), 5.15 (d, *J* = 3.5 Hz, 1H, H-1^{B}), 5.06 (s, 2H), 5.03 (d, *J* = 3.6 Hz, 1H, H-1^{C}), 5.00 – 4.90 (m, 7H, 7xH-1), 4.90 – 3.75 (m, 68H), 3.73 – 3.61 (m, 10H), 3.55 (d, *J* = 12.4 Hz, 1H), 3.46 (dt, *J* = 9.9, 6.4 Hz, 1H, H-7), 2.30 (t, *J* = 7.4 Hz, 2H, H-11), 1.66 – 1.53 (m, 4H, H-10, 8), 1.38 – 1.27 (m, 2H, H-9), 0.99 – 0.90 (m, 18H, *C*H$_3$). ^{13}C NMR (125 MHz, $CDCl_3$) δ 173.23 (C-12), 165.89, 165.31, 165.27, 165.22 (C=O, Bz), 137.70, 136.99, 136.95, 136.81, 136.77, 136.03, 133.37, 133.24, 133.20, 133.17, 133.10, 129.60, 129.57, 129.52, 129.48, 128.52, 128.50, 128.47, 128.45, 128.43, 128.39, 128.14, 128.09, 127.88, 127.84, 127.80, 127.76, 127.54, 127.21, 127.18, 127.15 (aromatic C/C*H*), 98.80 (C-1), 98.73 (C-1), 97.94 (C-1^{A}), 75.52, 75.41, 75.29, 75.13, 74.76, 73.25, 72.97, 72.90, 72.82, 72.73, 72.69, 72.45, 72.37, 72.34, 72.26, 72.20, 71.95, 71.77, 70.24, 69.44, 68.75, 68.57, 68.15 (C-7), 67.62, 66.77 (C-6^{I}), 66.02 (C*H*$_2$*Ph*), 62.53, 61.23, 61.11 (C-6), 60.38, 60.35, 60.29, 59.73, 58.65 (C-2), 34.04 (C-11), 28.91 (C-8), 27.53 (C*H*$_3$), 27.21 (C*H*$_3$), 25.59 (C-9), 24.49 (C-10), 23.22 (C-*Si*), 20.59 (C-*Si*). ^{13}C-HMBC ($CDCl_3$, 125 MHz): 98.80 ($J_{C1,H1}$ = 173 Hz), 98.73 ($J_{C1,H1}$ = 172 Hz), 97.94 ($J_{C1,H1}$ = 172 Hz). MALDI-MS: Calculated for $C_{194}H_{201}N_{27}O_{47}Si$ $[M+Na]^+$: 3711.3835, found: 3711.3517.

Nonasaccharide 55



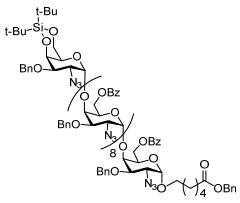
The reaction was carried out according to the general procedure C using compound **54** (1.16 g, 0.31 mmol) and HF/pyridine (70%, 49 µl, 1.89 mmol). The product was purified by column chromatography (pentane:EtOAc = 3:2-1:1). Compound **55** (1.04 g, 94% yield, pentane:EtOAc = 1:1, R*f* = 0.25-0.35) was obtained as yellow syrup. $[\alpha]_D^{25}$ +122.1 (c=1, $CHCl_3$). IR (neat, cm^{-1}) ν 1003, 1027, 1046, 1063, 1098, 1112, 1156, 1268, 1315, 1452, 1721, 2108, 2875, 2928, 3524. ^{1}H-NMR ($CDCl_3$, 500 MHz) δ 8.06 – 8.00 (m, 2H), 7.94 – 7.83 (m, 14H), 7.62 – 7.52 (m, 8H), 7.49 – 7.39 (m, 17H), 7.39 – 7.07 (m, 45H), 7.07 – 6.94 (m, 7H), 5.14 (d, *J* = 3.5 Hz, 1H, H-1^{B}), 5.06 (s, 2H), 5.01 (d, *J* = 3.5 Hz, 1H, H-1^{C}), 4.97 (d, *J* = 3.5 Hz, 1H, H-1^{A}), 4.96 – 4.54 (m, 27H, 6xH-1), 4.51 – 3.61 (m, 53H), 3.45 (dt, *J* = 9.6, 6.4 Hz, 1H, H-7), 3.38 (t, *J* = 5.8 Hz, 2H, H-6^{I}), 2.76 (bs, 1H, *O*H), 2.30 (t, *J* = 7.4 Hz, 2H, H-11), 2.10 (bs, 1H, *O*H), 1.65 – 1.53 (m, 4H, H-10, 8), 1.38 – 1.27 (m, 2H, H-9). ^{13}C NMR (125 MHz, $CDCl_3$) δ 173.35 (C-12), 165.98, 165.40, 165.35, 165.29 (C=O, Bz), 137.05, 136.88, 136.82, 133.44, 133.26, 133.16, 129.67, 129.64, 129.60, 129.57, 129.53, 128.61, 128.58, 128.50, 128.46, 128.21, 128.19, 128.16, 128.12, 127.99, 127.90, 127.85, 127.65, 127.63, 127.34, 127.32, 127.25, 99.44 (C-1), 98.90 (C-1), 98.79 (C-1), 97.99 (C-1^{A}), 76.38, 75.52, 75.34, 75.22, 73.74, 73.32, 72.91, 72.80, 72.51, 72.41, 72.34, 72.29, 71.83, 69.58, 68.82, 68.63, 68.22 (C-7), 67.53, 66.11 (C*H*$_2$*Ph*), 62.65, 62.59, 61.15 (C-6), 60.42, 60.26, 59.79, 59.68 (C-2), 34.11 (C-11), 28.97 (C-8), 25.65 (C-9), 24.56 (C-10). MALDI-MS: Calculated for $C_{186}H_{185}N_{27}O_{47}$ $[M+Na]^+$: 3571.2814, found: 3571.2493.

Nonasaccharide 56



The reaction was carried out according to the general procedure D using compound **55** (802 mg, 0.23 mmol), PhCOOBt (270 mg, 1.13 mmol) and Et_3N (173 µl, 1.24 mmol). The product was purified by column chromatography (pentane:EtOAc = 2:1-3:2). Compound **56** (743 mg, 90% yield, pentane:EtOAc = 3:2, R*f* = 0.30-0.40) was obtained as yellow syrup. $[\alpha]_D^{25}$ +128.5 (c=1, $CHCl_3$). IR (neat, cm^{-1}) ν 474, 804, 820, 1002, 1026, 1045, 1063, 1096, 1109, 1156, 1176, 1266, 1315, 1452, 1720, 2108, 2873, 2926. ^{1}H-NMR ($CDCl_3$, 400 MHz) δ 8.03 (d, *J* = 7.4 Hz, 2H), 7.96 – 7.81 (m, 16H), 7.64 – 6.91 (m, 80H), 5.14 (d, *J* = 3.6 Hz, 1H, H-1^B), 5.07 (s, 2H), 5.01 (d, *J* = 3.6 Hz, 1H, H-1^C), 4.98 (d, *J* = 3.5 Hz, 1H, H-1^A), 4.96 – 3.60 (m, 81H, 6xH-1), 3.45 (dt, *J* = 9.9, 6.5 Hz, 1H, H-7), 2.30 (t, *J* = 7.4 Hz, 2H, H-11), 1.67 – 1.52 (m, 4H, H-10, 8), 1.38 – 1.23 (m, 2H, H-9). ^{13}C NMR (100 MHz, $CDCl_3$) δ 173.32 (C-12), 165.94, 165.88, 165.35, 165.30, 165.25, 165.20 (C=O, Bz), 137.13, 137.00, 136.83, 136.81, 136.78, 136.76, 136.03, 133.42, 133.29, 133.24, 133.15, 133.01, 129.75, 129.64, 129.61, 129.55, 129.52, 129.48, 128.56, 128.54, 128.47, 128.42, 128.26, 128.18, 128.14, 127.97, 127.90, 127.86, 127.82, 127.48, 127.26, 127.19, 99.09 (C-1), 98.87 (C-1), 98.76 (C-1), 97.95 (C-1^A), 76.31, 75.30, 75.20, 75.05, 73.32, 73.28, 72.93, 72.86, 72.76, 72.46, 72.38, 72.28, 72.02, 68.76, 68.58, 68.17 (C-7), 67.98, 66.08, 65.36 (C-4^I), 62.55, 62.14, 61.22, 61.08 (C-6), 60.37, 60.22, 59.74, 59.62 (C-2), 34.08 (C-11), 28.94 (C-8), 25.61 (C-9), 24.52 (C-10). MALDI-MS: Calculated for $C_{193}H_{189}N_{27}O_{48}$ $[M+Na]^+$: 3675.3076, found: 3675.2795.

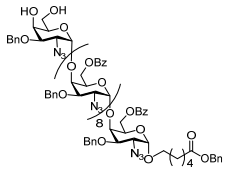
Decasaccharide 57



The reaction was carried out according to the general procedure B. The donor **2b** (327 mg, 0.54 mmol) and the acceptor **56** (690 mg, 0.19 mmol) were co-evaporated with toluene (three times). The residue was dissolved in 3 ml dry DCM under nitrogen and stirred over fresh flame-dried molecular sieves 4Å. The solution was cooled to 0 ºC, after which TfOH (2 µl, 0.02 mmol) was added. The reaction was stirred at 0 ºC for 1 h. Then the reaction was quenched with Et_3N, diluted with DCM, washed with saturated $NaHCO_3$ and brine. The organic phase was dried with anhydrous $MgSO_4$, filtered and concentrated *in vacuo*. The product was purified by silica gel column chromatography (pentane:EtOAc = 3:1). Compound **57** (499 mg, 65% yield, pentane: EtOAc = 2:1, R*f* = 0.55-0.65) was obtained as yellow syrup. $[\alpha]_D^{25}$ +135.7 (c=1, $CHCl_3$). IR (neat, cm^{-1}) ν 737, 824, 1003, 1027, 1046, 1063, 1096, 1109, 1156, 1266, 1315, 1452, 1721, 2108, 2859, 2929. ^{1}H-NMR ($CDCl_3$, 500 MHz) δ 8.07 – 8.01 (m, 2H), 7.96 – 7.84 (m, 16H), 7.62 – 7.51 (m, 9H), 7.49 – 7.08 (m, 68H), 7.07 – 6.94 (m, 8H), 5.15 (d, *J* = 3.6 Hz, 1H, H-1^B), 5.07 (s, 2H), 5.02 (d, *J* = 3.6 Hz, 1H, H-1^C), 4.98 (d, *J* = 3.5 Hz, 1H, H-1^A), 4.96 – 3.76 (m, 78H, 7xH-1), 3.73 – 3.60 (m, 10H), 3.54 (d, *J* = 12.4 Hz, 1H), 3.46 (dt, *J* = 9.8, 6.3 Hz, 1H, H-7), 2.30 (t, *J* = 7.4 Hz, 2H, H-11), 1.68 – 1.52 (m, 4H, H-10, 8), 1.38 – 1.27 (m, 2H, H-9), 0.95 (d, *J* = 13.3 Hz, 18H, *C*H$_3$). ^{13}C NMR (125 MHz, $CDCl_3$) δ 173.11 (C-12), 165.75, 165.17, 165.12, 165.08, 165.06, 165.04 (C=O, Bz), 137.54, 136.83, 136.79, 136.65, 136.61, 135.87, 133.23, 133.10, 133.06, 133.03, 132.96, 129.46, 129.42, 129.37, 129.35, 129.31, 128.38, 128.36, 128.32, 128.30, 128.28, 128.24, 128.22, 128.00, 127.95, 127.73, 127.70, 127.64, 127.62, 127.36, 127.03, 126.98, 98.66 (C-1), 97.78 (C-1^A), 75.39, 75.27, 75.13, 75.00, 74.62,

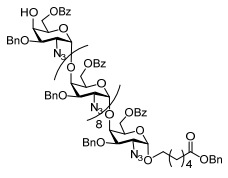
73.10, 72.81, 72.75, 72.67, 72.55, 72.29, 72.20, 72.12, 72.09, 72.04, 71.79, 71.60, 70.10, 69.28, 68.58, 68.41, 68.00 (C-7), 67.45, 66.61 (C-6^{J}), 65.89 (CH_2*Ph*), 62.37, 61.07, 60.94 (C-6), 60.21, 59.57, 58.49 (C-2), 33.89 (C-11), 28.76 (C-8), 27.38 (CH_3), 27.05 (CH_3), 25.44 (C-9), 24.34 (C-10), 23.08 (C-*Si*), 20.44 (C-*Si*). ^{13}C-HMBC ($CDCl_3$, 125 MHz): 98.66 ($J_{C1,H1}$ = 173 Hz), 97.78 ($J_{C1,H1}$ = 174 Hz). MALDI-MS: Calculated for $C_{214}H_{220}N_{30}O_{52}Si$ $[M+Na]^+$: 4092.5160, found: 4092.4824.

Decasaccharide 58



The reaction was carried out according to the general procedure C using compound **57** (472 mg, 0.12 mmol) and HF/pyridine (70%, 48 µl, 1.85 mmol). The product was purified by column chromatography (DCM:EtOAc = 15:1-10:1). Compound **58** (450 g, 96% yield, pentane:EtOAc = 1:1, R*f* = 0.55-0.65) was obtained as yellow syrup. $[\alpha]_D^{25}$ +122.2 (c=1, $CHCl_3$). IR (neat, cm^{-1}) ν 1005, 1027, 1046, 1065, 1098, 1112, 1269, 1315, 1724, 2109, 2873, 2928, 3502. ^{1}H-NMR ($CDCl_3$, 500 MHz) δ 8.15 – 7.81 (m, 18H), 7.69 – 6.90 (m, 83H), 5.14 (d, *J* = 3.6 Hz, 1H, H-1B), 5.06 (s, 2H), 5.02 (d, *J* = 3.6 Hz, 1H, H-1C), 4.98 (d, *J* = 3.5 Hz, 1H, H-1A), 4.96 – 3.59 (m, 84H, 7xH-1), 3.51 – 3.33 (m, 3H, H-6^{j}, 7), 2.77 (bs, 1H, *O*H), 2.30 (t, *J* = 7.5 Hz, 2H, H-11), 2.10 (bs, 1H, *O*H), 1.68 – 1.49 (m, 4H, H-10, 8), 1.38 – 1.21 (m, 2H, H-9). ^{13}C NMR (125 MHz, $CDCl_3$) δ 173.27 (C-12), 165.90, 165.32, 165.27, 165.21 (C=O, Bz), 136.99, 136.81, 136.75, 136.73, 136.02, 133.38, 133.25, 133.20, 133.10, 129.60, 129.58, 129.54, 129.50, 129.46, 128.53, 128.50, 128.47, 128.44, 128.41, 128.39, 128.14, 128.09, 128.05, 127.92, 127.87, 127.84, 127.79, 127.58, 127.25, 127.18, 99.38 (C-1), 98.83 (C-1), 98.73 (C-1), 97.92 (C-1^{A}), 76.30, 75.42, 75.28, 75.17, 75.14, 73.65, 73.25, 72.90, 72.83, 72.73, 72.44, 72.36, 72.34, 72.27, 72.20, 71.71, 69.51, 68.74, 68.56, 68.14 (C-7), 67.44, 66.04 (CH_2*Ph*), 62.58, 62.53, 61.22, 61.08 (C-6), 60.36, 60.18, 59.72, 59.61 (C-2), 34.04 (C-11), 28.90 (C-8), 25.58 (C-9), 24.49 (C-10). MALDI-MS: Calculated for $C_{206}H_{204}N_{30}O_{52}$ $[M+Na]^+$: 3952.4139, found: 3952.3777.

Decasaccharide 59



The reaction was carried out according to the general procedure D using compound **58** (430 mg, 0.11 mmol), PhCOOBt (118 mg, 0.49 mmol) and Et_3N (76 µl, 0.55 mmol). The product was purified by column chromatography (DCM:EtOAc = 10:1). Compound **59** (420 mg, 94% yield, pentane:EtOAc:DCM = 5:2:1, R*f* = 0.30-0.40) was obtained as yellow syrup. $[\alpha]_D^{25}$ +135.5 (c=1, $CHCl_3$). IR (neat, cm^{-1}) ν 737, 1003, 1027, 1046, 1063, 1098, 1112, 1156, 1268, 1315, 1452, 1720, 2108, 2872, 2928. ^{1}H-NMR ($CDCl_3$, 500 MHz) δ 8.09 – 8.00 (m, 2H), 7.97 – 7.82 (m, 18H), 7.60 – 6.94 (m, 87H), 5.14 (d, *J* = 3.6 Hz, 1H, H-1^{B}), 5.06 (s, 2H), 5.02 (d, *J* = 3.6 Hz, 1H, H-1^{C}), 4.98 (d, *J* = 3.5 Hz, 1H, H-1^{A}), 4.96 – 4.55 (m, 29H, 7xH-1), 4.54 – 3.59 (m, 59H), 3.45 (dt, *J* = 9.8, 6.4 Hz, 1H, H-7), 2.48 (bs, 1H, *O*H), 2.30 (t, *J* = 7.4 Hz, 2H, H-11), 1.66 – 1.53 (m, 4H, H-10, 8), 1.36 – 1.27 (m, 2H, H-9). ^{13}C NMR (125 MHz, $CDCl_3$) δ 173.29 (C-12), 165.91, 165.85, 165.32, 165.27, 165.21, 165.17 (C=O, Bz), 137.11, 136.98, 136.81, 136.79, 136.76, 136.74, 136.01, 133.40, 133.26, 133.22, 133.13, 132.99, 129.73,

129.62, 129.59, 129.53, 129.50, 129.46, 128.54, 128.52, 128.47, 128.45, 128.43, 128.39, 128.24, 128.16, 128.11, 127.94, 127.88, 127.84, 127.80, 127.46, 127.23, 127.16, 99.06 (C-1), 98.85 (C-1), 98.74 (C-1), 97.93 (C-1^A), 76.28, 75.28, 75.19, 75.15, 75.03, 73.25, 72.91, 72.83, 72.78, 72.73, 72.44, 72.36, 72.26, 71.99, 68.74, 68.56, 68.15 (C-7), 67.97, 66.05 (CH_2*Ph*), 65.34 (C-4^J), 62.53, 62.13, 61.21, 61.06 (C-6), 60.36, 60.20, 59.72, 59.59 (C-2), 34.05 (C-11), 28.92 (C-8), 25.59 (C-9), 24.50 (C-10). MALDI-MS: Calculated for $C_{213}H_{208}N_{30}O_{53}$ $[M+Na]^+$: 4056.4401, found: 4056.4084.

Undecasaccharide 60

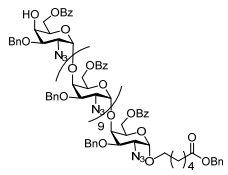
The reaction was carried out according to the general procedure B. The donor **2b** (180 mg, 0.30 mmol) and the acceptor **59** (400 mg, 0.10 mmol) were co-evaporated with toluene (three times). The residue was dissolved in 1 ml dry DCM under nitrogen and stirred over fresh flame-dried molecular sieves 4Å. The solution was cooled to 0 ºC, after which TfOH (1 µl, 0.01 mmol) was added. The reaction was stirred at 0 ºC for 1 h. Then the reaction was quenched with Et_3N, diluted with DCM, washed with saturated $NaHCO_3$ and brine. The organic phase was dried with anhydrous $MgSO_4$, filtered and concentrated *in vacuo*. The product was purified by silica gel column chromatography (DCM:EtOAc = 20:1). Compound **60** (315 mg, 73% yield, pentane:EtOAc:DCM = 21:5:5, R*f* = 0.35-0.45) was obtained as yellow syrup. $[\alpha]_D^{25}$ +134.8 (c=1, $CHCl_3$). IR (neat, cm^{-1}) ν 1005, 1046, 1065, 1112, 1269, 1315, 1452, 1724, 2109, 2860, 2931. ^{1}H-NMR ($CDCl_3$, 500 MHz) δ 8.02 (d, *J* = 7.8 Hz, 2H), 7.96 – 7.77 (m, 18H), 7.66 – 6.89 (m, 100H), 5.12 (d, *J* = 3.7 Hz, 1H, H-1B), 5.07 (s, 2H), 4.99 (d, *J* = 3.6 Hz, 1H, H-1^C), 4.97 (d, *J* = 3.7 Hz, 1H, H-1^A), 4.95 – 4.51 (m, 35H, 8xH-1), 4.53 – 3.72 (m, 58H), 3.72 – 3.57 (m, 12H), 3.56 – 3.41 (m, 2H), 2.30 (t, *J* = 5.6 Hz, 2H, H-11), 1.71 – 1.52 (m, 4H, H-10, 8), 1.39 – 1.24 (m, 2H, H-9), 1.01 – 0.85 (m, 18H, *C*H_3). ^{13}C NMR (125 MHz, $CDCl_3$) δ 173.02 (C-12), 165.73, 165.19, 165.15, 165.10 (C=O, Bz), 137.60, 136.90, 136.83, 136.70, 136.65, 135.95, 133.19, 133.06, 133.02, 132.95, 129.46, 129.42, 128.36, 128.34, 128.30, 128.26, 128.24, 128.00, 127.97, 127.92, 127.74, 127.69, 127.60, 127.48, 127.18, 127.09, 98.66 (C-1), 97.83 (C-1^A), 75.35, 75.22, 74.96, 74.61, 73.17, 72.73, 72.62, 72.35, 72.25, 72.16, 72.10, 71.85, 71.74, 70.10, 69.37, 68.67, 68.50, 68.02 (C-7), 67.53, 66.66 (C-6^k), 65.85 (CH_2*Ph*), 62.45, 61.19, 61.06 (C-6), 60.30, 59.65, 58.57 (C-2), 33.89 (C-11), 28.76 (C-8), 27.42 (CH_3), 27.10 (CH_3), 25.45 (C-9), 24.35 (C-10), 23.07 (C-*Si*), 20.46 (C-*Si*). ^{13}C-HMBC ($CDCl_3$, 125 MHz): 98.66 ($J_{C1,H1}$ = 172 Hz, 171Hz), 97.83 ($J_{C1,H1}$ = 173 Hz). MALDI-MS: Calculated for $C_{234}H_{239}N_{33}O_{57}Si$ $[M+Na]^+$: 4473.6485, found: 4473.6102.

Undecasaccharide 61

The reaction was carried out according to the general procedure C using compound **60** (300 mg, 69 µmol) and HF/pyridine (70%, 29 µl, 1.1 mmol). The product was purified by column chromatography (DCM:MeOH = 150:1). Compound **61** (244 mg, 84% yield, pentane:EtOAc = 1:1, R*f* = 0.25-0.35) was obtained as yellow syrup. $[\alpha]_D^{20}$ +138.7 (c=1, $CHCl_3$). IR (neat, cm^{-1}) ν 1047, 1112, 1271, 1316, 1452, 1724, 2109,

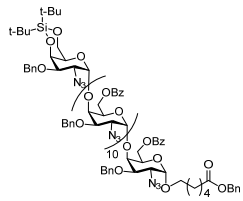
2873, 2929. ^{1}H-NMR ($CDCl_3$, 500 MHz) δ 8.08 – 8.00 (m, 2H), 7.95 – 7.84 (m, *J* = 7.5 Hz, 18H), 7.64 – 7.51 (m, 10H), 7.49 – 7.08 (m, 75H), 7.07 – 6.92 (m, 9H), 5.14 (d, *J* = 3.5 Hz, 1H, H-1^{B}), 5.06 (s, 2H), 5.03 (d, *J* = 3.6 Hz, 1H, H-1^{C}), 5.00 – 3.83 (m, 83H, 9xH-1), 3.79 (dd, *J* = 10.2, 3.0 Hz, 2H), 3.75 – 3.60 (m, 11H), 3.52 – 3.34 (m, 3H), 2.77 (s, 1H), 2.30 (t, *J* = 7.4 Hz, 2H, H-11), 2.08 (bs, *O*H), 1.67 – 1.53 (m, 4H, H-10, 8), 1.40 – 1.21 (m, 2H, H-9). ^{13}C NMR (125 MHz, $CDCl_3$) δ 173.25 (C-12), 165.89, 165.32, 165.27, 165.21 (C=O, Bz), 136.99, 136.98, 136.80, 136.74, 136.72, 136.01, 133.36, 133.23, 133.19, 129.59, 129.56, 129.53, 129.49, 129.46, 128.51, 128.49, 128.45, 128.43, 128.40, 128.37, 128.13, 128.08, 128.04, 127.90, 127.86, 127.83, 127.78, 127.58, 127.26, 127.18, 127.17, 99.37 (C-1), 98.82 (C-1), 98.71 (C-1), 97.92 (C-1^{A}), 77.36, 76.28, 75.41, 75.28, 75.14, 73.65, 73.25, 72.83, 72.72, 72.43, 72.35, 72.33, 72.26, 72.19, 71.69, 69.52, 68.75, 68.56, 68.14 (C-7), 67.43 (C-4^{K}), 66.02 (C*H$_2$Ph*), 62.58, 62.53, 61.22, 61.09 (C-6), 60.36, 60.18, 59.72, 59.61 (C-2), 34.03 (C-11), 28.89 (C-8), 25.57 (C-9), 24.48 (C-10). MALDI-MS: Calculated for $C_{226}H_{223}N_{33}O_{57}$ $[M+Na]^+$: 4333.5463, found: 4333.5101.

Undecasaccharide 62



The reaction was carried out according to the general procedure D using compound **61** (238 mg, 56.5 µmol), PhCOOBt (61 mg, 0.25 mmol) and Et_3N (39 µl, 0.28 mmol). The product was purified by column chromatography (DCM:Acetone = 200:1-50:1). Compound **62** (227 mg, 93% yield, DCM:Acetone = 50:1, R*f* = 0.30-0.40) was obtained as yellow syrup. $[\alpha]_D^{20}$ +152.7 (c=1, $CHCl_3$). IR (neat, cm^{-1}) ν 1047, 1098, 1112, 1271, 1315, 1452, 1724, 2111, 2872, 2928, 3510. ^{1}H-NMR ($CDCl_3$, 500 MHz) δ 8.03 (d, *J* = 7.7 Hz, 2H), 7.97 – 7.83 (m, 20H), 7.63 – 6.92 (m, 96H), 5.15 (d, *J* = 3.6 Hz, 1H, H-1^{B}), 5.06 (s, 2H), 5.03 (d, *J* = 3.6 Hz, 1H, H-1^{C}), 4.99 – 4.54 (m, 33H, 9xH-1), 4.53 – 3.57 (m, 66H), 3.51 – 3.39 (m, 1H, H-7), 2.30 (t, *J* = 7.4 Hz, 2H, H-11), 1.66 – 1.52 (m, 4H, H-10, 8), 1.38 – 1.28 (m, 2H, H-9). ^{13}C NMR (125 MHz, $CDCl_3$) δ 173.26 (C-12), 165.90, 165.85, 165.33, 165.28, 165.22, 165.18 (C=O, Bz), 137.12, 136.99, 136.81, 136.79, 136.76, 136.74, 136.02, 133.37, 133.24, 133.20, 133.11, 132.97, 129.74, 129.61, 129.58, 129.50, 129.47, 128.52, 128.50, 128.47, 128.44, 128.41, 128.38, 128.23, 128.14, 128.09, 127.93, 127.88, 127.84, 127.80, 127.49, 127.26, 127.20, 99.05 (C-1), 98.83 (C-1), 98.72 (C-1), 97.93 (C-1), 76.24, 75.29, 75.15, 75.00, 73.27, 72.91, 72.84, 72.75, 72.44, 72.37, 72.35, 72.27, 72.24, 71.97, 68.76, 68.73, 68.58, 68.15 (C-7), 68.00, 66.03 (C*H$_2$Ph*), 65.37 (C-4^{K}), 62.54, 62.18, 61.23, 61.08 (C-6), 60.37, 60.21, 59.73, 59.61 (C-2), 34.04 (C-11), 28.90 (C-8), 25.58 (C-9), 24.49 (C-10). MALDI-MS: Calculated for $C_{233}H_{227}N_{33}O_{58}$ $[M+Na]^+$: 4437.5725, found: 4437.5306.

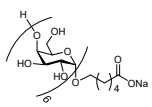
Dodecasaccharide 63



The reaction was carried out according to the general procedure B. The donor **2b** (94 mg, 0.16 mmol) and the acceptor **62** (223 mg, 0.05 mmol) were co-evaporated with toluene (three times). The residue was dissolved in 1 ml dry DCM under nitrogen and stirred over fresh flame-dried molecular sieves 4Å. The solution was cooled to 0 °C, after which TfOH (0.5 µl, 5.2 µmol) was added. The reaction was stirred at 0

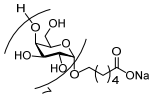
ºC for 1 h. Then the reaction was quenched with Et_3N, diluted with DCM, washed with saturated $NaHCO_3$ and brine. The organic phase was dried with anhydrous $MgSO_4$, filtered and concentrated *in vacuo*. The product was purified by silica gel column chromatography (DCM:EtOAc = 20:1). Compound **63** (194 mg, 79% yield, pentane:EtOAc:DCM = 21:5:5, R*f* = 0.35-0.45) was obtained as yellow syrup. $[\alpha]_D^{20}$ +140.7 (c=1, $CHCl_3$). IR (neat, cm^{-1}) ν 1003, 1027, 1046, 1065, 1112, 1269, 1452, 1724, 2109, 2869, 3932. ^{1}H-NMR ($CDCl_3$, 500 MHz) δ 8.05 – 7.99 (m, 2H), 7.94 – 7.81 (m, 20H), 7.62 – 7.51 (m, 11H), 7.50 – 6.91 (m, 94H), 5.12 (d, *J* = 3.6 Hz, 1H, H-1B), 5.07 (s, 2H), 4.99 (d, *J* = 3.6 Hz, 1H, H-1C), 4.96 (d, *J* = 3.6 Hz, 1H, H-1A), 4.94 – 4.52 (m, 36H, 9xH-1), 4.51 – 3.72 (m, 60H), 3.70 – 3.57 (m, 12H), 3.56 – 3.49 (m, 1H, H-6^I), 3.45 (dt, *J* = 9.8, 6.4 Hz, 1H, H-7), 2.30 (t, *J* = 7.5 Hz, 2H, H-11), 1.68 – 1.54 (m, 4H, H-10 ,8), 1.38 – 1.26 (m, 2H, H-9), 0.98 – 0.87 (m, 18H, *C*H_3). ^{13}C NMR (125 MHz, $CDCl_3$) δ 173.30 (C-12), 165.93, 165.35, 165.29, 165.25, 165.23 (C=O, Bz), 137.72, 137.00, 136.97, 136.83, 136.78, 136.04, 133.42, 133.29, 133.24, 133.21, 133.14, 129.64, 129.60, 129.52, 129.48, 128.56, 128.54, 128.49, 128.46, 128.42, 128.40, 128.19, 128.14, 127.91, 127.88, 127.81, 127.79, 127.53, 127.19, 127.15, 98.87 (C-1), 98.80 (C-1), 97.95 (C-1A), 77.36, 75.57, 75.46, 75.30, 75.19, 74.81, 73.27, 72.99, 72.93, 72.85, 72.75, 72.70, 72.47, 72.38, 72.29, 72.21, 71.97, 71.77, 70.28, 69.45, 68.75, 68.58, 68.18 (C-7), 67.63 (C-4^I), 66.79 (C-6^I), 66.08 (C*H*$_2$*Ph*), 62.54, 61.22, 61.09 (C-6), 60.38, 59.74, 58.66 (C-2), 34.08 (C-11), 28.94 (C-8), 27.56 (C*H*$_3$), 27.23 (C*H*$_3$), 25.62 (C-9), 24.53 (C-10), 23.26 (C-*Si*), 20.62 (C-*Si*). MALDI-MS: Calculated for $C_{254}H_{258}N_{36}O_{62}Si$ $[M+Na]^+$: 4854.7809, found: 4854.7480.

Hexasaccharide 64



(4.0 mg, 69% yield). The reaction was carried out according to the general procedure C and E. ^{1}H NMR (500 MHz, D_2O) δ 5.02 – 4.93 (m, 6H, 6xH-1), 4.41 – 4.33 (m, 4H, H-5), 4.29 (t, *J* = 6.5 Hz, 1H, H-5^B), 4.11 (d, *J* = 2.9 Hz, 4H, H-4), 4.05 (d, *J* = 3.2 Hz, 1H, H-4^B), 4.01 – 3.74 (m, 24H), 3.72 – 3.66 (m, 3H, H-6^F, H-7), 3.52 (dt, *J* = 9.8, 6.1 Hz, 1H, H-7), 2.16 (t, *J* = 7.4 Hz, 2H, H-11), 1.72 – 1.50 (m, 4H, H-8, H-10), 1.43 – 1.28 (m, 2H, H-9). ^{13}C NMR (125 MHz, D_2O) δ 183.95 (C-12), 100.45 (C-1), 100.35 (C-1), 100.28 (C-1), 98.25 (C-1^A), 78.81 (C-4^A), 78.52 (C-4^B), 78.43 (C-4), 71.17 (C-5), 71.03 (C-5), 70.94 (C-5), 69.12, 69.03, 68.90, 68.86, 68.80, 68.73, 68.54, 68.38, 68.29 (C-7), 60.50 (C-6), 60.35 (C-6), 59.87 (C-6), 59.70 (C-6), 37.47 (C-11), 28.35 (C-8), 25.57 (C-10), 25.32 (C-9). HR-MS: Calculated for $C_{42}H_{72}O_{33}$ $[M+H]^+$: 1105.4034, found: 1105.4029.

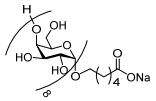
Heptasaccharide 65



(6.0 mg, 75% yield). The reaction was carried out according to the general procedure C and E. ^{1}H NMR (500 MHz, D_2O) δ 5.07 – 4.96 (m, 7H, H-1), 4.41 (m, 5H, H-5), 4.32 (t, *J* = 6.5 Hz, 1H, H-5^B), 4.14 (d, *J* = 2.9 Hz, 5H, H-4), 4.09 (d, *J* = 3.1 Hz, 1H, H-4^B), 4.06 – 3.77 (m, 29H), 3.75-3.66 (m, 3H, H-6^G, H-7), 3.56 (dt, *J* = 9.9, 6.2 Hz, 1H, H-7), 2.19 (t, *J* = 7.4 Hz, 11H), 1.71 - 1.52 (m, 4H, H-8, H-10), 1.43 – 1.33 (m, *J* = 6.3 Hz, 2H, H-9). ^{13}C NMR (125 MHz, D_2O) δ 184.06 (C-12), 100.58 (C-1), 100.48 (C-1), 100.41 (C-1), 98.38 (C-1^A), 78.94 (C-4), 78.66 (C-4), 78.58 (C-4), 71.29 (C-5), 71.19 (C-5), 71.13

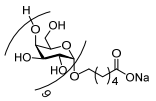
(C-5), 71.09 (C-5), 69.25, 69.17, 69.04, 69.00, 68.94, 68.87, 68.67, 68.52, 68.43 (C-7), 60.65 (C-6), 60.48 (C-6), 60.03 (C-6), 59.86 (C-6), 37.60 (C-11), 28.48 (C-8), 25.69 (C-10), 25.45 (C-9). HR-MS: Calculated for $C_{48}H_{82}O_{38}$ $[M+H]^+$: 1267.4562, found: 1267.4557.

Octasaccharide 66



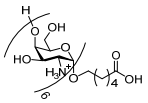
(2.5 mg, 25% yield). The reaction was carried out according to the general procedure C and E. ^{1}H NMR (500 MHz, D_2O) δ 5.07 – 4.95 (m, 8H, H-1), 4.40 (q, *J* = 5.9 Hz, 6H, H-5), 4.32 (t, *J* = 6.5 Hz, 1H, H-5^B), 4.18 – 4.11 (m, 6H, H-4), 4.08 (d, *J* = 3.2 Hz, 1H, H-4^B) 4.05 – 3.77 (m, 31H), 3.75 - 3.68 (m, 3H, H-6^H, H-7), 3.55 (dt, *J* = 9.9, 6.2 Hz, 1H, H-7), 2.18 (t, *J* = 7.4 Hz, 2H, H-11), 1.71 - 1.52 (m, 4H, H-8, H-10), 1.41-1.33 (m, 2H, H-9). ^{13}C NMR (125 MHz, D_2O) δ 184.05 (C-12), 100.55 (C-1), 100.45 (C-1), 98.35 (C-1^A), 78.91, 78.62, 78.54, 71.27, 71.14, 71.05, 69.21, 69.13, 69.00, 68.84, 68.64, 68.48, 68.39 (C-7), 60.60 (C-6), 60.45 (C-6), 59.98 (C-6), 59.81 (C-6), 37.57 (C-11), 28.45 (C-8), 25.66 (C-10), 25.42 (C-9). HR-MS: Calculated for $C_{54}H_{92}O_{43}$ $[M+H]^+$: 1429.5091, found: 1429.5085.

Nonasaccharide 67



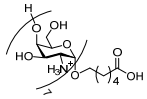
(3.5 mg, 29% yield). The reaction was carried out according to the general procedure C and E. ^{1}H NMR (500 MHz, D_2O) δ 5.04 (d, *J* = 4.0 Hz, 9H, H-1), 4.40 (t, *J* = 6.2 Hz, 7H, H-5), 4.32 (t, *J* = 6.5 Hz, 2H, H-5^B), 4.16 – 3.77 (m, 45H), 3.75 – 3.69 (m, 3H, H-6^C, H-7), 3.58 – 3.52 (m, 1H, H-7), 2.18 (t, *J* = 7.4 Hz, 2H, H-11), 1.68 - 1.53 (m, 4H, H-8, H-10), 1.44 - 1.32 (m, 2H, H-9). ^{13}C NMR (125 MHz, D_2O) δ 183.45 (C-12), 100.46 (C-1), 98.37 (C-1), 78.94, 78.57, 71.17, 69.24, 69.04, 68.86, 68.66, 68.51, 68.42, 60.64, 60.47, 60.02, 59.85, 37.59, 28.47, 25.68, 25.44, 23.32. HR-MS: Calculated for $C_{60}H_{102}O_{48}$ $[M+H]^+$: 1591.5619, found: 1591.5613.

Hexasaccharide 68



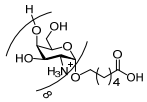
(7.3 mg, 67% yield). The reaction was carried out according to the general procedure C and E. ^{1}H NMR (500 MHz, D_2O) δ 5.48-5.31 (m, 5H, H-1), 5.23 (d, *J* = 3.8 Hz, 1H, H-1^A), 4.58 – 4.44 (m, 5H, H-5), 4.35 – 4.11 (m, 13H), 4.10 - 4.02 (m, 3H), 3.95 – 3.54 (m, 24H), 2.41 (t, *J* = 7.3 Hz, 2H, H-11), 1.73 – 1.59 (m, 4H, H-8, H-10), 1.48 - 1.35 (m, 2H, H-9). ^{13}C NMR (125 MHz, D_2O) δ 179.41 (C-12), 96.04 (C-1), 95.95 (C-1), 95.89 (C-1), 95.28 (C-1^A), 76.46 (C-4), 76.31 (C-4), 71.44 (C-5^F), 70.55 (C-5), 70.52 (C-5), 70.44 (C-5), 68.47 (C-7), 67.90, 66.36, 65.99, 65.84, 60.74 (C-6), 60.57 (C-6), 60.34 (C-6), 60.28 (C-6), 51.05 (C-2), 50.91 (C-2), 50.83 (C-2), 33.93 (C-11), 28.28 (C-8), 24.94 (C-10), 24.10 (C-9). HR-MS: Calculated for $C_{42}H_{78}N_6O_{27}$ $[M+2H]^{2+}$: 550.25357, found: 550.25302.

Heptasaccharide 69



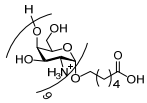
(7.6 mg, 56% yield). The reaction was carried out according to the general procedure C and E. ^{1}H NMR (500 MHz, D_2O) δ 5.45 - 5.29 (m, 6H, H-1), 5.21 (d, *J* = 3.8 Hz, 1H, H-1^{A}), 4.56 – 4.41 (m, 6H, H-5), 4.36 – 4.16 (m, 12H), 4.16 – 3.99 (m, 5H), 3.89 – 3.70 (m, 21H), 3.65 (dd, *J* = 11.1, 3.8 Hz, 1H), 3.62 - 3.52 (m, 3H, H-2, H-7), 2.39 (t, *J* = 7.3 Hz, 2H, H-11), 1.72 – 1.58 (m, 4H, H-8, H-10), 1.46 – 1.37 (m, 2H, H-9). ^{13}C NMR (125 MHz, D_2O) δ 179.48 (C-12), 96.03 (C-1), 95.93 (C-1), 95.87 (C-1), 95.26 (C-1^{A}), 76.44 (C-4), 76.29 (C-4), 76.27 (C-4), 71.43 (C-5^{G}), 70.55 (C-5), 70.50 (C-5), 70.45 (C-5), 68.46 (C-7), 67.87, 66.35, 66.31, 65.98, 65.83, 60.71 (C-6), 60.55 (C-6), 60.32 (C-6), 60.25 (C-6), 51.04 (C-2), 50.90 (C-2), 50.81 (C-2), 33.96 (C-11), 28.26 (C-8), 24.93 (C-10), 24.10 (C-9). HR-MS: Calculated for $C_{48}H_{89}N_7O_{31}$ $[M+2H]^{2+}$: 630.78798, found: 630.78743.

Octasaccharide 70



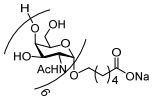
(7.1 mg, 66% yield). The reaction was carried out according to the general procedure C and E. ^{1}H NMR (500 MHz, D_2O) δ 5.30 (dd, *J* = 24.1, 3.8 Hz, 7H, H-1), 5.14 (d, *J* = 3.9 Hz, 1H, H-1^{A}), 4.50 - 4.43 (m, 5H), 4.39 (t, *J* = 6.4 Hz, 2H), 4.27 – 4.10 (m, 16H), 4.06 (dd, *J* = 11.0, 3.1 Hz, 2H), 3.98 (dd, *J* = 12.3, 4.2 Hz, 4H), 3.83 – 3.45 (m, 32H), 2.32 (t, *J* = 7.3 Hz, 2H, H-11), 1.65 – 1.51 (m, 4H, H-10, 8), 1.39 – 1.29 (m, 2H, H-9). ^{13}C NMR (125 MHz, D_2O) δ 179.14 (C-12), 95.98 (C-1), 95.90 (C-1), 95.84 (C-1), 95.24 (C-1), 76.41, 76.26, 71.39, 70.49, 70.42, 68.42, 67.85, 66.31, 65.94, 65.79, 65.73, 60.71, 60.52, 60.29, 60.24, 60.20, 51.00, 50.86, 50.78, 33.70 (C-11), 28.24 (C-8), 24.88 (C-10), 23.98 (C-9). HR-MS: Calculated for $C_{54}H_{100}N_8O_{35}$ $[M+3H]^{3+}$: 474.55086, found: 474.55031.

Nonasaccharide 71



(9.0 mg, 55% yield). The reaction was carried out according to the general procedure C and E. ^{1}H NMR (500 MHz, D_2O) δ 5.45 – 5.31 (m, 8H, H-1), 5.22 (d, *J* = 3.8 Hz, 1H, H-1), 4.58 – 4.44 (m, 8H), 4.38 – 3.99 (m, 23H), 3.90 – 3.70 (m, 28H), 3.66 (dd, *J* = 11.0, 3.8 Hz, 2H), 3.58 (dt, *J* = 9.7, 3.0 Hz, 3H), 2.40 (t, *J* = 7.3 Hz, 2H, H-11), 1.72 – 1.58 (m, 4H, H-10, 8), 1.47 – 1.37 (m, 2H, H-9). ^{13}C NMR (125 MHz, D_2O) δ 179.65 (C-12), 96.03 (C-1), 95.94 (C-1), 95.27 (C-1), 76.46, 76.29, 71.44, 70.52, 70.46, 68.47, 67.89, 66.36, 65.99, 65.84, 60.73, 60.56, 60.33, 60.27, 51.05, 50.91, 50.83, 34.01 (C-11), 28.27 (C-8), 24.94 (C-10), 24.13 (C-9). HR-MS: Calculated for $C_{60}H_{111}N_9O_{39}$ $[M+3H]^{3+}$: 528.24046, found: 528.23991.

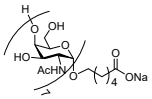
Hexasaccharide 72



(5.0 mg, 44% yield). The reaction was carried out according to the general procedure C and E. ^{1}H NMR (500 MHz, D_2O) δ 5.09 – 4.92 (m, 6H, H-1), 4.44 - 4.36 (m, 5H, H-5), 4.35 - 4.36 (m, 4H), 4.26 – 4.20 (m, 2H), 4.19 – 3.99 (m, 13H), 3.76 - 3.62 (m, 13H), 3.53 - 3.45 (m, 1H, H-7), 2.20 (t, *J* = 7.4 Hz, 2H, H-11), 2.13 – 2.02 (m, 18H, *C*H$_3$), 1.64 - 1.52 (m, 4H, H-8, H-10), 1.44 – 1.32 (m, 2H, H-9). ^{13}C NMR (125 MHz, D_2O) δ 183.99 (C-12), 174.75 (C=O, Ac), 174.66 (C=O, Ac), 174.60 (C=O, Ac), 98.42 (C-1), 98.28 (C-1), 96.96 (C-1^{A}), 76.95 (C-4), 76.59 (C-4), 76.39 (C-4), 71.68 (C-5), 71.47 (C-5), 71.38 (C-5), 70.83

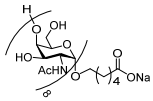
(C-5), 68.38, 68.32 (C-7), 67.30, 67.19, 66.82, 66.74, 66.64, 60.63 (C-6), 60.55 (C-6), 59.73 (C-6), 59.60 (C-6), 50.42 (C-2), 50.30 (C-2), 37.62 (C-2), 28.38 (C-11), 25.66 (C-8), 25.46 (C-10), 22.01 (C-9), 21.97 (CH_3). HR-MS: Calculated for $C_{54}H_{90}N_6O_{33}$ $[M+H]^+$: 1351.5627, found: 1351.5622.

Heptasaccharide 73



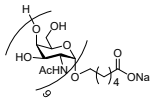
(6.6 mg, 47% yield). The reaction was carried out according to the general procedure C and E. ^{1}H NMR (500 MHz, D_2O) δ 5.08 – 4.90 (m, 7H, H-1), 4.46 – 4.33 (m, 6H), 4.33 – 4.25 (m, 5H), 4.24 – 4.18 (m, 3H), 4.18 – 4.08 (m, 9H), 4.07 – 3.96 (m, 7H), 3.80 – 3.57 (m, 17H), 3.52 – 3.45 (m, 1H), 2.18 (t, *J* = 7.4 Hz, 2H), 2.11 – 2.00 (m, 20H), 1.66 – 1.52 (m, 4H), 1.42 – 1.30 (m, 2H). ^{13}C NMR (125 MHz, D_2O) δ 183.97 (C-12), 174.74, 174.65, 174.58 (C=O, Ac), 98.40 (C-1), 98.27 (C-1), 96.95 (C-1), 76.95, 76.57, 76.38, 76.32, 71.65, 71.44, 71.34, 70.79, 68.32, 68.30, 67.27, 67.17, 66.79, 66.71, 66.61, 60.58, 60.53, 59.70, 59.57, 50.39, 50.27, 50.21, 37.60, 28.37, 25.64, 25.45, 22.00, 21.95. HR-MS: Calculated for $C_{62}H_{103}N_7O_{38}$ $[M+H]^+$: 1554.6421, found: 1554.6415.

Octasaccharide 74



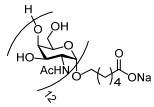
(6.8 mg, 46% yield). The reaction was carried out according to the general procedure C and E. ^{1}H NMR (500 MHz, D_2O) δ 5.05 – 4.90 (m, 8H, H-1), 4.43 – 4.31 (m, 7H), 4.31 – 4.23 (m, 6H), 4.22 – 4.16 (m, 3H), 4.16 – 4.06 (m, 11H), 4.04 – 3.95 (m, 6H), 3.75 – 3.53 (m, 16H), 3.50 – 3.43 (m, 1H), 2.16 (t, *J* = 7.4 Hz, 2H), 2.08 – 1.98 (m, 24H), 1.64 – 1.50 (m, 4H), 1.39 – 1.29 (m, 2H). ^{13}C NMR (125 MHz, D_2O) δ 183.97 (C-12), 174.70, 174.60, 174.58, 174.53 (C=O, Ac), 98.35 (C-1), 98.24 (C-1), 98.21 (C-1), 96.90 (C-1), 76.89, 76.49, 76.30, 76.23, 71.59, 71.35, 71.26, 70.72, 68.25, 68.23, 67.22, 67.11, 66.73, 66.65, 66.55, 60.49, 59.61, 59.48, 50.31, 50.21, 50.15, 37.56, 28.33, 25.61, 25.41, 21.94, 21.90. HR-MS: Calculated for $C_{70}H_{116}N_8O_{43}$ $[M+H]^+$: 1757.7214, found: 1757.7209.

Nonasaccharide 75



(10 mg, 62% yield). The reaction was carried out according to the general procedure C and E. ^{1}H NMR (500 MHz, D_2O) 5.09 – 4.91 (m, 9H, H-1), 4.47 – 3.93 (m, 39H), 3.78 – 3.57 (m, 21H), 3.54 – 3.45 (m, 1H), 2.18 (t, *J* = 7.4 Hz, 2H), 2.12 – 2.00 (m, 26H), 1.67 – 1.51 (m, 4H), 1.43 – 1.31 (m, 2H). ^{13}C NMR (125 MHz, D_2O) δ 183.97 (C-12), 174.73, 174.64, 174.62, 174.57 (C=O, Ac), 98.40 (C-1), 98.28 (C-1), 96.94 (C-1), 76.94, 76.56, 76.37, 76.31, 71.64, 71.42, 71.33, 70.77, 68.31, 68.29, 67.26, 67.16, 66.78, 66.70, 66.61, 60.56, 60.52, 59.69, 59.55, 50.36, 50.26, 50.20, 37.59, 28.36, 25.64, 25.44, 21.99, 21.95. HR-MS: Calculated for $C_{78}H_{129}N_9O_{48}$ $[M+2H]^{2+}$: 980.90433, found: 980.90377.

Dodecasaccharide 76



(7.2 mg, 54% yield). The reaction was carried out according to the general procedure C and E. ^{1}H NMR (500 MHz, D_2O) δ 5.08 – 4.87 (m, 12H, H-1), 4.43 – 3.92 (m, 49H), 3.74 – 3.54 (m, 25H), 3.50 – 3.42 (m, 1H), 2.15 (t, *J* = 7.4 Hz, 2H, H-11), 2.10 – 1.95 (m, 36H, CH_3), 1.60 – 1.49 (m, 4H, H-10, 8), 1.38 – 1.30 (m, 2H, H-9). ^{13}C NMR (125 MHz, D_2O) δ 183.86 (C-12), 174.60, 174.51, 174.44 (C=O, Ac), 128.71, 128.20, 128.03, 98.26, 98.14, 96.81, 76.80, 76.40, 76.21, 71.50, 71.17, 70.63, 68.16, 68.14, 67.13, 67.02, 66.56, 60.40, 59.52, 59.38, 50.21, 50.12, 50.06, 37.46, 28.24, 25.51, 25.31, 21.85, 21.81. HR-MS: Calculated for $C_{102}H_{168}N_{12}O_{63}$ $[M+2H]^{2+}$: 1285.52338, found: 1285.52283.

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Chapter 3

Synthesis of GAG hetero-oligomers featuring α-galactose, α-galactosamine and α-*N*-acetyl galactosamines linkages

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Introduction

Galactosaminogalactan (GAG), a heteropolysaccharide that is bound to and secreted by the hyphae of *Aspergillus fumigatus,* has been identified as an important factor during infection and invasion of this pathogen into the host. It is not only required for biofilm formation and adherence of the fungus to host cells, but GAG also hides the immunostimulatory β-glucans from the host immune system and inhibits the generation of proinflammatory T-helper 1 and T-helper 17 cytokines.[1-6] Given the multiple roles that GAG plays in pathogenesis, the biosynthetic pathway of GAG is a promising target for the development of novel antifungal therapies. Sheppard's group proposed a biosynthesis route through gene disruption and structural and biochemical studies.[1, 7] At the start of the biosynthesis the cytosolic enzyme glucose-4 epimerase (Uge3) transforms UDP-*N*-GlcNAc

and UDP-Glc into UDP-*N*-GalNAc and UDP-Gal. It is postulated that the glycosyl transferase Gtb3 uses these substrates for linking of the saccharides and subsequent export of the polymer to the extracellular space. Three other enzymes with carbohydrate modifying capacity were discovered of which the hydrolases Sph3 and Ega3 seem to be involved in the export of the mature GAG polymer. Lastly, the enzyme Agd3 deacetylates GalNAc residues in the secreted GAG polymer, a process that is required for adhesion to the surface of hyphae and biofilm formation.

To deepen the insight of the biosynthesis of GAG at the molecular level and characterize the enzymes involved therein, well-defined fragments of GAG polymers are indispensable tools. Chapter 2 described the successful synthesis of homo-oligomers of Gal, GalN and GalNAc up to a dodecasaccharide by application of Kiso's di-*tert*-butylsilyene (DTBS)-directed α-selective galactosylation methodology.[8-15] The Gal, GalN and GalNAc constituents are interconnected through 1,4-*cis* glycosidic linkages but their distribution in the GAG polymer is unknown. It is likely that this structural variation is important for the interaction with both fungal biosynthesis enzymes and the host immune system. On this basis attention was focused on the construction of four sets of α-1,4 linked hetero-oligomers composed of: (i) GalN and GalNAc, (ii) Gal, GalN and GalNAc, (iii) Gal and GalN, (iv) Gal and GalNAc (Figure 1). To enable the assembly of these hetero-oligosaccharides, the same methodology as outlined in Chapter 2 will be used, requiring the availability of glycosyl donors **1**, **2** and **3** as well as the hexanoic acid spacer. The Gal donor **1** and $GalN_3$ donor **2** will serve as precursors for Gal and GalN, respectively. The trichloroacetamide donor **3**, the neighboring-group participation capacity of which is lost by the presence of the 4,6-O-DTBS group, will be used for the introduction of α-GalNAc moieties.

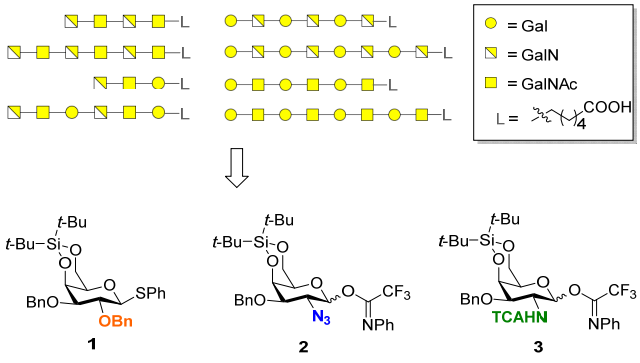


Figure 1. The designed GAG hetero-oligomers and building blocks utilized to prepare the GAG fragment library.

Results and discussion

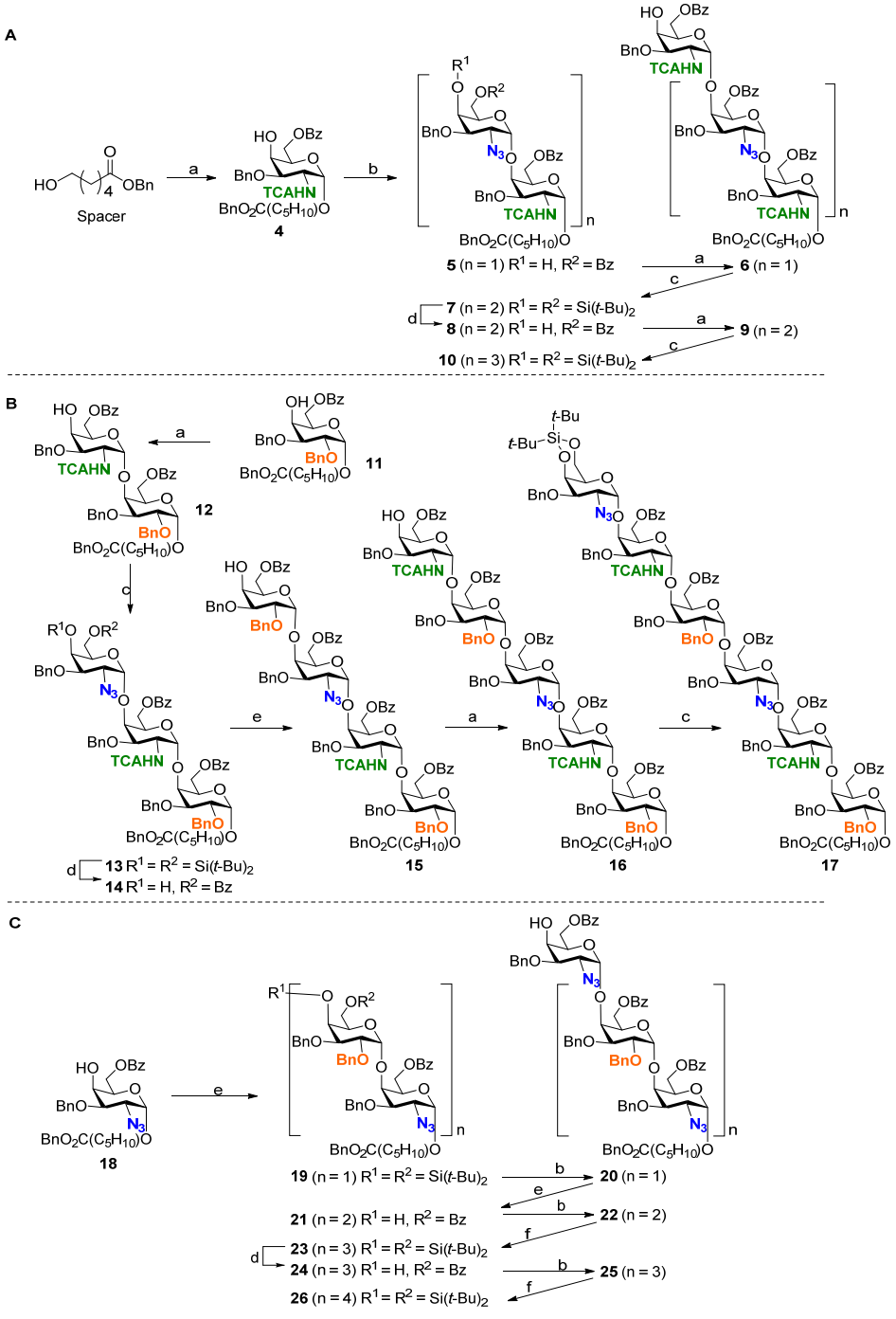
The projected GAG oligomers were constructed by the same elongation cycle as described in Chapter 2, comprising the following three reactions: 1) DTBS-directed glycosylation; 2) DTBS-removal with HF/pyridine and 3) selective benzoylation of the primary alcohol group with benzoyl-hydroxybenzotriazole (BzOBt) as a mild acylating agent[16].

The assembly of hetero-oligomers containing alternating $GalN_3$ and GalNTCA is depicted in Scheme 1A. The synthesis of the fully protected oligomers **7** and **10** started with the triflic acid mediated condensation of the GalNTCA-donor **3** with the spacer benzyl 6-hydroxyhexanoate. Even though donor **3** is equipped with a C-2-trichloroacetamide group, intrinsically capable of neighboring group participation, the α-linked product was selectively formed (94% yield, α/β = 8:1) when the reaction was performed at 0 °C. Lowering the temperature to -20 °C increased the selectivity to 14:1 (α/β). The α-linked product was then transformed into the C4-OH acceptor **4**, using the desilylation-benzoylation sequence as described above. Next, the $GalN_3$-GalNTCA dimer **5** was obtained by coupling of **4** with $GalN_3$ donor **2**, followed by protective group manipulation in which DTBS is replaced by the benzoyl at the C6-OH (80% yield over three steps). Repetition of the elongation cycle, using alternatively GalNTCA donor **3** and $GalN_3$ donor **2** in the coupling step afforded after two cycles tetrasaccharide **7** and after another two cycles hexasaccharide **10**.

The assembly of hetero-oligomers containing alternating Gal, GalNTCA and $GalN_3$ is depicted in Scheme 1B. Fully protected hexasaccharide **17** was synthesized using donors **1**, **2** and **3** in combination with the above-described elongation cycle. Thus, spacer containing acceptor Gal acceptor **11** (See Chapter 2) in combination with GalNTCA donor **3** delivered Gal-GalNTCA dimer **12**. Elongation of this dimer with $GalN_3$ **2** delivered the trisaccharide **14**, featuring the three structural C2 modifications. Similar elongation of **14**, using consecutively donors **1**, **3** and **2** in the coupling step furnished the fully protected hexasaccharide **17**.

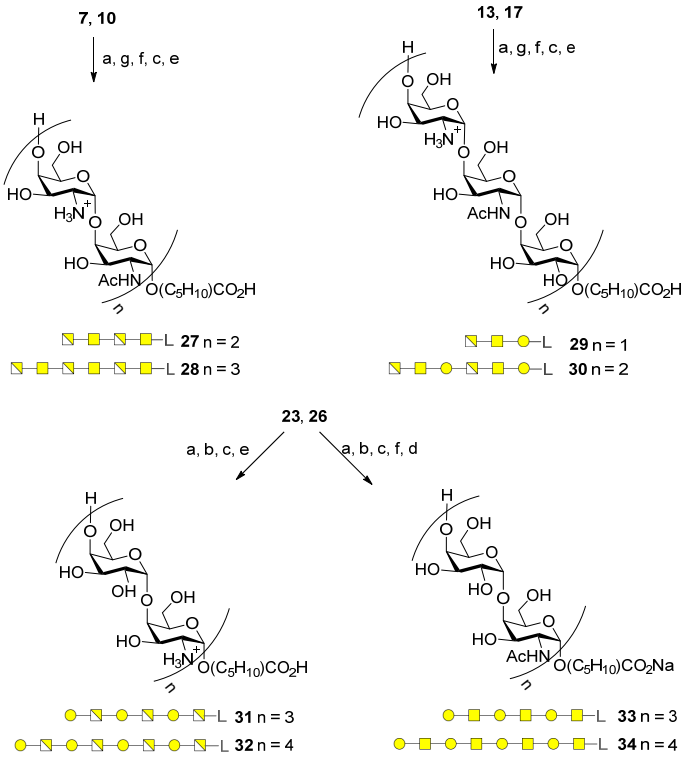
The remaining two sets of oligomers featuring Gal and GalN or Gal and GalNAc are accessible from the same protected oligomers, the synthesis route of which is shown in Scheme 1C. Known $GalN_3$ acceptor **18** (Chapter 2) was coupled with Gal donor **1**, affording the Gal-$GalN_3$ dimer **19** in 77% yield. After the same two step protecting group manipulation sequence, dimer **20** was elongated seven times, using the same cycle with consecutively $GalN_3$ donor **2**, and Gal donor **1** in the coupling step. All elongations, including the cycles to the protected hexamer **23** and octamer **26,** containing 3 and 4 Gal-$GalN_3$ repeating units

proceeded uneventfully, showing the chemistry developed to be applicable to any type of GAG-target.



Scheme 1. Synthesis of heteropolymers of Gal, $GalN_3$ and GalNTCA. a) i) **3**, TfOH, 4Å MS, DCM, 0 °C; ii) HF/pyridine (70%), THF, rt; iii) BzOBt, Et_3N, DCM, rt, yields (over 3 steps) for **4**: 70% or 69% (-20 °C); for **6**: 76%; for **9**: 78%; for **12**: 78%; for **16**: 63%. b) i) **2**, TfOH, 4Å MS, DCM, 0 °C; ii) HF/pyridine (70%), THF, rt; iii) BzOBt, Et_3N, DCM, rt, yields (over 3 steps) for **5**: 80%; for **20**: 83%; for **22**: 80%; for 2**5**: 79%. c) **2**, TfOH, 4Å MS, DCM, 0 °C, for **7**: 91%; for **10**: 86%; for **13**: 86%; for **17**: 73%. d) i) HF/pyridine (70%), THF, rt; ii) BzOBt, Et_3N, DCM, rt, yields (over 2 steps) for **8**: 86%; for **14**: 88%; for **24**: 91%. e) i) **1**, NIS, TfOH, 4Å MS, DCM, 0 °C, 87%; ii) HF/pyridine (70%), THF, rt, 97%; iii) BzOBt, Et_3N, DCM, rt, yields (over 3 steps) for **15**: 92%; for **19**: 77%; for **21**: 75%. f) **1**, NIS, TfOH, 4Å MS, DCM, 0 °C, for **23**: 82%; for **26**: 80%.

With all protected GAG hetero-oligomers available attention was directed to the removal of all protecting groups in each type of GAG oligomer (Scheme 2). The GalN-GalNAc tetra- and hexasaccharide **27** and **28**, were obtained from the fully protected $GalN_3$-GalNTCA tetramer **7** and hexamer **10** in 34% and 44% yield, respectively by the following sequence of events; 1) removal of the silylidene ketal, 2) saponification of the benzoates, benzyl ester and trichloroacetamides, 3) acetylation of the exposed amines, 4) hydrogenolysis of the benzyl ethers and reduction of the azides, 5) ion exchange to give the ammonium function chloride counterions. Next, the GalN-GalNAc-Gal-trisaccharide **29** and hexasaccharide **30** were generated in 68% and 65% yield, respectively from the fully protected progenitors **13** and **17** using the same deprotection procedure. Finally, the fully protected Gal-$GalN_3$ hexamer **23** and octamer **26** were subjected to the following four steps: 1) removal of the silylidene ketal; 2) saponification of the benzoates and benzyl ester; 3) hydrogenolysis the benzyl ethers and reduction of the azides; and 4) ion exchange, delivering **31** and **32** in 62% and 55% yield respectively. The corresponding Gal-GalNAc oligomers were also generated from Gal-$GalN_3$ hexamer **23** and octamer **26**, by acetylation of the released amines after the third reaction to afford **33** and **34** in 54% and 59%, respectively, after an ion exchange.



Scheme 2. Deprotection of synthesized oligosaccharides. a) HF/pyridine (70%), THF, 0 °C to rt; b) 1M NaOH, THF, MeOH; c) $Pd(OH)_2/C$, THF/H_2O/*t*-BuOH, H_2; d) Dowex-Na^+, **33**: 54%; **34**: 59%. e) Amberlite Cl form, **27**: 34%; **28**: 44%; **29**: 68%; **30**: 65%; **31**: 62%; **32**: 55%. f) Ac_2O, $NaHCO_3$, H_2O/THF, g) 2M NaOH, THF, MeOH.

In the groups of Sheppard and Howell, the GAG oligomers, described above and in the previous Chapter, have been used to investigate the glycosidases and deacetylase involved in the GAG-biosynthetic pathway. The α-1,4-GalNAc hexamers and heptamers were treated with the Sph3 hydrolase to determine the minimum substrate length that can be cleaved by $Sph3_h$ and the degradation products were analyzed by MALDI-TOF MS fingerprinting.[17] As shown in Figure 2B and 2C, GalNAc heptasaccharides but not hexamers were rapidly hydrolyzed by the enzyme $Sph3_h$, indicating that the minimum substrate size of the hydrolase Sph3 is seven. Hydrolysis of GalNAc heptamer by $Sph3_h$ resulted in the accumulation of pentasaccharides (Figure 2C), suggesting that it functions as an endo-α-1,4-*N*-acetylgalactosaminidase. In contrast, Ega 3 was shown to be only capable of cleaving GalN linkages and a 24-h treatment of α-1,4-$(GalN)_9$ with Ega3 resulted in the disappearance of this nonamer and emergence of trisaccharide products suggesting that Ega3 also acts as

endoglycosidase (Figure 2D).[18] Figure 2E shows the substrate specificity of the deacetylase Agd3 using the synthesized GAG oligosaccharides.[3] No statistically significant difference was found between the binding of $(GalNAc)_6$ and $(GalNAc)_7$, suggesting that the binding site spans six or fewer residues. Agd3 binding of $(Gal)_6$ was negligible, suggesting that Agd3 is specific for regions of the GAG polymer that are GalNAc/GalN rich. Interestingly, there was slight, but significant, higher affinity for a mixed GalN-GalNAc oligosaccharide (Ka 400 ± 90M^{-1}). This finding suggests that partial deacetylation of the polymer could lead to higher affinity, and hence accelerated deacetylation after the initial deacetylation events have occurred.

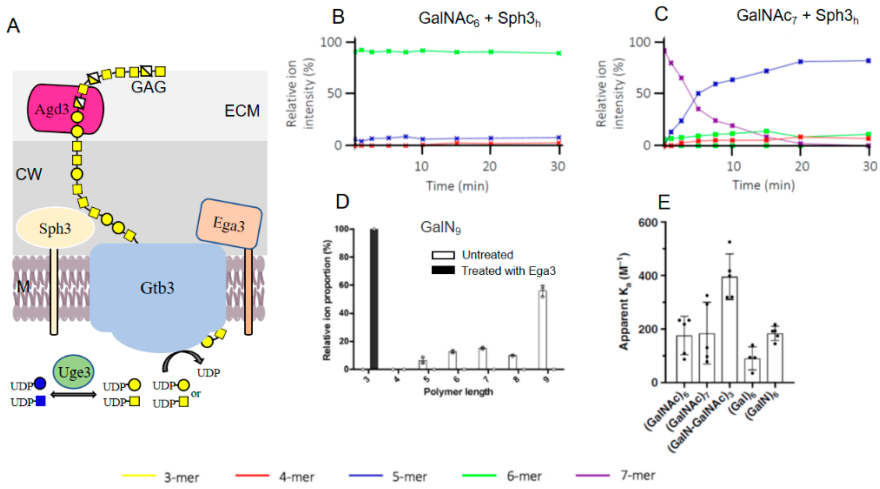


Figure 2. A) Biosynthetic pathway of GAG polysaccharide. B) $Sph3_h$ degradation kinetic of α-1,4-GalNAc 6-mers. C) $Sph3_h$ degradation kinetics of α-1,4-GalNAc 7-mers. D) MS analyses of α-1,4-GalNAc 9-mers before (*white bars*) and after treatment with 10_M Ega3 for 24 h (*black bars*). E) Apparent K_a (M^{-1}) for Agd3 for α-1,4-linked carbohydrate ligands determined by a direct ESI-MS assay.

Conclusion

In conclusion, the palette of GAG homo-oligomers was significantly expanded by the assembly of GAG hetero-oligomers incorporating all possible natural structural variations. The developed strategy, based on the use of silylidene protected Gal or GalN donors proved to be effective for the introduction of all required *cis*- Gal/GalN linkages in a highly stereoselective manner. These synthetic GAG fragments have allowed to map substrate specificities of the enzymes Sph3, Ega3 and Agd3 involved in the biosynthetic pathway of GAG. Sph3 and Ega3 were found to be endoglycosidases, with the former cleaving *N*-acetylgalactosamine linkages and the latter only capable of hydrolysing galactosamine linkages. The deacetylase Agd3 is specific for GAG polymers and has higher affinity for partially deacetylated polymers. The chemistry described here may be used to generate fluorogenic substrates that can be used in the discovery of inhibitors of these enzymes and in the conception of endo-galactosaminidase probes and inhibitors to further explore and exploit the GAG-biomachinery in the development of anti-fungal agents.

Experimental section

General procedure for glycosylation with thiodonor 1 (procedure A)

The donor (1.5 – 3.0 eq) and the acceptor (1.0 eq) were co-evaporated with toluene (three times). The residue was dissolved in dry DCM (0.1 M acceptor in DCM) under nitrogen and stirred over fresh flame-dried molecular sieves 3Å. The solution was cooled to 0 ºC, after which NIS (2.0 – 6.0 eq) and TfOH (0.1 – 0.3 eq) were added. The reaction was stirred at 0 ºC until TLC-analysis showed complete conversion of the acceptor. The reaction was quenched with saturated $Na_2S_2O_3$, diluted with DCM, washed with saturated $NaHCO_3$ and brine. The organic phase was dried with anhydrous $MgSO_4$, filtered and concentrated *in vacuo*. The products were purified by silica gel column chromatography (See experimental description below for eluent system).

General procedure for glycosylation with imidate donors (2, 3) (procedure B)

The donor (1.5 – 3.0 eq) and acceptor (1.0 eq) were co-evaporated with toluene (three times). The residue was dissolved in dry DCM (0.1 M acceptor in DCM) under nitrogen and stirred over fresh flame-dried molecular sieves 4Å. The solution was cooled to 0 ºC, after which TfOH (0.1 – 0.3 eq) was added. The reaction was stirred at 0 ºC until TLC-analysis showed complete conversion of the acceptor. The reaction was quenched with Et_3N, diluted with DCM, washed with saturated $NaHCO_3$ and brine. The organic phase was dried with anhydrous $MgSO_4$, filtered and concentrated *in vacuo*. The products were purified by silica gel column chromatography (See experimental description below for eluent system).

General procedure for the deprotection of di-*tert*-butyl silylidene group (general procedure C)

HF/pyridine (16 eq) solution was added to a solution of starting material in THF at 0 ºC. The reaction was warmed to room temperature and stirred until TLC-analysis indicated full consumption of the starting material (± 1h). Then the mixture was diluted with DCM and washed with saturated $NaHCO_3$ and brine, dried with anhydrous $MgSO_4$, filtered and concentrated *in vacuo*. The product was purified by silica gel column chromatography (See experimental description below for eluent system).

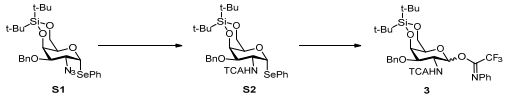
General procedure for selective benzoylation of primary alcohol (general procedure D)

PhCOOBt (4.5 eq) and Et_3N (5.0 eq) were added to the solution of starting material in DCM (0.05 M). The reaction was allowed to stirred overnight at room temperature. Then the mixture was diluted with DCM and washed with saturated $NaHCO_3$ and brine, dried with anhydrous $MgSO_4$, filtered and concentrated *in vacuo*. The product was purified by silica gel column chromatography (See experimental description below for eluent system).

General procedure for saponification and hydrogenation of the oligosaccharides (general procedure E)

1 M NaOH solution was added to the mixture of the starting material in THF/MeOH (2 ml/0.9 ml) at 0 ºC. The solution was warmed to room temperature slowly and stirred overnight. The reaction was cooled to 0 ºC and neutralized by Amberlite IR120 (H+) resin. After filtration, the filtrate was concentrated *in vacuo*. The residue was dissolved in THF/H_2O/*tert*-BuOH (2 ml/2 ml/0.8 ml) before a catalytic amount of $Pd(OH)_2/C$ was added. The reaction mixture was stirred for 3 days under a H_2 atmosphere, filtered and concentrated *in vacuo*. A white powder was obtained, which was purified by gel filtration (HW-40, 0.15M NH_4OAc in H_2O). The products were transformed into the sodium salts over a short Dowex Na^+ column or chloride salts in the mixture of Ambelite (Cl form) and water, after which the compounds were lyophilized.

Experimental Procedures and Characterization Data of Products



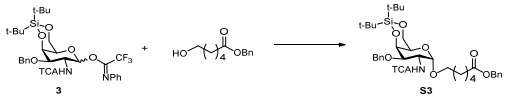
Phenyl 3-*O*-benzyl-2-deoxy-1-seleno-4,6-di-*tert*-butylsilylidene-2-trichloroacetamido-α-D-galactopyranoside (S2)

1,3-Dithiolpropane (5.1 ml, 51 mmol) and trimethylamine (5.9 ml, 42.5 mmol) were added to the solution of compound **S1** in pyridine/water (32 ml/8ml). The mixture was protected from light and stirred at room temperature overnight. The fluent was evaporated and co-evaporated with toluene. The residue was dissolved in 30 ml pyridine, after which TCACl (1.4 ml, 12.8 mmol) was added at 0 ºC. The reaction was slowly warmed to room temperature and stirred overnight. The reaction was quenched with Methanol and concentrated *in vacuo*. The product was purified by silica gel column chromatography (pentane:EtOAc = 40:1 – 15:1). Compound **S2** (5.42 g, 92% yield, pentane: EtOAc = 10:1, R*f* = 0.40-0.50) was obtained as white solid. $[\alpha]_D^{25}$ +148.4 (c=1, $CHCl_3$). IR (neat, cm^{-1}) ν 653, 740, 798, 824, 1070, 1082, 1163, 1475, 1508, 1717, 2859, 2933, 3417. ^{1}H-NMR ($CDCl_3$, 400 MHz) δ 7.55 – 7.49 (m, 2H), 7.41 – 7.22 (m, 8H), 6.90 (d, *J* = 7.0 Hz, 1H, *N*H), 6.14 (d, *J* = 4.7 Hz, 1H, H-1), 4.83 – 4.73 (m, 2H, *CHH*, H-2), 4.70 (d, *J* = 2.8, 1H, H-4), 4.58 (d, *J* = 11.8 Hz, 1H, *CHH*), 4.33 (dd, *J* = 12.6, 2.2 Hz, 1H, H-6), 4.17 (dd, *J* = 12.7, 1.6 Hz, 1H, H-6), 4.06 (q, *J* = 1.6 Hz, 1H, H-5), 3.51 (dd, *J* = 11.0, 2.7 Hz, 1H, H-3), 1.08 (s, 9H, *CH*$_3$), 1.07 (s, 9H, *CH*$_3$). ^{13}C NMR (100 MHz, $CDCl_3$) δ 161.75 (*CONH*), 137.45, 134.49, 134.44, 134.39, 129.45, 128.81, 128.59, 128.24, 128.21, 127.90, 92.53 (*CCl*$_3$), 89.20 (C-1), 76.55 (C-3), 70.94 (C-5), 69.72 (*CH*$_2$), 69.07 (C-4), 67.28 (C-6), 51.03 (C-2), 27.75 (*CH*$_3$), 27.41 (*CH*$_3$), 23.54, 20.92 (C-*Si*). HR-MS: Calculated for $C_{29}H_{38}Cl_3NO_5SiSe$ $[M+H]^+$: 694.0828, found: 694.0819.

3-*O*-benzyl-2-deoxy-1-*O*-(*N*-phenyl-trifluoroacetimidoyl)-4,6-di-*tert*-butylsilylidene-2-trichloroacetamido-α/β-D-galactopyranoside (3)

NIS (1.76 g, 7.83 mmol) was added to the solution of compound **S2** (3.87 g, 5.59 mmol) in Acetone/H_2O (30 ml/3 ml) at 0 ºC. The reaction was slowly warmed to room temperature stirred for about 2 hours. Then the mixture was

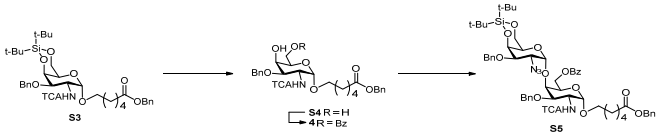
diluted with DCM and washed with saturated $Na_2S_2O_3$ and brine, dried with anhydrous $MgSO_4$, filtered and concentrated *in vacuo*. The residue was purified by silica gel column chromatography (pentane:EtOAc = 3:1) to get S2. $Cs_{2C}O_3$ was added to the solution of hemiacetal S2 in 30 ml acetone. The mixture was stirred at 0 °C for 15 minutes. Then CF_{3C}(=NPh)Cl (1.38 g, 6.68 mmol) was added to the solution, which was slowly warmed to room temperature and stirred overnight. The reaction was quenched with Et_3N and concentrated *in vacuo*. The product **3** was purified by silica gel column chromatography (pentane:Et_2O = 10:1-5:1). Compound **3** (3.20 g, 79% yield, pentane: Et_2O = 5:1, R*f* = 0.25-0.35) was obtained as white solid. ^{1}H-NMR ($CDCl_3$, 500 MHz, 333 K) δ 7.90 (s, 1H), 7.56 – 7.49 (m, 1H), 7.39 – 7.18 (m, 10H), 7.11 – 7.04 (m, 1H), 6.80 – 6.74 (m, 2H), 6.56 (d, *J* = 7.4 Hz, 1H), 6.51 (bs, 1H, H-1α), 6.14 (bs, H-1β), 4.78 (d, *J* = 11.8 Hz, 1H), 4.75 – 4.65 (m, 2H), 4.59 (d, *J* = 11.9 Hz, 1H), 4.32 – 4.16 (m, 2H), 3.79 (dd, *J* = 11.0, 2.6 Hz, 1H), 3.72 (s, 1H), 1.14 – 1.03 (m, 20H). ^{13}C NMR (125 MHz, $CDCl_3$, 333K) δ 161.96, 143.06, 137.38, 135.18, 129.22, 128.66, 128.56, 128.54, 128.43, 128.01, 127.97, 127.90, 127.81, 127.71, 126.23, 124.51, 124.26, 120.56, 119.33, 119.28, 117.34, 94.70 (C-1α), 93.65 (C-1β), 92.35, 75.61, 74.38, 72.38, 70.79, 70.20, 69.84, 69.07, 68.97, 66.80, 66.77, 53.82, 49.53, 27.54, 27.52, 27.31, 27.16, 23.28, 20.70. HR-MS: Calculated for $C_{31}H_{38}Cl_{3F3}N_2O_6Si$ $[M+Na]^+$: 747.1415, found: 747.1409.



6-(Benzyl hexanoyl) 3-*O*-benzyl-2-deoxy-4,6-di-*tert*-butylsilylidene-2-trichloroacetamido-α-D-galactopyranoside (S3)

The reaction was carried out according to the general procedure B. The donor **3** (2.0 g, 2.76 mmol) and linker alcohol (613 mg, 2.76 mmol) were co-evaporated with toluene (three times). The residue was dissolved in dry 27 ml DCM under nitrogen and stirred over fresh flame-dried molecular sieves 4Å. The solution was cooled to -20 °C, after which TfOH (25 µl, 0.28 mmol) was added. The reaction was stirred at -20 °C for 2 h. Then the reaction was quenched with Et_3N, diluted with DCM, washed with saturated $NaHCO_3$ and brine. The organic phase was dried with anhydrous $MgSO_4$, filtered and concentrated *in vacuo*. The product was purified by silica gel column chromatography (pentane:EtOAc = 6:1). Compound **S3** (2.09 g, 88% yield, pentane: EtOAc = 3:1, R*f* = 0.65-0.75) was obtained as yellow syrup. α isomer: $[\alpha]_D^{25}$ +87.3 (c=1, $CHCl_3$). IR (neat, cm^{-1}) ν 651, 678, 697, 736, 763, 796, 823, 863, 920, 974, 1003, 1029, 1047, 1066, 1080, 1100, 1172, 1474, 1511, 1724, 2858, 2929, 3429. ^{1}H-NMR ($CDCl_3$, 400 MHz) δ 7.40 – 7.21 (m, 10H, aromatic H), 6.79 (d, *J* = 8.7 Hz, 1H, *N*H), 5.10 (s, 2H, *C*H_2*Ph*), 5.00 (d, *J* = 3.6 Hz, 1H, H-1), 4.74 (d, *J* = 12.2 Hz, 1H, *C*H_2*Ph*), 4.64 – 4.54 (m, 3H, *C*H_2*Ph*, H-2, 4), 4.26 (dd, *J* = 12.5, 2.1 Hz, 1H, H-6), 4.16 (dd, *J* = 12.5, 1.7 Hz, 1H, H-6), 3.72 – 3.58 (m, 3H, H-3, 5, 7), 3.40 (dt, *J* = 10.0, 6.5 Hz, 1H, H-7), 2.33 (t, *J* = 7.4 Hz, 2H, H-11), 1.70 – 1.49 (m, 4H, H-10, 8), 1.41 – 1.28 (m, 2H, H-9), 1.16 – 1.00 (m, 18H, *C*H_3). ^{13}C NMR (100 MHz, $CDCl_3$) δ 173.23 (C-12), 161.64 (C*ONH*), 137.96, 128.55, 128.46, 128.23, 128.15, 127.75, 127.64 (aromatic C/C*H*), 97.03 (C-1), 92.74 (C*Cl*$_3$), 75.30 (C-3), 69.82 (CH_2*Ph*), 69.53 (C-4), 67.96 (C-7),

67.65 (C-5), 67.22 (C-6), 66.13 (C*H*$_2$*Ph*), 49.93 (C-2), 34.02 (C-11), 28.93 (C-8), 27.66 (C*H*$_3$), 27.37 (C*H*$_3$), 25.69 (C-9), 24.55 (C-10), 23.43 (C-*Si*), 20.74 (C-*Si*). ^{13}C-HMBC ($CDCl_3$, 100 MHz): 97.03 ($J_{C1,H1}$ = 171 Hz). HR-MS: HR-MS: Calculated for $C_{36}H_{50}Cl_3NO_8Si$ $[M+NH_4]^+$: 775.2715, found: 775.2707. β isomer: $[\alpha]_D^{25}$ +87.2 (c=1, $CHCl_3$). IR (neat, cm^{-1}) ν 650, 697, 734, 796, 826, 863, 920, 1003, 1046, 1066, 1100, 1124, 1172, 1212, 1473, 1522, 1701, 1731, 2859, 2933, 3427. ^{1}H-NMR ($CDCl_3$, 400 MHz) δ ^{1}H NMR ($CDCl_3$, 400 MHz) δ 7.40 – 7.25 (m, 10H, aromatic H), 6.95 (d, *J* = 7.1 Hz, 1H, *N*H), 5.10 (s, 2H, *C*H$_2$*Ph*), 4.94 (d, *J* = 8.3 Hz, 1H, H-1), 4.68 (d, *J* = 11.5 Hz, 1H, *C*H$_2$*Ph*), 4.58 (d, *J* = 11.5 Hz, 1H, *C*H$_2$*Ph*), 4.51 (d, *J* = 2.9 Hz, 1H, H-4), 4.27 – 4.14 (m, 3H, H-3, 6), 3.90 – 3.69 (m, 2H, H-2, 7), 3.48 (dt, *J* = 9.7, 6.4 Hz, 1H, H-7), 3.37 (s, 1H, H-5), 2.33 (t, *J* = 7.6 Hz, 2H, H-11), 1.70 – 1.50 (m, 4H, H-10, 8), 1.43 – 1.30 (m, 2H, H-9), 1.10 – 1.04 (m, 18H, *C*H$_3$). ^{13}C NMR (100 MHz, $CDCl_3$) δ 173.66 (C-12), 161.98 (C*ONH*), 137.87, 136.18, 128.68, 128.66, 128.61, 128.31, 128.23, 128.11, 127.79 (aromatic C/C*H*), 98.91 (C-1), 92.73 (C*Cl*$_3$), 75.70 (C-3), 71.36 (C-5), 71.02 (C*H*$_2$*Ph*), 69.45 (C-7), 69.42 (C-4), 67.47 (C-6), 66.24 (C*H*$_2$*Ph*), 55.18 (C-2), 34.29 (C-11), 29.33 (C-8), 27.71 (C*H*$_3$), 27.67 (C*H*$_3$), 25.68 (C-9), 24.74 (C-10), 23.56 (C-*Si*), 20.93 (C-*Si*). ^{13}C-HMBC ($CDCl_3$, 100 MHz): 98.91 ($J_{C1,H1}$ = 162 Hz). HR-MS: Calculated for $C_{36}H_{50}Cl_3NO_8Si$ $[M+NH_4]^+$: 775.2715, found: 775.2705.



6-(Benzyl hexanoyl) 3-*O*-benzyl-2-deoxy-2-trichloroacetamido-α-D-galactopyranoside (S4)

The reaction was carried out according to the general procedure C using compound **S3** (1.12 g, 1.47 mmol) and HF/pyridine (70%, 612 µl, 23.6 mmol). The product was purified by column chromatography (pentane:EtOAc = 1:1). Compound **S4** (982 mg, 92% yield, pentane:EtOAc = 1:2, R*f* = 0.35-0.45) was obtained as yellow syrup. $[\alpha]_D^{25}$ +68.9 (c=1, $CHCl_3$). IR (neat, cm^{-1}) ν 820, 1029, 1052, 1098, 1152, 1713, 2872, 2933, 3421. ^{1}H-NMR ($CDCl_3$, 400 MHz) δ 7.44 – 7.19 (m, 10H, aromatic H), 6.84 (d, *J* = 9.2 Hz, 1H, *N*H), 5.10 (s, 2H, *C*H$_2$*Ph*), 4.91 (d, *J* = 3.7 Hz, 1H, H-1), 4.68 (d, *J* = 11.9 Hz, 1H, *C*H$_2$*Ph*), 4.53 (d, *J* = 12.3 Hz, 1H, *C*H$_2$*Ph*), 4.46 (ddd, *J* = 10.6, 9.2, 3.7 Hz, 1H, H-2), 4.19 (d, *J* = 3.0 Hz, 1H, H-4), 3.97 – 3.75 (m, 3H, H-5, 6), 3.75 – 3.61 (m, 2H, H-3, 7), 3.39 (dt, *J* = 10.0, 6.4 Hz, 1H, H-7), 3.10 (bs, 1H, *O*H), 2.34 (t, *J* = 7.4 Hz, 2H, H-11), 1.74 – 1.47 (m, 4H, H-10, 8), 1.41 – 1.28 (m, 2H, H-9). ^{13}C NMR (100 MHz, $CDCl_3$) δ 173.45 (C-12), 161.77 (C*ONH*), 137.28, 135.92, 128.56, 128.24, 128.16, 127.99, 127.71 (aromatic C/C*H*), 96.96 (C-1), 92.65 (C*Cl*$_3$), 76.00 (C-3), 71.10 (C*H*$_2$*Ph*), 69.93 (C-5), 67.88 (C-7), 66.20 (C*H*$_2$*Ph*), 66.19 (C-4), 62.42 (C-6), 50.50 (C-2), 34.05 (C-11), 28.88 (C-8), 25.70 (C-9), 24.53 (C-10). HR-MS: Calculated for $C_{28}H_{34C}l_3NO_8$ $[M+H]^+$: 618.1428, found: 618.1423.

6-(Benzyl hexanoyl) 6-O-benzoyl-3-*O*-benzyl-2-deoxy-2-trichloroacetamido-α-D-galactopyranoside (4)

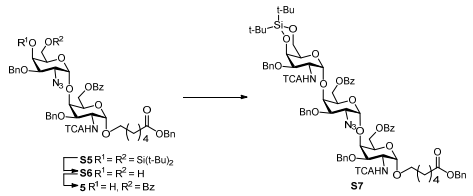
The reaction was carried out according to the general procedure D using compound **S4** (950 mg, 1.54 mmol), PhCOOBt (1.84 g, 7.70 mmol) and Et_3N (1.2 ml, 8.50 mmol). The product was purified by column chromatography

(pentane:EtOAc = 4:1). Compound **4** (1.01 g, 91% yield, pentane:EtOAc = 3:1, R*f* = 0.30-0.40) was obtained as yellow syrup. $[\alpha]_D^{25}$ +57.4 (c=1, $CHCl_3$). IR (neat, cm^{-1}) ν 780, 821, 839, 1027, 1050, 1065, 1100, 1126, 1153, 1241, 1278, 1294, 1316, 1341, 1452, 1523, 1706, 2869, 2938, 3327, 3499. ^{1}H-NMR ($CDCl_3$, 500 MHz) δ 8.06 – 8.00 (m, 2H, *C*H, Bz), 7.59 – 7.22 (m, 13H), 6.82 (d, *J* = 9.2 Hz, 1H, *N*H), 5.08 (s, 2H, *C*H_2*Ph*), 4.92 (d, *J* = 3.7 Hz, 1H, H-1), 4.69 (d, *J* = 11.9 Hz, 1H, *C*H_2*Ph*), 4.63 (dd, *J* = 11.5, 4.7 Hz, 1H, H-6), 4.60 – 4.53 (m, 2H, *C*H_2*Ph*, H-6), 4.50 (ddd, *J* = 10.5, 9.2, 3.8 Hz, 1H, H-2), 4.17 (d, *J* = 2.6 Hz, 1H, H-4), 4.09 (ddd, *J* = 7.6, 4.7, 1.2 Hz, 1H, H-5), 3.72 (dd, *J* = 10.6, 3.0 Hz, 1H, H-3), 3.65 (dt, *J* = 10.0, 6.5 Hz, 1H, H-7), 3.40 (dt, *J* = 10.0, 6.6 Hz, 1H, H-7), 2.28 (t, *J* = 7.4 Hz, 2H, H-11), 1.65 – 1.49 (m, 4H, H-10, 8), 1.33 – 1.23 (m, 2H, H-9). ^{13}C NMR (125 MHz, $CDCl_3$) δ 173.27 (C-12), 166.32 (C=O, Bz), 161.69 (C*ONH*), 137.20, 135.94, 133.18, 130.05, 129.81, 129.61, 128.58, 128.53, 128.41, 128.37, 128.33, 128.21, 128.12, 128.04, 127.73, 127.70 (aromatic C/C*H*), 96.87 (C-1), 92.65 (C*Cl*$_3$), 76.03 (C-3), 71.41 (CH_2*Ph*), 68.22 (C-5), 67.93 (C-7), 66.12 (CH_2*Ph*), 65.68 (C-4), 64.14 (C-6), 50.43 (C-2), 33.99 (C-11), 28.82 (C-8), 25.64 (C-9), 24.45 (C-10). ^{13C}-HMBC ($CDCl_3$, 100 MHz): 96.87 ($J_{C1,H1}$ = 171 Hz). HR-MS: Calculated for $C_{35}H_{38}Cl_3NO_9$ $[M+H]^+$: 722.1690, found: 722.1685.

6-(Benzyl hexanoyl) 2-azido-3-*O*-benzyl-2-deoxy-4,6-di-*tert*-butylsilylidene-α-D-galactopyranosyl-(1→4)-6-O-benzoyl-3-*O*-benzyl-2-deoxy-2-trichloroacetamido-α-D-galactopyranoside (S5)

The reaction was carried out according to the general procedure B. The donor **2** (2.35 g, 3.88 mmol) and the acceptor **4** (1.12 g, 1.55 mmol) were co-evaporated with toluene (three times). The residue was dissolved in 16 ml dry DCM under nitrogen and stirred over fresh flame-dried molecular sieves 4Å. The solution was cooled to 0 °C, after which TfOH (14 µl, 0.16 mmol) was added. The reaction was stirred at 0 °C for 1 h. Then the reaction was quenched with Et_3N, diluted with DCM, washed with saturated $NaHCO_3$ and brine. The organic phase was dried with anhydrous $MgSO_4$, filtered and concentrated *in vacuo*. The product was purified by silica gel column chromatography (pentane:EtOAc = 6:1). Compound **S5** (1.69 g, 92% yield, pentane: EtOAc = 5:1, R*f* = 0.25-0.35) was obtained as yellow syrup. $[\alpha]_D^{25}$ +107.8 (c=1, $CHCl_3$). IR (neat, cm^{-1}) ν 738, 796, 823, 980, 1009, 1027, 1046, 1063, 1105, 1168, 1271, 1454, 1508, 1721, 2112, 2859, 2933, 3424. ^{1}H-NMR ($CDCl_3$, 500 MHz) δ 8.09 – 8.01 (m, 2H, *C*H, Bz), 7.61 – 7.22 (m, 1H), 7.50 – 7.42 (m, 4H), 7.40 – 7.22 (m, 14H, aromatic H), 6.83 (d, *J* = 9.5 Hz, 1H, *N*H), 5.10 - 5.06 (m, 3H, *C*H_2*Ph*, H-1^B), 4.98 (d, *J* = 3.7 Hz, 1H, H-1^A), 4.82 – 4.48 (m, 8H, *C*H_2*Ph*, H-2^A, 6^A, 4^B), 4.27 (d, *J* = 2.6 Hz, 1H, H-4^A), 4.16 (q, *J* = 1.6 Hz, 1H, H-5^B), 4.11 (t, *J* = 6.8 Hz, 1H, H-5^A), 4.04 (dd, *J* = 10.6, 2.7 Hz, 1H, H-3^B), 3.94 (dd, *J* = 10.6, 3.5 Hz, 1H, H-2^B), 3.73 – 3.63 (m, 4H, H-3^A, 6^B, 7), 3.44 (dt, *J* = 10.0, 6.5 Hz, 1H, H-7), 2.30 (t, *J* = 7.4 Hz, 2H, H-11), 1.65 – 1.50 (m, 4H, H-10, 8), 1.36 – 1.22 (m, 2H, H-9), 1.06 – 0.96 (m, 18H, *C*H_3). ^{13}C NMR (125 MHz, $CDCl_3$) δ 173.24 (C-12), 166.08 (C=O, Bz), 161.81 (C*ONH*), 137.90, 137.15, 136.01, 133.43, 129.71, 129.64, 128.61, 128.59, 128.55, 128.50, 128.29, 128.21, 128.09, 127.81, 127.79, 126.99 (aromatic C/C*H*), 99.44 (C-1^B), 97.01 (C-1^A), 92.70 (C*Cl*$_3$), 76.24 (C-3^A), 76.05 (C-3^B), 72.46 (C-4^A), 71.77 (CH_2*Ph*), 70.68 (CH_2*Ph*), 69.60 (C-4^B), 69.08 (C-5^A), 68.06 (C-7), 67.96 (C-5^B), 66.91 (C-6^B), 66.19 (CH_2*Ph*), 62.76 (C-6^A), 58.84 (C-2^B), 50.89 (C-2^A), 34.05 (C-11), 28.94 (C-8), 27.65 (3xCH_3), 27.38 (3xCH_3), 25.72 (C-9), 24.52 (C-10),

23.33 (C-*Si*), 20.74 (C-*Si*). ^{13}C-HMBC ($CDCl_3$, 100 MHz): 99.44 ($J_{C1,H1}$ = 170Hz), 97.01 ($J_{C1,H1}$ = 173Hz). HR-MS: Calculated for $C_{56}H_{69}Cl_3N_4O_{13}Si$ $[M+H]^+$: 1139.3774, found: 1139.3769.



6-(Benzyl hexanoyl) 2-azido-3-*O*-benzyl-2-deoxy-α-D-galactopyranosyl-(1→4)-6-O-benzoyl-3-*O*-benzyl-2-deoxy-2-trichloroacetamido-α-D-galactopyranoside (S6)

The reaction was carried out according to the general procedure C using compound **S5** (1.65 g, 1.45 mmol) and HF/pyridine (70%, 0.6 ml, 23.2 mmol). The product was purified by column chromatography (pentane:EtOAc = 3:1 - 1:1). Compound **S6** (1.35 g, 93% yield, pentane:EtOAc = 1:1, R*f* = 0.25-0.35) was obtained as yellow syrup. $[\alpha]_D^{25}$ +77.3 (c=1, $CHCl_3$). IR (neat, cm^{-1}) ν 555, 698, 713, 736, 820, 1027, 1046, 1154, 1272, 1315, 1453, 1511, 1717, 2110, 2872, 2929, 3421, 3500. ^{1}H-NMR ($CDCl_3$, 400 MHz) δ 8.08 – 8.00 (m, 2H, *C*H, Bz), 7.62 – 7.53 (m, 1H), 7.52 – 7.22 (m, 18H, aromatic H), 6.88 (d, *J* = 9.4 Hz, 1H, *N*H), 5.07 (s, 2H, *CH*$_2$*Ph*), 5.04 (d, *J* = 3.6 Hz, 1H, H-1^B), 4.97 (d, *J* = 3.7 Hz, 1H, H-1^A), 4.80 – 4.63 (m, 5H, *CH*$_2$*Ph*, H-6^A), 4.59 – 4.49 (m, 2H, *CHHPh*, H-2^A), 4.27 – 4.15 (m, 3H, H-4^B, 5^B, 4^A), 4.10 (t, *J* = 6.8 Hz, 1H, H-5^A), 4.03 (dd, *J* = 10.5, 3.0 Hz, 1H, H-3^B), 3.90 (dd, *J* = 10.4, 3.5 Hz, 1H, H-2^B), 3.75 – 3.63 (m, 2H, H-3^A, 7), 3.54 – 3.37 (m, 3H, H-6^B, 7), 2.97 (bs, 1H, *O*H), 2.50 (bs, 1H, *O*H), 2.29 (t, *J* = 7.4 Hz, 2H, H-11), 1.66 – 1.49 (m, 4H, H-10, 8), 1.35 – 1.22 (m, 2H, H-9). ^{13}C NMR (100 MHz, $CDCl_3$) δ 173.23 (C-12), 166.04 (C=O, Bz), 162.01 (C*ONH*), 137.21, 137.13, 135.92, 133.37, 129.62, 129.55, 128.60, 128.55, 128.23, 128.14, 128.06, 127.96, 127.33 (aromatic C/C*H*), 99.64 (C-1^B), 96.91 (C-1^A), 92.53 (C*Cl*$_3$), 76.76 (C-3^B), 76.06 (C-3^A), 73.87 (C-4^A), 71.89 (C*H*$_2$*Ph*), 71.81 (C*H*$_2$*Ph*), 69.87 (C-5^B), 69.07 (C-5^A), 68.03 (C-7), 67.39 (C-4^B), 66.14 (C*H*$_2$*Ph*), 62.69 (C-6^A), 62.54 (C-6^B), 59.79 (C-2^B), 50.91 (C-2^A), 33.98 (C-11), 28.85 (C-8), 25.64 (C-9), 24.44 (C-10). HR-MS: Calculated for $C_{48}H_{53}Cl_3N_4O_{13}$ $[M+H]^+$: 999.2753, found: 999.2748.

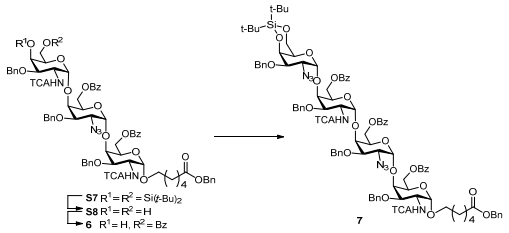
6-(Benzyl hexanoyl) 2-azido-6-O-benzoyl-3-*O*-benzyl-2-deoxy-4,6-di-*tert*-butylsilylidene-α-D-galactopyranosyl-(1→4)-6-O-benzoyl-3-*O*-benzyl-2-deoxy-2-trichloroacetamido-α-D-galactopyranoside (5)

The reaction was carried out according to the general procedure D using compound **S6** (1.31 g, 1.31 mmol), PhCOOBt (1.41 g, 5.90 mmol) and Et_3N (913 µl, 6.55 mmol). The product was purified by column chromatography (pentane:EtOAc = 4:1). Compound **5** (1.36 g, 94% yield, pentane:EtOAc = 3:1, R*f* = 0.30-0.40) was obtained as yellow syrup. $[\alpha]_D^{25}$ +88.7 (c=1, $CHCl_3$). IR (neat, cm^{-1}) ν 689, 698, 711, 736, 820, 1027, 1049, 1109, 1156, 1271, 1315, 1452, 1511, 1717, 2111, 2871, 2929, 3486, 3506. ^{1}H-NMR ($CDCl_3$, 400 MHz) δ 8.09 – 8.01 (m, 2H, *C*H, Bz), 7.98 – 7.89 (m, 2H, *C*H, Bz), 7.63 – 6.98 (m, 21H, aromatic H), 6.80 (d, *J* = 9.2 Hz, 1H, *N*H), 5.09 (d, *J* = 3.6 Hz, 1H, H-1^B), 5.08 (s, 2H, *CH*$_2$*Ph*), 5.01 (d, *J* = 3.7 Hz, 1H, H-1^A), 4.87 – 4.70 (m, 4H, 3x*CHHPh*, H-6^A), 4.69 – 4.49 (m, 4H, *CHHPh*, H-2^A, 6^A, 4^B), 4.43 (dd, *J* = 10.6, 8.7 Hz, 1H, H-6^B), 4.26 (d, *J* = 2.6 Hz, 1H, H-4^A), 4.19 – 4.07

(m, 3H, H-5^{A}, 3^{B}, 5^{B}), 3.95 – 3.83 (m, 2H, H-2^{B}, 6^{B}), 3.77 – 3.64 (m, 2H, H-3^{A}, 7), 3.44 (dt, *J* = 9.9, 6.5 Hz, 1H, H-7), 2.51 (bs, 1H, *O*H), 2.30 (t, *J* = 7.4 Hz, 2H, H-11), 1.66 – 1.48 (m, 4H, H-10, 8), 1.37 – 1.20 (m, 2H, H-9). ^{13}C NMR (100 MHz, $CDCl_3$) δ 173.32 (C-12), 166.07 (C=O, Bz), 165.97 (C=O, Bz), 161.85 (C*ONH*), 137.25, 136.99, 135.99, 133.48, 133.01, 129.90, 129.84, 129.70, 129.56, 128.67, 128.63, 128.61, 128.49, 128.45, 128.31, 128.29, 128.21, 128.18, 127.79, 127.03 (aromatic C/C*H*), 99.34 (C-1^{B}), 96.96 (C-1^{A}), 92.68 (CCl_3), 76.52 (C-3^{B}), 75.77 (C-3^{A}), 72.97 (C-4^{A}), 72.28 (CH_2Ph), 71.89 (CH_2Ph), 68.90 (C-5^{A}), 68.13 (C-7), 68.11 (C-4^{B}), 66.21 (CH_2Ph), 65.48 (C-5^{B}), 62.53 (C-6^{A}), 62.02 (C-6^{B}), 59.58 (C-2^{B}), 51.02 (C-2^{A}), 34.06 (C-11), 28.93 (C-8), 25.71 (C-9), 24.52 (C-10). HR-MS: Calculated for $C_{55}H_{57}Cl_3N_4O_{14}$ $[M+Na]^+$: 1125.2835, found: 1125.2829.

6-(Benzyl hexanoyl) 3-*O*-benzyl-2-deoxy-4,6-di-*tert*-butylsilylidene-2-trichloroacetamido-α-D-galactopyranosyl-(1→4)-2-azido-6-O-benzoyl-3-*O*-benzyl-2-deoxy-α-D-galactopyranosyl-(1→4)-6-O-benzoyl-3-*O*-benzyl-2-deoxy-2-trichloro-acetamido-α-D-galactopyranoside (S7)

The reaction was carried out according to the general procedure B. The donor **3** (1.55 g, 2.14 mmol) and the acceptor **5** (1.31 g, 1.19 mmol) were co-evaporated with toluene (three times). The residue was dissolved in 12 ml dry DCM under nitrogen and stirred over fresh flame-dried molecular sieves 4Å. The solution was cooled to 0 ºC, after which TfOH (11 µl, 0.12 mmol) was added. The reaction was stirred at 0 ºC for 1 h. Then the reaction was quenched with Et_3N, diluted with DCM, washed with saturated $NaHCO_3$ and brine. The organic phase was dried with anhydrous $MgSO_4$, filtered and concentrated *in vacuo*. The product was purified by silica gel column chromatography (pentane:EtOAc = 5:1). Compound **S7** (1.83 g, 93% yield, pentane: EtOAc = 3:1, R*f* = 0.50-0.60) was obtained as yellow syrup. $[\alpha]_D^{25}$ +129.8 (c=1, $CHCl_3$). IR (neat, cm^{-1}) ν 651, 685, 697, 711, 734, 797, 820, 859, 1003, 1027, 1046, 1158, 1266, 1315, 1452, 1508, 1720, 2111, 2859, 2933, 3423. ^{1}H-NMR ($CDCl_3$, 400 MHz) δ 8.09 – 8.00 (m, 2H, *C*H, Bz), 7.98 – 7.91 (m, 2H, *C*H, Bz), 7.68 – 7.03 (m, 26H, aromatic H), 6.84 (d, *J* = 9.1 Hz, 1H, *N*H), 6.71 (d, *J* = 9.1 Hz, 1H, *N*H), 5.19 (d, *J* = 3.6 Hz, 1H, H-1^{C}), 5.07 (s, 2H, *C*H$_2$*Ph*), 5.05 (d, *J* = 3.6 Hz, 1H, H-1^{B}), 4.97 (d, *J* = 3.7 Hz, 1H, H-1^{A}), 4.81 – 4.47 (m, 11H, 3x*C*H$_2$*Ph*, H-2^{A}, 6^{A}, 5^{B}, 2^{C}), 4.41 (d, *J* = 2.6 Hz, 1H, H-4^{B}), 4.39 – 4.31 (m, 2H, H-4^{C}, 6^{B}), 4.22 (d, *J* = 2.6 Hz, 1H, H-4^{A}), 4.14 – 4.05 (m, 2H, H-3^{B}, 5^{A}), 4.03 – 3.89 (m, 2H, H-5^{C}, 6^{B}), 3.77 – 3.61 (m, 5H, H-2^{B}, 3^{A}, 3^{C}, 6^{C}, 7), 3.48 – 3.30 (m, 2H, H-6^{C}, 7), 2.30 (t, *J* = 7.4 Hz, 2H, H-11), 1.68 – 1.48 (m, 4H, H-10, 8), 1.37 – 1.20 (m, 2H, H-9), 1.05 – 0.92 (m, 18H, 6x*C*H$_3$). ^{13}C NMR (100 MHz, $CDCl_3$) δ 173.25 (C-12), 165.94 (C=O, Bz), 164.99 (C=O, Bz), 161.76, 161.47 (2 C*ONH*), 137.83, 137.09, 136.95, 135.97, 133.63, 133.21, 129.85, 129.61, 129.51, 129.39, 128.72, 128.59, 128.57, 128.53, 128.41, 128.28, 128.19, 128.00, 127.87, 127.85, 127.52, 126.97 (aromatic), 98.83 (C-1^{B}), 97.09 (C-1^{C}), 96.95 (C-1^{A}), 92.69 (CCl_3), 92.56 (CCl_3), 76.14 (C-3^{B}), 74.98 (C-3^{A}), 74.67 (C-3^{C}), 72.95 (C-4^{A}), 72.47, 72.22, 69.79 (3 CH_2Ph), 69.59 (C-4^{B}), 69.32 (C-4^{C}), 68.82 (C-5^{B}), 68.67 (C-5^{A}), 68.12 (C-7), 67.99 (C-5^{C}), 66.80 (C-6^{C}), 66.18 (CH_2Ph), 62.47 (C-6^{A}), 60.58 (C-2^{B}), 60.23 (C-6^{B}), 51.00 (C-2^{A}), 49.78 (C-2^{C}), 34.03 (C-11), 28.89 (C-8), 27.60 (CH_3), 27.25 (CH_3), 25.67 (C-9), 24.49 (C-10), 23.31 (C-*Si*), 20.65 (C-*Si*). ^{13}C-HMBC ($CDCl_3$, 100 MHz): 98.83 ($J_{C1,H1}$ = 171 Hz), 97.09 ($J_{C1,H1}$ = 174 Hz), 96.95 ($J_{C1,H1}$ = 172 Hz). HR-MS: Calculated for $C_{78}H_{89}Cl_6N_5O_{19}Si$ $[M+H]^+$: 1638.4130, found: 1638.4125.



6-(Benzyl hexanoyl) 3-*O*-benzyl-2-deoxy-2-trichloroacetamido-α-D-galactopyranosyl-(1→4)-2-azido-6-O-benzoyl-3-*O*-benzyl-2-deoxy-α-D-galactopyranosyl-(1→4)-6-O-benzoyl-3-*O*-benzyl-2-deoxy-2-trichloroacet-amido-α-D-galactopyranoside (S8)

The reaction was carried out according to the general procedure C using compound **S7** (1.78 g, 1.09 mmol) and HF/pyridine (70%, 450 µl, 17.4 mmol). The product was purified by column chromatography (pentane:EtOAc = 3:2). Compound **S8** (1.55 g, 95% yield, pentane:EtOAc = 1:1, R*f* = 0.30-0.40) was obtained as yellow syrup. $[\alpha]_D^{25}$ +128.3 (c=1, $CHCl_3$). IR (neat, cm^{-1}) ν 685, 700, 713, 738, 820, 1007, 1027, 1046, 1109, 1158, 1269, 1315, 1452, 1511, 1720, 2111, 2875, 2929, 3420, 3500. ^{1}H-NMR ($CDCl_3$, 400 MHz) δ 8.09 – 8.01 (m, 2H, *C*H, Bz), 7.97 – 7.88 (m, 2H, *C*H, Bz), 7.68 – 6.97 (m, 26H, aromatic), 6.84 (d, *J* = 9.4 Hz, 1H, *N*H), 6.77 (d, *J* = 9.2 Hz, 1H, *N*H), 5.07 (d, *J* = 5.6 Hz, 4H, *CH*$_2$*Ph*, H-1^B, 1^C), 4.97 (d, *J* = 3.6 Hz, 1H, H-1^A), 4.87 (d, *J* = 11.6 Hz, 1H, *CHHPh*), 4.83 – 4.44 (m, 10H), 4.34 (d, *J* = 2.5 Hz, 1H, H-4^B), 4.23 (d, *J* = 2.5 Hz, 1H, H-4^A), 4.17 – 4.02 (m, 6H), 3.79 – 3.62 (m, 4H), 3.43 (dt, *J* = 9.9, 6.4 Hz, 2H), 3.34 (dd, *J* = 11.8, 4.1 Hz, 1H, H-6^C), 2.94 (bs, 1H, *O*H), 2.30 (t, *J* = 7.4 Hz, 2H, H-11), 1.66 – 1.49 (m, 4H, H-10, 8), 1.38 – 1.23 (m, 2H, H-9). ^{13}C NMR (100 MHz, $CDCl_3$) δ 173.31 (C-12), 165.99, 165.15 (2 C=O, Bz), 161.81, 161.53 (2 C*ONH*), 137.23, 137.07, 136.90, 135.97, 133.64, 133.28, 129.94, 129.63, 129.53, 129.34, 128.73, 128.68, 128.67, 128.61, 128.56, 128.44, 128.30, 128.21, 128.11, 128.07, 128.02, 127.98, 127.27 (aromatic), 98.97 (C-1^B), 97.66 (C-1^C), 97.03 (C-1^A), 92.60 (2xC*Cl*$_3$), 76.10 (C-3^B), 75.54 (C-3^A), 75.24 (C-3^C), 73.21 (C-4^A), 72.55, 72.43, 71.00 (3 C*H*$_2$*Ph*), 70.57 (C-4^B), 69.54, 68.89 (C-5^A), 68.17 (C-7), 66.58, 66.22 (C*H*$_2$*Ph*), 62.56 (C-6^A), 62.42 (C-6^C), 60.54 (C-2^B), 60.52 (C-6^B), 51.03 (C-2^A), 50.33 (C-2^C), 34.05 (C-11), 28.92 (C-8), 25.70 (C-9), 24.51 (C-10). HR-MS: Calculated for $C_{70}H_{73}Cl_6N_5O_{19}$ $[M+H]^+$: 1498.3109, found: 1498.3104.

6-(Benzyl hexanoyl) 6-O-benzoyl-3-*O*-benzyl-2-deoxy-2-trichloroacetamido-α-D-galactopyranosyl-(1→4)-2-azido-6-O-benzoyl-3-*O*-benzyl-2-deoxy-α-D-galactopyranosyl-(1→4)-6-O-benzoyl-3-*O*-benzyl-2-deoxy-2-trichloroacet-amido-α-D-galactopyranoside (6)

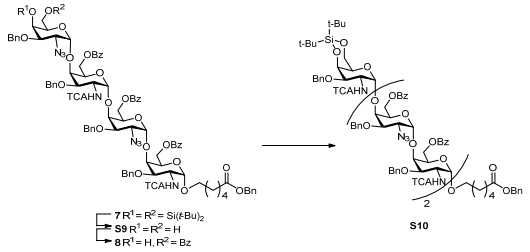
The reaction was carried out according to the general procedure D using compound **S8** (1.52 g, 1.01 mmol), PhCOOBt (1.10 g, 4.56 mmol) and Et_3N (710 µl, 5.07 mmol). The product was purified by column chromatography (pentane:EtOAc = 3:1). Compound **6** (1.40 g, 86% yield, pentane:EtOAc = 2:1, R*f* = 0.35-0.45) was obtained as yellow syrup. $[\alpha]_D^{25}$ +114.7 (c=1, $CHCl_3$). IR (neat, cm^{-1}) ν 689, 700, 711, 737, 820, 1027, 1047, 1109, 1159, 1269, 1315, 1452, 1508, 1717, 2111, 2879, 2931, 3420, 3504. ^{1}H-NMR ($CDCl_3$, 400 MHz) δ 8.13 – 8.07 (m, 2H, *C*H, Bz), 8.00 – 7.92 (m, 4H, *C*H, Bz), 7.72 – 7.47 (m, 7H), 7.45 – 7.22 (m, 19H), 7.17 (t, *J* = 7.7 Hz, 2H), 7.13 – 7.07 (m,

1H), 7.07 – 6.99 (m, 1H), 6.92 (d, *J* = 9.3 Hz, 1H, *N*H), 6.83 (d, *J* = 9.2 Hz, 1H, *N*H), 5.19 (d, *J* = 3.6 Hz, 1H, H-1^{C}), 5.12 (s, 3H, *C*H$_2$*Ph*, H-1^{B}), 5.02 (d, *J* = 3.6 Hz, 1H, H-1^{A}), 4.91 (d, *J* = 11.6 Hz, 1H), 4.87 – 4.79 (m, 2H), 4.79 – 4.46 (m, 10H), 4.39 – 4.27 (m, 2H), 4.26 – 3.99 (m, 6H), 3.87 – 3.68 (m, 4H), 3.48 (dt, *J* = 10.0, 6.5 Hz, 1H, H-7), 2.73 (bs, 1H, *O*H), 2.35 (t, *J* = 7.4 Hz, 2H, H-11), 1.73 – 1.54 (m, 4H, H-10, 8), 1.42 – 1.28 (m, 2H, H-9). ^{13}C NMR (100 MHz, $CDCl_3$) δ 173.28 (C-12), 165.97, 165.91, 165.07 (3 C=O, Bz), 161.76, 161.51 (C*ONH*), 137.08, 136.85, 136.81, 135.94, 133.61, 133.23, 133.14, 129.84, 129.79, 129.61, 129.60, 129.47, 129.26, 128.70, 128.68, 128.63, 128.57, 128.51, 128.48, 128.44, 128.35, 128.26, 128.17, 128.15, 128.03, 127.90, 127.86, 127.21, 127.17 (aromatic), 98.88 (C-1^{B}), 97.00 (C-1^{A}, 1^{C}), 92.59 (C*Cl$_3$*), 75.87 (C-3^{B}), 75.46 (C-3^{A}), 75.26 (C-3^{C}), 73.04 (C-4^{B}), 72.75, 72.35, 71.37 (3 C*H$_2$Ph*), 70.04 (C-4^{C}), 68.86, 68.73, 68.19, 68.12 (C-7), 66.18 (C*H$_2$Ph*), 65.03, 62.76 (C-6^{A}), 62.56 (C-6^{C}), 60.45 (C-2^{B}), 60.40 (C-6^{B}), 50.98 (C-2^{A}), 50.40 (C-2^{C}), 34.01 (C-11), 28.88 (C-8), 25.66 (C-9), 24.47 (C-10). HR-MS: Calculated for $C_{77}H_{77}Cl_6N_5O_{20}$ $[M+H]^+$: 1602.3371, found: 1602.3366.

6-(Benzyl hexanoyl) 2-azido-3-*O*-benzyl-2-deoxy-4,6-di-*tert*-butylsilylidene-α-D-galactopyranosyl-(1→4)-6-O-benzoyl-3-*O*-benzyl-2-deoxy-2-trichloroacetamido-α-D-galactopyranosyl-(1→4)-2-azido-6-O-benzoyl-3-*O*-benzyl-2-deoxy-α-D-galactopyranosyl-(1→4)-6-O-benzoyl-3-*O*-benzyl-2-deoxy-2-trichloroacetamido-α-D-galactopyranoside (7)

The reaction was carried out according to the general procedure B. The donor **2** (1.03 g, 1.70 mmol) and the acceptor **6** (1.37 g, 0.85 mmol) were co-evaporated with toluene (three times). The residue was dissolved in 9 ml dry DCM under nitrogen and stirred over fresh flame-dried molecular sieves 4Å. The solution was cooled to 0 °C, after which TfOH (8 µl, 0.09 mmol) was added. The reaction was stirred at 0 °C for 1 h. Then the reaction was quenched with Et_3N, diluted with DCM, washed with saturated $NaHCO_3$ and brine. The organic phase was dried with anhydrous $MgSO_4$, filtered and concentrated *in vacuo*. The product was purified by silica gel column chromatography (pentane:EtOAc = 3:1). Compound **7** (1.57 g, 91% yield, pentane: EtOAc = 5:2, R*f* = 0.35-0.45) was obtained as yellow syrup. $[\alpha]_D^{25}$ +131.9 (c=1, $CHCl_3$). IR (neat, cm^{-1}) ν 555, 651, 685, 698, 710, 736, 796, 820, 977, 1005, 1027, 1046, 1063, 1166, 1266, 1315, 1452, 1508, 1720, 2111, 2859, 2933, 3420. ^{1}H-NMR ($CDCl_3$, 400 MHz) δ 8.09 – 8.01 (m, 2H, *C*H, Bz), 7.97 – 7.86 (m, 4H, *C*H, Bz), 7.67 – 7.17 (m, 34H), 7.13 (t, *J* = 7.6 Hz, 2H), 7.05 – 6.95 (m, 2H), 6.89 (d, *J* = 9.6 Hz, 1H, *N*H), 6.76 (d, *J* = 9.3 Hz, 1H, *N*H), 5.14 (d, *J* = 3.6 Hz, 1H, H-1^{C}), 5.08 (s, 2H, *C*H$_2$*Ph*), 5.04 (d, *J* = 3.6 Hz, 1H, H-1^{B}), 4.97 (d, *J* = 3.7 Hz, 1H, H-1^{A}), 4.92 – 4.84 (m, 2H, H-1^{D}), 4.84 – 4.34 (m, 18H), 4.26 (dd, *J* = 19.4, 4.0 Hz, 2H), 4.19 – 4.05 (m, 5H), 4.05 – 3.91 (m, 2H), 3.86 – 3.65 (m, 7H), 3.60 (dd, *J* = 10.7, 3.6 Hz, 1H, H-2^{B}), 3.44 (dt, *J* = 10.1, 6.5 Hz, 1H, H-7), 2.31 (t, *J* = 7.4 Hz, 2H, H-11), 1.67 – 1.49 (m, 4H, H-10, 8), 1.38 – 1.23 (m, 2H, H-9), 1.00 – 0.93 (m, 18H, *C*H$_3$). ^{13}C NMR (100 MHz, $CDCl_3$) δ 173.29 (C-12), 165.98, 165.42, 165.18 (3 C=O, Bz), 161.77, 161.64 (C*ONH*), 137.95, 137.06, 136.89, 136.79, 135.99, 133.67, 133.37, 133.26, 129.92, 129.72, 129.64, 129.62, 129.53, 129.31, 128.76, 128.63, 128.57, 128.45, 128.42, 128.33, 128.23, 128.03, 127.98, 127.93, 127.69, 127.60, 127.26, 127.19 (aromatic), 99.51 (C-1^{D}), 98.92 (C-1^{B}), 97.08 (C-1^{A}, 1^{C}), 92.66, 92.62 (2 C*Cl$_3$*), 76.28 (C-3^{D}), 75.61 (C-3^{A}, 3^{B}), 75.57 (C-3^{C}), 74.97 (C-4^{B}), 73.07, 72.67 (2 C*H$_2$Ph*),

72.49 (C-4^{D}), 72.22, 71.43 (2 CH_2Ph), 70.60, 70.15, 69.58, 68.89, 68.74, 68.19 (C-7), 67.97 (C-5^{d}), 67.05 (C-6^{D}), 66.24 (CH_2Ph), 62.53 (C-6), 61.72 (C-6), 60.45 (C-2^{B}), 58.88 (C-2^{D}), 51.02 (C-2^{A}), 50.79 (C-2^{C}), 34.07 (C-11), 28.95 (C-8), 27.67 (CH_3), 27.35 (CH_3), 25.73 (C-9), 24.53 (C-10), 23.31 (C-*Si*), 20.71 (C-*Si*). ^{13}C-HMBC ($CDCl_3$, 100 MHz): 99.51 ($J_{C1,H1}$ = 170 Hz), 98.92 ($J_{C1,H1}$ = 171 Hz), 97.08 ($J_{C1,H1}$ = 174 Hz). HR-MS: Calculated for $C_{98}H_{108}Cl_6N_8O_{24}Si$ $[M+NH_4]^+$: 2036.5721, found: 2036.5763.



6-(Benzyl hexanoyl) 2-azido-3-*O*-benzyl-2-deoxy-α-D-galactopyranosyl-(1→4)-6-O-benzoyl-3-*O*-benzyl-2-deoxy-2-trichloroacetamido-α-D-galactopyranosyl-(1→4)-2-azido-6-O-benzoyl-3-*O*-benzyl-2-deoxy-α-D-galactopyranosyl-(1→4)-6-O-benzoyl-3-*O*-benzyl-2-deoxy-2-trichloroacetamido-α-D-galactopyranoside (S9)

The reaction was carried out according to the general procedure C using compound **7** (1.54 g, 0.76 mmol) and HF/pyridine (70%, 320 µl, 12.2 mmol). The product was purified by column chromatography (pentane:EtOAc = 3:2). Compound **S9** (1.33 g, 93% yield, pentane:EtOAc = 1:1, R*f* = 0.25-0.35) was obtained as yellow syrup. $[\alpha]_D^{25}$ +111.2 (c=1, $CHCl_3$). IR (neat, cm^{-1}) ν 687, 700, 711, 737, 820, 1005, 1027, 1046, 1109, 1156, 1269, 1315, 1452, 1509, 1720, 2111, 2926, 3418, 3526. ^{1}H-NMR ($CDCl_3$, 400 MHz) δ 8.10 – 8.02 (m, 2H, *C*H, Bz), 7.98 – 7.90 (m, 2H, *C*H, Bz), 7.90 – 7.82 (m, 2H, *C*H, Bz), 7.66 – 7.55 (m, 3H), 7.53 – 7.40 (m, 6H), 7.39 – 7.21 (m, 19H), 7.20 – 7.07 (m, 4H), 7.03 – 6.89 (m, 3H), 6.81 (d, *J* = 9.3 Hz, 1H, *N*H), 5.09 (d, *J* = 3.5 Hz, 1H, H-1^{C}), 5.07 (s, 2H, *C*H$_2Ph$), 5.04 (d, *J* = 3.7 Hz, 1H, H-1^{B}), 4.97 (d, *J* = 3.7 Hz, 1H, H-1^{A}), 4.90 – 4.34 (m, 17H), 4.28 – 3.96 (m, 9H), 3.92 (dd, *J* = 10.4, 3.0 Hz, 1H, H-3^{D}), 3.81 – 3.65 (m, 4H), 3.65 – 3.50 (m, 3H), 3.44 (dt, *J* = 10.0, 6.5 Hz, 1H, H-7), 2.62 (bs, 1H, *O*H), 2.30 (t, *J* = 7.4 Hz, 2H, H-11), 2.03 (bs, 1H, *O*H), 1.69 – 1.49 (m, 4H, H-10, 8), 1.38 – 1.21 (m, 2H, H-9). ^{13}C NMR (100 MHz, $CDCl_3$) δ 173.24 (C-12), 165.91, 165.31, 165.11 (3 C=O, Bz), 161.95, 161.75 (C*ONH*), 137.13, 137.04, 136.80, 136.66, 135.91, 133.62, 133.32, 133.15, 129.85, 129.67, 129.57, 129.50, 129.45, 129.24, 128.69, 128.62, 128.55, 128.52, 128.48, 128.46, 128.42, 128.25, 128.14, 128.06, 128.04, 127.99, 127.88, 127.82, 127.04, 126.99 (aromatic), 100.00 (C-1^{D}), 98.90 (C-1^{B}), 97.22 (C-1^{C}), 97.03 (C-1^{A}), 92.58, 92.42 (2 CCl_3), 77.00 (C-3^{D}), 75.77 (C-3^{A}), 75.72 (C-3^{B}), 74.57 (C-3^{C}), 74.05, 73.24, 72.63, 72.49, 71.86, 71.44 (4 CH_2Ph), 70.20, 70.02, 69.47, 68.85, 68.65, 68.13 (C-7), 67.21 (C-5^{D}), 66.16 (CH_2Ph), 62.47 (C-6^{A}, 6^{D}), 61.54 (C-6^{C}), 60.49 (C-2^{B}), 60.36 (C-6^{B}), 59.90 (C-2^{d}), 50.95 (C-2^{A}), 50.77 (C-2^{C}), 33.98 (C-11), 28.86 (C-8), 25.64 (C-9), 24.44 (C-10). HR-MS: Calculated for $C_{90}H_{92C}l_6N_8O_{24}$ $[M+H]^+$: 1879.4434, found: 1879.4428.

6-(Benzyl hexanoyl) 2-azido-6-O-benzoyl-3-*O*-benzyl-2-deoxy-α-D-galactopyranosyl-(1→4)-6-O-benzoyl-3-*O*-benzyl-2-deoxy-2-trichloroacetamido-α-D-galactopyranosyl-(1→4)-2-azido-6-O-benzoyl-3-*O*-benzyl-2-

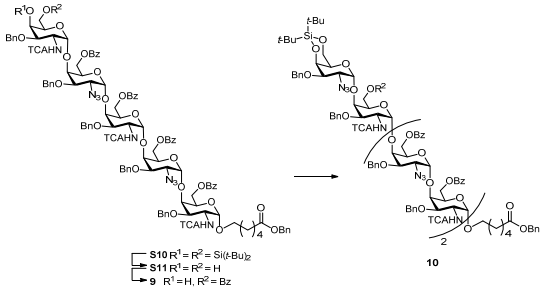
deoxy-α-D-galactopyranosyl-(1→4)-6-O-benzoyl-3-*O*-benzyl-2-deoxy-2-trichloroacetamido-α-D-galactopyranoside (8)

The reaction was carried out according to the general procedure D using compound **S9** (1.15 g, 0.61 mmol), PhCOOBt (660 mg, 2.75 mmol) and Et_3N (430 µl, 3.05 mmol). The product was purified by column chromatography (pentane:EtOAc = 5:2). Compound **8** (1.12 g, 92% yield, pentane:EtOAc = 2:1, R*f* = 0.30-0.40) was obtained as yellow syrup. $[\alpha]_D^{25}$ +107.4 (c=1, $CHCl_3$). IR (neat, cm^{-1}) ν 687, 711, 737, 820, 1005, 1027, 1047, 1110, 1158, 1268, 1315, 1452, 1508, 1720, 2111, 2874, 2929, 3423, 3509. ^{1}H-NMR ($CDCl_3$, 500 MHz) δ 8.16 – 7.89 (m, 8H, *C*H, Bz), 7.70 – 7.12 (m, 38H), 7.07 – 6.98 (m, 2H), 6.91 (d, *J* = 9.4 Hz, 1H, *N*H), 6.85 (d, *J* = 9.3 Hz, 1H, *N*H), 5.20 (d, *J* = 3.5 Hz, 1H, H-1^C), 5.12 (s, 2H, *C*H_2*Ph*), 5.09 (d, *J* = 3.6 Hz, 1H, H-1^B), 5.03 (d, *J* = 3.7 Hz, 1H, H-1^A), 4.97 – 4.55 (m, 16H, H-1^D), 4.54 – 4.41 (m, 4H), 4.30 (d, *J* = 2.6 Hz, 1H, H-4A), 4.25 – 4.06 (m, 8H), 4.03 (dd, *J* = 10.5, 4.5 Hz, 1H), 3.90 – 3.78 (m, 3H), 3.74 (dt, *J* = 10.0, 6.4 Hz, 1H), 3.66 (dd, *J* = 10.7, 3.5 Hz, 1H), 3.49 (dt, *J* = 10.0, 6.4 Hz, 1H, H-7), 2.63 (bs, 1H, *O*H), 2.35 (t, *J* = 7.4 Hz, 2H, H-11), 1.71 – 1.54 (m, 4H, H-10, 8), 1.42 – 1.26 (m, 2H, H-9). ^{13}C NMR (125 MHz, $CDCl_3$) δ 173.20 (C-12), 165.97, 165.89, 165.23, 165.08 (C=O, Bz), 161.70, 161.53 (*CONH*), 137.19, 136.88, 136.82, 136.70, 135.90, 133.56, 133.24, 133.20, 133.16, 132.90, 129.96, 129.92, 129.84, 129.79, 129.57, 129.54, 129.50, 129.44, 129.26, 128.65, 128.52, 128.51, 128.48, 128.46, 128.35, 128.32, 128.24, 128.21, 128.11, 128.04, 127.98, 127.85, 127.80, 127.70, 127.06 (aromatic), 99.39 (C-1^D), 98.85 (C-1^B), 97.21 (C-1^C), 96.99 (C-1^A), 92.57, 92.51 (2 C*Cl$_3$*), 76.59 (C-3^D), 75.68 (C-3^B), 75.60 (C-3^A), 74.24 (C-3^C), 73.07, 72.92, 72.61, 72.39, 72.08, 71.51 (4 C*H$_2$Ph*), 70.24, 69.34 (C-5^C), 68.83 (C-5^A), 68.69 (C-5^B), 68.08 (C-7), 66.12 (C*H$_2$Ph*), 65.38 (C-5^D), 62.48 (C-6^A), 61.91 (C-6^D), 61.50 (C-6^C), 60.45 (C-2^B), 60.41 (C-6^B), 59.60 (C-2^D), 50.94 (C-2^A), 50.75 (C-2^C), 33.95 (C-11), 28.83 (C-8), 25.61 (C-9), 24.41 (C-10). HR-MS: Calculated for $C_{97}H_{96}Cl_6N_8O_{25}$ $[M+H]^+$: 1983.4696, found: 1983.4690.

Pentasaccharide S10

The reaction was carried out according to the general procedure B. The donor **3** (630 mg, 0.87 mmol) and the acceptor **8** (1.08 g, 0.54 mmol) were co-evaporated with toluene (three times). The residue was dissolved in 5.5 ml dry DCM under nitrogen and stirred over fresh flame-dried molecular sieves 4Å. The solution was cooled to 0 °C, after which TfOH (5 µl, 0.05 mmol) was added. The reaction was stirred at 0 °C for 1 h. Then the reaction was quenched with Et_3N, diluted with DCM, washed with saturated $NaHCO_3$ and brine. The organic phase was dried with anhydrous $MgSO_4$, filtered and concentrated *in vacuo*. The product was purified by silica gel column chromatography (pentane:EtOAc = 4:1). Compound **S10** (1.19 g, 87% yield, pentane: EtOAc = 5:2, R*f* = 0.35-0.45) was obtained as yellow syrup. $[\alpha]_D^{25}$ +138.5 (c=1, $CHCl_3$). IR (neat, cm^{-1}) ν 651,685, 698, 710, 736, 819, 1003, 1027, 1046, 1096, 1108,1159, 1266, 1315, 1452, 1508, 1720, 2111, 2860, 2933, 3421. ^{1}H-NMR ($CDCl_3$, 500 MHz) δ 8.09 – 8.03 (m, 2H, *C*H, Bz), 8.00 – 7.94 (m, 2H, *C*H, Bz), 7.94 – 7.86 (m, 4H, *C*H, Bz), 7.71 – 7.60 (m, 2H), 7.59 – 7.47 (m, 6H), 7.46 – 7.38 (m, 4H), 7.37 – 7.09 (m, 30H), 6.99 (t, *J* = 7.4 Hz, 1H), 6.91 (t, *J* = 7.4 Hz, 1H), 6.76 - 6.74 (m, 3H, 3x*N*H), 5.16 (d, *J* = 3.6 Hz, 1H, H-1^E), 5.07 (s, 3H, H-1C, *C*H_2*Ph*), 5.01 (d, *J* = 3.6 Hz, 1H, H-1^B), 4.97 (d, *J* =

3.7 Hz, 1H, H-1^{A}), 4.90 – 4.47 (m, 19H, H-1^{D}), 4.46 – 4.31 (m, 6H), 4.23 (d, *J* = 2.6 Hz, 1H, H-4^{A}), 4.15 – 3.85 (m, 9H), 3.82 – 3.53 (m, 6H), 3.52 – 3.39 (m, 2H), 3.32 (dd, *J* = 12.9, 2.0 Hz, 1H, H-6^{E}), 2.31 (t, *J* = 7.4 Hz, 2H, H-11), 1.66 – 1.51 (m, 4H, H-10, 8), 1.36 – 1.23 (m, 2H, H-9), 1.00 – 0.91 (m, 18H, *C*H$_3$). ^{13}C NMR (125 MHz, $CDCl_3$) δ 173.26 (C-12), 165.96, 165.19, 165.08, 165.06 (4 C=O, Bz), 161.78, 161.53, 161.45 (3 C*ONH*), 137.76, 137.11, 136.92, 136.86, 136.77, 135.97, 133.67, 133.49, 133.29, 133.17, 129.90, 129.62, 129.55, 129.53, 129.32, 128.75, 128.71, 128.69, 128.61, 128.54, 128.52, 128.49, 128.41, 128.30, 128.20, 128.13, 128.05, 127.95, 127.83, 127.81, 127.76, 127.18, 126.98, 126.88, 98.92 (C-1^{D}), 98.89 (C-1^{B}), 97.30 (C-1^{C}), 97.09 (C-1^{E}), 97.07 (C-1^{A}), 92.62 (2x C*Cl$_3$*), 92.47 (C*Cl$_3$*), 76.24 (C-3^{D}), 75.97 (C-3^{B}), 75.62 (C-3^{A}), 74.44 (C-3^{E}), 73.51, 73.19, 72.84, 72.64, 72.47, 72.36, 71.98, 70.15, 69.75, 69.58, 69.31, 69.24, 68.90, 68.73, 68.63, 68.18 (C-7), 67.98 (C-5E), 66.78 (C-6^{E}), 66.21 (C*H$_2$Ph*), 62.50 (C-6), 61.49 (C-6), 60.61 (C-2^{B}), 60.58 (C-2^{D}), 60.39 (C-6), 60.05 (C-6), 50.99 (C-2^{A}), 50.71 (C-2^{C}), 49.74 (C-2^{E}), 34.04 (C-11), 28.92 (C-8), 27.61 (C*H$_3$*), 27.28 (C*H$_3$*), 25.70 (C-9), 24.51 (C-10), 23.31 (C-*Si*), 20.66 (C-*Si*). ^{13}C-HMBC ($CDCl_3$, 100 MHz): 98.92 ($J_{C1,H1}$ = 172 Hz), 98.89 ($J_{C1,H1}$ = 171 Hz), 97.30 ($J_{C1,H1}$ = 174 Hz), 97.09 ($J_{C1,H1}$ = 174 Hz), 97.07 ($J_{C1,H1}$ = 173 Hz). MALDI-MS: Calculated for $C_{120}H_{128}Cl_9N_9O_{30}Si$ $[M+Na]^+$: 2540.5631, found: 2540.5485.



Pentasaccharide S11

The reaction was carried out according to the general procedure C using compound **S10** (1.16 g, 0.46 mmol) and HF/pyridine (70%, 190 µl, 7.34 mmol). The product was purified by column chromatography (pentane:EtOAc = 3:2). Compound **S11** (1.04 g, 94% yield, pentane:EtOAc = 1:1, R*f* = 0.25-0.35) was obtained as yellow syrup. $[\alpha]_D^{25}$ +126.0 (c=1, $CHCl_3$). IR (neat, cm^{-1}) ν 711, 738, 820, 1005, 1027, 1046, 1110, 1158, 1268, 1315, 1508, 1720, 2111, 2872, 2929, 3419, 3509. ^{1}H-NMR ($CDCl_3$, 500 MHz) δ 8.09 – 8.01 (m, 2H, *C*H, Bz), 8.00 – 7.85 (m, 6H, *C*H, Bz), 7.72 – 7.07 (m, 42H), 6.98 (t, *J* = 7.5 Hz, 1H), 6.89 (t, *J* = 7.4 Hz, 1H), 6.84 – 6.71 (m, 3H, 3x*N*H), 5.08 (d, *J* = 3.3 Hz, 1H, H-1^{E}), 5.07 (s, 2H, *CH$_2$Ph*), 5.04 - 5.31 (m, 2H, H-1^{B}, 1^{C}), 4.97 (d, *J* = 3.7 Hz, 1H, H-1^{A}), 4.86 (d, *J* = 11.7 Hz, 1H), 4.82 – 4.34 (m, 20H, H-1^{D}), 4.31 (d, *J* = 2.6 Hz, 1H, H-4^{B}), 4.23 (d, *J* = 2.6 Hz, 1H, H-4^{A}), 4.20 – 3.92 (m, 11H), 3.83 – 3.65 (m, 3H), 3.64 – 3.55 (m, 2H), 3.50 (dd, *J* = 10.7, 3.6 Hz, 1H), 3.47 – 3.35 (m, 2H), 3.28 (dt, *J* = 12.0, 3.5 Hz, 1H), 2.90 (bs, 1H, *O*H), 2.30 (t, *J* = 7.4 Hz, 2H, H-11), 1.67 – 1.50 (m, 4H, H-10, 8), 1.37 – 1.23 (m, 2H, H-9). ^{13}C NMR (125 MHz, $CDCl_3$) δ 173.27 (C-12), 165.95, 165.20, 165.16, 165.08 (4 C=O, Bz), 161.78, 161.54, 161.45 (C*ONH*), 137.19, 136.96, 136.84, 136.81, 136.73, 135.94, 133.64, 133.45, 133.29, 133.20, 129.95, 129.87, 129.61, 129.59, 129.54, 129.49, 129.41, 129.28, 128.71, 128.64, 128.58, 128.55, 128.51, 128.49, 128.40, 128.27,

128.17, 128.07, 128.05, 127.92, 127.78, 127.19, 127.14, 126.83, 99.01 (C-1^D), 98.91 (C-1^B), 97.60 (C-1^C), 97.36 (C-1^E), 97.04 (C-1^A), 92.59, 92.49, 92.45 (3 C*Cl*$_3$), 76.16 (C-3^D), 75.96 (C-3), 75.62 (C-3^A), 74.85, 74.06 (C-3^E), 73.24, 73.08, 72.64, 72.46, 72.36, 72.12, 70.83, 70.46, 70.25, 69.44, 69.29, 68.88, 68.79, 68.70, 68.16 (C-7), 66.51, 66.18 (C*H*$_2$*Ph*), 62.51 (C-6A), 62.36 (C-6^E), 61.46 (C-6), 60.57 (C-2^B), 60.54 (C-2^D), 60.37 (C-6), 60.29 (C-6), 50.98 (C-2^A), 50.71 (C-2^C), 50.21 (C-2^E), 34.01 (C-11), 28.89 (C-8), 25.67 (C-9), 24.47 (C-10). HR-MS: Calculated for $C_{112}H_{112}Cl_9N_9O_{30}$ $[M+NH_4]^+$: 2395.50556, found: 2395.50778.

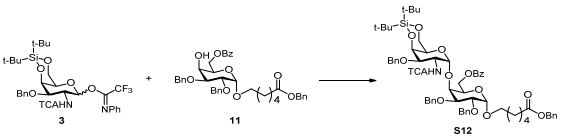
Pentasaccharide 9

The reaction was carried out according to the general procedure D using compound **S11** (1.0 g, 0.42 mmol), PhCOOBt (451 mg, 1.89 mmol) and Et_3N (300 µl, 2.1 mmol). The product was purified by column chromatography (pentane:EtOAc = 5:2). Compound **9** (994 mg, 95% yield, pentane:EtOAc = 2:1, R*f* = 0.25-0.30) was obtained as yellow syrup. $[\alpha]_D^{25}$ +131.0 (c=1, $CHCl_3$). IR (neat, cm^{-1}) ν 711, 738, 820, 1005, 1027, 1047, 1110, 1159, 1269, 1315, 1508, 1720, 2110, 2872, 2929, 3421. ^{1}H-NMR ($CDCl_3$, 500 MHz) δ 8.05 (d, *J* = 7.7 Hz, 2H, *C*H, Bz), 7.99 – 7.81 (m, 8H, *C*H, Bz), 7.71 – 7.04 (m, 43H), 7.03 – 6.86 (m, 3H), 6.85 – 6.73 (m, 3H, 3x*N*H), 5.11 (d, *J* = 3.6 Hz, 1H, H-1^E), 5.09 (d, *J* = 3.4 Hz, 1H, H-1^C), 5.07 (s, 2H, *C*H$_2$*Ph*), 5.03 (d, *J* = 3.6 Hz, 1H, H-1^B), 4.97 (d, *J* = 3.7 Hz, 1H, H-1^A), 4.90 – 4.33 (m, 23H, H-1^D), 4.34 - 4.23 (m, 3H), 4.16 – 3.89 (m, 10H), 3.84 – 3.65 (m, 4H), 3.63 – 3.52 (m, 2H), 3.44 (dt, *J* = 10.1, 6.5 Hz, 1H, H-7), 2.60 (bs, 1H, *O*H), 2.30 (t, *J* = 7.4 Hz, 2H, H-11), 1.66 – 1.49 (m, 4H, H-10, 8), 1.36 – 1.21 (m, 2H, H-9). ^{13}C NMR (125 MHz, $CDCl_3$) δ 173.26 (C-12), 165.95, 165.88, 165.18, 165.11, 165.08 (5 C=O, Bz), 161.78, 161.51, 161.46 (3 C*ONH*), 136.99, 136.85, 136.80, 136.74, 135.94, 133.63, 133.46, 133.28, 133.16, 133.08, 129.86, 129.79, 129.59, 129.53, 129.48, 129.35, 129.28, 128.71, 128.66, 128.63, 128.57, 128.51, 128.49, 128.42, 128.39, 128.35, 128.33, 128.26, 128.16, 128.13, 128.06, 127.91, 127.78, 127.73, 127.15, 127.13, 126.86, 98.96 (C-1^D), 98.90 (C-1^B), 97.36 (C-1^C), 97.03 (C-1^E), 96.99 (C-1^A), 92.59, 92.50, 92.49 (3 CCl_3), 75.94, 75.90, 75.62, 74.99, 73.96, 73.22, 72.95, 72.62, 72.59, 72.44, 72.09, 71.26, 70.22, 69.93, 69.29, 68.88, 68.68, 68.15 (C-7), 68.09, 66.17 (C*H*$_2$*Ph*), 64.97 (C-5^E), 62.69 (C-6), 62.52 (C-6), 61.49 (C-6), 60.55 (C-2^B), 60.51 (C-2^D), 60.38 (C-6), 60.20 (C-6), 50.98 (C-2^A), 50.69 (C-2^C), 50.33 (C-2^E), 34.00 (C-11), 28.88 (C-8), 25.66 (C-9), 24.46 (C-10). MALDI-MS: Calculated for $C_{119}H_{116}Cl_9N_9O_{31}$ $[M+Na]^+$: 2504.4872, found: 2504.4680.

Hexasaccharide 10

The reaction was carried out according to the general procedure B. The donor **2** (469 mg, 0.77 mmol) and the acceptor **9** (961 mg, 0.39 mmol) were co-evaporated with toluene (three times). The residue was dissolved in 4 ml dry DCM under nitrogen and stirred over fresh flame-dried molecular sieves 4Å. The solution was cooled to 0 °C, after which TfOH (4 µl, 0.04 mmol) was added. The reaction was stirred at 0 °C for 1 h. Then the reaction was quenched with Et_3N, diluted with DCM, washed with saturated $NaHCO_3$ and brine. The organic phase was dried with anhydrous $MgSO_4$, filtered and concentrated *in vacuo*. The product was purified by silica gel column chromatography (pentane:EtOAc = 7:2). Compound **10** (970 mg, 87% yield, pentane: EtOAc = 2:1, R*f* = 0.55-0.65)

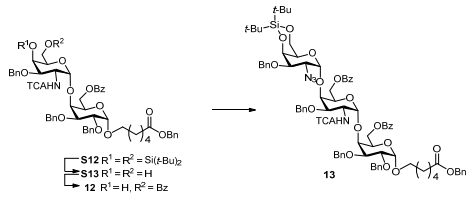
was obtained as yellow syrup. $[\alpha]_D^{25}$ +137.6 (c=1, $CHCl_3$). IR (neat, cm^{-1}) ν 685, 710, 737, 820, 1005, 1027, 1046, 1063, 1109, 1159, 1266, 1315, 1452, 1507, 1720, 2111, 2860, 2932, 3419. ^{1}H-NMR ($CDCl_3$, 500 MHz) δ 8.08 – 8.02 (m, 2H, *C*H, Bz), 7.99 – 7.94 (m, 2H, *C*H, Bz), 7.94 – 7.84 (m, 6H, *C*H, Bz), 7.67 – 7.07 (m, 49H), 7.03 – 6.97 (m, 1H), 6.94 – 6.87 (m, 2H), 6.82 – 6.72 (m, 3H, 3x*N*H), 5.11 (d, *J* = 3.5 Hz, 1H, H-1^E), 5.07 (s, 3H, *CH*$_2$*Ph*, H-1^C), 5.02 (d, *J* = 3.6 Hz, 1H, H-1^B), 4.96 (d, *J* = 3.7 Hz, 1H, H-1^A), 4.89 – 4.83 (m, 2H, *CHHPh*, H-1^D), 4.82 – 3.90 (m, 41H), 3.85 – 3.56 (m, 8H), 3.49 – 3.36 (m, 2H), 2.31 (t, *J* = 7.4 Hz, 2H, H-11), 1.67 – 1.51 (m, 4H, H-10, 8), 1.38 – 1.23 (m, 2H, H-9), 0.96 (d, *J* = 15.7 Hz, 18H, *C*H$_3$). ^{13}C NMR (125 MHz, $CDCl_3$) δ 173.28 (C-12), 165.98, 165.38, 165.24, 165.19, 165.13 (C=O, Bz), 161.82, 161.59, 161.52 (C*ONH*), 138.00, 136.98, 136.90, 136.86, 136.79, 136.02, 133.68, 133.50, 133.34, 133.30, 133.19, 129.96, 129.93, 129.76, 129.67, 129.65, 129.60, 129.58, 129.44, 129.35, 128.77, 128.71, 128.69, 128.64, 128.59, 128.55, 128.47, 128.44, 128.41, 128.33, 128.23, 128.11, 128.08, 128.02, 128.00, 127.95, 127.84, 127.79, 127.74, 127.67, 127.23, 127.21, 126.92, 99.51 (C-1^D), 99.01 (C-1^F), 98.98 (C-1^B), 97.42 (C-1^C), 97.11 (C-1A, 1^E), 92.66 (C*Cl*$_3$), 92.56 (2x C*Cl*$_3$), 76.33, 76.01, 75.67, 74.51, 74.17, 73.29, 73.00, 72.70, 72.54, 72.50, 72.22, 71.25, 70.61, 70.27, 70.04, 69.60, 69.43, 69.36, 68.95, 68.78, 68.69, 68.23 (C-7), 67.98, 67.09 (C-6^F), 66.24 (C*H*$_2$*Ph*), 62.55 (2xC-6), 61.71 (C-6), 61.53 (C-6), 60.63 (C-2B), 60.50 (C-2^D), 60.42 (C-6), 60.30 (C-6), 58.92 (C-2^F), 51.04 (C-2^A), 50.74 (C-2C, 2^E), 34.07 (C-11), 28.96 (C-8), 27.68 (C*H*$_3$), 27.36 (C*H*$_3$), 25.74 (C-9), 24.54 (C-10), 23.32 (C-*Si*), 20.72 (C-*Si*). ^{13}C-HMBC ($CDCl_3$, 100 MHz): 99.51 ($J_{C1,H1}$ = 171 Hz), 99.01 ($J_{C1,H1}$ = 174 Hz), 98.98 ($J_{C1,H1}$ = 171 Hz), 97.42 ($J_{C1,H1}$ = 174 Hz), 97.11 ($J_{C1,H1}$ = 173 Hz). MALDI-MS: Calculated for $C_{140}H_{147}Cl_9N_{12}O_{35}Si$ $[M+Na]^+$: 2921.6959, found: 2921.6714.



6-(Benzyl hexanoyl) 3-*O*-benzyl-2-deoxy-4,6-di-*tert*-butylsilylidene-2-trichloroacetamido-α-D-galactopyranosyl-(1→4)-6-O-benzoyl-2,3-di-*O*-benzyl-α-D-galactopyranoside (S12)

The reaction was carried out according to the general procedure B. The donor **3** (205 mg, 0.28 mmol) and the acceptor **11** (96 mg, 0.14 mmol) were co-evaporated with toluene (three times). The residue was dissolved in 1.5 ml dry DCM under nitrogen and stirred over fresh flame-dried molecular sieves 4Å. The solution was cooled to 0 °C, after which TfOH (2 µl, 0.01 mmol) was added. The reaction was stirred at 0 °C for 1 h. Then the reaction was quenched with Et_3N, diluted with DCM, washed with saturated $NaHCO_3$ and brine. The organic phase was dried with anhydrous $MgSO_4$, filtered and concentrated *in vacuo*. The product was purified by silica gel column chromatography (pentane:EtOAc = 7:1). Compound **S12** (150 mg, 88% yield, pentane: EtOAc = 3:1, R*f* = 0.50-0.60) was obtained as yellow syrup. $[\alpha]_D^{25}$ +99.3 (c=1, $CHCl_3$). IR (neat, cm^{-1}) ν 651, 698, 713, 738, 796, 824, 1005, 1027, 1047, 1098, 1271, 1508, 1724, 2859, 2933, 3418. ^{1}H-NMR ($CDCl_3$, 400 MHz) δ 8.04 – 7.97 (m, 2H, *C*H, Bz), 7.59 – 7.51 (m, 1H), 7.46 – 7.23 (m, 22H, aromatic H), 6.94 (d, *J* = 9.1 Hz, 1H, *N*H), 5.22 (d, *J* = 3.6 Hz, 1H, H-1^B), 5.08 (s, 2H, *C*H$_2$*Ph*), 4.82 (d, *J* = 11.4 Hz, 1H, *CHHPh*), 4.79 – 4.66 (m, 4H, *C*H$_2$*Ph*, H-1A, 2^B), 4.65 – 4.51 (m, 4H,

*C*H$_2$*Ph*, H-6^A), 4.41 (d, *J* = 2.8 Hz, 1H, H-4^B), 4.26 (d, *J* = 3.0 Hz, 1H, H-4^A), 4.21 (dd, *J* = 11.1, 6.9 Hz, 1H, H-6^A), 4.11 - 4.04 (m, 2H, H-5^A, 5^B), 3.86 (dd, *J* = 10.1, 3.0 Hz, 1H, H-3^A), 3.80 – 3.71 (m, 2H, H-2^A, 6^B), 3.66 (dd, *J* = 10.8, 2.5 Hz, 1H, H-3^B), 3.59 (dt, *J* = 9.9, 6.9 Hz, 1H, H-7), 3.48 (dd, *J* = 12.8, 2.1 Hz, 1H, H-6^B), 3.40 (dt, *J* = 9.8, 6.6 Hz, 1H, H-7), 2.28 (t, *J* = 7.5 Hz, 2H, H-11), 1.64 – 1.52 (m, 4H, H-10, 8), 1.34 – 1.22 (m, 2H, H-9), 1.07 (s, 9H, *C*H$_3$), 1.01 (s, 9H, *C*H$_3$). ^{13}C NMR (100 MHz, $CDCl_3$) δ 173.35 (C-12), 165.71 (C=O, Bz), 161.69 (C*ONH*), 138.22, 138.04, 136.07, 133.38, 129.72, 129.43, 128.55, 128.52, 128.47, 128.45, 128.42, 128.19, 128.15, 128.01, 127.94, 127.91, 127.77, 127.73, 127.70, 127.44, 97.00 (C-1^B), 96.96 (C-1^A), 92.65 (C*Cl$_3$*), 76.81 (C-3^A), 76.58 (C-2^A), 75.16 (C-3^B), 73.61 (C*H$_2$Ph*), 73.07 (C*H$_2$Ph*), 72.07 (C-4^A), 69.60 (C*H$_2$Ph*), 69.43 (C-4^B), 68.08 (C-7), 67.95 (C-5^A), 67.85 (C-5^B), 66.84 (C-6^B), 66.07 (C*H$_2$Ph*), 62.07 (C-6^A), 49.94 (C-2^B), 34.10 (C-11), 29.02 (C-8), 27.64 (C*H$_3$*), 27.37 (C*H$_3$*), 25.67 (C-9), 24.60 (C-10), 23.35 (C-*Si*), 20.72 (C-*Si*). ^{13}C-HMBC ($CDCl_3$, 100 MHz): 97.00 ($J_{C1,H1}$ = 170 Hz), 96.96 ($J_{C1,H1}$ = 169 Hz). HR-MS: Calculated for $C_{63}H_{76}Cl_3NO_{14}Si$ $[M+H]^+$: 1204.4179, found: 1204.4173.



6-(Benzyl hexanoyl) 3-*O*-benzyl-2-deoxy-2-trichloroacetamido-α-D-galactopyranosyl-(1→4)-6-O-benzoyl-2,3-di-*O*-benzyl-α-D-galactopyranoside (S13)

The reaction was carried out according to the general procedure C using compound **S12** (2.70 g, 2.24 mmol) and HF/pyridine (70%, 0.93 ml, 35.84 mmol). The product was purified by column chromatography (pentane:EtOAc = 1:1). Compound **S13** (2.17 g, 95% yield, pentane:EtOAc = 1:1, R*f* = 0.20-0.30) was obtained as yellow syrup. $[\alpha]_D^{25}$ +83.3 (c=1, $CHCl_3$). IR (neat, cm^{-1}) ν 580, 598, 697, 713, 734, 819, 1026, 1040, 1095, 1156, 1271, 1452, 1511, 1720, 2872, 2933, 3411. ^{1}H-NMR ($CDCl_3$, 400 MHz) δ 8.06 – 7.96 (m, 2H, *C*H, Bz), 7.60 – 7.51 (m, 1H), 7.49 – 7.27 (m, 22H, aromatic H), 6.98 (d, *J* = 9.2 Hz, 1H, *N*H), 5.16 (d, *J* = 3.7 Hz, 1H, H-1^B), 5.10 (s, 2H, *C*H$_2$*Ph*), 4.87 – 4.77 (m, 3H, H-1^A, *C*H$_2$*Ph*), 4.76 – 4.65 (m, 3H, *C*H$_2$*Ph*), 4.62 – 4.43 (m, 3H, H-2^B, 6^A, *C*H$_2$*Ph*), 4.30 (dd, *J* = 11.1, 6.2 Hz, 1H, H-6^A), 4.25 (d, *J* = 2.9 Hz, 1H, H-4^A), 4.23 – 4.18 (m, 1H, H-5^B), 4.17 – 4.13 (m, 1H, H-4^B), 4.13 – 4.07 (m, 1H, H-5^A), 3.90 (dd, *J* = 10.1, 2.8 Hz, 1H, H-3^A), 3.78 (dd, *J* = 10.1, 3.6 Hz, 1H, H-2^A), 3.69 – 3.47 (m, 4H, H-3^B, 6^B, 7), 3.42 (dt, *J* = 9.8, 6.6 Hz, 1H, H-7), 3.17 (bs, 1H, *O*H), 2.30 (t, *J* = 7.5 Hz, 2H, H-11), 1.67 – 1.54 (m, 4H, H-10, 8), 1.35 – 1.24 (m, 2H, H-9). ^{13}C NMR (100 MHz, $CDCl_3$) δ 173.39 (C-12), 165.80 (C=O, Bz), 161.81 (C*ONH*), 138.30, 138.26, 137.19, 136.06, 133.39, 129.69, 129.41, 128.62, 128.56, 128.53, 128.48, 128.45, 128.20, 128.15, 128.07, 127.91, 127.88, 127.77, 127.66, 97.44 (C-1^B), 96.98 (C-1^A), 92.52 (C*Cl$_3$*), 76.90 (C-3^A), 76.18 (C-2^A), 75.78 (C-3^B), 73.54 (C*H$_2$Ph*), 73.34 (C-4^A), 72.90, 70.98 (2 C*H$_2$Ph*), 69.55 (C-5^B), 68.34 (C-5^A), 68.08 (C-7), 66.73 (C-

4^B), 66.09 (CH_2Ph), 62.61 (C-6^B), 62.58 (C-6^A), 50.65 (C-2^B), 34.11 (C-11), 29.00 (C-8), 25.66 (C-9), 24.60 (C-10). HR-MS: Calculated for $C_{55}H_{60}Cl_3NO_{14}$ $[M+H]^+$: 1064.3158, found: 1064.3152.

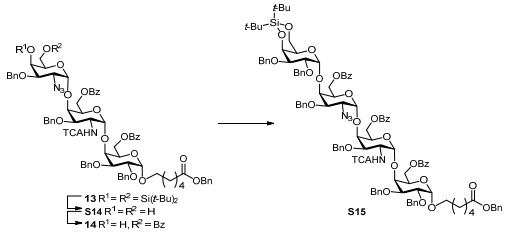
6-(Benzyl hexanoyl) 6-*O*-benzoyl-3-*O*-benzyl-2-deoxy-2-trichloroacetamido-α-D-galactopyranosyl-(1→4)-6-O-benzoyl-2,3-di-*O*-benzyl-α-D-galactopyranoside (12)

The reaction was carried out according to the general procedure D using compound **S13** (2.26 g, 2.21 mmol), PhCOOBt (2.38 g, 11.05 mmol) and Et_3N (1.54 ml, 8.47 mmol). The product was purified by column chromatography (pentane:EtOAc = 3:1). Compound **12** (2.31 g, 93% yield, pentane:EtOAc = 2:1, R*f* = 0.30-0.40) was obtained as yellow syrup. $[\alpha]_D^{25}$ +78.2 (c=1, $CHCl_3$). IR (neat, cm^{-1}) ν 698, 711, 736, 820, 1027, 1049, 1070, 1096, 1159, 1271, 1315, 1452, 1511, 1720, 2869, 2929, 3416, 3500. ^{1}H-NMR ($CDCl_3$, 400 MHz) δ 8.01 – 7.96 (m, 2H, *C*H, Bz), 7.93 – 7.87 (m, 2H, *C*H, Bz), 7.57 – 7.47 (m, 2H), 7.42 – 7.22 (m, 23H), 7.21 – 7.15 (m, 2H), 7.13 – 7.07 (m, 1H), 6.94 (d, *J* = 9.2 Hz, 1H, *N*H), 5.17 (d, *J* = 3.6 Hz, 1H, H-1^B), 5.08 (s, 2H, CH_2Ph), 4.82 (d, *J* = 11.7 Hz, 1H, C*H*HPh), 4.79 – 4.74 (m, 2H, H-1A, C*H*HPh), 4.73 – 4.46 (m, 7H, C*H*HPh, H-2^B, 5^B, 6^A), 4.37 (dd, *J* = 11.0, 6.9 Hz, 1H, H-6^B), 4.30 (d, *J* = 3.0 Hz, 1H, H-4^A), 4.24 - 4.20 (m, 2H, H-6^A, 6^B), 4.09 (t, *J* = 7.2 Hz, 1H, H-5^A), 4.05 (dd, *J* = 2.9, 1.4 Hz, 1H, H-4^B), 3.89 (dd, *J* = 10.1, 3.0 Hz, 1H, H-3^A), 3.78 (dd, *J* = 10.1, 3.6 Hz, 1H, H-2^A), 3.71 (dd, *J* = 10.6, 2.8 Hz, 1H, H-3^B), 3.60 (dt, *J* = 9.9, 6.9 Hz, 1H, H-7), 3.40 (dt, *J* = 9.8, 6.6 Hz, 1H, H-7), 2.72 (bs, 1H, *O*H), 2.29 (t, *J* = 7.5 Hz, 2H, H-11), 1.68 – 1.51 (m, 4H, H-10, 8), 1.35 – 1.21 (m, 2H, H-9). ^{13}C NMR (100 MHz, $CDCl_3$) δ 173.41 (C-12), 165.98, 165.77 (2 C=O, Bz), 161.76 (C*ONH*), 138.30, 138.12, 137.23, 136.08, 133.41, 133.09, 129.91, 129.71, 129.63, 129.34, 128.68, 128.58, 128.52, 128.46, 128.37, 128.32, 128.23, 128.19, 128.15, 127.93, 127.90, 127.86, 127.68, 127.41 (aromatic), 97.05 (C-1^A), 96.88 (C=1^B), 92.59 (CCl_3), 76.66 (C-3^A), 76.21 (C-2^A), 75.88 (C-3^B), 73.57, 72.89 (2 CH_2Ph), 72.39 (C-4^A), 71.40 (CH_2Ph), 68.18 (C-5^B), 68.15 (C-7), 68.10 (C-5^A), 66.12 (CH_2Ph), 65.26 (C-4^B), 62.98 (C-6^B), 62.25 (C-6^A), 50.62 (C-2^B), 34.14 (C-11), 29.03 (C-8), 25.67 (C-9), 24.63 (C-10). HR-MS: Calculated for $C_{62}H_{64}Cl_3NO_{15}$ $[M+H]^+$: 1168.3420, found: 1168.3414.

6-(Benzyl hexanoyl) 2-azido-3-*O*-benzyl-2-deoxy-4,6-di-*tert*-butylsilylidene-α-D-galactopyranosyl-(1→4)-6-*O*-benzoyl-3-*O*-benzyl-2-deoxy-2-trichloroacetamido-α-D-galactopyranosyl-(1→4)-6-O-benzoyl-2,3-di-*O*-benzyl-α-D-galactopyranoside (13)

The reaction was carried out according to the general procedure B. The donor **2** (1.94 g, 3.20 mmol) and the acceptor **12** (2.40 g, 2.13 mmol) were co-evaporated with toluene (three times). The residue was dissolved in 12 ml dry DCM under nitrogen and stirred over fresh flame-dried molecular sieves 4Å. The solution was cooled to 0 °C, after which TfOH (19 µl, 0.21 mmol) was added. The reaction was stirred at 0 °C for 1 h. Then the reaction was quenched with Et_3N, diluted with DCM, washed with saturated $NaHCO_3$ and brine. The organic phase was dried with anhydrous $MgSO_4$, filtered and concentrated *in vacuo*. The product was purified by silica gel column chromatography (pentane:EtOAc = 6:1). Compound **13** (2.92 g, 86% yield, pentane: EtOAc = 3:1, R*f* = 0.50-0.60) was obtained as yellow syrup. $[\alpha]_D^{25}$ +96.2 (c=1, $CHCl_3$). IR (neat, cm^{-1}) ν 442, 474, 650, 697, 711, 734, 796, 823, 977, 1009, 1027, 1043, 1065, 1098, 1166, 1268, 1315, 1452, 1508, 1724, 2112, 2859, 2932, 3413. ^{1}H-NMR ($CDCl_3$,

400 MHz) δ 8.03 – 7.96 (m, 2H, *C*H, Bz), 7.94 – 7.87 (m, 2H, *C*H, Bz), 7.62 – 7.50 (m, 2H), 7.49 – 7.14 (m, 30H), 7.13 – 7.05 (m, 1H), 7.02 (d, *J* = 9.5 Hz, 1H, *N*H), 5.24 (d, *J* = 3.6 Hz, 1H, H-1^{B}), 5.08 (s, 2H, *C*H$_2$*Ph*), 5.04 (d, *J* = 3.6 Hz, 1H, H-1^{C}), 4.88 (d, *J* = 11.9 Hz, 1H, *CHHPh*), 4.79 (d, *J* = 3.6 Hz, 1H, H-1^{A}), 4.77 – 4.70 (m, 4H, *C*H$_2$*Ph*), 4.70 – 4.43 (m, 8H, *C*H$_2$*Ph*, H-2^{B}, 5^{B}, 6^{A}, 6^{B}), 4.40 (dd, *J* = 10.2, 7.8 Hz, 1H, H-6^{B}), 4.31 (d, *J* = 3.0 Hz, 1H, H-4^{A}), 4.27 – 4.16 (m, 3H, H-4^{B}, 5^{C}, 6^{A}), 4.09 (t, *J* = 7.1 Hz, 1H, H-5^{A}), 4.03 (dd, *J* = 10.6, 2.7 Hz, 1H, H-3^{C}), 3.92 – 3.84 (m, 2H, H-2^{A}, 2^{C}), 3.76 (dd, *J* = 10.0, 3.6 Hz, 1H, H-3^{A}), 3.74 – 3.66 (m, 3H, H-3^{B}, 6^{C}), 3.61 (dt, *J* = 9.9, 6.9 Hz, 1H, H-7), 3.40 (dt, *J* = 9.9, 6.6 Hz, 1H, H-7), 2.29 (t, *J* = 7.5 Hz, 2H, H-11), 1.68 – 1.53 (m, 4H, H-10, 8), 1.35 - 1.32 (m, 2H, H-9), 0.99 (s, 9H, *C*H$_3$), 0.99 (s, 9H, *C*H$_3$). ^{13}C NMR (100 MHz, $CDCl_3$) δ 173.38 (C-12), 165.77, 165.47 (2 C=O, Bz), 161.87 (C*ONH*), 138.25, 138.22, 137.92, 137.19, 136.09, 133.48, 133.26, 129.75, 129.70, 129.60, 129.33, 128.59, 128.57, 128.54, 128.52, 128.47, 128.44, 128.35, 128.24, 128.19, 128.09, 127.96, 127.91, 127.88, 127.83, 127.76, 127.68, 127.37, 127.00 (aromatic), 99.37 (C-1^{C}), 97.00 (C-1^{A}), 96.79 (C-1^{B}), 92.62 (C*Cl$_3$*), 76.29 (C-3^{A}), 76.17 (C-3^{C}), 76.07 (C-2^{A}, 3^{B}), 73.47 (C*H$_2$*), 72.76 (C*H$_2$*), 72.40 (C-4^{A}), 72.02 (C-4^{B}), 71.62, 70.68 (C*H$_2$*), 69.64 (C-4^{C}), 69.26 (C-5^{B}), 68.15 (C-7), 68.06 (C-5^{A}), 67.94 (C-5^{C}), 66.97 (C-6^{C}), 66.13 (C*H$_2$*), 62.26 (C-6^{A}), 61.74 (C-6^{B}), 58.80 (C-2^{C}), 51.05 (C-2^{B}), 34.14 (C-11), 29.03 (C-8), 27.67 (C*H$_3$*), 27.40 (C*H$_3$*), 27.35 (C-8), 25.70 (C-9), 24.64 (C-10), 23.32 (C-*Si*), 20.71 (C-*Si*). ^{13}C-HMBC ($CDCl_3$, 100 MHz): 99.37 ($J_{C1,H1}$ = 171 Hz), 97.00 ($J_{C1,H1}$ = 168 Hz), 96.79 ($J_{C1,H1}$ = 172 Hz). HR-MS: Calculated for $C_{83}H_{95}Cl_3N_4O_{19}Si$ $[M+H]^+$: 1585.5504, found: 1585.5498.



6-(Benzyl hexanoyl) 2-azido-3-*O*-benzyl-2-deoxy-α-D-galactopyranosyl-(1→4)-6-*O*-benzoyl-3-*O*-benzyl-2-deoxy-2-trichloroacetamido-α-D-galactopyranosyl-(1→4)-6-O-benzoyl-2,3-di-*O*-benzyl-α-D-galactopyranoside (S14)

The reaction was carried out according to the general procedure C using compound **13** (2.87 g, 1.81 mmol) and HF/pyridine (70%, 750 µl, 28.93 mmol). The product was purified by column chromatography (pentane:EtOAc = 2:1-3:2). Compound **S14** (2.54 g, 97% yield, pentane:EtOAc = 1:1, R*f* = 0.30-0.40) was obtained as yellow syrup. $[\alpha]_D^{25}$ +85.2 (c=1, $CHCl_3$). IR (neat, cm^{-1}) ν 698, 711, 737, 820, 1027, 1046, 1156, 1271, 1315, 1452, 1511, 1720, 2111, 2870, 2927, 3421, 3500. ^{1}H-NMR ($CDCl_3$, 400 MHz) δ 8.04 – 7.96 (m, 2H, *C*H, Bz), 7.94 – 7.87 (m, 2H, *C*H, Bz), 7.62 – 6.99 (m, 33H), 5.20 (d, *J* = 3.6 Hz, 1H, H-1^{B}), 5.07 (s, 2H, *C*H$_2$), 4.94 (d, *J* = 3.6 Hz, 1H, H-1^{C}), 4.90 – 4.44 (m, 13H, H-1^{A}), 4.38 – 4.17 (m, 5H), 4.15 – 4.06 (m, 2H), 4.00 (dd, *J* = 10.4, 2.9 Hz, 1H, H-3^{C}), 3.90 (dd, *J* = 10.0, 3.0 Hz, 1H, H-3^{A}), 3.85 – 3.70 (m, 3H), 3.62 (dt, *J* = 9.8, 6.9 Hz, 1H, H-7), 3.51 (d, *J* = 4.7 Hz, 2H), 3.41 (dt,

J = 9.9, 6.6 Hz, 1H, H-7), 2.94 (bs, 1H, *O*H), 2.57 (bs, 1H, *O*H), 2.28 (t, *J* = 7.5 Hz, 2H, H-11), 1.68 – 1.52 (m, 4H, H-10, 8), 1.38 – 1.21 (m, 2H, H-9). ^{13}C NMR (100 MHz, $CDCl_3$) δ 173.29 (C-12), 165.68, 165.42 (2 C=O, Bz), 162.09 (C*ONH*), 138.15, 138.02, 137.22, 137.13, 135.98, 133.40, 133.15, 129.63, 129.48, 129.25, 128.53, 128.49, 128.46, 128.43, 128.37, 128.33, 128.26, 128.14, 128.08, 128.03, 127.97, 127.95, 127.84, 127.74, 127.62, 127.42, 127.27 (aromatic), 99.79 (C-1^{C}), 96.93 (C-1^{A}), 96.81 (C-1^{B}), 92.41 (C*Cl*$_3$), 76.79 (C-3^{C}), 76.34 (C-2^{A}), 76.31 (C-3^{A}), 75.72 (C-3^{B}), 73.77 (C-4^{B}), 73.51 (C*H*$_2$), 72.78 (C*H*$_2$), 72.51 (C-4^{A}), 71.81 (C*H*$_2$), 71.62 (C*H*$_2$), 69.90 (C-5^{C}), 69.27 (C-5^{B}), 68.08 (C-7), 68.03 (C-5^{A}), 67.33 (C-4^{C}), 66.02 (C*H*$_2$), 62.48 (C-6^{C}), 62.25 (C-6^{A}), 61.64 (C-6^{B}), 59.80 (C-2^{C}), 51.04 (C-2^{B}), 34.03 (C-11), 28.93 (C-8), 25.59 (C-9), 24.53 (C-10). HR-MS: Calculated for $C_{75}H_{79}Cl_3N_4O_{19}$ $[M+H]^+$: 1445.4482, found: 1445.4477.

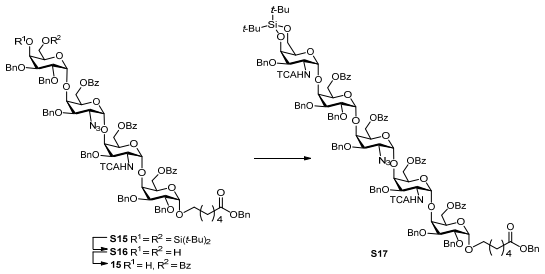
6-(Benzyl hexanoyl) 2-azido-6-*O*-benzoyl-3-*O*-benzyl-2-deoxy-α-D-galactopyranosyl-(1→4)-6-*O*-benzoyl-3-*O*-benzyl-2-deoxy-2-trichloroacetamido-α-D-galactopyranosyl-(1→4)-6-O-benzoyl-2,3-di-*O*-benzyl-α-D-galactopyranoside (14)

The reaction was carried out according to the general procedure D using compound **S14** (2.30 g, 1.59 mmol), PhCOOBt (1.71 g, 7.15 mmol) and Et_3N (1.1 ml, 7.95 mmol). The product was purified by column chromatography (pentane:EtOAc = 3:1). Compound **14** (2.35 g, 95% yield, pentane:EtOAc = 2:1, R*f* = 0.35-0.45) was obtained as yellow syrup. $[\alpha]_D^{25}$ +81.1 (c=1, $CHCl_3$). IR (neat, cm^{-1}) ν 698, 711, 736, 820, 1027, 1047, 1070, 1096, 1109, 1157, 1269, 1315, 1452, 1508, 1720, 2111, 2929, 3422, 3500. ^{1}H-NMR ($CDCl_3$, 400 MHz) δ 8.06 – 7.88 (m, 6H, *C*H, Bz), 7.61 – 7.49 (m, 3H), 7.47 – 7.12 (m, 31H), 7.10 – 6.96 (m, 3H), 5.26 (d, *J* = 3.6 Hz, 1H, H-1B), 5.07 (s, 2H, *C*H$_2$), 5.02 (d, *J* = 3.6 Hz, 1H, H-1^{C}), 4.92 - 4.83 (m, 2H), 4.80 (d, *J* = 3.6 Hz, 1H, H-1^{A}), 4.79 – 4.56 (m, 8H), 4.54 – 4.38 (m, 5H), 4.34 – 4.22 (m, 2H), 4.19 (d, *J* = 2.3 Hz, 1H), 4.16 – 4.05 (m, 3H), 3.96 – 3.82 (m, 3H), 3.81 – 3.73 (m, 2H), 3.61 (dt, *J* = 9.8, 6.9 Hz, 1H, H-7), 3.40 (dt, *J* = 9.8, 6.5 Hz, 1H, H-7), 2.60 (bs, 1H, *O*H), 2.28 (t, *J* = 7.5 Hz, 2H, H-11), 1.66 – 1.52 (m, 4H, H-10, 8), 1.36 – 1.22 (m, 2H, H-9). ^{13}C NMR (100 MHz, $CDCl_3$) δ 173.31 (C-12), 165.90, 165.70, 165.34 (3 C=O, Bz), 161.81 (C*ONH*), 138.21, 138.11, 137.21, 136.99, 136.01, 133.38, 133.24, 132.91, 129.91, 129.78, 129.66, 129.58, 129.52, 129.30, 128.54, 128.51, 128.48, 128.47, 128.44, 128.37, 128.28, 128.24, 128.15, 128.10, 128.07, 128.04, 127.83, 127.76, 127.74, 127.62, 127.30, 127.04 (aromatic), 99.29 (C-1^{C}), 96.95 (C-1^{A}), 96.90 (C-1^{B}), 92.52 (C*Cl*$_3$), 76.47 (C-3^{C}), 76.32 (C-2^{A}), 76.29 (C-3^{A}), 75.47 (C-3^{B}), 73.49, 72.77, 72.72 (C-4^{B}), 72.69 (C-4^{A}), 72.14, 71.72, 69.12 (C-5^{B}), 68.09 (C-5^{A}, 5^{C}, 7), 66.04, 65.41 (C-4^{C}), 62.28 (C-6^{C}), 61.92 (C-6^{A}), 61.53 (C-6^{B}), 59.55 (C-2^{C}), 51.08 (C-2^{B}), 34.05 (C-11), 28.95 (C-8), 25.61 (C-9), 24.55 (C-10). HR-MS: Calculated for $C_{82}H_{83C}l_3N_4O_{20}$ $[M+H]^+$: 1549.4744, found: 1549.4739.

6-(Benzyl hexanoyl) 2,3-di-*O*-benzyl-4,6-di-*tert*-butylsilylidene-α-D-galactopyranosyl-(1→4)-2-azido-6-*O*-benzoyl-3-*O*-benzyl-2-deoxy-α-D-galactopyranosyl-(1→4)-6-*O*-benzoyl-3-*O*-benzyl-2-deoxy-2-trichloroacetamido-α-D-galactopyranosyl-(1→4)-6-O-benzoyl-2,3-di-*O*-benzyl-α-D-galactopyranoside (S15)

The reaction was carried out according to the general procedure A. The donor **1** (2.65 g, 4.47 mmol) and the acceptor **14** (2.12 g, 1.37 mmol) were co-evaporated with toluene (three times). The residue was dissolved in 15 ml

dry DCM under nitrogen and stirred over fresh flame-dried molecular sieves 4Å. The solution was cooled to 0 ºC, after which NIS (1.68 g, 7.45 mmol) and TfOH (13 µl, 0.149 mmol) were added. The reaction was stirred at 0 ºC for 2 h. Then the reaction was quenched with saturated $Na_2S_2O_3$, diluted with DCM, washed with saturated $NaHCO_3$ and brine. The organic phase was dried with anhydrous $MgSO_4$, filtered and concentrated *in vacuo*. The product was purified by silica gel column chromatography (pentane:EtOAc = 7:1). Compound **S15** (2.42 g, 87% yield, pentane:EtOAc = 4:1, R*f* = 0.50-0.55) was obtained as colorless syrup. $[\alpha]_D^{25}$ +105.1 (c=1, $CHCl_3$). IR (neat, cm^{-1}) ν 444, 474, 650, 697, 710, 734, 734, 797, 822, 976, 1005, 1027, 1047, 1095, 1269, 1315, 1452, 1497, 1721, 2110, 2859, 2932, 3421. ^{1}H-NMR ($CDCl_3$, 400 MHz) δ 8.02 – 7.89 (m, 6H), 7.65 – 6.99 (m, 46H), 6.89 (d, *J* = 9.2 Hz, 1H), 5.23 (d, *J* = 3.5 Hz, 1H, H-1^B), 5.07 (s, 2H), 5.05 (d, *J* = 3.5 Hz, 1H, H-1^C), 4.95 – 4.82 (m, 4H, H-1^D), 4.77 (d, *J* = 3.5 Hz, 1H, H-1^A), 4.82 – 4.04 (m, 25H), 4.02 – 3.70 (m, 7H), 3.67 – 3.55 (m, 3H), 3.39 (dt, *J* = 9.8, 6.5 Hz, 1H, H-7), 2.28 (t, *J* = 7.5 Hz, 2H, H-11), 1.66 – 1.51 (m, 4H, H-10, 8), 1.35 – 1.22 (m, 2H, H-9), 0.96 (s, 9H), 0.84 (s, 9H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 173.33 (C-12), 165.73, 165.40, 165.38 (3 C=O, Bz), 161.74 (C*ONH*), 139.00, 138.30, 138.16, 138.11, 137.36, 137.16, 136.07, 133.39, 133.30, 132.99, 129.95, 129.80, 129.71, 129.65, 129.62, 129.34, 128.86, 128.56, 128.48, 128.44, 128.40, 128.37, 128.31, 128.25, 128.21, 128.16, 127.88, 127.81, 127.77, 127.65, 127.60, 127.46, 127.37, 127.30, 127.22, 100.10 (C-1^D), 99.33 (C-1^C), 97.00 (C-1^A), 96.84 (C-1^B), 92.51 (C*Cl*$_3$), 77.86 (C-3^D), 76.58 (C-2^A), 76.44 (C-3^A), 76.13 (C-3^C), 74.91 (C-3^B), 73.93, 73.56, 72.97, 72.72 (C-2^D), 72.68 (C-4^C), 72.50 (C-4^A, 4^B), 72.24, 71.62, 70.54 (C-4^D), 70.09, 69.36 (C-5^C), 69.12 (C-5^B), 68.10 (C-7), 68.06 (C-5^A), 67.59 (C-5^D), 66.95 (C-6^D), 66.08, 62.23 (C-6^C), 61.61 (C-6^A), 60.86 (C-6^B), 60.27 (C-2^C), 51.12 (C-2^B), 34.11 (C-11), 29.01 (C-8), 27.66, 27.19, 25.67 (C-9), 24.61 (C-10), 23.31, 20.57 (2 C-*Si*). ^{13}C-HMBC ($CDCl_3$, 100 MHz): 100.10 ($J_{C1,H1}$ = 169 Hz), 99.33 ($J_{C1,H1}$ = 172 Hz), 97.00 ($J_{C1,H1}$ = 168 Hz), 96.84 ($J_{C1,H1}$ = 173 Hz). HR-MS: Calculated for $C_{110}H_{121C}l_3N_4O_{25}Si$ $[M+NH_4]^+$: 2048.7498, found: 2048.7493.



6-(Benzyl hexanoyl) 2,3-di-*O*-benzyl-α-D-galactopyranosyl-(1→4)-2-azido-6-*O*-benzoyl-3-*O*-benzyl-2-deoxy-α-D-galactopyranosyl-(1→4)-6-*O*-benzoyl-3-*O*-benzyl-2-deoxy-2-trichloroacetamido-α-D-galactopyranosyl-(1→4)-6-O-benzoyl-2,3-di-*O*-benzyl-α-D-galactopyranoside (S16)

The reaction was carried out according to the general procedure C using compound **S15** (2.37 g, 1.17 mmol) and HF/pyridine (70%, 485 µl, 18.6 mmol). The product was purified by column chromatography (pentane:EtOAc = 3:2). Compound **S16** (2.14 g, 97% yield, pentane:EtOAc = 1:1, R*f* = 0.25-0.35) was obtained as yellow syrup. $[\alpha]_D^{25}$

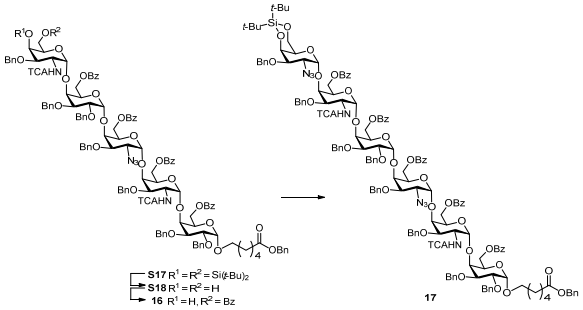
+105.8 (c=1, $CHCl_3$). IR (neat, cm^{-1}) ν 698, 711, 736, 820, 1005, 1047, 1096, 1296, 1315, 1360, 1452, 1497, 1720, 2111, 2870, 2926, 3421, 3500. ^{1}H-NMR ($CDCl_3$, 400 MHz) δ 8.04 – 7.89 (m, 6H), 7.65 – 6.98 (m, 45H), 6.93 (d, *J* = 9.3 Hz, 1H, *N*H), 5.24 (d, *J* = 3.6 Hz, 1H, H-1^B), 5.07 (s, 2H), 5.05 (d, *J* = 3.6 Hz, 1H, H-1^C), 4.93 (d, *J* = 3.5 Hz, 1H, H-1^D), 4.91 – 4.83 (m, 3H), 4.78 (d, *J* = 3.6 Hz, 1H, H-1^A), 4.77 – 4.02 (m, 25H), 3.96 – 3.69 (m, 6H), 3.60 (dt, *J* = 9.9, 6.9 Hz, 1H, H-7), 3.45 – 3.31 (m, 2H), 2.78 (bs, 1H), 2.28 (t, *J* = 7.5 Hz, 2H, H-11), 1.68 – 1.49 (m, 4H, H-10, 8), 1.36 – 1.21 (m, 2H, H-9). ^{13}C NMR (100 MHz, $CDCl_3$) δ 173.33 (C-12), 165.71, 165.37, 165.36 (3 C=O, Bz), 161.72 (C*ONH*), 138.23, 138.11, 137.91, 137.25, 137.05, 136.02, 133.38, 133.26, 133.03, 129.80, 129.68, 129.59, 129.29, 128.52, 128.49, 128.45, 128.40, 128.37, 128.32, 128.27, 128.20, 128.17, 128.12, 127.91, 127.84, 127.76, 127.73, 127.62, 127.55, 127.26, 127.19, 100.27 (C-1^D), 99.26 (C-1^C), 96.95 (C-1^A), 96.85 (C-1^B), 92.48 (C*Cl$_3$*), 77.80 (C-3^D), 76.49 (C-2^A), 76.41 (C-3^A), 76.10 (C-3^C), 75.07 (C-3^B), 74.59 (C-2^D), 74.39 (C-4^C), 73.83, 73.53, 72.87, 72.62, 72.49 (C-4^B), 72.40 (C-4^A), 72.08, 71.61, 69.38 (C-5^C, 5^D), 69.11 (C-4^D), 69.03 (C-5^B), 68.08 (C-7), 68.02 (C-5^A), 66.06 (C*H$_2$*), 62.76, 62.21, 61.61, 60.93 (4 C-6), 60.12 (C-2^C), 51.06 (C-2^B), 34.07 (C-11), 28.96 (C-8), 25.62 (C-9), 24.56 (C-10). HR-MS: Calculated for $C_{102}H_{105Cl}l_3N_4O_{25}$ $[M+NH_4]^+$: 1908.6477, found: 1908.6472.

6-(Benzyl hexanoyl) 6-*O*-benzoyl-2,3-di-*O*-benzyl-α-D-galactopyranosyl-(1→4)-2-azido-6-*O*-benzoyl-3-*O*-benzyl-2-deoxy-α-D-galactopyranosyl-(1→4)-6-*O*-benzoyl-3-*O*-benzyl-2-deoxy-2-trichloroacetamido-α-D-galactopyranosyl-(1→4)-6-O-benzoyl-2,3-di-*O*-benzyl-α-D-galactopyranoside (15)

The reaction was carried out according to the general procedure D using compound **S16** (2.10 g, 1.11 mmol), PhCOOBt (1.33 g, 5.55 mmol) and Et_3N (850 µl, 6.11 mmol). The product was purified by column chromatography (pentane:EtOAc = 5:2). Compound **15** (1.98 g, 92% yield, pentane:EtOAc = 2:1, R*f* = 0.30-0.40) was obtained as yellow syrup. $[\alpha]_D^{25}$ +96.4 (c=1, $CHCl_3$). IR (neat, cm^{-1}) ν 697, 710, 735, 820, 1003, 1026, 1047, 1070, 1095, 1156, 1269, 1315, 1361, 1452, 1497, 1508, 1720, 2111, 2870, 2927, 3422. ^{1}H-NMR ($CDCl_3$, 400 MHz) δ 8.05 – 7.89 (m, 8H), 7.63 – 6.99 (m, 48H), 6.94 (d, *J* = 9.3 Hz, 1H), 5.24 (d, *J* = 3.5 Hz, 1H, H-1^B), 5.07 (s, 3H, *C*H$_2$, H-1^C), 4.97 (d, *J* = 3.5 Hz, 1H, H-1^D), 4.92 - 4.83 (m, 3H), 4.79 (d, *J* = 3.6 Hz, 1H, H-1^A), 4.78 – 4.13 (m, 24H), 4.09 (t, *J* = 7.1 Hz, 1H), 4.05 – 3.71 (m, 8H), 3.60 (dt, *J* = 9.8, 6.9 Hz, 1H, H-7), 3.40 (dt, *J* = 9.9, 6.6 Hz, 1H, H-7), 2.28 (t, *J* = 7.5 Hz, 2H, H-11), 1.66 – 1.51 (m, 4H, H-10, 8), 1.32 – 1.20 (m, 2H, H-9). ^{13}C NMR (100 MHz, $CDCl_3$) δ 173.34 (C-12), 165.92, 165.73, 165.38, 165.36 (4 C=O, Bz), 161.72 (C*ONH*), 138.24, 138.12, 138.03, 137.95, 137.11, 137.06, 136.03, 133.39, 133.28, 133.05, 132.91, 129.99, 129.93, 129.82, 129.78, 129.69, 129.60, 129.31, 128.53, 128.49, 128.47, 128.43, 128.41, 128.36, 128.33, 128.29, 128.24, 128.18, 128.13, 127.86, 127.81, 127.76, 127.65, 127.63, 127.59, 127.56, 127.28, 127.17, 99.77 (C-1^D), 99.28 (C-1^C), 96.96 (C-1^A), 96.89 (C-1^B), 92.52 (C*Cl$_3$*), 77.81 (C-3^D), 76.48 (C-2^A), 76.43 (C-3^A), 75.96 (C-3^C), 75.11 (C-3^B), 74.93 (C-2^D), 73.93, 73.88 (C-4^C), 73.53, 72.88, 72.69, 72.52 (C-4^A), 72.36 (C-4^B), 72.27, 71.64, 69.35 (C-5^C), 69.13 (C-5^B), 68.09 (C-7), 68.05 (C-5^A), 67.83 (C-5^D), 66.60 (C-4^D), 66.07 (C*H$_2$*), 62.31, 62.24, 61.63, 60.95 (4 C-6), 60.19 (C-2^C), 51.08 (C-2^B), 34.08 (C-11), 28.98 (C-8), 25.64 (C-9), 24.57 (C-10). HR-MS: Calculated for $C_{109}H_{109}Cl_3N_4O_{26}$ $[M+NH_4]^+$: 2012.6739, found: 2012.6734.

Pentasaccharide S17

The reaction was carried out according to the general procedure B. The donor **3** (968 mg, 1.34 mmol) and the acceptor **15** (1.78 g, 0.89 mmol) were co-evaporated with toluene (three times). The residue was dissolved in 9 ml dry DCM under nitrogen and stirred over fresh flame-dried molecular sieves 4Å. The solution was cooled to 0 ºC, after which TfOH (8 µl, 0.09 mmol) was added. The reaction was stirred at 0 ºC for 1 h. Then the reaction was quenched with Et_3N, diluted with DCM, washed with saturated $NaHCO_3$ and brine. The organic phase was dried with anhydrous $MgSO_4$, filtered and concentrated *in vacuo*. The product was purified by silica gel column chromatography (pentane:EtOAc = 4:1). Compound **S17** (1.60 g, 71% yield, pentane: EtOAc = 5:2, R*f* = 0.35-0.45) was obtained as yellow syrup. $[\alpha]_D^{25}$ +107.1 (c=1, $CHCl_3$). IR (neat, cm^{-1}) ν 698, 711, 736, 820, 1003, 1027, 1047, 1096, 1269, 1452, 1508, 1724, 2111, 2860, 2932, 3416. ^{1}H-NMR ($CDCl_3$, 400 MHz) δ 8.04 – 7.88 (m, 8H), 7.68 – 7.08 (m, 51H), 7.06 – 6.91 (m, 3H), 6.81 (d, *J* = 9.2 Hz, 1H), 5.22 (d, *J* = 3.5 Hz, 1H, H-1^B), 5.11 (d, *J* = 3.6 Hz, 1H, H-1^E), 5.07 (s, 2H), 5.01 (d, *J* = 3.5 Hz, 1H, H-1^D), 4.79 (d, *J* = 3.6 Hz, 1H, H-1^A), 4.92 – 3.66 (m, 44H), 3.61 (dt, *J* = 9.8, 6.9 Hz, 1H, H-7), 3.52 (dd, *J* = 10.7, 2.5 Hz, 1H), 3.49 – 3.34 (m, 2H), 2.29 (t, *J* = 7.5 Hz, 2H, H-11), 1.66 – 1.52 (m, 4H, H-10, 8), 1.35 – 1.26 (m, 2H, H-9), 1.02 – 0.92 (m, 18H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 173.36 (C-12), 165.77, 165.39, 165.38, 165.15 (4 C=O, Bz), 161.73, 161.52 (2 C*ONH*), 138.26, 138.15, 138.05, 137.87, 137.13, 137.03, 136.06, 133.45, 133.29, 133.20, 133.16, 129.87, 129.77, 129.75, 129.73, 129.66, 129.62, 129.50, 129.33, 128.57, 128.54, 128.52, 128.48, 128.46, 128.43, 128.41, 128.39, 128.32, 128.30, 128.22, 128.17, 128.03, 127.88, 127.83, 127.80, 127.71, 127.69, 127.66, 127.55, 127.31, 127.26, 126.94, 99.22 (C-1^D), 99.08 (C-1^C), 96.98 (C-1^A, 1^B), 96.85 (C-1^E), 92.65, 92.58 (2 C*Cl$_3$*), 76.42, 75.64 (C-3^D), 75.53 (C-3^B), 75.43 (C-3^E), 74.02 (C-3^C), 73.66, 73.54, 72.98, 72.92, 72.84, 72.55 (C-4^A), 72.31 (C-4^C), 71.74, 71.36 (C-4^D), 69.67, 69.45, 69.25, 69.23 (C-5^D), 68.42 (C-5^C), 68.13 (C-7), 68.09 (C-5^A), 67.72 (C-5^E), 66.88 (C-6^E), 66.11 (C*H$_2$*), 62.28, 61.64, 61.26, 60.98 (4 C-6), 60.27 (C-2^C), 51.07 (C-2^B), 49.84 (C-2^E), 34.12 (C-11), 29.02 (C-8), 27.62, 27.29, 25.68 (C-9), 24.61 (C-10), 23.34, 20.66. ^{13}C-HMBC ($CDCl_3$, 100 MHz): 99.22 ($J_{C1,H1}$ = 171 Hz), 99.08 ($J_{C1,H1}$ = 169 Hz), 96.98 ($J_{C1,H1}$ = 170 Hz), 96.85 ($J_{C1,H1}$ = 173 Hz). MALDI-MS: Calculated for $C_{132}H_{141}Cl_6N_5O_{31}Si$ $[M+Na]^+$: 2552.7409, found: 2552.7212.



Pentasaccharide S18

The reaction was carried out according to the general procedure C using compound **S17** (1.57 g, 0.62 mmol) and HF/pyridine (70%, 260 µl, 9.9 mmol). The product was purified by column chromatography (pentane:EtOAc = 3:2).

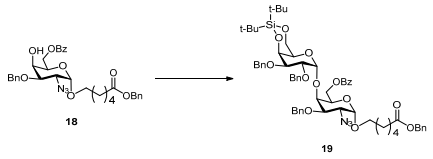
Compound **S18** (1.39 g, 94% yield, pentane:EtOAc = 1:1, R*f* = 0.25-0.35) was obtained as yellow syrup. $[\alpha]_D^{25}$ +105.2 (c=1, $CHCl_3$). IR (neat, cm^{-1}) ν 698, 711, 736, 820, 1003, 1027, 1046, 1096, 1157, 1269, 1315, 1452, 1508, 1720, 2111, 2872, 2928, 3413. ^{1}H-NMR ($CDCl_3$, 500 MHz) δ 8.04 – 7.87 (m, 8H), 7.67 – 7.50 (m, 4H), 7.49 – 7.07 (m, 48H), 7.07 – 6.94 (m, 3H), 6.80 (d, *J* = 9.4 Hz, 1H, *N*H), 5.22 (d, *J* = 3.4 Hz, 1H, H-1^B), 5.07 (s, 2H), 5.02 (d, *J* = 3.6 Hz, 1H, H-1^D), 4.98 (d, *J* = 3.6 Hz, 1H, H-1^E), 4.90 – 4.21 (m, 28H), 4.21 – 3.87 (m, 12H), 3.82 (dd, *J* = 10.7, 3.5 Hz, 1H), 3.76 (dd, *J* = 10.1, 3.7 Hz, 2H), 3.69 (dd, *J* = 10.2, 3.4 Hz, 1H), 3.61 (dt, *J* = 9.9, 6.9 Hz, 1H, H-7), 3.51 – 3.36 (m, 4H), 2.96 (bs, 1H), 2.28 (t, *J* = 7.5 Hz, 2H, H-11), 1.65 – 1.53 (m, 4H), 1.34 – 1.27 (m, 2H). ^{13}C NMR (125 MHz, $CDCl_3$) δ 173.37 (C-12), 165.76, 165.40, 165.38, 165.21 (4 C=O, Bz), 161.77, 161.59 (2 C*ONH*), 138.24, 138.12, 138.02, 137.96, 137.11, 137.00, 136.04, 133.44, 133.30, 133.22, 133.18, 129.85, 129.75, 129.70, 129.63, 129.61, 129.38, 129.31, 128.55, 128.53, 128.50, 128.46, 128.45, 128.41, 128.31, 128.28, 128.20, 128.15, 128.00, 127.86, 127.83, 127.78, 127.74, 127.69, 127.65, 127.62, 127.57, 127.30, 126.87, 99.22 (C-1^D), 99.00 (C-1^C), 97.51 (C-1^E), 96.97 (C-1^A, 1^B), 92.56, 92.48 (2 C*Cl$_3$*), 76.75, 76.41 (C-3^C), 76.38 (C-3^D, 3^E), 75.92 (C-3^B), 75.58, 75.14 (C-4^B), 73.89, 73.89, 73.54, 73.33, 72.97, 72.80, 72.70 (C-4^D), 72.62 (C-4^A), 72.40 (C-4^C), 71.77, 71.11, 69.28 (C-5^D), 69.21 (C-5^B), 68.67 (C-5^C), 68.12 (C-7), 68.09 (C-5^A), 66.79 (C-5^E), 66.09 (C*H$_2$*), 62.56, 62.29, 61.60, 61.28, 61.17 (5 C-6), 60.33 (C-2^C), 51.05 (C-2^B), 50.44 (C-2^E), 34.10 (C-11), 28.99 (C-8), 25.65 (C-9), 24.59 (C-10). HR-MS: Calculated for $C_{124}H_{125}Cl_6N_5O_{31}$ $[M+NH_4]^+$: 2407.68334, found: 2407.68279.

Pentasaccharide 16

The reaction was carried out according to the general procedure D using compound **S18** (1.38 g, 0.58 mmol), PhCOOBt (689 mg, 2.88 mmol) and Et_3N (440 µl, 3.17 mmol). The product was purified by column chromatography (pentane:EtOAc = 5:2). Compound **16** (1.35 g, 94% yield, pentane:EtOAc = 2:1, R*f* = 0.25-0.30) was obtained as yellow syrup. $[\alpha]_D^{25}$ +105.6 (c=1, $CHCl_3$). IR (neat, cm^{-1}) ν 700, 711, 737, 819, 1003, 1027, 1047, 1096, 1159, 1269, 1315, 1452, 1508, 1720, 2111, 2872, 2929, 3413. ^{1}H-NMR ($CDCl_3$, 500 MHz) δ 8.05 – 7.86 (m, 10H), 7.69 – 6.92 (m, 57H), 6.79 (d, *J* = 9.4 Hz, 1H), 5.23 (d, *J* = 3.5 Hz, 1H, H-1^B), 5.07 (s, 2H), 5.05 - 5.01 (m, 2H, H-1^D, 1^E), 4.85 (d, *J* = 3.5 Hz, 1H, H-1^C), 4.90 – 4.42 (m, 23H), 4.40 – 4.06 (m, 12H), 4.02 – 3.85 (m, 5H), 3.84 – 3.69 (m, 4H), 3.66 – 3.57 (m, 1H), 3.54 (dd, *J* = 10.6, 2.8 Hz, 1H), 3.44 – 3.36 (m, 1H), 2.60 (bs, 1H), 2.29 (t, *J* = 7.5 Hz, 2H), 1.66 – 1.52 (m, 4H), 1.36 – 1.22 (m, 2H). ^{13}C NMR (125 MHz, $CDCl_3$) δ 173.37 (C-12), 165.90, 165.76, 165.39, 165.17 (C=O, Bz), 161.76, 161.54 (C*ONH*), 138.25, 138.14, 137.98, 137.83, 137.16, 137.08, 137.01, 136.06, 133.45, 133.31, 133.20, 133.10, 129.90, 129.85, 129.76, 129.74, 129.72, 129.64, 129.62, 129.57, 129.36, 129.32, 128.58, 128.56, 128.55, 128.51, 128.48, 128.44, 128.43, 128.40, 128.35, 128.32, 128.29, 128.21, 128.20, 128.16, 128.06, 127.88, 127.81, 127.79, 127.75, 127.71, 127.67, 127.64, 127.34, 127.30, 126.90, 99.23 (C-1^D), 99.13 (C-1^C), 96.97 (C-1^A, 1^B), 96.93 (C-1^E), 92.57, 92.53 (C*Cl$_3$*), 76.67, 76.44, 76.42, 76.10, 75.82, 75.57, 75.03, 73.92, 73.56, 73.36, 73.00, 72.95, 72.81, 72.59, 72.37, 71.90, 71.52, 69.27, 69.22, 68.51, 68.13, 68.09, 67.99, 66.10, 65.26, 62.87, 62.29, 61.64, 61.26, 61.05 (5 C-6), 60.35 (C-2C), 51.06 (C-2B), 50.47 (C-2^E), 34.11 (C-11), 29.01 (C-8), 25.67 (C-9), 24.61 (C-10). MALDI-MS: Calculated for $C_{131}H_{129}Cl_6N_5O_{32}$ $[M+Na]^+$: 2516.6650, found: 2516.6458.

Hexasaccharide 17

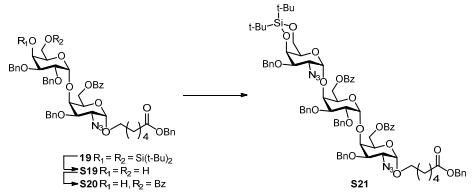
The reaction was carried out according to the general procedure B. The donor **2** (655 mg, 1.08 mmol) and the acceptor **16** (1.31 g, 0.54 mmol) were co-evaporated with toluene (three times). The residue was dissolved in 6 ml dry DCM under nitrogen and stirred over fresh flame-dried molecular sieves 4Å. The solution was cooled to 0 °C, after which TfOH (5 µl, 0.05 mmol) was added. The reaction was stirred at 0 °C for 1 h. Then the reaction was quenched with Et_3N, diluted with DCM, washed with saturated $NaHCO_3$ and brine. The organic phase was dried with anhydrous $MgSO_4$, filtered and concentrated *in vacuo*. The product was purified by silica gel column chromatography (pentane:EtOAc = 7:2). Compound **17** (1.19 g, 73% yield, pentane: EtOAc = 3:1, R*f* = 0.40-0.50) was obtained as yellow syrup. $[\alpha]_D^{25}$ +116.4 (c=1, $CHCl_3$). IR (neat, cm^{-1}) ν 651, 698, 710, 736, 797, 820, 1003, 1027, 1046, 1096, 1267, 1315, 1452, 1508, 1720, 2111, 2860, 2932, 3420. ^{1}H-NMR ($CDCl_3$, 500 MHz) δ 8.02 – 7.90 (m, 10H), 7.62 – 7.50 (m, 5H), 7.49 – 6.90 (m, 57H), 6.84 (d, *J* = 9.6 Hz, 1H), 5.23 (d, *J* = 3.5 Hz, 1H, H-1^B), 5.07 (s, 3H, *C*H$_2$, H-1^E), 5.03 (d, *J* = 3.5 Hz, 1H, H-1^D), 5.00 (d, *J* = 3.6 Hz, 1H, H-1^F), 4.89 – 4.44 (m, 27H), 4.43 – 4.06 (m, 14H), 4.03 – 3.57 (m, 13H), 3.53 (dd, *J* = 10.8, 2.3 Hz, 1H), 3.45 – 3.36 (m, 1H, H-7), 2.29 (t, *J* = 7.5 Hz, 2H, H-11), 1.66 – 1.54 (m, 4H, H-10, 8), 1.35 – 1.27 (m, 2H, H-9), 1.00 – 0.92 (m, 18H). ^{13}C NMR (125 MHz, $CDCl_3$) δ 173.33 (C-12), 165.76, 165.40, 165.24 (C=O, Bz), 161.76, 161.67 (2 C*ONH*), 138.28, 138.16, 138.00, 137.93, 137.16, 137.11, 137.03, 136.09, 133.44, 133.31, 133.28, 133.25, 133.18, 129.87, 129.77, 129.73, 129.68, 129.63, 129.56, 129.40, 129.36, 128.57, 128.54, 128.52, 128.49, 128.46, 128.44, 128.40, 128.33, 128.26, 128.22, 128.16, 128.14, 128.05, 127.88, 127.82, 127.79, 127.75, 127.72, 127.68, 127.66, 127.44, 127.33, 126.94, 126.86, 99.32 (C-1^F), 99.24 (C-1^D), 99.00 (C-1^C), 97.01 (C-1^A, 1^B, 1^E), 92.60, 92.53 (2 C*Cl$_3$*), 76.45, 76.24, 76.12, 76.04, 75.94, 75.61, 75.21, 73.78, 73.58, 73.21, 73.00, 72.94, 72.82, 72.59, 72.43, 72.18, 72.14, 71.82, 71.71, 70.63, 69.61, 69.29, 69.15, 68.15, 68.12, 67.89, 66.93 (C-6F), 66.10 (C*H$_2$*), 62.30, 61.66, 61.63, 61.30, 61.16 (5 C-6), 60.43 (C-2^C), 58.86 (C-2^F), 51.08 (C-2^B), 50.92 (C-2^E), 34.12 (C-11), 29.03 (C-8), 27.64, 27.34, 25.69 (C-9), 24.62 (C-10), 23.27, 20.69. ^{13}C-HMBC ($CDCl_3$, 100 MHz): 99.32 ($J_{C1,H1}$ = 172 Hz), 99.24 ($J_{C1,H1}$ = 171 Hz), 99.00 ($J_{C1,H1}$ = 169 Hz), 97.01 ($J_{C1,H1}$ = 173 Hz, 167 Hz). MALDI-MS: Calculated for $C_{152}H_{160}Cl_6N_8O_{36}Si$ [M+Na]$^+$: 2933.8733, found: 2933.8520.



6-(Benzyl hexanoyl) 2,3-di-*O*-benzyl-4,6-di-*tert*-butylsilylidene-α-D-galactopyranosyl-(1→4)-2-azido-6-*O*-benzoyl-3-*O*-benzyl-2-deoxy-α-D-galactopyranoside (19)

The reaction was carried out according to the general procedure A. The donor **1** (2.43 g, 4.11 mmol) and the acceptor **18** (1.65 g, 2.74 mmol) were co-evaporated with toluene (three times). The residue was dissolved in 22 ml dry DCM under nitrogen and stirred over fresh flame-dried molecular sieves 3Å. The solution was cooled to 0 °C, after which NIS (1.23 g, 5.48 mmol) and TfOH (24 µl, 0.27 mmol) were added. The reaction was stirred at 0 °C for

1 h. Then the reaction was quenched with saturated $Na_2S_2O_3$, diluted with DCM, washed with saturated $NaHCO_3$ and brine. The organic phase was dried with anhydrous $MgSO_4$, filtered and concentrated *in vacuo*. The product was purified by silica gel column chromatography (pentane:EtOAc = 8:1). Compound **19** (2.52 g, 85% yield) was obtained as colorless syrup. $[\alpha]_D^{25}$ +112.6 (c=1, $CHCl_3$). ^{1}H-NMR ($CDCl_3$, 400 MHz) δ 8.06 – 7.97 (m, 2H, *aromatic* H), 7.56– 7.09 (m, 23H, *aromatic* H), 5.04 (s, 2H, *PhC*H_2O), 4.97 (d, *J* = 3.5 Hz, 1H, H-1^A), 4.94 – 4.87 (m, 2H, H-1^B, *PhC*H*H*O), 4.86 – 4.70 (m, 4H, 3x*PhC*H*H*O, H-6^A), 4.69 – 4.53 (m, 3H, 2x*PhC*H*H*O, H-6^A), 4.49 (d, *J* = 2.8 Hz, 1H, H-4^B), 4.17 (d, *J* = 2.9 Hz, 1H, H-4^A), 4.13 – 4.00 (m, 3H, H-2^B, 5^A, 5^B), 3.99 – 3.86 (m, 2H, H-3^A, 3^B), 3.78 – 3.60 (m, 4H, H-6^B, 2^A, 7), 3.50 – 3.37 (m, 1H, H-7), 2.27 (t, *J* = 7.4 Hz, 2H, H-12), 1.56 (p, *J* = 8.0 Hz, 4H, H-8, 10), 1.40 – 1.23 (m, 2H, H-9), 1.00 (s, 9H, *C*H_3), 0.97 (s, 9H, *C*H_3). ^{13}C NMR (100 MHz, $CDCl_3$) δ 172.97 (C=O), 165.73 (C*OPh*), 138.80, 138.11, 137.17, 135.97, 133.04, 129.68, 129.46, 128.75, 128.34, 128.32, 128.30, 128.18, 128.13, 127.95, 127.94, 127.62, 127.46, 127.37, 127.26, 127.09 (*aromatic* C/*CH*), 100.36 (C-1^B), 97.86 (C-1^A), 77.77 (C-3^B), 75.51 (C-3^A), 74.00 (CH_2*Ph*), 73.57 (C-4^A), 72.96 (C-2^B), 71.73 (CH_2*Ph*), 70.42 (C-4^B), 70.01 (CH_2*Ph*), 68.69 (C-5^A), 67.86 (C-7), 67.60 (C-5^B), 66.81 (C-6^B), 65.79 (*C*=*O*CH_2*Ph*), 62.55 (C-6^A), 59.37 (C-2^A), 33.85 (C-11), 28.79 (C-8), 27.50 (CH_3), 27.15 (CH_3), 25.46 (C-9), 24.34 (C-10), 23.14 (C-*Si*), 20.49 (C-*Si*). HR-MS: Calculated for $C_{61}H_{75}O_{13}N_3Si$ $[M+Na]^+$: 1108.4967, found: 1108.4960.



6-(Benzyl hexanoyl) 2,3-di-*O*-benzyl-α-D-galactopyranosyl-(1→4)-2-azido-6-*O*-benzoyl-3-*O*-benzyl-2-deoxy-α-D-galactopyranoside (S19)

The reaction was carried out according to the general procedure C using compound **19** (2.50 g, 2.3 mmol) and HF/pyridine (70%, 960 µl, 36.8 mmol). The product was purified by column chromatography (pentane:EtOAc = 2:1). Compound **S19** (2.08 g, 96% yield) was obtained as syrup. $[\alpha]_D^{25}$ +94.5 (c=1, $CHCl_3$). ^{1}H-NMR ($CDCl_3$, 400 MHz) δ 8.05 – 7.96 (m, 2H, *aromatic* H), 7.62 – 7.13 (m, 23H, *aromatic* H), 5.07 (s, 2H, *C*H_2*Ph*), 4.99 (d, *J* = 2.9 Hz, 1H, H-1^B), 4.96 (d, *J* = 3.5 Hz, 1H, H-1^A), 4.88 – 4.58 (m, 8H, 3X*C*H_2*Ph*, H-6^A), 4.16 – 4.03 (m, 4H), 3.99 – 3.88 (m, 3H), 3.71 – 3.59 (m, 2H, H-2^A, 7), 3.57 – 3.39 (m, 3H, H-6^B, 7), 2.89 (bs, 1H, *O*H), 2.48 (bs, 1H, *O*H), 2.30 (t, *J* = 7.5 Hz, 2H, H-12), 1.66 – 1.50 (m, 4H, H-8, 10), 1.39 – 1.24 (m, 2H, H-9). ^{13}C NMR (100 MHz, $CDCl_3$) δ 173.36 (C=O), 165.98 (C*OPh*), 138.02, 137.89, 137.24, 136.05, 133.30, 129.72, 129.62, 128.57, 128.54, 128.40, 128.33, 128.17, 128.14, 128.09, 127.96, 127.79, 127.73 (*aromatic* C), 100.63 (C-1B), 98.00 (C-1A), 77.89 (C-3B), 75.80 (C-3A), 75.46 (C-4A), 75.22 (C-2A), 74.25 (CH_2*Ph*), 72.35 (CH_2*Ph*), 72.28 (CH_2*Ph*), 69.69 (C-5B), 69.17 (C-4B), 68.83 (C-5A), 68.13 (C-7), 66.07 (CH_2*Ph*), 62.92 (C-6B), 62.71 (C-6A), 59.50 (C-2B), 34.09 (C-11), 28.96 (C-8), 25.62 (C-9), 24.53 (C-10). HR-MS: Calculated for $C_{53}H_{59}O_{13}N_3$ $[M+Na]^+$: 968.3946, found: 968.3940.

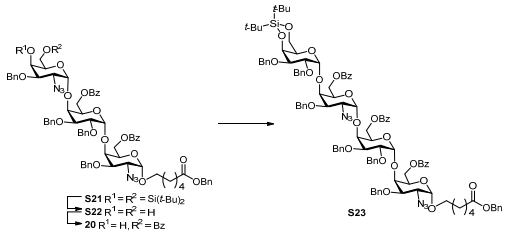
6-(Benzyl hexanoyl) 6-*O*-benzoyl-2,3-di-*O*-benzyl-α-D-galactopyranosyl-(1→4)-2-azido-6-*O*-benzoyl-3-*O*-benzyl-2-deoxy-α-D-galactopyranoside (S20)

The reaction was carried out according to the general procedure D using compound **S19** (2.06 g, 2.18 mmol), PhCOOBt (2.35 g, 9.81 mmol) and Et_3N (1.52 ml, 10.9 mmol). The product was purified by column chromatography (pentane:EtOAc = 4:1). Compound **S20** (2.43 g, 94% yield) was obtained as yellow syrup. $[\alpha]_D^{25}$ +92.1 (c=1, $CHCl_3$). ^{1}H-NMR ($CDCl_3$, 400 MHz) δ 8.04 – 7.97 (m, 2H, *aromatic* H), 7.96 – 7.89 (m, 2H, *aromatic* H), 7.61 – 7.49 (m, 2H, *aromatic* H), 7.48 – 7.15 (m, 23H, *aromatic* H), 7.13 – 7.05 (m, 1H, *aromatic* H), 5.07 (s, 2H, *CH*$_2$*Ph*), 5.03 (d, *J* = 3.4 Hz, 1H, H-1^B), 4.96 (d, *J* = 3.5 Hz, 1H, H-1^A), 4.86 (d, *J* = 11.8 Hz, 1H, *CHHPh*), 4.82 – 4.76 (m, 2H, 2x*CHHPh*), 4.76 – 4.57 (m, 5H, 3x*CHHPh*, H-6^A), 4.53 – 4.43 (m, 2H, H-5^B, 6^B), 4.14 (d, *J* = 2.7 Hz, 1H, H-4^A), 4.11 – 4.00 (m, 4H, H-4^B, 5^A, 3^B, 6^B), 3.97 (dd, *J* = 9.9, 3.3 Hz, 1H, H-2^B), 3.89 (dd, *J* = 10.8, 2.7 Hz, 1H, H-3^A), 3.72 (dd, *J* = 10.8, 3.5 Hz, 1H, H-2^A), 3.64 (dt, *J* = 9.7, 6.7 Hz, 1H, H-7), 3.43 (dt, *J* = 9.8, 6.5 Hz, 1H, H-7), 2.69 (s, 1H, *O*H), 2.30 (t, *J* = 7.5 Hz, 2H, H-11), 1.67 – 1.51 (m, 4H, H-8, 10), 1.37 – 1.22 (m, 2H, H-9). ^{13}C NMR (100 MHz, $CDCl_3$) δ 173.38 (C=O), 166.06 (C*OPh*), 165.99 (C*OPh*), 138.07, 138.02, 137.25, 136.08, 133.31, 132.96, 130.07, 129.92, 129.76, 129.62, 128.56, 128.55, 128.53, 128.44, 128.43, 128.40, 128.36, 128.26, 128.20, 128.17, 127.93, 127.83, 127.81, 127.52 (*aromatic CH*/C), 100.27 (C-1^B), 98.05 (C-1^A), 77.92 (C-3^B), 75.47 (C-3^A, 2^B), 75.03 (C-4^A), 74.38, 72.44, 72.27 (3 C*H*$_2$*Ph*), 68.86 (C-5^A), 68.14 (C-7), 68.12 (C-5^B), 66.84 (C-4^B), 66.10 (C*H*$_2$*Ph*), 62.82 (C-6^A), 62.56 (C-6^B), 59.61 (C-2^A), 34.12 (C-11), 28.99 (C-8), 25.64 (C-9), 24.56 (C-10). HR-MS: Calculated for $C_{60}H_{63}O_{14}N_3$ $[M+Na]^+$: 1072.4208, found: 1072.4202.

6-(Benzyl hexanoyl) 2-azido-3-*O*-benzyl-2-deoxy-4,6-di-*tert*-butylsilylidene-α-D-galactopyranosyl-(1→4)-6-*O*-benzoyl-2,3-di-*O*-benzyl-α-D-galactopyranosyl-(1→4)-2-azido-6-*O*-benzoyl-3-*O*-benzyl-2-deoxy-α-D-galactopyranoside (S21)

The reaction was carried out according to the general procedure B. The donor **2** (1.99 g, 3.29 mmol) and the acceptor **S20** (2.30 g, 2.19 mmol) were co-evaporated with toluene (three times). The residue was dissolved in 22 ml dry DCM under nitrogen and stirred over fresh flame-dried molecular sieves 3Å. The solution was cooled to 0 ºC, after which TfOH (19 µl, 0.22 mmol) were added. The reaction was stirred at 0 ºC for 1 h. Then the reaction was quenched with Et_3N, diluted with DCM, washed with saturated $NaHCO_3$ and brine. The organic phase was dried with anhydrous $MgSO_4$, filtered and concentrated *in vacuo*. The product was purified by silica gel column chromatography (pentane:EtOAc = 6:1). Compound **S21** (2.77 g, 86% yield) was obtained as white foam. $[\alpha]_D^{25}$ +109 (c=1, $CHCl_3$). ^{1}H-NMR ($CDCl_3$, 400 MHz) δ 8.05 – 7.99 (m, 2H, *aromatic* H), 7.98 – 7.92 (m, 2H, *aromatic* H), 7.62 – 7.50 (m, 2H, *aromatic* H), 7.49 – 7.15 (m, 28H, *aromatic* H), 7.15 – 7.08 (m, 1H, *aromatic* H), 5.12 (d, *J* = 2.2 Hz, 1H, H-1^B), 5.07 (d, *J* = 2.7 Hz, 1H, H-1^C), 5.06 (s, 2H, *CH*$_2$*Ph*), 4.95 (d, *J* = 3.5 Hz, 1H, H-1^A), 4.87 – 4.55 (m, 10H, 8x*CHHPh*, H-6^A), 4.52 – 4.32 (m, 4H, H-4^C, 5^B, 6^B), 4.26 (d, *J* = 1.7 Hz, 1H, H-4^B), 4.16 (d, *J* = 2.8 Hz, 1H, H-4^A), 4.11 – 4.04 (m, 1H, H-5^A), 4.04 – 3.97 (m, 3H, H-3^B, 2^B, 5^C), 3.89 (dd, *J* = 10.8, 2.7 Hz, 1H, H-3^A), 3.85 – 3.54 (m, 6H, H-2^C, 3^C, 6^C, 2^A, 7), 3.48 – 3.38 (m, 1H, H-7), 2.29 (t, *J* = 7.4 Hz, 2H, H-11), 1.65 – 1.51 (m,

4H, H-8, 10), 1.37 – 1.24 (m, 2H, H-9), 1.02 (s, 9H, C*H*$_3$), 0.97 (s, 9H, C*H*$_3$). ^{13}C NMR (100 MHz, $CDCl_3$) δ 173.16 (C=O), 165.87 (C*OPh*), 165.31 (C*OPh*), 138.06, 137.89, 137.82, 137.22, 135.99, 133.21, 132.98, 129.66, 129.62, 129.58, 129.51, 128.45, 128.44, 128.41, 128.39, 128.36, 128.30, 128.07, 128.04, 127.76, 127.74, 127.72, 127.54, 127.48, 127.24 (*aromatic* C/*CH*), 99.66 (C-1B), 98.39 (C-1C), 97.92 (C-1A), 76.79 (C-3B), 75.67 (C-3C), 75.37 (C-2B), 75.00 (C-3A), 74.77 (C-4A), 73.88 (C*H*$_2$*Ph*), 73.21 (C-4B), 72.83, 72.11, 70.12 (3 C*H*$_2$*Ph*), 69.50 (C-4C), 68.82 (C-5A), 68.76 (C-5B), 67.97 (C-7), 67.37 (C-5C), 66.82 (C-6C), 65.93 (C*H*$_2$*Ph*), 62.83 (C-6A), 61.34 (C-6B), 59.57 (C-2A), 58.71 (C-2C), 33.97 (C-11), 28.85 (C-8), 27.53 (C*H*$_3$), 27.20 (C*H*$_3$), 25.53 (C-9), 24.43 (C-10), 23.24, 20.58 (2 C-*Si*). HR-MS: Calculated for $C_{81}H_{94}O_{18}N_6Si$ $[M+Na]^+$: 1489.6292, found: 1489.6286.



6-(Benzyl hexanoyl) 2-azido-3-*O*-benzyl-2-deoxy-α-D-galactopyranosyl-(1→4)-6-*O*-benzoyl-2,3-di-*O*-benzyl-α-D-galactopyranosyl-(1→4)-2-azido-6-*O*-benzoyl-3-*O*-benzyl-2-deoxy-α-D-galactopyranoside (S22)

The reaction was carried out according to the general procedure C using compound **S21** (2.75 g, 1.87 mmol) and HF/pyridine (70%, 780 µl, 30 mmol). The product was purified by column chromatography (pentane:EtOAc = 2:1). Compound **S22** (2.46 g, 99% yield) was obtained as syrup. $[\alpha]_D^{25}$ +91.6 (c=1, $CHCl_3$). ^{1}H-NMR ($CDCl_3$, 400 MHz) δ 8.08 – 7.99 (m, 2H, *C*H, Bz), 7.96 – 7.88 (m, 2H, *C*H, Bz), 7.63 – 7.51 (m, 2H), 7.50 – 7.15 (m, 28H), 7.12 – 7.04 (m, 1H), 5.09 (d, *J* = 3.4 Hz, 1H, H-1^B), 5.06 (s, 2H, *PhC*H$_2$), 4.97 (d, *J* = 3.5 Hz, 1H, H-1^A), 4.91 (d, *J* = 3.0 Hz, 1H, H-1^C), 4.85 – 4.78 (m, 5H, 5x*PhCH*H), 4.74 – 4.59 (m, 5H, 3x*PhCH*H, H-6^A), 4.55 (t, *J* = 9.9 Hz, 1H, H-6^B), 4.47 – 4.40 (m, 1H, H-5^B), 4.17 (d, *J* = 2.7 Hz, 1H, H-4^A), 4.14 – 3.98 (m, 6H, H-3^C, 4^A, 4^C, 5^A, 5^C, 6^B), 3.98 – 3.87 (m, 2H, H-2^B, 3^A), 3.79 – 3.61 (m, 4H, H-2^A, 2^C, 3^B, 7), 3.53 – 3.41 (m, 3H, H-6^C, 7), 2.93 (bs, 1H, *O*H), 2.35 (bs, 1H, *O*H), 2.30 (t, *J* = 7.5 Hz, 2H, H-11), 1.67 – 1.52 (m, 4H, H-8, 10), 1.39 – 1.25 (m, 2H, H-9). ^{13}C NMR (100 MHz, $CDCl_3$) δ 173.26 (C-12), 165.90, 165.31 (2 C=O, Bz), 137.95, 137.11, 137.05, 135.93, 133.24, 132.97, 129.59, 129.51, 128.50, 128.46, 128.42, 128.38, 128.34, 128.29, 128.26, 128.06, 128.02, 127.80, 127.78, 127.73, 127.69, 127.66, 127.22 (aromatic), 99.74 (C-1^B), 99.14 (C-1^C), 97.90 (C-1^A), 76.90 (C-3^B), 76.63 (C-3^C), 75.65 (C-4^B), 75.17 (C-3^A), 74.83 (C-2^B), 74.64 (C-4^A), 73.57, 72.96, 72.17, 71.69 (4 C*H*$_2$), 69.34 (C-5), 68.89 (C-5), 68.74 (C-5), 68.01 (C-7), 67.38 (C-4^C), 65.96 (C*H*$_2$), 62.64 (C-6), 62.58 (C-6), 61.30 (C-6^B), 59.78 (C-2^C), 59.58 (C-2^A), 33.98 (C-11), 28.85 (C-8), 25.51 (C-9), 24.42 (C-10). HR-MS: Calculated for $C_{73}H_{78}O_{18}N_6$ $[M+Na]^+$: 1349.5270, found: 1349.5265.

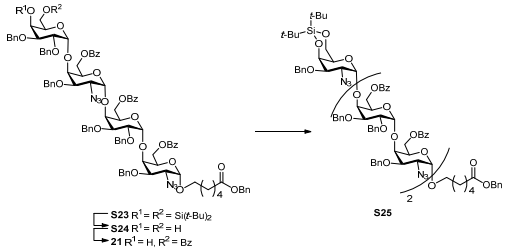
6-(Benzyl hexanoyl) 2-azido-6-*O*-benzoyl-3-*O*-benzyl-2-deoxy-α-D-galactopyranosyl-(1→4)-6-*O*-benzoyl-2,3-di-*O*-benzyl-α-D-galactopyranosyl-(1→4)-2-azido-6-*O*-benzoyl-3-*O*-benzyl-2-deoxy-α-D-galactopyranoside (20)

The reaction was carried out according to the general procedure D using compound **S22** (2.43 g, 1.83 mmol), PhCOOBt (1.97 g, 8.24 mmol) and Et_3N (1.3 ml, 9.15 mmol). The product was purified by column chromatography (pentane:EtOAc = 4:1). Compound **20** (2.56 g, 98% yield) was obtained as white solid. $[\alpha]_D^{25}$ +81 (c=1, $CHCl_3$). ^{1}H-NMR ($CDCl_3$, 400 MHz) δ 8.08 – 8.01 (m, 2H, *C*H, Bz), 7.97 – 7.89 (m, 4H, *C*H, Bz), 7.64 – 7.04 (m, 34H, aromatic), 5.10 (d, *J* = 3.2 Hz, 1H, H-1^B), 5.05 (s, 2H, *PhC*H$_2$), 4.99 (d, *J* = 3.0 Hz, 1H, H-1^C), 4.97 (d, *J* = 3.5 Hz, 1H, H-1^A), 4.91 – 4.77 (m, 5H, 5x*PhCH*H), 4.76 – 4.60 (m, 5H, 3x*PhCH*H, H-6^A), 4.59 – 4.39 (m, 4H, H-5, 6), 4.26 – 4.17 (m, 2H, H-4^A, 4^B), 4.17 – 3.97 (m, 6H), 3.91 (dd, *J* = 10.7, 2.7 Hz, 1H, H-3^A), 3.85 – 3.74 (m, 2H, H-2^C, 3^C), 3.73 – 3.58 (m, 2H, H-2^A, 7), 3.44 (dt, *J* = 9.6, 6.3 Hz, 1H, H-7), 2.73 (bs, 1H, *O*H), 2.29 (t, *J* = 7.4 Hz, 2H, H-11), 1.68 – 1.50 (m, 4H, H-8, 10), 1.41 – 1.23 (m, 2H, H-9). ^{13}C NMR (100 MHz, $CDCl_3$) δ 173.12 (C-12), 165.78, 165.73, 165.16 (3 C=O, Bz), 137.95, 137.82, 137.08, 137.03, 135.84, 133.13, 132.89, 129.63, 129.50, 129.46, 129.41, 129.36, 128.36, 128.31, 128.24, 128.20, 128.18, 128.16, 128.14, 127.95, 127.91, 127.70, 127.58, 127.43, 127.30, 127.14 (aromatic), 99.79 (C-1^B), 98.66 (C-1^C), 97.80 (C-1^A), 76.71 (C-3^B), 76.35 (C-3^C), 75.02 (C-3^A), 74.81, 74.71, 74.50 (C-4^A), 73.59, 72.74, 72.01, 71.73 (4 C*H*$_2$), 68.73 (C-5), 68.65 (C-5), 67.88 (C-7), 67.76 (C-5^C), 65.83 (C*H*$_2$), 65.35 (C-4^C), 62.56 (C-6^A), 62.27 (C-6^C), 61.17 (C-6^B), 59.60 (C-2^C), 59.48 (C-2^A), 33.85 (C-11), 28.74 (C-8), 25.40 (C-9), 24.30 (C-10). HR-MS: Calculated for $C_{80}H_{82}O_{19}N_6$ $[M+Na]^+$: 1453.5532, found: 1453.5527.

6-(Benzyl hexanoyl) 2,3-di-*O*-benzyl-4,6-di-*tert*-butylsilylidene-α-D-galactopyranosyl-(1→4)-2-azido-6-*O*-benzoyl-3-*O*-benzyl-2-deoxy-α-D-galactopyranosyl-(1→4)-6-*O*-benzoyl-2,3-di-*O*-benzyl-α-D-galactopyranosyl-(1→4)-2-azido-6-*O*-benzoyl-3-*O*-benzyl-2-deoxy-α-D-galactopyranoside (S23)

The reaction was carried out according to the general procedure A. The donor **1** (2.09 g, 3.53 mmol) and the acceptor **20** (2.53 g, 1.77 mmol) were co-evaporated with toluene (three times). The residue was dissolved in 18 ml dry DCM under nitrogen and stirred over fresh flame-dried molecular sieves 4Å. The solution was cooled to 0 ºC, after which NIS (2.07 g, 9.2 mmol) and TfOH (16 µl, 0.18 mmol) were added. The reaction was stirred at 0 ºC for 2 h. Then the reaction was quenched with saturated $Na_2S_2O_3$, diluted with DCM, washed with saturated $NaHCO_3$ and brine. The organic phase was dried with anhydrous $MgSO_4$, filtered and concentrated *in vacuo*. The product was purified by silica gel column chromatography (pentane:EtOAc = 6:1). Compound **S23** (2.85 g, 84% yield) was obtained as white solid. $[\alpha]_D^{25}$ +110 (c=1, $CHCl_3$). ^{1}H-NMR ($CDCl_3$, 400 MHz) δ 8.07 – 7.99 (m, 2H, *C*H, Bz), 7.96 – 7.89 (m, 4H, *C*H, Bz), 7.62 – 7.53 (m, 3H. aromatic), 7.48 – 7.38 (m, 10H, aromatic), 7.37 – 7.03 (m, 31H, aromatic), 5.06 (d, *J* = 4.8 Hz, 3H, *PhC*H$_2$, H-1), 5.03 – 4.94 (m, 4H, 3xH-1, *PhCH*H,), 4.92 – 4.45 (m, 18H), 4.37 (dd, *J* = 9.5, 5.5 Hz, 1H), 4.20 (d, *J* = 2.5 Hz, 1H, H-4^B), 4.15 (d, *J* = 2.8 Hz, 1H, H-4^A), 4.11 (d, *J* = 2.5 Hz, 1H, H-4^C), 4.09 – 3.85 (m, 8H), 3.84 – 3.71 (m, 2H), 3.70 – 3.56 (m, 4H), 3.45 (dt, *J* = 9.8, 6.4 Hz, 1H, H-7), 2.30 (t, *J* = 7.5 Hz, 2H, H-11), 1.67 – 1.52 (m, 4H, H-8, 10), 1.38 – 1.24 (m, 2H, H-9), 0.97 (s, 9H, *C*H$_3$), 0.90 (s, 9H, *C*H$_3$). ^{13}C

NMR (100 MHz, $CDCl_3$) δ 173.32 (C-12), 165.98, 165.38, 165.34 (3 C=O, Bz), 138.90, 138.37, 138.27, 138.12, 137.37, 137.21, 136.05, 133.31, 133.19, 133.11, 129.80, 129.72, 129.69, 129.67, 129.62, 129.60, 128.85, 128.55, 128.53, 128.51, 128.43, 128.41, 128.37, 128.33, 128.29, 128.25, 128.17, 128.13, 127.76, 127.69, 127.65, 127.62, 127.58, 127.55, 127.52, 127.39, 127.29, 126.83 (*aromatic*), 100.04 (C-1^B, 1^C), 98.95 (C-1^D), 98.01 (C-1^A), 77.81, 77.36, 76.36, 76.15, 75.46, 75.28, 75.06, 74.60 (C-4^A), 74.03, 73.76, 72.83 (3 CH_2), 72.70, 72.54, 72.19, 71.90 (2 CH_2), 70.50, 70.07 (CH_2), 68.90, 68.84, 68.08 (C-7), 67.59, 66.92 (C-6^D), 66.06 (CH_2), 62.72 (C-6^A), 61.33 (C-6), 61.09 (C-6), 60.62 (C-2^C), 59.66 (C-2^A), 34.08 (C-11), 28.96 (C-8), 27.64, 27.20, 25.63 (C-9), 24.53 (C-10), 23.29, 20.60 (2 C-*Si*). ^{13}C-HMBC ($CDCl_3$, 100 MHz): 100.04 ($J_{C1,H1}$ = 169 Hz, 170 Hz), 98.95 ($J_{C1,H1}$ = 172 Hz), 98.01 ($J_{C1,H1}$ = 171 Hz). HR-MS: Calculated for $C_{108}H_{120}O_{24}N_6Si$ $[M+Na]^+$: 1935.8021, found: 1935.8016.



6-(Benzyl hexanoyl) 2,3-di-*O*-benzyl-α-D-galactopyranosyl-(1→4)-2-azido-6-*O*-benzoyl-3-*O*-benzyl-2-deoxy-α-D-galactopyranosyl-(1→4)-6-*O*-benzoyl-2,3-di-*O*-benzyl-α-D-galactopyranosyl-(1→4)-2-azido-6-*O*-benzoyl-3-*O*-benzyl-2-deoxy-α-D-galactopyranoside (S24)

The reaction was carried out according to the general procedure C using compound **S23** (1.5 g, 0.78 mmol) and HF/pyridine (70%, 326 µl, 12.5 mmol). The product was purified by column chromatography (pentane:EtOAc = 3:2). Compound **S24** (1.29 g, 93% yield) was obtained as white solid. $[\alpha]_D^{25}$ +102 (c=1, $CHCl_3$). ^{1}H-NMR ($CDCl_3$, 400 MHz) δ 8.06 – 7.99 (m, 2H, *C*H, Bz), 7.98 – 7.90 (m, 4H, *C*H, Bz), 7.61 – 7.52 (m, 3H), 7.50 – 7.37 (m, 10H), 7.36 – 7.03 (m, 31H, *aromatic*), 5.07 (d, *J* = 6.4 Hz, 3H, *Ph*CH_2, H-1^B), 5.04 (d, *J* = 3.3 Hz, 1H, H-1^D), 5.01 (d, *J* = 2.5 Hz, 1H, H-1^C), 4.96 (d, *J* = 3.5 Hz, 1H, H-1^A), 4.94 – 4.75 (m, 6H), 4.74 – 4.35 (m, 13H), 4.21 – 3.84 (m, 12H), 3.84 – 3.74 (m, 2H), 3.71 – 3.58 (m, 2H, H-2^A, 7), 3.51 – 3.30 (m, 3H, H-6, 7), 2.30 (t, *J* = 7.4 Hz, 2H, H-11), 1.69 – 1.50 (m, 4H, H-8, 10), 1.38 – 1.24 (m, 2H, H-9). ^{13}C NMR (100 MHz, $CDCl_3$) δ 173.28 (C-12), 165.94, 165.34, 165.32 (3 C=O, Bz), 138.18, 138.12, 137.89, 137.81, 137.30, 137.15, 135.99, 133.27, 133.21, 133.06, 129.68, 129.64, 129.56, 129.53, 128.51, 128.50, 128.48, 128.43, 128.38, 128.36, 128.27, 128.22, 128.12, 128.08, 127.91, 127.84, 127.70, 127.67, 127.59, 127.54, 127.51, 127.35, 127.21, 100.37 (C-1^B), 99.91 (C-1^D), 98.77 (C-1^C), 97.94 (C-1^A), 77.73 (C-3^D), 76.20, 76.15, 75.29, 75.22, 75.01, 74.66, 74.52, 74.34, 73.99, 73.81, 72.78, 72.21, 72.17, 72.02 (6 CH_2), 69.26, 69.14, 69.02, 68.87, 68.80, 68.04 (C-7), 66.01 (CH_2), 62.78 (C-6), 62.68 (C-6), 61.34 (C-6), 61.22 (C-6), 60.41 (C-2^C), 59.62 (C-2^A), 34.02 (C-11), 28.90 (C-8), 25.57 (C-9), 24.47 (C-10). HR-MS: Calculated for $C_{100}H_{104}O_{24}N_6$ $[M+Na]^+$: 1795.7000, found: 1795.6994.

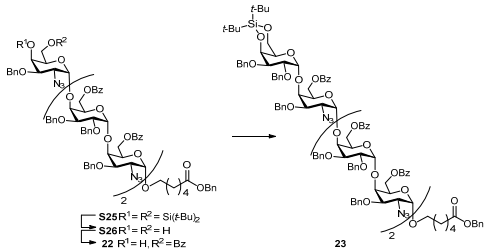
6-(Benzyl hexanoyl) 6-*O*-benzoyl-2,3-di-*O*-benzyl-α-D-galactopyranosyl-(1→4)-2-azido-6-*O*-benzoyl-3-*O*-benzyl-2-deoxy-α-D-galactopyranosyl-(1→4)-6-*O*-benzoyl-2,3-di-*O*-benzyl-α-D-galactopyranosyl-(1→4)-2-azido-6-*O*-benzoyl-3-*O*-benzyl-2-deoxy-α-D-galactopyranoside (21)

The reaction was carried out according to the general procedure D using compound **S24** (2.33 g, 1.31 mmol), PhCOOBt (1.41 g, 5.9 mmol) and Et_3N (913 µl, 6.55 mmol). The product was purified by column chromatography (pentane:EtOAc = 3:1). Compound **21** (2.36 g, 96% yield) was obtained as yellow syrup. $[\alpha]_D^{25}$ +86.3 (c=1, $CHCl_3$). ^{1}H-NMR ($CDCl_3$, 400 MHz) δ 8.08 – 7.99 (m, 2H, *C*H, Bz), 7.98 – 7.87 (m, 6H, *C*H, Bz), 7.63 – 7.00 (m, 47H, *aromatic*), 5.11 – 5.06 (m, 2H, H-1^B, 1^D), 5.06 (s, 2H, *PhC*H$_2$), 5.02 (d, *J* = 3.3 Hz, 1H, H-1^C), 4.96 (d, *J* = 3.5 Hz, 1H, H-1^A), 4.93 – 4.35 (m, 21H), 4.20 (d, *J* = 2.4 Hz, 1H, H-4), 4.18 – 4.13 (m, 2H), 4.11 – 3.77 (m, 11H), 3.71 – 3.59 (m, 2H, H-2^A, 7), 3.44 (dt, *J* = 9.7, 6.3 Hz, 1H, H-7), 2.60 (bs, 1H, *O*H), 2.30 (t, *J* = 7.5 Hz, 2H, H-11), 1.67 – 1.51 (m, 4H, H-8, 10), 1.39 – 1.24 (m, 2H, H-9). ^{13}C NMR (100 MHz, $CDCl_3$) δ 173.43 (C-12), 166.09, 165.97, 165.48, 165.47 (4 C=O, Bz), 138.38, 138.30, 138.10, 137.34, 137.32, 136.16, 133.42, 133.37, 133.22, 133.01, 130.03, 129.88, 129.83, 129.80, 129.73, 129.67, 128.66, 128.64, 128.56, 128.54, 128.52, 128.48, 128.43, 128.41, 128.33, 128.28, 128.24, 127.95, 127.87, 127.83, 127.77, 127.67, 127.38, 127.31, 100.19 (C-1^B), 100.11 (C-1^D), 99.00 (C-1^C), 98.11 (C-1^A), 78.01, 76.33, 76.20, 75.45, 75.20, 75.11, 74.70, 74.27, 74.03, 72.92, 72.42, 72.34, 72.31 (6 C*H*$_2$), 69.05, 68.97, 68.20 (C-7), 68.03, 66.58, 66.16 (C*H*$_2$), 62.86 (C-6), 62.24 (C-6), 61.52 (C-6), 61.39 (C-6), 60.65 (C-2^C), 59.79 (C-2^A), 34.19 (C-11), 29.07 (C-8), 25.73 (C-9), 24.63 (C-10). HR-MS: Calculated for $C_{107}H_{108}O_{25}N_6$ $[M+Na]^+$: 1899.7262, found: 1899.7256.

Pentasaccharide S25

The reaction was carried out according to the general procedure B. The donor **2** (973 mg, 1.6 mmol) and the acceptor **21** (2.01 g, 1.07 mmol) were co-evaporated with toluene (three times). The residue was dissolved in 11 ml dry DCM under nitrogen and stirred over fresh flame-dried molecular sieves 4Å. The solution was cooled to 0 °C, after which TfOH (10 µl, 0.11 mmol) was added. The reaction was stirred at 0 °C for 1 h. Then the reaction was quenched with Et_3N, diluted with DCM, washed with saturated $NaHCO_3$ and brine. The organic phase was dried with anhydrous $MgSO_4$, filtered and concentrated *in vacuo*. The product was purified by silica gel column chromatography (pentane:EtOAc = 5:1). Compound **S25** (2.10 g, 85% yield) was obtained as syrup. $[\alpha]_D^{25}$ +95.8 (c=2, $CHCl_3$). ^{1}H-NMR ($CDCl_3$, 400 MHz) δ 8.07 – 7.99 (m, 2H, *C*H, Bz), 7.99 – 7.87 (m, 6H, *C*H, Bz), 7.64 – 7.02 (m, 52H), 5.13 (d, *J* = 2.9 Hz, 1H, H-1), 5.07 (d, *J* = 3.2 Hz, 1H, H-1), 5.06 (s, 2H, *PhC*H$_2$), 5.00 (d, *J* = 3.0 Hz, 1H, H-1), 4.97 – 4.93 (m, 2H, H-1), 4.93 – 4.33 (m, 24H), 4.23 – 3.52 (m, 21H), 3.44 (dt, *J* = 9.8, 6.4 Hz, 1H, H-7), 2.30 (t, *J* = 7.5 Hz, 2H, H-11), 1.67 – 1.51 (m, 4H, H-8, 10), 1.38 – 1.24 (m, 2H, H-9), 1.00 (s, 9H, *C*H$_3$), 0.94 (s, 9H, *C*H$_3$). ^{13}C NMR (100 MHz, $CDCl_3$) δ 173.28 (C-12), 165.95, 165.39, 165.35, 165.23 (4 C=O, Bz), 138.19, 138.13, 138.03, 137.94, 137.92, 137.23, 137.19, 136.04, 133.30, 133.08, 132.99, 129.74, 129.71, 129.69, 129.66, 129.61, 129.59, 129.56, 128.57, 128.53, 128.51, 128.44, 128.42, 128.38, 128.31, 128.28, 128.21, 128.15, 128.11, 127.74, 127.72, 127.68, 127.55, 127.52, 127.44, 127.31, 127.25, 127.18, 99.95 (C-1), 99.63 (C-1), 98.77 (C-1), 98.48 (C-1),

97.98 (C-1^{A}), 76.65, 76.33, 75.75, 75.66, 75.46, 75.32, 75.07, 74.74, 74.57, 73.99, 73.65 (2 CH_2), 73.33, 72.82, 72.66, 72.20 (3 CH_2), 70.21 (CH_2), 69.51, 68.92, 68.83, 68.78, 68.07 (C-7), 67.39, 66.88 (C-6^{E}), 66.03 (CH_2), 62.69 (C-6), 61.39 (C-6), 61.16 (C-6), 60.56 (C-2), 59.66 (C-2), 58.86 (C-2), 34.06 (C-11), 28.94 (C-8), 27.58, 27.24, 25.61 (C-9), 24.51 (C-10), 23.30, 20.62 (2 C-*Si*). ^{13}C-HMBC ($CDCl_3$, 100 MHz): 99.95 ($J_{C1,H1}$ = 169 Hz), 99.63 ($J_{C1,H1}$ = 169 Hz), 98.77 ($J_{C1,H1}$ = 171 Hz), 98.48 ($J_{C1,H1}$ = 171 Hz), 97.98 ($J_{C1,H1}$ = 171 Hz). MALDI-MS: Calculated for $C_{128}H_{139}N_9O_{29}Si[M+Na]^+$: 2316.9346, found: 2316.9340.



Pentasaccharide S26

The reaction was carried out according to the general procedure C using compound **S25** (1.52 g, 0.66 mmol) and HF/pyridine (70%, 275 µl, 10.6 mmol). The product was purified by column chromatography (pentane:EtOAc = 2:1). Compound **S26** (1.85 g, 96% yield) was obtained as yellow syrup. $[\alpha]_D^{25}$ +82.6 (c=1, $CHCl_3$). ^{1}H-NMR ($CDCl_3$, 400 MHz) δ 8.08 – 7.91 (m, 6H, *C*H, Bz), 7.87 (d, *J* = 7.7 Hz, 2H, *C*H, Bz), 7.68 – 6.95 (m, 52H), 5.14 – 5.07 (m, 2H, H-1), 5.05 (s, 2H, *PhC*H$_2$), 5.02 (s, 1H, H-1), 4.96 (d, *J* = 3.5 Hz, 1H, H-1^{A}), 4.93 – 4.30 (m, 24H), 4.25 – 3.58 (m, 20H), 3.51 – 3.38 (m, 3H, H-6, 7), 2.93 (bs, 1H, *O*H), 2.36 (bs, 1H, *O*H), 2.29 (t, *J* = 7.4 Hz, 2H, H-11), 1.66 – 1.52 (m, 4H, H-8, 10), 1.38 – 1.24 (m, 2H, H-9). ^{13}C NMR (100 MHz, $CDCl_3$) δ 173.15 (C-12), 165.79, 165.23, 165.20, 165.05 (4 C=O, Bz), 137.98, 137.93, 137.84, 137.75, 137.02, 136.97, 135.84, 133.15, 132.95, 132.84, 129.54, 129.50, 129.49, 129.47, 129.41, 129.39, 128.43, 128.36, 128.33, 128.28, 128.24, 128.22, 128.17, 128.13, 128.05, 127.97, 127.92, 127.65, 127.61, 127.57, 127.55, 127.50, 127.37, 127.27, 127.05, 126.77, 99.74 (C-1), 99.58 (C-1), 99.01 (C-1), 98.62 (C-1), 97.81 (C-1^{A}), 76.63, 76.50, 76.17, 75.70, 75.40, 75.19, 74.61, 74.39, 74.13, 73.76, 73.66, 73.20, 72.66, 72.10, 72.04, 71.56, 69.16, 68.74, 68.65, 67.90 (C-7), 67.27, 65.86 (CH_2), 62.52 (C-6), 62.47 (C-6), 61.23 (C-6), 61.14 (C-6), 60.92 (C-6), 60.44 (C-2), 59.70 (C-2), 59.49 (C-2), 33.87 (C-11), 28.75 (C-8), 25.42 (C-9), 24.32 (C-10). HR-MS: Calculated for $C_{120}H_{123}N_9O_{29}[M+NH_4]^+$: 2176.8324, found: 2176.8319.

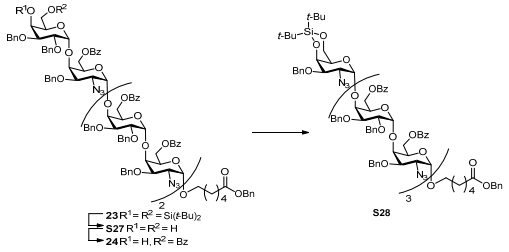
Pentasaccharide 22

The reaction was carried out according to the general procedure D using compound **S26** (1.83 g, 0.85 mmol), PhCOOBt (913 mg, 3.82 mmol) and Et_3N (592 µl, 4.25 mmol). The product was purified by column chromatography (pentane:EtOAc = 5:2). Compound **22** (1.87 g, 98% yield) was obtained as syrup. $[\alpha]_D^{25}$ +79.2 (c=1, $CHCl_3$). ^{1}H-NMR ($CDCl_3$, 400 MHz) δ 8.11 – 7.83 (m, 10H, *C*H, Bz), 7.70 – 6.98 (m, 55H), 5.09 (d, *J* = 3.3 Hz, 2H, H-1), 5.05 (s, 2H, *PhC*H$_2$), 5.03 (d, *J* = 3.0 Hz, 1H, H-1), 4.97 (d, *J* = 3.5 Hz, 1H, H-1^{A}), 4.96 – 4.34 (m, 26H), 4.26 – 3.58 (m, 20H), 3.44 (dt, *J* = 9.7, 6.3 Hz, 1H, H-7), 2.62 (bs, 1H, *O*H), 2.29 (t, *J* = 7.4 Hz, 2H, H-11), 1.68 – 1.50 (m, 4H, H-

8, 10), 1.39 – 1.24 (m, 2H, H-9). ^{13}C NMR (100 MHz, $CDCl_3$) δ 173.25 (C-12), 165.90, 165.82, 165.34, 165.31, 165.12 (5 C=O, Bz), 138.12, 138.06, 137.79, 137.20, 137.14, 137.10, 135.97, 133.25, 133.05, 133.01, 132.97, 129.76, 129.67, 129.62, 129.61, 129.59, 129.53, 129.51, 129.47, 128.54, 128.47, 128.44, 128.35, 128.33, 128.31, 128.28, 128.24, 128.20, 128.14, 128.08, 128.04, 128.02, 127.78, 127.68, 127.66, 127.62, 127.57, 127.54, 127.50, 127.48, 127.39, 127.17, 126.90, 99.87 (2xC-1), 98.78 (2xC-1), 97.92 (C-1^{A}), 76.63, 76.63, 76.25, 75.76, 75.31, 74.88, 74.72, 74.51, 74.14, 73.87 (CH_2), 73.78, 73.43, 72.77, 72.72, 72.17, 72.15, 71.90 (6 CH_2), 68.86, 68.78, 68.01 (C-7), 67.77, 65.97 (CH_2), 65.39 (C-4), 62.65, 62.25, 61.35, 61.25, 60.98 (5 C-6), 60.57 (C-2), 59.76 (C-2), 59.61 (C-2), 33.99 (C-11), 28.87 (C-8), 25.54 (C-9), 24.43 (C-10). MALDI-MS: Calculated for $C_{127}H_{127}N_9O_{30}$ $[M+Na]^+$: 2280.8587, found: 2280.8581.

Hexasaccharide 23

The reaction was carried out according to the general procedure A. The donor **1** (1.21 g, 2.04 mmol) and the acceptor **22** (1.84 g, 0.82 mmol) were co-evaporated with toluene (three times). The residue was dissolved in 8 ml dry DCM under nitrogen and stirred over fresh flame-dried molecular sieves 4Å. The solution was cooled to 0 ºC, after which NIS (597 mg, 2.65 mmol) and TfOH (7 µl, 0.08 mmol) was added. The reaction was stirred at 0 ºC for 1 h. Then the reaction was quenched with $Na_2S_2O_3$, diluted with DCM, washed with saturated $NaHCO_3$ and brine. The organic phase was dried with anhydrous $MgSO_4$, filtered and concentrated *in vacuo*. The product was purified by silica gel column chromatography (pentane:EtOAc = 4:1). Compound **23** (1.84 g, 82% yield) was obtained as yellow syrup. $[\alpha]_D^{25}$ +9.1 (c=1, $CHCl_3$). ^{1}H-NMR ($CDCl_3$, 400 MHz) δ 8.10 – 7.84 (m, 10H, *C*H, Bz), 7.64 – 6.95 (m, 65H), 5.10 (d, *J* = 3.3 Hz, 1H, H-1), 5.07 (d, *J* = 3.4 Hz, 1H, H-1), 5.05 (s, 2H, *PhC*H$_2$), 5.03 (d, *J* = 3.2 Hz, 1H, H-1), 5.00 – 3.52 (m, 59H), 3.51 – 3.40 (m, 1H, H-7), 2.29 (t, *J* = 7.4 Hz, 2H, H-11), 1.69 – 1.52 (m, 4H, H-8, 10), 1.40 – 1.25 (m, 2H, H-9), 0.96 (s, 9H, *C*H$_3$), 0.90 (s, 9H, *C*H$_3$). ^{13}C NMR (100 MHz, $CDCl_3$) δ 173.15 (C-12), 165.85, 165.30, 165.28, 165.24, 165.06 (5 C=O, Bz), 138.81, 138.19, 138.10, 138.09, 138.06, 138.05, 137.30, 137.14, 137.09, 135.98, 133.22, 133.10, 133.05, 132.98, 129.73, 129.67, 129.63, 129.60, 129.55, 129.51, 129.48, 128.74, 128.51, 128.46, 128.43, 128.35, 128.29, 128.25, 128.22, 128.18, 128.15, 128.06, 128.03, 127.76, 127.68, 127.64, 127.56, 127.48, 127.46, 127.41, 127.38, 127.29, 127.17, 126.81, 126.66, 99.95 (C-1), 99.87 (C-1), 98.82 (C-1), 98.72 (C-1), 97.94 (C-1), 77.69, 76.40, 76.27, 75.83, 75.67, 75.27, 74.67, 74.52, 74.29, 73.90, 73.83, 73.57, 73.34, 72.75, 72.59, 72.55, 72.38, 72.13, 71.81, 70.42, 69.99, 68.89, 68.75, 67.99 (C-7), 67.49, 66.80 (C-6^{F}), 65.92 (CH_2), 62.62 (C-6), 61.30 (C-6), 60.94 (C-6), 60.58 (C-2), 59.61 (C-2), 33.96 (C-11), 28.87 (C-8), 27.55, 27.12, 25.53 (C-9), 24.42 (C-10), 23.19, 20.50. ^{13}C-HMBC ($CDCl_3$, 100 MHz): 99.95 ($J_{C1,H1}$ = 168 Hz, 169 Hz), 99.87 ($J_{C1,H1}$ = 169 Hz), 99.82 ($J_{C1,H1}$ = 172 Hz), 99.72 ($J_{C1,H1}$ = 172 Hz), 97.94 ($J_{C1,H1}$ = 171 Hz). MALDI-MS: Calculated for $C_{155}H_{165}N_9O_{35}Si$ $[M+Na]^+$: 2763.1075, found: 2763.0660.



Hexasaccharide S27

The reaction was carried out according to the general procedure C using compound **23** (1.82 g, 0.66 mmol) and HF/pyridine (70%, 274 µl, 3.96 mmol). The product was purified by column chromatography (pentane:EtOAc = 3:2). Compound **S27** (1.62 g, 93% yield) was obtained as white foam. $[\alpha]_D^{25}$ +88.4 (c=10, $CHCl_3$). ^{1}H-NMR ($CDCl_3$, 400 MHz) δ 8.08 – 7.84 (m, 10H, *C*H, Bz), 7.63 – 7.51 (m, 5H), 7.50 – 6.95 (m, 60H), 5.10 – 5.07 (m, 2H, 2xH-1), 5.06 (s, 2H, *PhC*H_2), 5.04 – 4.99 (m, 2H, 2xH-1), 4.96 (d, *J* = 3.5 Hz, 1H, H-1^A), 4.94 – 4.27 (m, 31H), 4.25 – 3.58 (m, 24H), 3.44 (dt, *J* = 9.8, 6.4 Hz, 1H, H-7), 3.40 – 3.28 (m, 2H), 2.30 (t, *J* = 7.4 Hz, 2H, H-11), 1.68 – 1.50 (m, 4H, H-8, 10), 1.39 – 1.23 (m, 2H, H-9). ^{13}C NMR (100 MHz, $CDCl_3$) δ 173.25 (C-12), 165.90, 165.34, 165.32, 165.26, 165.13 (5 C=O, Bz), 138.11, 138.08, 137.97, 137.87, 137.79, 137.30, 137.15, 137.09, 135.97, 133.25, 133.18, 133.08, 133.01, 129.68, 129.66, 129.62, 129.59, 129.54, 129.51, 129.49, 128.53, 128.49, 128.46, 128.42, 128.39, 128.36, 128.31, 128.24, 128.21, 128.18, 128.10, 128.05, 127.84, 127.80, 127.68, 127.66, 127.57, 127.55, 127.49, 127.40, 127.23, 127.18, 126.79, 100.32 (C-1), 99.90 (C-1), 99.81 (C-11), 98.73 (C-1), 97.93 (C-1^A), 77.68, 76.34, 76.27, 75.90, 75.79, 75.27, 74.92, 74.71, 74.58, 74.51, 74.20, 73.92, 73.85, 73.58, 73.46, 72.76, 72.59, 72.19, 72.15, 71.98, 69.20, 69.12, 68.91, 68.77, 68.02 (C-7), 65.98 (CH_2*Ph*), 62.73, 62.62, 61.35, 61.25, 61.09, 61.03 (6 C-6), 60.59 (C-2), 60.44 (C-2), 59.61 (C-2^A), 34.00 (C-11), 28.88 (C-8), 25.55 (C-9), 24.45 (C-10). MALDI-MS: Calculated for $C_{147}H_{149}N_9O_{35}$ $[M+Na]^+$: 2623.0054, found: 2622.9908.

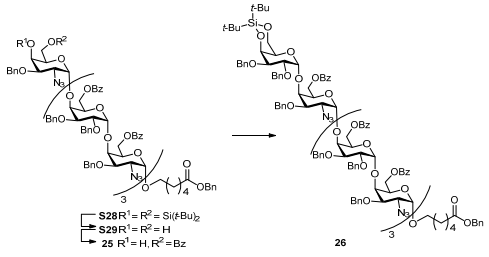
Hexasaccharide 24

The reaction was carried out according to the general procedure D using compound **S27** (1.32 g, 0.51 mmol), PhCOOBt (546 mg, 2.28 mmol) and Et_3N (0.353 ml, 2.54 mmol). The product was purified by column chromatography (pentane:EtOAc = 5:2). Compound **24** (1.34 g, 98% yield) was obtained as white solid. $[\alpha]_D^{25}$ +79.9 (c=2, $CHCl_3$). ^{1}H-NMR ($CDCl_3$, 400 MHz) δ 8.09 – 7.83 (m, 12H), 7.64 – 6.95 (m, 68H), 5.15 – 5.04 (m, 5H, 3xH-1, *PhC*H_2), 5.01 (d, *J* = 3.4 Hz, 1H, H-1), 4.97 (d, *J* = 3.5 Hz, 1H, H-1^A), 4.93 (d, *J* = 3.8 Hz, 1H, H-1), 4.91 – 4.28 (m, 31H), 4.24 – 3.60 (m, 23H), 3.45 (dt, *J* = 9.7, 6.3 Hz, 1H, H-7), 2.59 (bs, 1H, *O*H), 2.30 (t, *J* = 7.4 Hz, 2H, H-11), 1.69 – 1.51 (m, 4H, H-8, 10), 1.40 – 1.22 (m, 2H, H-9). ^{13}C NMR (100 MHz, $CDCl_3$) δ 173.24 (C-12), 165.91, 165.75, 165.34, 165.32, 165.23, 165.14 (6 C=O, Bz), 138.12, 138.09, 138.00, 137.92, 137.90, 137.15, 137.13, 137.11, 135.98, 133.25, 133.20, 133.08, 133.01, 132.82, 129.84, 129.70, 129.67, 129.63, 129.60, 129.54, 129.52, 129.47, 128.54, 128.49, 128.46, 128.37, 128.32, 128.25, 128.21, 128.18, 128.14, 128.10, 128.06, 127.76, 127.70, 127.68, 127.66, 127.63, 127.57, 127.52, 127.49, 127.41, 127.19, 127.02, 126.79, 99.99 (C-1), 99.91 (C-1), 99.86 (C-1),

98.81 (C-1), 98.78 (C-1), 97.94 (C-1^{A}), 77.81, 76.27, 76.20, 75.92, 75.81, 75.29, 74.95, 74.87, 74.73, 74.54, 74.05, 73.85, 73.54, 72.77, 72.59, 72.26, 72.15, 68.89, 68.78, 68.03 (C-7), 67.81, 66.36, 65.98 (CH_2*Ph*), 62.64, 61.98, 61.35, 61.25, 61.09, 61.04 (6 C-6), 60.59 (C-2), 60.51 (C-2), 59.62 (C-2^{A}), 34.01 (C-11), 28.89 (C-8), 25.56 (C-9), 24.45 (C-10). MALDI-MS: Calculated for $C_{154}H_{153}N_9O_{36}$ $[M+Na]^+$: 2727.0316, found: 2726.9908.

Heptasaccharide S28

The reaction was carried out according to the general procedure B. The donor **2** (583 mg, 0.96 mmol) and the acceptor **24** (1.30 g, 0.48 mmol) were co-evaporated with toluene (three times). The residue was dissolved in 5 ml dry DCM under nitrogen and stirred over fresh flame-dried molecular sieves 4Å. The solution was cooled to 0 ºC, after which TfOH (4 µl, 0.05 mmol) was added. The reaction was stirred at 0 ºC for 1 h. Then the reaction was quenched with Et_3N, diluted with DCM, washed with saturated $NaHCO_3$ and brine. The organic phase was dried with anhydrous $MgSO_4$, filtered and concentrated *in vacuo*. The product was purified by silica gel column chromatography (pentane:EtOAc = 4:1). Compound **S28** (1.28 g, 85% yield) was obtained as white solid. $[\alpha]_D^{25}$ +91.2 (c=2, $CHCl_3$). ^{1}H-NMR ($CDCl_3$, 400 MHz) δ 8.10 – 7.86 (m, 12H, *C*H, Bz), 7.64 – 6.92 (m, 73H, aromatic H), 5.25 – 3.52 (m, 73H), 3.50 – 3.39 (m, 1H, H-7), 2.29 (t, *J* = 7.4 Hz, 2H, H-11), 1.67 – 1.51 (m, 4H, H-8, 10), 1.38 – 1.24 (m, 2H, H-9), 1.02 (s, 9H, *C*H_3), 0.95 (s, 9H, *C*H_3). ^{13}C NMR (100 MHz, $CDCl_3$) δ 173.02 (C-12), 165.75, 165.22, 165.18, 165.02 (C=O, Bz), 138.01, 137.99, 137.85, 137.79, 137.75, 137.07, 137.01, 135.91, 133.15, 132.95, 132.83, 129.58, 129.55, 129.50, 129.47, 129.42, 129.38, 128.43, 128.38, 128.33, 128.28, 128.26, 128.20, 128.15, 128.11, 128.07, 128.05, 128.02, 127.96, 127.92, 127.57, 127.52, 127.49, 127.45, 127.40, 127.33, 127.20, 127.08, 126.94, 126.72, 99.79 (C-1), 99.44 (C-1), 98.64 (C-1), 98.33 (C-1), 97.86 (C-1^{A}), 76.38, 76.17, 75.79, 75.57, 75.19, 74.89, 74.62, 74.44, 73.73, 73.51, 73.45, 73.21, 72.69, 72.49, 72.05, 70.04, 69.36, 68.73, 67.89 (C-7), 67.23, 66.71 (C-6^{G}), 65.81 (CH_2*Ph*), 62.56 (C-6), 61.15 (C-6), 61.06 (C-6), 60.99 (C-6), 60.48 (C-2), 60.47 (C-2), 59.53 (C-2), 58.74 (C-2A), 33.85 (C-11), 28.77 (C-8), 27.43 (CH_3), 27.10 (CH_3), 25.44 (C-9), 24.32 (C-10), 23.12 (C-*Si*), 20.45 (C-*Si*). ^{13}C-HMBC ($CDCl_3$, 100 MHz): 99.79 ($J_{C1,H1}$ = 169 Hz), 99.44 ($J_{C1,H1}$ = 168 Hz), 98.64 ($J_{C1,H1}$ = 170 Hz), 98.33 ($J_{C1,H1}$ = 173 Hz), 97.86 ($J_{C1,H1}$ = 170 Hz). MALDI-MS: Calculated for $C_{175}H_{184}N_{12}O_{40}Si$ $[M+Na]^+$: 3144.2400, found: 3144.1828.



Heptasaccharide S29

The reaction was carried out according to the general procedure C using compound **S28** (1.24 g, 0.40 mmol) and HF/pyridine (70%, 165 µl, 6.35 mmol). The product was purified by column chromatography (pentane:EtOAc = 3:2). Compound **S29** (1.13 g, 95% yield) was obtained as white solid. $[\alpha]_D^{25}$ +80.6 (c=1, $CHCl_3$). ^{1}H-NMR ($CDCl_3$, 400 MHz) δ 8.09 – 7.81 (m, 12H, *C*H, Bz), 7.69 – 6.93 (m, 73H, aromatic H), 5.12 – 5.04 (m, 5H, 3xH-1, *C*H_2*Ph*), 5.01 (d, *J* = 3.5 Hz, 1H, H-1), 4.97 (d, *J* = 3.5 Hz, 1H, H-1^A), 4.93 (d, *J* = 3.1 Hz, 1H, H-1), 4.92 – 4.28 (m, 34H), 4.26 – 4.13 (m, 4H), 4.13 – 3.54 (m, 22H), 3.50 – 3.37 (m, 3H), 2.89 (bs, 1H, *O*H), 2.29 (t, *J* = 7.4 Hz, 2H, H-11), 2.20 (bs, 1H, *O*H), 1.67 – 1.52 (m, 4H, H-8, 10), 1.38 – 1.23 (m, 2H, H-9). ^{13}C NMR (100 MHz, $CDCl_3$) δ 173.24 (C-12), 165.89, 165.32, 165.30, 165.28, 165.14, 165.10 (6 C=O, Bz), 138.09, 138.05, 137.94, 137.90, 137.82, 137.13, 137.07, 137.06, 135.95, 133.24, 133.06, 133.02, 132.92, 129.64, 129.62, 129.60, 129.56, 129.52, 129.48, 128.54, 128.52, 128.46, 128.43, 128.38, 128.34, 128.31, 128.28, 128.23, 128.19, 128.16, 128.13, 128.09, 128.07, 128.03, 128.01, 127.74, 127.67, 127.65, 127.58, 127.55, 127.52, 127.47, 127.39, 127.16, 126.75, 99.87 (C-1), 99.67 (C-1), 99.10 (C-1), 98.72 (C-1), 97.92 (C-1^A), 76.74, 76.53, 76.25, 75.97, 75.49, 75.26, 74.72, 74.65, 74.50, 74.16, 73.83, 73.66, 73.53, 73.26, 72.74, 72.59, 72.23, 72.14, 71.67, 69.23, 68.81, 68.00 (C-7), 67.39, 65.96 (CH_2*Ph*), 62.59 (C-6), 61.33 (C-6), 61.20 (C-6), 61.15 (C-6), 60.97 (C-6), 60.95 (C-6), 60.58 (C-2), 59.80 (C-2), 59.59 (C-2^A), 33.98 (C-11), 28.86 (C-8), 25.53 (C-9), 24.42 (C-10). MALDI-MS: Calculated for $C_{167}H_{168}N_{12}O_{40}$ $[M+Na]^+$: 3004.1378, found: 3004.0885.

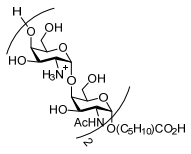
Heptasaccharide 25

The reaction was carried out according to the general procedure D using compound **S29** (1.10 g, 0.37 mmol), PhCOOBt (396 mg, 1.66 mmol) and Et_3N (256 µl, 1.84 mmol). The product was purified by column chromatography (pentane:EtOAc = 2:1). Compound **25** (1.12 g, 98% yield) was obtained as white solid. $[\alpha]_D^{25}$ +71.3 (c=1, $CHCl_3$). ^{1}H-NMR ($CDCl_3$, 400 MHz) δ 8.08 – 7.83 (m, 14H, *C*H, Bz), 7.66 – 6.93 (m, 76H), 5.13 – 5.04 (m, 5H, 3xH-1, *C*H_2*Ph*), 5.02 (d, *J* = 3.5 Hz, 1H, H-1), 4.97 (d, *J* = 3.4 Hz, 1H, H-1^A), 4.94 – 4.29 (m, 38H), 4.24 – 4.14 (m, 4H), 4.11 – 3.60 (m, 23H), 3.45 (dt, *J* = 9.7, 6.3 Hz, 1H, H-7), 2.59 (bs, 1H, OH), 2.30 (t, *J* = 7.4 Hz, 2H, H-11), 1.66 – 1.52 (m, 4H, H-8, 10), 1.39 – 1.24 (m, 2H, H-9). ^{13}C NMR (100 MHz, $CDCl_3$) δ 173.23 (C-12), 165.90, 165.81, 165.33, 165.31, 165.29, 165.14, 165.07 (7 C=O, Bz), 138.11, 138.07, 138.06, 137.93, 137.77, 137.20, 137.15, 137.09, 135.97, 133.25, 133.07, 133.01, 132.95, 129.76, 129.67, 129.65, 129.62, 129.61, 129.57, 129.53, 129.50, 129.47, 128.54, 128.47, 128.46, 128.44, 128.36, 128.31, 128.28, 128.24, 128.20, 128.17, 128.12, 128.10, 128.08, 128.04, 128.01, 127.77, 127.69, 127.66, 127.56, 127.53, 127.50, 127.48, 127.41, 127.18, 126.78, 99.88 (C-1), 98.75 (C-1), 97.93 (C-1^A), 76.64, 76.57, 76.26, 75.94, 75.28, 74.87, 74.73, 74.65, 74.53, 74.06, 73.84, 73.68, 73.55, 73.38, 72.77, 72.71, 72.59, 72.20, 72.15, 71.90, 68.86, 68.77, 68.01 (C-7), 67.74, 65.96 (CH_2*Ph*), 65.39, 62.64, 62.23, 61.35, 61.20, 61.14, 61.05, 60.92 (7 C-6), 60.60 (C-2), 59.76 (C-2), 59.61 (C-2^A), 33.99 (C-11), 28.87 (C-8), 25.54 (C-9), 24.44 (C-10). MALDI-MS: Calculated for $C_{174}H_{172}N_{12}O_{41}$ $[M+Na]^+$: 3108.1641, found: 3108.1095.

Octasaccharide 26

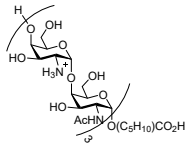
The reaction was carried out according to the general procedure A. The donor **1** (622 mg, 1.05 mmol) and the acceptor **25** (1.08 g, 0.35 mmol) were co-evaporated with toluene (three times). The residue was dissolved in 3.5 ml dry DCM under nitrogen and stirred over fresh flame-dried molecular sieves 4Å. The solution was cooled to 0 °C, after which NIS (307 mg, 1.37 mmol) and TfOH (3 µl, 0.04 mmol) were added. The reaction was stirred at 0 °C for 1 h. Then the reaction was quenched with Et_3N, diluted with DCM, washed with saturated $NaHCO_3$ and brine. The organic phase was dried with anhydrous $MgSO_4$, filtered and concentrated *in vacuo*. The product was purified by silica gel column chromatography (pentane:EtOAc = 3:1). Compound **26** (1.01 g, 80% yield) was obtained as white solid. $[\alpha]_D^{25}$ +103 (c=1, $CHCl_3$). ^{1}H-NMR ($CDCl_3$, 500 MHz) δ 8.07 – 7.84 (m, 14H, *C*H, Bz), 7.61 – 7.50 (m, 7H, aromatic H), 7.48 – 6.94 (m, 79H, aromatic H), 5.17 – 5.07 (m, 2H, H-1), 5.06 (s, 2H, *C*H_2*Ph*), 5.05 – 5.00 (m, 2H, H-1), 4.99 – 3.50 (m, 77H), 3.50 – 3.40 (m, 1H, H-7), 2.30 (t, *J* = 7.4 Hz, 2H, H-11), 1.66 – 1.53 (m, 4H, H-8, 10), 1.39 – 1.24 (m, 2H, H-9), 0.96 (s, 9H, *C*H_3), 0.90 (s, 9H, *C*H_3). ^{13}C NMR (125 MHz, $CDCl_3$) δ 173.18 (C-12), 165.89, 165.34, 165.32, 165.29, 165.26, 165.16, 165.07 (7 C=O, Bz), 138.82, 138.20, 138.12, 138.10, 138.07, 138.05, 137.94, 137.32, 137.16, 137.12, 136.01, 133.23, 133.11, 133.05, 132.98, 129.76, 129.70, 129.66, 129.61, 129.59, 129.56, 129.53, 129.50, 128.75, 128.52, 128.48, 128.45, 128.43, 128.37, 128.33, 128.29, 128.25, 128.17, 128.11, 128.08, 128.06, 128.04, 128.01, 127.83, 127.70, 127.66, 127.59, 127.52, 127.44, 127.42, 127.32, 127.21, 126.84, 126.74, 126.71, 99.95 (C-1), 99.89 (C-1), 99.82 (C-1), 98.82 (C-1), 98.74 (C-1), 97.96 (C-1A), 77.70, 76.40, 76.26, 76.02, 75.92, 75.60, 75.33, 75.24, 74.73, 74.64, 74.56, 74.32, 73.91, 73.86, 73.55, 73.34, 72.79, 72.60, 72.43, 72.17, 71.85, 70.48, 70.05, 68.89, 68.80, 68.03 (C-7), 67.51, 66.81 (C-6H), 65.96 (CH_2*Ph*), 62.67 (C-6), 61.39 (C-6), 61.26 (C-6), 61.21 (C-6), 60.96 (C-6), 60.62 (C-2), 59.64 (C-2), 34.00 (C-11), 28.89 (C-8), 27.57 (CH_3), 27.14 (CH_3), 25.56 (C-9), 24.45 (C-10), 23.21 (C-*Si*), 20.52 (C-*Si*). ^{13}C-HMBC ($CDCl_3$, 125 MHz): 99.95 ($J_{C1,H1}$ = 171 Hz), 99.89 ($J_{C1,H1}$ = 169 Hz), 99.82 ($J_{C1,H1}$ = 167 Hz), 98.82 ($J_{C1,H1}$ = 172 Hz), 98.74 ($J_{C1,H1}$ = 172 Hz, 171 Hz), 97.96 ($J_{C1,H1}$ = 171 Hz). MALDI-MS: Calculated for $C_{202}H_{210}N_{12}O_{46}Si$ $[M+Na]^+$: 3590.4129, found: 3590.3372.

5-Carboxypentyl 2-amino-2-deoxy-α-D-galactopyranosyl-(1→4)-2-acetamino-2-deoxy-α-D-galactopyranosyl-(1→4)-2-amino-2-deoxy-α-D-galactopyranosyl-(1→4)-2-acetamino-2-deoxy-α-D-galactopyranoside (27)



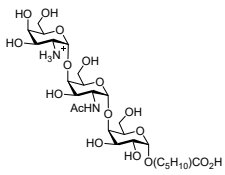
(3.4 mg, 34% yield). The reaction was carried out according to the general procedure C and E. ^{1}H-NMR (H_2O, 500 MHz) δ 5.24 (d, *J* = 3.9 Hz, 1H, H-1), 5.20 (d, *J* = 3.8 Hz, 1H, H-1), 5.02 (d, *J* = 3.8 Hz, 1H, H-1), 4.93 (d, *J* = 3.7 Hz, 1H, H-1), 4.44 (t, *J* = 7.0 Hz, 2H), 4.38 (t, *J* = 6.4 Hz, 1H), 4.30 (dd, *J* = 11.4, 3.8 Hz, 1H), 4.26 – 3.98 (m, 11H), 3.86 – 3.58 (m, 10H), 3.54 – 3.39 (m, 4H), 2.17 (t, *J* = 7.3 Hz, 2H, H-11), 2.06 (s, 3H, *C*H_3), 2.03 (s, 3H, *C*H_3), 1.65 – 1.51 (m, 4H, H-10, 8), 1.41 – 1.30 (m, 2H, H-9). ^{13}C NMR (125 MHz, D_2O) δ 183.70 (C-12), 174.51, 174.41 (C=O, Ac), 98.05 (C-1), 96.77 (C-1), 76.64, 75.80, 71.45, 71.08, 70.62, 70.35, 68.12, 67.84, 66.97, 66.57, 60.56, 60.40, 60.08, 59.31, 50.99, 50.81, 49.98, 49.90, 37.32 (C-11), 28.12 (C-8), 25.35 (C-10), 25.18 (C-9), 21.73 (CH_3), 21.66 (CH_3). HR-MS: Calculated for $C_{34}H_{60}N_4O_{21}$ $[M+2H]^+$: 431.19533, found: 431.19478.

Hexasaccharide 28



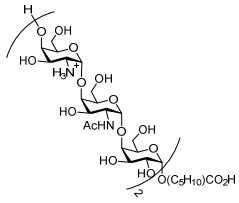
(5.4 mg, 44% yield). The reaction was carried out according to the general procedure C and E. ^{1}H NMR (500 MHz, D_2O) δ 5.40 (d, *J* = 3.8 Hz, 1H, H-1), 5.37 (d, *J* = 3.9 Hz, 1H, H-1), 5.35 (d, *J* = 3.8 Hz, 1H, H-1), 5.06 (d, *J* = 3.8 Hz, 2H, H-1C, H-1^{E}), 4.98 (d, *J* = 3.8 Hz, 1H, H-1^{A}), 4.54 – 4.40 (m, 5H, H-5), 4.37 – 3.96 (m, 16H), 3.89 – 3.57 (m, 16H), 3.52 (dt, *J* = 10.1, 6.1 Hz, 1H, H-7), 2.42 (t, *J* = 7.3 Hz, 2H, H-11), 2.13 – 2.03 (m, 9H, Ac), 1.70 – 1.60 (m, 4H, H-8, H-10), 1.47 – 1.38 (m, 2H, H-9). ^{13}C NMR (125 MHz, D_2O) δ 179.15 (C-12), 174.75 (C=O, Ac), 174.67 (C=O, Ac), 98.26 (C-1^{C}, 1^{E}), 97.01 (C-1^{A}), 95.79 (2xC-1), 95.72 (C-1), 76.67 (C-4), 75.72 (C-4), 75.65 (C-4), 71.73 (C-5), 71.65 (C-5), 71.30 (C-5), 70.47 (C-5), 70.29 (C-5), 70.21 (C-12), 68.21 (C-7), 67.97, 67.12, 66.71, 66.31, 65.79, 65.73, 60.92 (C-6), 60.61 (C-6), 60.43 (C-6), 60.38 (C-6), 59.53 (C-6), 59.45 (C-6), 51.11 (C-2), 50.05 (C-2), 33.82 (C-11), 28.18 (C-8), 24.95 (C-10), 24.05 (C-9), 21.96 (C*H*$_3$), 21.93 (C*H*$_3$). HR-MS: Calculated for $C_{48}H_{84}N_6O_{30}$ $[M+2H]^{2+}$: 613.26942, found: 613.26887.

5-Carboxypentyl 2-amino-2-deoxy-α-D-galactopyranosyl-(1→4)-2-acetamino-2-deoxy-α-D-galactopyranosyl -(1→4)-α-D-galactopyranoside (29)



(68% yield). The reaction was carried out according to the general procedure C and E. ^{1}H NMR (500 MHz, D_2O) δ 5.31 (d, *J* = 3.9 Hz, 1H, H-1^{C}), 4.95 (d, *J* = 3.9 Hz, 1H, H-1^{A}), 4.93 (d, *J* = 3.8 Hz, 1H, H-1^{B}), 4.43 (t, *J* = 5.6 Hz, 1H, H-5^{B}), 4.41 – 4.36 (m, 1H, H-5^{C}), 4.30 – 4.23 (m, 2H, H-2^{B}, 4^{B}), 4.13 (dd, *J* = 11.1, 3.1 Hz, 1H, H-3^{C}), 4.09 (dd, *J* = 11.5, 2.9 Hz, 1H, H-3^{B}), 4.04 – 3.99 (m, 2H, H-4^{A}, 4^{C}), 3.97 (t, *J* = 6.5 Hz, 1H, H-5^{A}), 3.92 (dd, *J* = 10.6, 3.1 Hz, 1H, H-3^{A}), 3.83 (dd, *J* = 10.5, 3.9 Hz, 1H, H-2^{A}), 3.79 (dd, *J* = 11.7, 5.0 Hz, 1H, H-6^{C}), 3.76 – 3.64 (m, 6H, H-7, 6^{A}, 6^{B}, 6^{C}), 3.56 – 3.49 (m, 2H, H-2^{C}, 7), 2.16 (t, *J* = 7.4 Hz, 2H, H-11), 2.06 (s, 3H, *C*H$_3$), 1.68 – 1.51 (m, 4H, H-10, 8), 1.40 – 1.31 (m, 2H, H-9). ^{13}C NMR (125 MHz, D_2O) δ 183.98 (C-12), 174.61 (C=O, Ac), 98.32 (C-1^{A}, 1^{B}), 96.09 (C-1^{C}), 77.49 (C-4^{A}), 76.94 (C-4^{B}), 71.50 (C-5^{A}), 71.22 (C-5^{C}), 70.07 (C-5^{B}), 68.96 (C-3^{A}), 68.36 (C-7), 68.34 (C-2^{A}), 67.95 (C-4^{C}), 66.69 (C-3^{B}), 66.50 (C-3^{C}), 60.52, 60.34, 60.27 (3 C-6), 51.03 (C-2C), 50.13 (C-2B), 37.51 (C-11), 28.43 (C-8), 25.62 (C-10), 25.41 (C-9), 21.89 (C*H*$_3$). HR-MS: Calculated for $C_{26}H_{46}N_2O_{17}$ $[M+H]^{+}$: 659.2875, found: 659.2869.

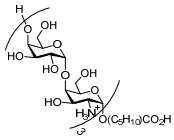
Hexasaccharide 30



(12.9 mg, 65% yield). The reaction was carried out according to the general procedure C and E. ^{1}H NMR (500 MHz, D_2O) δ 5.40 (d, *J* = 3.8 Hz, 1H, H-1^{C}), 5.38 (d, *J* = 3.8 Hz, 1H, H-1^{F}), 5.11 (d, *J* = 3.8 Hz, 1H, H-1^{E}), 5.03 (d, *J* = 3.8 Hz, 1H, H-1^{D}), 5.00 (d, *J* = 3.9 Hz, 1H, H-1^{A}), 4.98 (d, *J* = 3.8 Hz, 1H, H-1^{B}), 4.53 – 4.38 (m, 6H), 4.37 – 4.26 (m, 5H), 4.23 – 4.18 (m, 2H), 4.17 – 3.93 (m, 9H), 3.92 – 3.64 (m, 17H), 3.63 – 3.54 (m, 2H), 2.25 (t, *J* = 7.4 Hz, 2H), 2.10 (d, *J* = 3.2 Hz, 6H), 1.73 – 1.56 (m, 4H), 1.47 – 1.33 (m, 2H). ^{13}C NMR (125 MHz, D_2O) δ 183.24 (C-12), 174.65 (C=O, Ac), 100.45 (C-1^{E}), 98.35 (C-1^{A}, 1^{B}, 1^{D}), 95.99 (C-1^{C}), 95.91 (C-1^{F}), 77.52, 77.35, 77.11, 77.03, 71.66, 71.53, 71.38, 71.29, 70.81, 70.09,

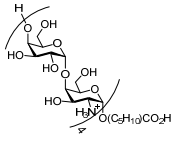
70.02, 69.01, 68.64, 68.57, 68.38, 68.26, 67.97, 66.73, 66.67, 66.35, 65.99, 60.57, 60.46, 60.38, 60.31, 59.80, 59.63 (6 C-6), 51.30, 51.08, 50.17, 50.11 (4 C-2), 36.96 (C-11), 28.44 (C-8), 25.41 (C-10), 25.37 (C-9), 21.95 (C*H*$_3$). HR-MS: Calculated for $C_{46}H_{80}N_4O_{31}$ $[M+2H]^{2+}$: 593.24815, found: 593.24760.

Hexasaccharide 31



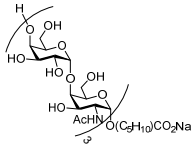
(13.1 mg, 62% yield). The reaction was carried out according to the general procedure C and E. ^{1}H-NMR (H_2O, 500 MHz) 5.27 – 5.22 (m, 2H, H-1^C, 1^E), 5.16 (d, *J* = 3.7 Hz, 1H, H-1^A), 5.07 (d, *J* = 3.9 Hz, 1H, H-1), 5.03 (d, *J* = 3.5 Hz, 1H, H-1), 5.02 (d, *J* = 3.9 Hz, 1H, H-1), 4.48 (t, *J* = 6.2 Hz, 2H, H-5), 4.39 (dt, *J* = 8.0, 5.9 Hz, 2H, H-5), 4.29 (t, 1H, H-5^A), 4.22 (d, *J* = 2.6 Hz, 2H), 4.18 – 4.07 (m, 6H), 4.06 – 3.98 (m, 4H), 3.97 – 3.66 (m, 19H), 3.58 – 3.48 (m, 4H, H-2^A, 2^C, 2^E, 7), 2.18 (t, *J* = 7.2 Hz, 2H, H-11), 1.71 – 1.53 (m, 4H, H-8, 10), 1.38 (q, *J* = 7.5 Hz, 2H, H-9). ^{13}C NMR (125 MHz, $CDCl_3$) δ 184.02 (C-12), 100.62 (C-1B), 100.30 (C-1$^{D/F}$), 100.23 (C-1$^{D/F}$), 96.85 (C-1$^{C/E}$), 96.78 (C-1$^{C/E}$), 95.33 (C-1A), 77.91 (C-3), 77.46 (C-3), 77.16 (C-3), 77.06 (C-3), 71.50 (C-5), 71.36 (C-5), 71.29 (C-5), 70.59 (C-5), 70.49 (C-5), 69.15, 68.96 (C-4A), 68.73, 68.69, 68.48 (C-2), 68.42, 68.33, 66.79 (C-4), 66.70 (C-4), 66.53 (C-4), 60.68 (C-6A), 60.30, 60.22, 60.14, 60.01, 59.71 (5 C-6), 51.39 (C-2), 51.25 (C-2), 51.09 (C-2), 37.45 (C-11), 28.28 (C-8), 25.47 (C-10), 25.32 (C-9). HR-MS: Calculated for $C_{42}H_{75}N_3O_{30}$ $[M+Na]^+$: 1124.4333, found: 1124.4328.

Octasaccharide 32



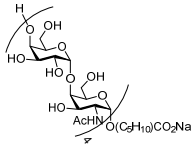
(12.7 mg, 54% yield). The reaction was carried out according to the general procedure C and E. ^{1}H NMR (500 MHz, D_2O) δ 5.08 (d, *J* = 4.0 Hz, 1H), 5.04 (d, *J* = 4.1 Hz, 1H), 5.01 (d, *J* = 4.0 Hz, 1H), 4.99 – 4.96 (m, 2H, H-1), 4.93 (d, *J* = 3.7 Hz, 1H, H-1^A), 4.49 – 4.43 (m, 2H, H-5), 4.41 – 4.33 (m, 2H, H-5), 4.31 – 4.23 (m, 3H), 4.19 (dd, *J* = 11.3, 3.7 Hz, 1H, H-2^A), 4.17 – 4.13 (m, 2H), 4.11 – 3.99 (m, 9H), 3.98 – 3.77 (m, 10H), 3.75 – 3.57 (m, 7H), 3.49 (dt, *J* = 10.0, 6.0 Hz, 1H, H-7), 2.21 – 2.14 (m, 2H, H-11), 2.09 – 1.99 (m, 9H, Ac), 1.68 – 1.50 (m, 4H, H-8, 10), 1.36 (p, *J* = 7.1, 6.7 Hz, 2H, H-9). ^{13}C NMR (125 MHz, D_2O) δ 183.96 (C-12), 174.70, 174.61, 174.59 (3 C=O, Ac), 100.72 (C-1), 100.57 (C-1), 100.45 (C-1), 98.40 (C-1), 98.37 (C-1), 96.97 (C-1^A), 78.69 (C-3), 78.30 (C-3), 78.18 (C-3), 77.11, 77.08, 71.56 (C-5), 71.41 (C-5), 71.28 (C-5), 71.11 (C-5), 70.90 (C-5), 69.18, 69.01, 68.76, 68.72, 68.69, 68.65, 68.31 (C-7), 67.25 (C-4), 66.98 (C-4), 66.90 (C-4), 60.61, 60.54, 60.01, 59.82, 59.57, 59.49 (6 C-6), 50.49, 50.44, 50.35 (3 C-2), 37.57 (C-11), 28.36 (C-8), 25.62 (C-10), 25.42 (C-9), 21.96 (C*H*$_3$), 21.91 (C*H*$_3$). HR-MS: Calculated for $C_{54}H_{96}N_4O_{39}$ $[M+2H]^{2+}$: 713.2904, found: 713.2899.

Hexasaccharide 33



(11.5 mg, 55% yield). The reaction was carried out according to the general procedure C and E. ^{1}H-NMR ($CDCl_3$, 500 MHz) δ 5.31 (d, *J* = 3.8 Hz, 3H, H-1), 5.18 (d, *J* = 3.7 Hz, 1H, H-1^{A}), 5.09 (d, *J* = 3.9 Hz, 2H, H-1), 5.06 – 5.00 (m, 2H, H-1), 4.51 (t, *J* = 6.3 Hz, 3H, H-5), 4.41 (t, *J* = 5.7 Hz, 3H, H-5), 4.34 – 4.28 (m, 1H, H-5^{A}), 4.27 – 4.13 (m, 10H), 4.10 (d, *J* = 3.2 Hz, 1H), 4.07 – 3.99 (m, 5H), 3.98 – 3.51 (m, 29H), 2.27 (t, *J* = 7.2 Hz, 2H, H-11), 1.75 – 1.53 (m, 4H, H-8, 10), 1.40 (q, *J* = 7.6 Hz, 2H, H-9). ^{13}C NMR (125 MHz, D_2O) δ 182.12 (C-12), 100.64 (C-1), 100.27 (C-1), 100.22 (C-1), 95.93 (C-1), 95.89 (C-1), 95.16 (C-1A), 77.73, 77.45, 76.97, 76.84, 71.50, 71.35, 71.26, 70.34, 70.24, 69.15, 68.94, 68.66, 68.46, 68.40, 68.36, 68.34 (C-7), 66.32 (C-4), 66.04 (C-4), 65.82 (C-4), 60.66, 60.28, 59.95, 59.60 (C-6), 51.33 (C-2), 51.16 (C-2), 51.08 (C-2), 35.98 (C-11), 28.25 (C-8), 25.15 (C-10), 24.89 (C-9). HR-MS: Calculated for $C_{48}H_{81}N_3O_{33}$ $[M+NH_4]^+$: 1245.5096, found: 1245.5091.

Octasaccharide (34)



(13.8 mg, 59% yield). The reaction was carried out according to the general procedure C and E. ^{1}H NMR (500 MHz, D_2O) δ 5.08 (d, *J* = 4.0 Hz, 2H, H-1), 5.03 (d, *J* = 4.0 Hz, 1H, H-1), 5.01 (d, *J* = 4.0 Hz, 1H, H-1), 5.00 – 4.95 (m, 3H, H-1), 4.93 (d, *J* = 3.7 Hz, 1H, H-1A), 4.50 – 4.42 (m, 3H, H-5), 4.40 – 4.32 (m, 3H), 4.32 – 4.23 (m, 4H), 4.22 – 4.13 (m, 4H), 4.12 – 3.99 (m, 12H), 3.98 – 3.76 (m, 13H), 3.74 – 3.56 (m, 9H), 3.48 (dt, *J* = 9.9, 6.0 Hz, 1H, H-7), 2.21 – 2.14 (m, 2H, H-11), 2.09 – 1.98 (m, 12H, Ac), 1.66 – 1.52 (m, 4H, H-8, 10), 1.37 (q, *J* = 7.6 Hz, 2H, H-9). ^{13}C NMR (125 MHz, D_2O) δ 183.96 (C-12), 174.70, 174.61, 174.59 (C=O, Ac), 100.72 (C-1), 100.57 (C-1), 100.45 (C-1), 98.40 (C-1), 98.37 (C-1), 96.97 (C-1), 78.69, 78.29, 78.18, 77.11, 77.08, 71.56, 71.41, 71.28, 71.11, 70.90, 69.18, 69.01, 68.72, 68.69, 68.65, 68.31 (C-7), 67.25 (C-4), 66.98 (C-4), 66.89 (C-4), 60.61 (C-6), 60.54 (C-6), 60.02 (C-6), 59.82 (C-6), 59.56 (C-6), 59.49 (C-6), 50.50 (C-2), 50.44 (C-2), 50.35 (C-2), 37.57 (C-11), 28.36 (C-8), 25.62 (C-10), 25.42 (C-9), 21.96 (C*H*$_3$), 21.91 (C*H*$_3$). HR-MS: Calculated for $C_{62}H_{104}N_4O_{43}$ $[M+Na]^+$: 1615.5972, found: 1615.5967.

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Chapter 4

Synthesis of an azido-GAG heptasaccharide featuring α-GalN_3 and α-GalNAc linkages

Introduction

Aspergillus fumigatus is a saprophytic mold that causes invasive and chronic infections in immunocompromised patients with high mortality rates.[1-5] Galactosaminogalactan (GAG), an extracellular polysaccharide produced by *A. fumigatus*, is a key virulence factor and plays an essential role in biofilm formation. This exopolysaccharide, which is composed of 1,4-linked α-Gal, α-GalN and α-GalNAc residues that are distributed in a seemingly random manner, is a potential lead compound in the development of anti-inflammatory therapies. Chapter 2 and 3 described the synthesis of a library of GAG oligomers, comprising both homo- and hetero-oligomers. Some of the synthetic GAG oligomers have been applied to

probe enzymes involved in the GAG biosynthetic pathway, resulting in better structural and mechanistic understanding of the hydrolases Sph3 and Ega3 as well as the involvement of the deacetylase Agd3.[6-8] Sph3 is a retaining endoglycoside hydrolase, which belongs to glycoside hydrolase family 135 (GH 135)[9]. Retaining glycoside hydrolases can also perform transglycosylation reactions and have been used in the laboratory to produce polysaccharides as an substitution of glycosyltransferases (GT).[10-14] They generally operate through a "Koshland" double displacement mechanism (Figure 1).[15] First a covalent glycosyl enzyme intermediate is formed by attack of the active site nucleophilic carboxylate promoted by the protonation of the leaving group by an acid residue on the opposite side of the substrate. In the second displacement, the intermediate is hydrolyzed or attacked by a nucleophilic acceptor, such as an alcohol, with the assistance of the deprotonated carboxylate, giving the hydrolyzed or glycosylated product.

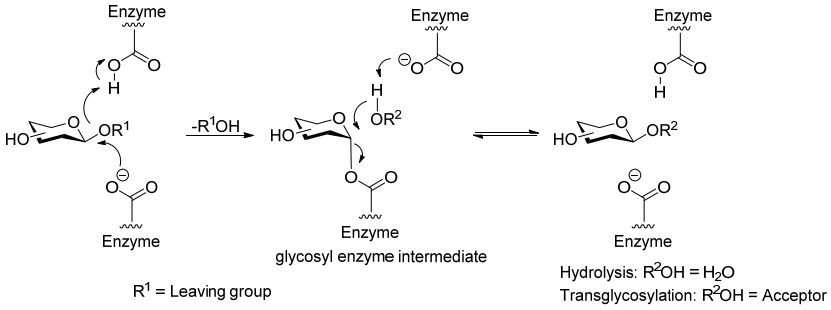
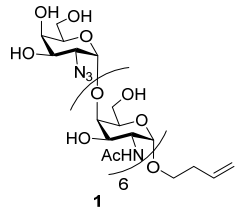


Figure 1. Hydrolysis and transglycosylation reactions of the retaining GH enzymes

Metabolic glycan labeling has recently been introduced as a powerful method that enables the visualization of glycans as they function in their native setting.[16-17] It has been applied for imaging cell-surface glycans in living organisms, such as plants, zebrafish and mice.[16, 18-29] This labeling approach comprises two steps, in which the first step is to metabolically incorporate an unnatural and modified monosaccharide into the organism's glycome. The modified monomer contains a reactive group, which functions as a "chemical reporter". Subsequently, the chemical reporter can be labeled and visualized with an imaging probe *via* a bioorthogonal reaction.

Though a handful of reactions possess the quality of bioorthogonality, the azide group is often chosen as chemical reporter. This functional group is small enough not to interfere with normal uptake and often has relatively little influence on the recognition by (biosynthetic) enzymes. What's more, azides are capable of undergoing chemoselective reactions, such as the copper-catalyzed 1,3-cycloaddition, the Staudinger ligation with phosphines and Cu-free

click chemistry with strained alkynes. To probe potential transglycosylase activity of Sph3, this Chapter describes the conception of an azido-GAG oligosaccharide, that can be used to introduce azido groups in the GAG exopolysaccharide, which can then be visualized with a fluorogenic click reagent. On the basis of the finding that the minimal GAG length of the substrates for the hydrolase Sph3 are seven monomers in length the azide-containing heptasaccharide **1** was designed (Figure 2). Because of the similar size of the azide, in comparison to the native acetamide, it is expected that this modification in the oligosaccharide probe is well tolerated by the hydrolase.



1

Figure 2. Structure of azido-GAG **1**.

Results and discussion

The retrosynthesis, depicted in Figure 3 shows that the target heptasaccharide **1** can be obtained from the protected heptamer **2** by a final three-steps deprotection sequence, including the desilylation of DTBS group and saponification of benzoyl esters and trifluoroacetamides, followed by *N*-acetylation. The trichloroacetyl (TCA) group, used in the synthesis of GAG hetero-oligomers as described in Chapter 3, is replaced in the current synthetic route by the more base-labile TFA-group. Kiso's di-*tert*-butylsilyene (DTBS)-directed α-selective galactosylation methodology, which has been successfully used for the synthesis of GAG homo- and heteropolymers, described in Chapter 2 and 3, is applied again to ensure the stereoselective construction of the α-galactosamine linkages.[30-35] These considerations, together with the moderate glycosylating properties of the selenophenyl $GalN_3$ donor (See Chapter 2) led to the design of the imidate donors **3** and **4** to assemble the heptamer **2**. The elongation procedure toward the heptamer consists of repetition of the following three-steps: 1) glycosylation; 2) DTBS-removal and 3) selective benzoylation of the primary alcohol group with benzoyl-hydroxybenzotriazole (BzOBt) as a mild, regioselective acylating agent.[36] The $GalN_3$ donor **3** will serve as precursor of $GalN_3$ and the GalNHTFA donor **4** will serve as precursor of the GalNAc residues.

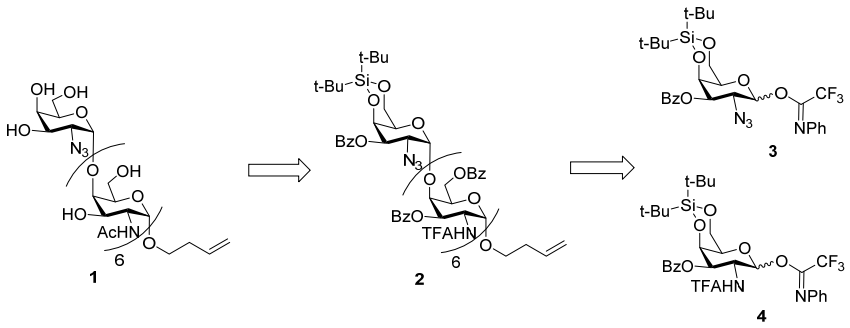
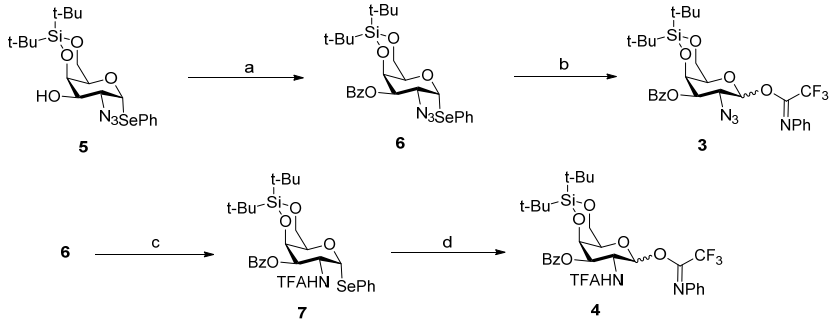


Figure 3. Retrosynthetic analysis towards target azido-GAG **1**

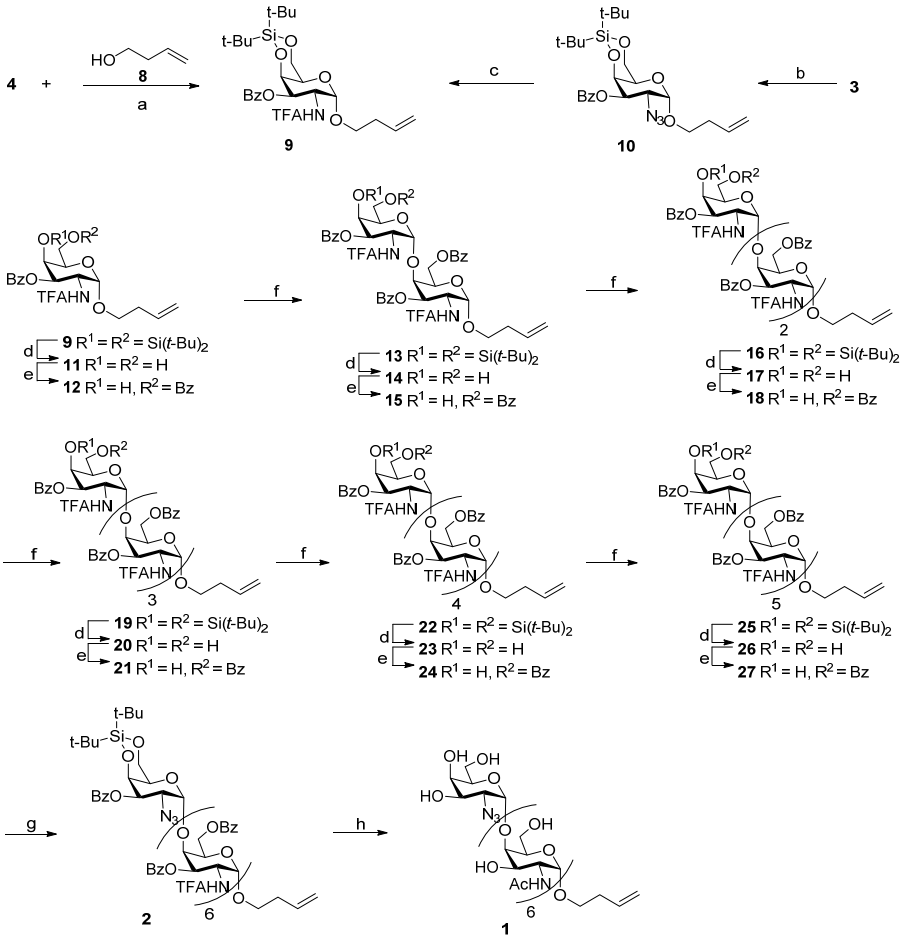
The preparation of the $GalN_3$ and GalNHTFA donors is described in Scheme 1. First $GalN_3$ donor **3** was obtained from known $GalN_3$ **5** through benzoylation, hydrolysis of the selenophenyl acetal and reaction of the anomeric hydroxyl with *N*-phenyltrifluoroacetamidoyl chloride, affording donor **3** in 72% yield over these three steps. To generate the GalNHTFA donor **4**, the azido group in compound **6** was first reduced with $HS(CH_2)_3SH$, followed by trifluoroacetylation of the formed amino group to give the selenophenyl glycoside **7** in 86% yield, which was transformed to trifluoroacetimidate donor **4** in 79% yield through the same procedure as described for the conversion of **6** into **3.**



Scheme 1. Preparation of donors **3** and **4**. a) BzCl, pyridine, DMAP, DCM, 0 °C to rt, 95%. b) i) NIS, Acetone/H_2O (10/1), 0 °C; ii) $CF_3C(=NPh)Cl$, Cs_2CO_3, acetone, 76%. c) i) $HS(CH_2)_3SH$, Et_3N, pyridine/H_2O; ii) TFA_2O, pyridine, 86%. d) i) NIS, Acetone/H_2O (10/1), 91%; ii) $CF_3C(=NPh)Cl$, K_2CO_3, acetone, 87%.

With $GalN_3$ and GalNHTFA donors in hand, elongation of the N_3-GAG chain was performed, as outlined in Scheme 2. Owing to the neighboring group participation effect and high nucleophilicity of the homoallylic alcohol, coupling of GalNHTFA donor **4** with the acceptor **8** at -40 °C afforded the α/β-glycosylation mixture **9** in 91% yield with the ratio

3.2/1. To avoid the formation of β-product, 3-buten-1-ol **8** was treated with $GalN_3$ donor **3**, affording compound **10** in 85% yield and with complete α-selectivity. The azido group in **10** could be reduced with Staudinger reaction, after which the generated amino group was protected with TFA group to give compound **9** in 83% yield. Removal of the silylidene ketal in the α-linked product was performed in HF/pyridine solution and then the liberated C6-hydroxyl group was benzoylated selectively with BzOBt to afford the C4-OH acceptor **12**. Condensation of the formed monomer **12** with GalNHTFA donor **4** provided the dimer **13** in 86% yield with exclusive α-selectivity, overcoming the neighboring group participation effect of C2-NHTFA group. The DTBS-protected dimer was transformed to the C4-OH acceptor **15** by desilylation and selective benzoylation reactions in 72% yield. Elongation of this dimer with another copy of the GalNHTFA donor **4** delivered trisaccharide **16** in good yield. Repetition of the three-step elongation procedure for another three times led to the hexasaccharide **25**. All glycosylation reactions resulted in excellent α-selectivity, and the desilylation and regioselective benzoylation reactions proceeded in excellent yields (84%-96% and 80%-97%, respectively). However, it needs to be noted that the glycosylation yields for the pentamer **22** and hexamer **25** decreased to 68% (for the pentamer) and 18% (for the hexamer), as the reactivity of the acceptors diminishes with growing chain length. The yield of hexamer **25** could be increased to 54% by increasing the concentration of the condensation from 0.05 M to 0.2 M. In the last coupling protected heptamer **2** was isolated in 84% yield by treatment of the hexamer acceptor **27** with $GalN_3$ donor **3**. Finally, the protecting groups in heptamer **2** were removed through desilylation, saponification and chemo-selective acetylation reactions, furnishing the target compound **1** in 60% yield.



Scheme 2. Synthesis of azido-GAG **1**. a) TfOH, DCM, 3Å MS, -40 °C, 91% (α/β = 3.2/1). b) **8**, TfOH, DCM, 3Å MS, 0 °C, 86%; c) i) PPh_3, H_2O, pyridine, THF ii) TFA_2O, pyridine, 83%. d) HF/pyridine, THF, yields for **11**: 89%; for **14**: 90%; for **17**: 90%; for **20**: 88%; for **23**: 96%; for **26**: 84%. e) BzOBt, Et_3N, DCM, yields for **12**: 97%; for **15**: 80%; for **18**: 96%; for **21**: 94%; for **24**: 84%; for **27**: 91%. f) **4**, TfOH, DCM, 3Å MS, 0 °C, yields for **13**: 86%; for **16**: 75%; for **19**: 84%; for **22**: 68%; for **25**: 18% (0.05M), 54% (0.2 M). g) **3**, TfOH, DCM, 3Å MS, 0 °C, 84%. h) i) HF/pyridine, THF; ii) 1M NaOH, THF/MeOH; iii) Ac_2O, $NaHCO_3$, H_2O, 60%.

Conclusion

In conclusion, an azido-GAG heptamer with a C2-N_3 group at the non-reducing end was successfully assembled based on the previously developed synthesis approach. The glycosylation results show that in DTBS-protected $GalN_3$ and GalNHTFA donors the ability of neighboring group participation can be overruled to afford excellent α-stereoselectivity. Although the use of the benzoyl group to mask the C3-OH in the glycosyl building blocks facilitated the deprotection of the target heptamer in the final stage of the synthesis, the reactivities of corresponding donors and acceptors are reduced at the same time. Since the reactivity of acceptors decreases with growing chain length, lower yields were obtained for the glycosylation reactions toward the penta- and hexamer. Increasing the concentration of the reaction significantly improved the yields of the couplings. The developed synthetic methodology will be applicable for the assembly of other azido-GAGs. The synthesized azido-GAG will be used to probe transglycosylation activity of the Sph3 *N*-acetyl galactosaminidase in the biosynthetis of GAG-polysaccharides at the cellular level.

Experimental section

General procedure for glycosylation with imidate donors 3 and 4 (procedure A)

The donor (1.5 – 3.0 eq) and acceptor (1.0 eq) were co-evaporated with toluene (three times). The residue was dissolved in dry DCM (0.1 M acceptor in DCM) under nitrogen and stirred over fresh flame-dried molecular sieves 4Å. The solution was cooled to 0 ºC, after which TfOH (0.1 – 0.3 eq) was added. The reaction was stirred at 0 ºC until TLC-analysis showed complete conversion of the acceptor. The reaction was quenched with Et_3N, diluted with DCM, washed with saturated $NaHCO_3$ and brine. The organic phase was dried with anhydrous $MgSO_4$, filtered and concentrated *in vacuo*. The products were purified by silica gel column chromatography (See experimental description below for eluent system).

General procedure for the deprotection of di-*tert*-butyl silylidene group (general procedure B)

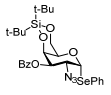
HF/pyridine (16 eq) solution was added to a solution of starting material in THF at 0 ºC. The reaction was warmed to room temperature and stirred until TLC-analysis indicated full consumption of the starting material (± 1h). Then the mixture was diluted with DCM and washed with saturated $NaHCO_3$ and brine, dried with anhydrous $MgSO_4$, filtered and concentrated *in vacuo*. The product was purified by silica gel column chromatography (See experimental description below for eluent system).

General procedure for selective benzoylation of primary alcohol (general procedure C)

PhCOOBt (4.5 eq) and Et_3N (5.0 eq) were added to the solution of starting material in DCM (0.05 M). The reaction was allowed to stirred overnight at room temperature. Then the mixture was diluted with DCM and washed with saturated $NaHCO_3$ and brine, dried with anhydrous $MgSO_4$, filtered and concentrated *in vacuo*. The product was purified by silica gel column chromatography (See experimental description below for eluent system).

Experimental Procedures and Characterization Data of Products

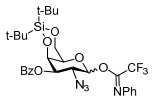
Phenyl 2-azido-3-*O*-benzoyl-2-deoxy-1-seleno-4,6-di-*tert*-butylsilylidene-α-D-galactopyranoside (6)



To the solution of **5**[1] (1.0 g, 2.06 mmol) in 10 mL DCM and 1.7 mL pyridine (20.6 mmol) was added BzCl (360 ul, 3.1 mmol, 1.5 mmol) and DMAP (25 mg, 0.21 mmol), which was allowed to stir at rt for overnight. The reaction mixture was washed with water, sat. $NaHCO_3$ solution and brine subsequently, and dried with $MgSO_4$. The product was purified by silica gel column chromatography (pentane:Et_2OAc = 50:1 – 20:1). Compound **6** (1.1 g, 95% yield) was obtained as colorless syrup. ^{1}H-NMR ($CDCl_3$, 400 MHz) δ 8.13 – 8.06 (m, 2H, *C*H, Bz), 7.64 – 7.56 (m, 3H, *aromatic*), 7.51 – 7.44 (m, 2H, *aromatic*), 7.33 – 7.25 (m, 3H, *aromatic*), 6.05 (d, *J* = 5.2 Hz, 1H, H-1), 5.15 (dd, *J* = 10.6, 3.0 Hz, 1H, H-3), 4.90 (dd, *J* = 3.1, 1.0 Hz, 1H, H-4), 4.58 (dd, *J* = 10.6, 5.2 Hz, 1H, H-2), 4.33 – 4.23 (m, 2H, H-5, 6), 4.03 (dd, *J* = 12.6, 1.5 Hz, 1H, H-6), 1.05 (s, 9H, *C*H_3), 0.94 (s, 9H, *C*H_3). ^{13}C NMR (100 MHz, $CDCl_3$) δ 165.92 (C=O, Bz), 134.70, 133.54, 129.84, 129.57, 129.30, 128.63, 128.31, 128.08 (*aromatic* C/C*H*), 85.39 (C-1), 74.60 (C-3), 69.87 (C-4), 69.79 (C-5), 66.90 (C-6),

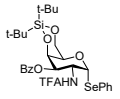
59.00 (C-2), 27.58 (CH_3), 27.34 (CH_3), 23.28 (C-*Si*), 20.80 (C-*Si*). HR-MS: Calculated for $C_{27}H_{35}N_3O_5SeSi$ $[M+H]^+$: 612.1409, found: 612.1403.

2-Azido-3-*O*-benzoyl-2-deoxy-4,6-di-*tert*-butylsilylidene-1-*O*-(*N*-phenyl-trifluoroacetimidoyl)-α/β-D-galactopyranoside (3)



NIS (1.65 g, 8.65 mmol) was added to the solution of compound **6** (3.3 g, 5.76 mmol) in Acetone/H_2O (40 ml/4 ml) at 0 ºC. The reaction was slowly warmed to room temperature stirred for about 2 hours. Then the mixture was diluted with DCM and washed with saturated $Na_2S_2O_3$ and brine, dried with anhydrous $MgSO_4$, filtered and concentrated *in vacuo*. The residue was purified by silica gel column chromatography (pentane:EtOAc = 4:1) to get the hemiacetyl. K_2CO_3 (919 mg, 6.65 mmol) was added to the solution of hemiacetal in 25 ml acetone. The mixture was stirred at 0 ºC for 15 minutes. Then $CF_3C(=NPh)Cl$ (1.49 g, 7.20 mmol) was added to the solution, which was slowly warmed to room temperature and stirred overnight. The reaction was quenched with Et_3N and concentrated *in vacuo*. The product **3** was purified by silica gel column chromatography (pentane:Et_2O = 10:1). Compound **3** (1.10 g, 76% yield) was obtained as white solid. ^{1}H-NMR ($CDCl_3$, 400 MHz) δ 8.07 – 7.97 (m, 2H, *C*H, Bz), 7.63 – 7.52 (m, 1H), 7.44 (t, *J* = 7.8 Hz, 2H), 7.31 (t, *J* = 7.9 Hz, 2H), 7.18 – 7.09 (m, 1H), 6.98 (d, *J* = 8.5 Hz, 1H, *N*H), 6.82 (d, *J* = 7.8 Hz, 2H), 6.58 (bs, 1H, H-1), 5.47 – 5.32 (m, 1H, H-3), 5.15 – 4.97 (m, 1H, H-2), 4.82 (d, *J* = 4.1 Hz, 1H, H-4), 4.39 – 4.16 (m, 2H, H-6), 3.94 (bs, 1H, H-5), 1.10 (s, 9H, *C*H_3), 1.02 (s, 9H, *C*H_3). ^{13}C NMR (100 MHz, $CDCl_3$) δ 167.39 (C=O, Bz), 157.72 (*a*d, *J* = 37 Hz, *CF_3CO*), 142.96, 133.99, 129.95, 128.99, 128.86, 128.75, 124.90, 119.90, 115.61 (*a*d, *J* = 286 Hz, C*F_3*), 94.68 (C-1), 70.71 (C-3), 70.13 (C-4), 69.92 (C-5), 66.62 (C-6), 48.14 (C-2), 27.61 (CH_3), 27.25 (CH_3), 23.41 (C-*Si*), 20.87 (C-*Si*). HR-MS: Calculated for $C_{29}H_{35}N_4O_6F_3Si$ $[M+Na]^+$: 643.2176, found: 643.2170.

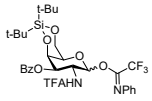
Phenyl 3-*O*-benzoyl-2-deoxy-1-seleno-4,6-di-*tert*-butylsilylidene-2-trifluoroacetamido-α-D-galactopyranoside (7)



1,3-Dithiolpropane (3.0 ml, 29.6 mmol) and trimethylamine (3.4 ml, 24.7 mmol) were added to the solution of compound **6** (2.83 g, 4.94 mmol)in pyridine/water (20 ml/5 ml). The mixture was protected from light and stirred at room temperature overnight. The fluent was evaporated and co-evaporated with toluene. The residue was dissolved in 25 ml pyridine, after which TFA_2O (1.0 ml, 7.41 mmol) was added at 0 ºC. The reaction was slowly warmed to room temperature and stirred overnight. The reaction was quenched with Methanol and concentrated *in vacuo*. The product was purified by silica gel column chromatography (pentane:EtOAc = 30:1 – 20:1). Compound **7** (2.90 g, 89% yield) was obtained as white solid. ^{1}H-NMR ($CDCl_3$, 400 MHz) δ 8.25 – 8.11 (m, 2H, *C*H, Bz), 7.66 – 7.63 (m, 1H), 7.52 (d, *J* = 7.5 Hz, 1H), 7.39 – 7.35 (m, 2H), 7.31 – 7.23 (m, 1H), 7.21 – 7.14 (m, 1H), 6.93 (d, *J* = 7.7 Hz, 2H), 6.71 (bs, 1H, H-1), 5.49 (dd, *J* = 10.7, 2.8 Hz, 1H, H-3), 5.08 – 4.93 (m, 1H, H-4), 4.51 – 4.23 (m, 3H, H-2, 6), 4.02 (s, 1H, H-5), 1.13 (s, 9H, *C*H_3), 1.03 (s, 9H, *C*H_3). ^{13}C NMR (100 MHz, $CDCl_3$) δ ^{13}C NMR (101 MHz, $CDCl_3$) δ 166.10 (C=O, Bz), 143.25, 135.35, 133.66, 129.85, 129.41, 129.32, 128.88, 128.72, 128.65, 126.34, 124.60, 120.75, 119.39, 94.41 (C-1), 72.06 (C-3), 69.90 (C-4),

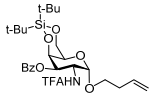
69.65 (C-5), 66.60 (C-6), 57.11 (C-2), 27.51 (CH_3), 27.23 (CH_3), 23.24 (C-*Si*), 20.77 (C-*Si*). HR-MS: Calculated for $C_{29}H_{36}NO_6SeSi$ $[M+H]^+$: 682.1327, found: 682.1322.

2-Trifluoroacetamido-3-*O*-benzoyl-2-deoxy-4,6-di-*tert*-butylsilylidene-1-*O*-(*N*-phenyl-trifluoroacetimidoyl)-α/β-D-galactopyran-oside (4)



NIS (410 mg, 1.82 mmol) was added to the solution of compound **7** (800 g, 1.21 mmol) in Acetone/H_2O (10 ml/1 ml) at 0 ºC. The reaction was slowly warmed to room temperature stirred for about 2 hours. Then the mixture was diluted with DCM and washed with saturated $Na_2S_2O_3$ and brine, dried with anhydrous $MgSO_4$, filtered and concentrated *in vacuo*. The residue was purified by silica gel column chromatography (pentane:EtOAc = 4:1) to get the hemiacetal. K_2CO_3 (183 mg, 1.32 mmol) was added to the solution of hemiacetal in 11 ml acetone. The mixture was stirred at 0 ºC for 15 minutes. Then $CF_3C(=NPh)Cl$ (343 mg, 1.65 mmol) was added to the solution, which was slowly warmed to room temperature and stirred overnight. The reaction was quenched with Et_3N and concentrated *in vacuo*. The product **4** was purified by silica gel column chromatography (pentane:Et_2O = 50:1-20:1). Compound **4** (580 mg, α:β > 10:1, 81% yield) was obtained as syrup. α-Isomer: ^{1}H-NMR ($CDCl_3$, 400 MHz) δ 8.07 – 7.97 (m, 2H, *C*H, Bz), 7.63 – 7.52 (m, 1H), 7.44 (t, *J* = 7.8 Hz, 2H), 7.31 (t, *J* = 7.9 Hz, 2H), 7.18 – 7.09 (m, 1H), 6.98 (d, *J* = 8.5 Hz, 1H, *N*H), 6.82 (d, *J* = 7.8 Hz, 2H), 6.58 (bs, 1H, H-1), 5.47 – 5.32 (m, 1H, H-3), 5.15 – 4.97 (m, 1H, H-2), 4.82 (d, *J* = 4.1 Hz, 1H, H-4), 4.39 – 4.16 (m, 2H, H-6), 3.94 (bs, 1H, H-5), 1.10 (s, 9H, CH_3), 1.02 (s, 9H, CH_3). ^{13}C NMR (100 MHz, $CDCl_3$) δ 167.39 (C=O, Bz), 157.72 (*a*d, *J* = 37 Hz, *CF*$_3$*CO*), 142.96, 133.99, 129.95, 128.99, 128.86, 128.75, 124.90, 119.90, 115.61 (*a*d, *J* = 286 Hz, C*F*$_3$), 94.68 (C-1), 70.71 (C-3), 70.13 (C-4), 69.92 (C-5), 66.62 (C-6), 48.14 (C-2), 27.61 (CH_3), 27.25 (CH_3), 23.41 (C-*Si*), 20.87 (C-*Si*). HR-MS: Calculated for $C_{31}H_{36}N_2O_7F_6Si$ $[M+Na]^+$: 713.2094, found: 713.2088.

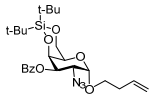
3-Butenyl 3-*O*-benzoyl-2-deoxy-4,6-di-*tert*-butylsilylidene-2-trifluoroacetamido-α-D-galactopyranoside (9)



The reaction was carried out according to the general procedure A. The donor **4** (200 mg, 0.29 mmol) and acceptor **8** (51 µL, 0.59 mmol) were co-evaporated with toluene (three times). The residue was dissolved in dry 5 ml DCM under nitrogen and stirred over fresh flame-dried molecular sieves 4Å. The solution was cooled to -40 ºC, after which TfOH (3 µl, 0.03 mmol) was added. The reaction was stirred at -40 ºC for 2 h. Then the reaction was quenched with Et_3N, diluted with DCM, washed with saturated $NaHCO_3$ and brine. The organic phase was dried with anhydrous $MgSO_4$, filtered and concentrated *in vacuo*. The product was purified by silica gel column chromatography (pentane:EtOAc = 6:1). Compound **9** (151 mg, 91% yield, a/b = 3.2/1) was obtained as yellow solid. **α isomer**: $[\alpha]_D^{25}$ +131.2 (c=1, $CHCl_3$). ^{1}H-NMR ($CDCl_3$, 400 MHz) δ 8.09 – 8.01 (m, 2H, *C*H, Bz), 7.61 – 7.53 (m, 1H), 7.50 – 7.40 (m, 2H), 6.64 (d, *J* = 9.6 Hz, 1H, *N*H), 5.86 – 5.72 (m, 1H, H-9), 5.23 (dd, *J* = 10.9, 2.9 Hz, 1H, H-3), 5.17 – 5.06 (m, 2H, H-10), 5.02 (d, *J* = 3.7 Hz, 1H, H-1), 4.97 – 4.88 (m, 1H, H-2), 4.81 – 4.76 (m, 1H, H-4), 4.32 (dd, *J* = 12.6, 2.1 Hz, 1H, H-6), 4.22 (dd, *J* = 12.6, 1.7 Hz, 1H, H-6), 3.89 – 3.76 (m, 2H, H-5, 7), 3.57 (dt, *J* = 10.0, 6.5 Hz, 1H, H-7), 2.36 (qd, *J* = 6.1, 3.0 Hz, 2H, H-8), 1.11 (s, 9H, CH_3), 0.99 (s, 9H, CH_3). ^{13}C NMR (100 MHz, $CDCl_3$) δ 166.87 (C=O, Bz), 157.20 (*a*d, *J* = 37 Hz, *CF*$_3$*CO*), 134.65 (C-9),

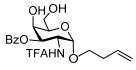
133.55, 129.93, 129.31, 128.59, 117.42 (C-10), 115.61 (*a*d, *J* = 286 Hz, C*F*$_3$), 97.18 (C-1), 71.90 (C-3), 70.40 (C-4), 67.64 (C-5), 67.32 (C-7), 67.03 (C-6), 47.99 (C-2), 33.72 (C-8), 27.59 (C*H*$_3$), 27.33 (C*H*$_3$), 23.38 (C-*Si*), 20.81 (C-*Si*). HR-MS: HR-MS: Calculated for $C_{27}H_{28}O_7NF_3Si$ $[M+NH_4]^+$: 591.2713, found: 591.2711. **β isomer**: $[\alpha]_D^{25}$ +46.3 (c=2, $CHCl_3$). IR (neat, cm^{-1}) ν 650, 697, 734, 796, 826, 863, 920, 1003, 1046, 1066, 1100, 1124, 1172, 1212, 1473, 1522, 1701, 1731, 2859, 2933, 3427. ^{1}H-NMR ($CDCl_3$, 400 MHz) δ 8.06 – 7.96 (m, 2H, *C*H, Bz), 7.64 – 7.55 (m, 1H), 7.45 (t, *J* = 7.7 Hz, 2H), 6.60 (d, *J* = 8.7 Hz, 1H, *N*H), 5.78 (ddt, *J* = 17.0, 10.2, 6.6 Hz, 1H, H-9), 5.39 – 5.30 (m, 1H, H-3), 5.14 – 4.99 (m, 2H, H-10), 4.75 (d, *J* = 8.3 Hz, 1H, H-1), 4.72 (d, *J* = 3.0 Hz, 1H, H-4), 4.42 (dt, *J* = 11.1, 8.5 Hz, 1H, H-2), 4.35 – 4.24 (m, 2H, H-6), 3.95 (dt, *J* = 9.7, 6.5 Hz, 1H, H-7), 3.63 – 3.51 (m, 2H, H-5, 7), 2.33 (qt, *J* = 6.7, 1.4 Hz, 2H, H-8), 1.11 (s, 9H, *C*H$_3$), 0.98 (s, 9H, *C*H$_3$). ^{13}C NMR (100 MHz, $CDCl_3$) δ 166.66 (C=O, Bz), 157.55 (*a*d, *J* = 37 Hz, *CF$_3$CO*),, 134.87 (C-9), 133.66, 129.91, 129.39, 128.67, 116.73 (C-10), 115.72 (*a*d, *J* = 286 Hz, C*F*$_3$), 100.09 (C-1), 72.79 (C-3), 71.39 (C-5), 70.13 (C-4), 68.77 (C-7), 67.15 (C-6), 51.70 (C-2), 34.03 (C-8), 27.60 (C*H*$_3$), 27.53 (C*H*$_3$), 23.41 (C-*Si*), 20.90 (C-*Si*). HR-MS: Calculated for $C_{27}H_{28}O_7NF_3Si$ $[M+NH_4]^+$: 591.2713, found: 591.2710.

3-Butenyl 2-azido-2-deoxy-3-*O*-benzoyl-4,6-di-*tert*-butylsilylidene-α-D-galactopyranoside (10)



The reaction was carried out according to the general procedure A. The donor **3** (1.2 g, 1.93 mmol) and acceptor **8** (333 µL, 3.87 mmol) were co-evaporated with toluene (three times). The residue was dissolved in dry 17 ml DCM under nitrogen and stirred over fresh flame-dried molecular sieves 4Å. The solution was cooled to 0 ºC, after which TfOH (17 µl, 0.19 mmol) was added. The reaction was stirred at 0 ºC for 2 h. Then the reaction was quenched with Et_3N, diluted with DCM, washed with saturated $NaHCO_3$ and brine. The organic phase was dried with anhydrous $MgSO_4$, filtered and concentrated *in vacuo*. The product was purified by silica gel column chromatography (pentane:Et_2O = 20:1). Compound **10** (834 mg, 86% yield) was obtained as white foam. $[\alpha]_D^{25}$ +101.6 (c=1, $CHCl_3$). ^{1}H-NMR ($CDCl_3$, 400 MHz) δ 7.40 – 7.21 (m, 10H, aromatic H), 6.79 (d, *J* = 8.7 Hz, 1H, *N*H), 5.10 (s, 2H, *C*H$_2$*Ph*), 5.00 (d, *J* = 3.6 Hz, 1H, H-1), 4.74 (d, *J* = 12.2 Hz, 1H, *C*H$_2$*Ph*), 4.64 – 4.54 (m, 3H, *C*H$_2$*Ph*, H-2, 4), 4.26 (dd, *J* = 12.5, 2.1 Hz, 1H, H-6), 4.16 (dd, *J* = 12.5, 1.7 Hz, 1H, H-6), 3.72 – 3.58 (m, 3H, H-3, 5, 7), 3.40 (dt, *J* = 10.0, 6.5 Hz, 1H, H-7), 2.33 (t, *J* = 7.4 Hz, 2H, H-11), 1.70 – 1.49 (m, 4H, H-10, 8), 1.41 – 1.28 (m, 2H, H-9), 1.16 – 1.00 (m, 18H, *C*H$_3$). ^{13}C NMR (100 MHz, $CDCl_3$) δ 173.23 (C-12), 161.64 (C*ONH*), 137.96, 128.55, 128.46, 128.23, 128.15, 127.75, 127.64 (aromatic C/C*H*), 97.03 (C-1), 92.74 (C*Cl$_3$*), 75.30 (C-3), 69.82 (C*H$_2$Ph*), 69.53 (C-4), 67.96 (C-7), 67.65 (C-5), 67.22 (C-6), 66.13 (C*H$_2$Ph*), 49.93 (C-2), 34.02 (C-11), 28.93 (C-8), 27.66 (C*H$_3$*), 27.37 (C*H$_3$*), 25.69 (C-9), 24.55 (C-10), 23.43 (C-*Si*), 20.74 (C-*Si*). ^{13}C-HMBC ($CDCl_3$, 100 MHz): 97.03 ($J_{C1,H1}$ = 171 Hz). HR-MS: HR-MS: Calculated for $C_{25}H_{37}N_3O_6Si$ $[M+Na]^+$: 526.2349, found: 526.2344.

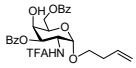
3-Butenyl 3-*O*-benzoyl-2-deoxy-2-trifluoroacetamido-α-D-galactopyranoside (11)



The reaction was carried out according to the general procedure B using compound **9** (1.15 g, 2.0 mmol) and HF/pyridine (70%, 830 µl, 32.1 mmol). The product was purified by column

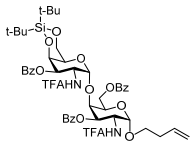
chromatography (pentane:EtOAc = 3:2). Compound **11** (771 mg, 89% yield) was obtained as white foam. $[\alpha]_D^{25}$ +127.4 (c=1, $CHCl_3$). ^{1}H-NMR ($CDCl_3$, 400 MHz) δ 8.04 – 7.89 (m, 2H, *C*H, Bz), 7.52 (t, *J* = 7.4 Hz, 1H), 7.37 (t, *J* = 7.6 Hz, 2H), 6.75 (d, *J* = 9.6 Hz, 1H, *N*H), 5.77 (ddt, *J* = 17.0, 10.2, 6.7 Hz, 1H, H-9), 5.27 (dd, *J* = 11.0, 2.8 Hz, 1H, H-3), 5.18 – 5.04 (m, 2H, H-10), 4.98 (d, *J* = 3.7 Hz, 1H, H-1), 4.87 (td, *J* = 10.3, 3.7 Hz, 1H, H-2), 4.37 (s, 1H, H-4), 4.02 – 3.75 (m, 4H, H-5, 6, 7), 3.51 (dt, *J* = 9.9, 6.5 Hz, 1H, H-7), 3.18 (s, 1H, *O*H), 2.47 – 2.27 (m, 2H, H-8). ^{13}C NMR (100 MHz, $CDCl_3$) δ 166.73 (C=O, Bz), 157.46 (*a*d, *J* = 37 Hz, *CF*$_3$*CO*), 134.64 (C-9), 133.73, 129.93, 128.85, 128.60, 117.45 (C-10), 115.60 (*a*d, *J* = 286 Hz, C*F*$_3$), 97.02 (C-1), 72.30 (C-3), 69.84 (C-5), 68.28 (C-4), 67.26 (C-7), 62.76 (C-6), 48.29 (C-2), 33.64 (C-8). HR-MS: Calculated for $C_{19}H_{22}O_7NF_3$ $[M+Na]^+$: 456.1246, found: 456.1241.

3-Butenyl 3-*O*-benzoyl-6-O-benzyl-2-deoxy-2-trifluoroacetamido-α-D-galactopyranoside (12)



The reaction was carried out according to the general procedure C using compound **11** (66 mg, 0.15 mmol), PhCOOBt (164 mg, 0.68 mmol) and Et_3N (105 µl, 0.75 mmol). The product was purified by column chromatography (pentane:EtOAc = 6:1). Compound **12** (79 mg, 97% yield) was obtained as white power. $[\alpha]_D^{25}$ +58.3 (c=1, $CHCl_3$). ^{1}H-NMR ($CDCl_3$, 400 MHz) δ 8.04 – 7.96 (m, 4H, *C*H, Bz), 7.61 – 7.50 (m, 2H), 7.47 – 7.35 (m, 4H), 6.68 (d, *J* = 9.6 Hz, 1H, NH), 5.76 (ddt, *J* = 17.0, 10.2, 6.7 Hz, 1H, H-9), 5.36 (dd, *J* = 11.0, 2.9 Hz, 1H, H-3), 5.16 – 5.04 (m, 2H, H-10), 5.02 (d, *J* = 3.7 Hz, 1H, H-1), 4.91 (ddd, *J* = 11.0, 9.7, 3.7 Hz, 1H, H-2), 4.63 (dd, *J* = 11.6, 5.5 Hz, 1H, H-6), 4.54 (dd, *J* = 11.5, 7.0 Hz, 1H, H-6), 4.35 (dd, *J* = 3.0, 1.1 Hz, 1H, H-4), 4.30 (ddd, *J* = 6.8, 5.5, 1.2 Hz, 1H, H-5), 3.84 (dt, *J* = 10.0, 6.3 Hz, 1H, H-7), 3.58 (dt, *J* = 10.0, 6.5 Hz, 1H, H-7), 3.04 (bs, 1H, OH), 2.38 (qt, *J* = 6.9, 1.3 Hz, 2H, H-8). ^{13}C NMR (100 MHz, $CDCl_3$) δ 166.59, 166.58 (2 C=O, Bz), 157.40 (*a*d, *J* = 37 Hz, *CF*$_3$*CO*), 134.52 (C-9), 133.80, 133.43, 130.01, 129.79, 129.63, 128.82, 128.67, 128.57, 117.50 (C-10), 115.60 (*a*d, *J* = 286 Hz, C*F*$_3$), 96.99 (C-1), 72.05 (C-3), 68.65 (C-5), 67.41 (C-7), 67.20 (C-4), 63.62 (C-6), 48.28 (C-2), 33.72 (C-8). HR-MS: Calculated for $C_{26}H_{26}O_8NF_3$ $[M+Na]^+$: 560.1508, found: 560.1503.

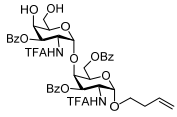
3-Butenyl 3-*O*-benzoyl-2-deoxy-4,6-di-*tert*-butylsilylidene-2-trifluoroacetamido-α-D-galactopyranosyl-(1→4)-3,6-di-*O*-benzoyl-2-deoxy-2-trifluoroacetamido-α-D-galactopyranoside (13)



The reaction was carried out according to the general procedure A. The donor **4** (385 mg, 0.56 mmol) and the acceptor **12** (200 mg, 0.37 mmol) were co-evaporated with toluene (three times). The residue was dissolved in 4 ml dry DCM under nitrogen and stirred over fresh flame-dried molecular sieves 4Å. The solution was cooled to 0 °C, after which TBSOTf (17 µl, 0.07 mmol) was added. The reaction was stirred at 0 °C for 1 h. Then the reaction was quenched with Et_3N, diluted with DCM, washed with saturated $NaHCO_3$ and brine. The organic phase was dried with anhydrous $MgSO_4$, filtered and concentrated *in vacuo*. The product was purified by silica gel column chromatography (pentane:Et_2O = 10:1). Compound **13** (59 g, 86% yield) was obtained as white foam. $[\alpha]_D^{25}$ +121.4 (c=1, $CHCl_3$). ^{1}H-NMR ($CDCl_3$, 400 MHz) δ 8.07 – 7.96 (m, 6H, *C*H, Bz), 7.64 – 7.55 (m, 3H), 7.51 – 7.42 (m, 6H), 7.05 (d, *J* = 9.2 Hz, 1H, *N*H), 6.56 (d, *J* = 9.7 Hz, 1H, *N*H), 5.82 – 5.70 (m, 1H, H-9), 5.43 (dd, *J* = 11.2, 2.7 Hz, 1H,

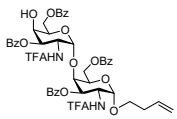
H-3^{B}), 5.34 (dd, *J* = 11.3, 2.6 Hz, 1H, H-3^{A}), 5.27 (d, *J* = 3.7 Hz, 1H, H-1^{B}), 5.14 – 4.97 (m, 4H, H-10, 1A, 2^{B}), 4.96 – 4.86 (m, 1H, H-2^{A}), 4.69 (d, *J* = 2.7 Hz, 1H, H-4^{B}), 4.63 (dd, *J* = 11.1, 7.2 Hz, 1H, H-6^{A}), 4.49 (d, *J* = 2.6 Hz, 1H, H-4^{A}), 4.38 (t, *J* = 6.9 Hz, 1H, H-5^{A}), 4.27 (dd, *J* = 11.1, 6.7 Hz, 1H, H-6^{A}), 4.08 (s, 1H, H-5^{B}), 3.87 (dt, *J* = 10.0, 6.2 Hz, 1H, H-7), 3.61 (dt, *J* = 10.0, 6.5 Hz, 1H, H-7), 3.45 – 3.30 (m, 2H, H-6^{B}), 2.39 (q, *J* = 6.2 Hz, 2H, H-8), 1.03 (s, 9H, *C*H$_3$), 0.91 (s, 9H, *C*H$_3$). ^{13}C NMR (100 MHz, $CDCl_3$) δ 167.12, 166.24, 165.85 (3 C=O, Bz), 157.53 (*a*d, *J* = 37 Hz, 2x*CF$_3$CO*), 134.44 (C-9), 134.19, 133.72, 133.67, 133.65, 130.00, 129.86, 129.20, 129.17, 129.04, 128.69, 128.67, 128.59, 117.73 (C-10), 115.70 (*a*d, *J* = 286 Hz, 2x*CF$_3$*), 98.12 (C-1B), 96.90 (C-1A), 73.29 (C-4A), 71.39 (C-3A), 71.17 (C-3B), 70.49 (C-4B), 68.74 (C-5A), 68.25 (C-5B), 67.49 (C-7), 66.31 (C-6B), 61.73 (C-6A), 48.64 (C-2B), 48.20 (C-2A), 33.68 (C-8), 27.53 (*CH$_3$*), 27.26 (*CH$_3$*), 23.31 (C-*Si*), 20.75 (C-*Si*). HR-MS: Calculated for $C_{49}H_{56}O_{14}N_2F_6Si$ $[M+Na]^+$: 1061.3303, found: 1061.3297.

3-Butenyl 3-*O*-benzoyl-2-deoxy-2-trifluoroacetamido-α-D-galactopyranosyl-(1→4)-3,6-di-*O*-benzoyl-2-deoxy-2-trifluoroacetamido-α-D-galactopyranoside (14)



The reaction was carried out according to the general procedure B using compound **13** (417 mg, 0.40 mmol) and HF/pyridine (70%, 0.17 ml, 6.4 mmol). The product was purified by column chromatography (pentane:EtOAc = 2:1). Compound **14** (360 mg, 90% yield) was obtained as white foam. $[\alpha]_D^{25}$ +89.4 (c=1, $CHCl_3$). ^{1}H-NMR ($CDCl_3$, 400 MHz) δ 8.04 – 7.91 (m, 6H, *C*H, Bz), 7.63 – 7.45 (m, 3H), 7.45 – 7.37 (m, 4H), 7.34 (t, *J* = 7.8 Hz, 2H), 7.23 (d, *J* = 9.0 Hz, 1H, *N*H), 6.74 (d, *J* = 9.6 Hz, 1H, *N*H), 5.71 (ddt, *J* = 17.0, 10.2, 6.7 Hz, 1H, H-9), 5.47 (dd, *J* = 11.3, 2.7 Hz, 1H, H-3^{B}), 5.32 (dd, *J* = 11.3, 2.6 Hz, 1H, H-3^{A}), 5.21 (d, *J* = 3.7 Hz, 1H, H-1^{B}), 5.12 – 5.00 (m, 3H, H-10, 1^{A}), 4.96 (ddd, *J* = 11.2, 9.1, 3.6 Hz, 1H, H-2^{B}), 4.88 (ddd, *J* = 11.2, 9.7, 3.8 Hz, 1H, H-2^{A}), 4.59 – 4.49 (m, 1H, H-6^{A}), 4.46 (d, *J* = 2.6 Hz, 1H, H-4^{A}), 4.40 – 4.35 (m, 2H, H-4^{B}, 6^{A}), 4.13 – 4.08 (m, 1H, H-5^{B}), 4.04 – 3.99 (m, 1H, H-5^{A}), 3.81 (dt, *J* = 10.0, 6.3 Hz, 1H, H-7), 3.56 (dt, *J* = 10.0, 6.5 Hz, 1H, H-7), 3.22 (q, *J* = 13.0, 8.8 Hz, 2H, H-6^{B}), 2.70 (s, 1H, OH), 2.39 – 2.28 (m, 2H, H-8). ^{13}C NMR (100 MHz, $CDCl_3$) δ 166.94, 166.38, 165.91 (3 C=O, Bz), 157.53 (*a*d, *J* = 37 Hz, 2x*CF$_3$CO*), 134.31 (C-9), 134.04, 133.65, 133.50, 129.95, 129.88, 129.85, 129.70, 129.13, 128.85, 128.82, 128.63, 128.55, 128.48, 117.45 (C-10), 115.60 (*a*d, *J* = 286 Hz, 2x*CF$_3$*), 98.19 (C-1^{B}), 96.65 (C-1^{A}), 73.86 (C-4^{A}), 71.46 (C-3^{A}), 71.35 (C-3^{B}), 70.08 (C-5^{B}), 68.95 (C-4^{B}), 68.49 (C-5^{A}), 67.32 (C-7), 62.41 (C-6^{B}), 62.25 (C-6^{A}), 48.90 (C-2^{B}), 48.33 (C-2^{A}), 33.50 (C-8). HR-MS: Calculated for $C_{41}H_{40}O_{14}N_2F_6$ $[M+Na]^+$: 921.2281, found: 921.2276.

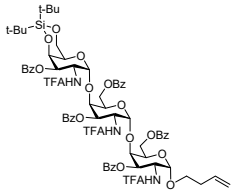
3-Butenyl 3,6-di-*O*-benzoyl-2-deoxy-2-trifluoroacetamido-α-D-galactopyranosyl-(1→4)-3,6-di-*O*-benzoyl-2-deoxy-2-trifluoroacetamido-α-D-galactopyranoside (15)



The reaction was carried out according to the general procedure C using compound **14** (0.53 g, 0.59 mmol), PhCOOBt (634 mg, 2.65 mmol) and Et_3N (493 µl, 3.54 mmol). The product was purified by column chromatography (pentane:EtOAc = 4:1). Compound **15** (472 mg, 80% yield) was obtained as white foam. $[\alpha]_D^{25}$ +100.4 (c=1, $CHCl_3$). ^{1}H-NMR ($CDCl_3$, 400 MHz) δ 8.07 – 7.97 (m, 4H, *C*H, Bz), 7.89 – 7.80 (m, 2H, *C*H, Bz), 7.77 – 7.69 (m, 2H, *C*H, Bz), 7.58 – 7.47 (m, 3H), 7.43

– 7.32 (m, 6H), 7.23 – 7.11 (m, 4H, *aromatic*, *N*H), 6.67 (d, *J* = 9.6 Hz, 1H, *N*H), 5.73 (ddt, *J* = 17.0, 10.3, 6.7 Hz, 1H, H-9), 5.61 (dd, *J* = 11.2, 2.7 Hz, 1H, H-3^{B}), 5.35 (dd, *J* = 10.8, 2.8 Hz, 1H, H-3^{A}), 5.28 (d, *J* = 3.7 Hz, 1H, H-1^{B}), 5.13 – 4.90 (m, 5H, H-2^{A}, 2^{B}, 1^{A}, 10), 4.68 – 4.53 (m, 2H, 4^{A}, 6^{A}), 4.43 (dt, *J* = 16.8, 6.7 Hz, 2H, H-5^{B}, 5^{A}), 4.34 – 4.24 (m, 2H, H-4^{B}, 6^{A}), 4.13 (dd, *J* = 11.0, 8.3 Hz, 1H, H-6^{B}), 3.83 (dt, *J* = 10.1, 6.2 Hz, 1H, H-7), 3.68 – 3.51 (m, 2H, H-7, 6^{B}), 3.30 (bs, 1H, OH), 2.42 – 2.29 (m, 2H, H-8). ^{13}C NMR (100 MHz, $CDCl_3$) δ 166.62, 166.28, 165.91, 165.79 (4 C=O, Bz), 157.46 (*a*d, *J* = 37 Hz, 2x*CF$_3$CO*), 134.33 (C-9), 133.84, 133.70, 133.56, 133.22, 129.93, 129.72, 129.70, 129.65, 129.32, 129.07, 128.79, 128.77, 128.64, 128.59, 128.55, 128.49, 128.29, 128.23, 117.55 (C-10), 115.61 (*a*d, *J* = 286 Hz, 2x*CF$_3$*), 97.47 (C-1^{B}), 96.69 (C-1^{A}), 72.17 (C-4^{A}), 71.38 (C-3^{A}), 71.00 (C-3^{B}), 68.71 (C-5^{B}), 68.53 (C-5^{A}), 67.36 (C-7), 66.29 (C-4^{B}), 61.78 (C-6^{B}), 61.69 (C-6^{A}), 48.64 (C-2^{B}), 48.21 (C-2^{A}), 33.53 (C-8). HR-MS: Calculated for $C_{48}H_{44}O_{15}N_2F_6$ $[M+Na]^+$: 1025.2544, found: 1025.2538.

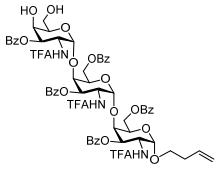
3-Butenyl 3-*O*-benzoyl-2-deoxy-4,6-di-*tert*-butylsilylidene-2-trifluoroacetamido-α-D-galactopyranosyl-(1→4)-3,6-di-*O*-benzoyl-2-deoxy-2-trifluoroacetamido-α-D-galactopyranosyl-(1→4)-3,6-di-*O*-benzoyl-2-deoxy-2-trifluoroacetamido-α-D-galactopyranoside (16)



The reaction was carried out according to the general procedure A. The donor **4** (464 mg, 0.67 mmol) and the acceptor **15** (450 mg, 0.45 mmol) were co-evaporated with toluene (three times). The residue was dissolved in 4.5 ml dry DCM under nitrogen and stirred over fresh flame-dried molecular sieves 4Å. The solution was cooled to 0 °C, after which TfOH (4 µl, 0.05 mmol) was added. The reaction was stirred at 0 °C for 1 h. Then the reaction was quenched with Et_3N, diluted with DCM, washed with saturated $NaHCO_3$ and brine. The organic phase was dried with anhydrous $MgSO_4$, filtered and concentrated *in vacuo*. The product was purified by silica gel column chromatography (pentane:EtOAc = 10:1). Compound **16** (504 mg, 75% yield) was obtained as yellow foam. $[\alpha]_D^{25}$ +120.3 (c=1, $CHCl_3$). ^{1}H-NMR ($CDCl_3$, 500 MHz) δ 8.11 – 7.99 (m, 6H, *C*H, Bz), 7.96 – 7.90 (m, 2H, *C*H, Bz), 7.84 – 7.77 (m, 2H, *C*H, Bz), 7.68 – 7.61 (m, 1H), 7.61 – 7.49 (m, 5H), 7.42 (td, *J* = 7.7, 3.4 Hz, 6H), 7.31 – 7.23 (m, 2H), 7.22 – 7.15 (m, 1H), 7.05 (d, *J* = 9.6 Hz, 1H, *N*H), 6.84 (d, *J* = 9.3 Hz, 1H, *N*H), 6.64 (d, *J* = 9.7 Hz, 1H, *N*H), 5.86 – 5.72 (m, 1H, H-9), 5.70 (dd, *J* = 11.5, 2.5 Hz, 1H, H-3^{B}), 5.47 (dd, *J* = 11.1, 2.9 Hz, 1H, H-3^{C}), 5.44 (d, *J* = 3.7 Hz, 1H, H-1^{B}), 5.39 (dd, *J* = 11.2, 2.7 Hz, 1H, H-3^{A}), 5.15 – 5.05 (m, 5H, H-1^{A}, 1^{C}, 2^{B}, 10), 5.00 (td, *J* = 10.3, 3.9 Hz, 1H, H-2^{C}), 4.93 (ddd, *J* = 11.2, 9.3, 3.7 Hz, 1H, H-2^{A}), 4.78 – 4.60 (m, 4H, H-4^{A}, 4^{C}, 5^{B}, 6^{A}), 4.56 (d, *J* = 2.4 Hz, 1H, H-4^{B}), 4.46 (t, *J* = 7.3 Hz, 1H, H-5^{A}), 4.27 (dd, *J* = 11.2, 7.5 Hz, 1H, H-6^{A}), 4.10 (s, 1H, H-5^{C}), 3.97 (dd, *J* = 11.2, 6.6 Hz, 1H, H-6^{B}), 3.88 (dt, *J* = 10.0, 6.2 Hz, 1H, H-7), 3.74 (dd, *J* = 11.1, 8.6 Hz, 1H, H-6^{B}), 3.62 (dt, *J* = 10.1, 6.5 Hz, 1H, H-7), 3.43 (d, *J* = 12.9 Hz, 1H, H-6^{C}), 3.34 (d, *J* = 12.0 Hz, 1H, H-6^{C}), 2.39 (q, *J* = 6.6 Hz, 2H, H-8), 0.93 (s, 9H, *C*H$_3$), 0.90 (s, 9H, *C*H$_3$). ^{13}C NMR (125 MHz, $CDCl_3$) δ 166.84, 166.12, 166.07, 165.63, 164.68 (5 C=O, Bz), 157.43 (*a*d, *J* = 37 Hz, 3x*CF$_3$CO*), 134.31 (C-9), 134.27, 134.14, 133.98, 133.93, 133.67, 133.61, 133.55, 133.32, 131.12, 130.25, 130.09, 129.91, 129.83, 129.79, 129.67, 129.65, 129.60, 129.03, 128.95, 128.91, 128.83, 128.71, 128.60, 128.52, 128.50, 128.36, 128.04, 117.60 (C-10), 115.54 (*a*d, *J* = 286 Hz, 3x*CF$_3$*), 97.93 (C-1^{C}), 96.90 (C-1^{B}), 96.76 (C-1^{A}), 72.46 (C-4^{B}), 71.50 (C-4^{A}), 70.94 (C-3^{C}), 70.92 (C-3^{A}), 70.47 (C-

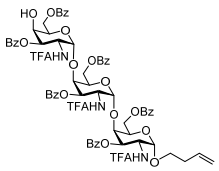
3^{B}), 70.32 (C-4^{C}), 69.03 (C-5^{B}), 68.23 (C-5^{A}), 68.12 (C-5^{C}), 67.49 (C-7), 66.21 (C-6^{C}), 61.25 (C-6^{A}), 60.38 (C-6^{B}), 48.34 (C-2^{C}), 48.29 (C-2^{B}), 48.17 (C-2^{A}), 33.52 (C-8), 27.40 (C*H*$_3$), 26.99 (C*H*$_3$), 23.14 (C-*Si*), 20.52 (C-*Si*). ^{13}C-HMBC ($CDCl_3$, 125 MHz): 97.93 ($J_{C1,H1}$ = 172 Hz), 96.90 ($J_{C1,H1}$ = 174 Hz), 96.76 ($J_{C1,H1}$ = 172 Hz). HR-MS: Calculated for $C_{71}H_{74}O_{21}N_3F_9Si$ $[M+Na]^+$: 1526.4338, found: 1526.4333.

3-Butenyl 3-*O*-benzoyl-2-deoxy-2-trifluoroacetamido-α-D-galactopyranosyl-(1→4)-3,6-di-*O*-benzoyl-2-deoxy-2-trifluoroacetamido-α-D-galactopyranosyl-(1→4)-3,6-di-*O*-benzoyl-2-deoxy-2-trifluoroacetamido-α-D-galactopyranoside (17)



The reaction was carried out according to the general procedure B using compound **16** (486 mg, 0.32 mmol) and HF/pyridine (70%, 134 µl, 5.17 mmol). The product was purified by column chromatography (pentane:EtOAc = 3:2). Compound **17** (392 mg, 90% yield) was obtained as white foam. $[\alpha]_D^{25}$ +113.8 (c=1, $CHCl_3$). ^{1}H-NMR ($CDCl_3$, 400 MHz) δ 8.08 – 7.93 (m, 6H, *C*H, Bz), 7.92 – 7.84 (m, 2H, *C*H, Bz), 7.79 – 7.70 (m, 2H, *C*H, Bz), 7.66 – 7.30 (m, 12H), 7.26 – 7.04 (m, 4H), 7.00 (d, *J* = 9.4 Hz, 1H, *N*H), 6.76 (d, *J* = 9.5 Hz, 1H, *N*H), 5.74 (ddt, *J* = 17.0, 10.2, 6.6 Hz, 1H, H-9), 5.65 (d, *J* = 12.0 Hz, 1H, H-3B), 5.51 – 5.37 (m, 2H, H-3A, 3C), 5.35 (d, *J* = 3.6 Hz, 1H, H-1B), 5.16 – 4.92 (m, 6H, H-1A, 1C, 2B, 2C, 10), 4.91 – 4.81 (m, 1H, H-2A), 4.71 – 4.47 (m, 4H, H-4A, 4B, 5B, 6A), 4.42 (t, *J* = 7.1 Hz, 1H, H-5A), 4.33 – 4.16 (m, 2H, H-4C, 6A), 4.09 (d, *J* = 4.6 Hz, 1H, H-5C), 3.92 – 3.72 (m, 3H, H-6B, 7), 3.59 (dt, *J* = 10.3, 6.5 Hz, 1H, H-7), 3.09 (s, 2H, H-6C), 2.76 (bs, 1H, OH), 2.36 (q, *J* = 6.6 Hz, 2H, H-8). ^{13}C NMR (100 MHz, $CDCl_3$) δ 166.76, 166.23, 166.11, 165.84, 164.64 (6 C=O, Bz), 157.47 (*a*d, *J* = 37 Hz, 3x*CF*$_3$*CO*), 134.22 (C-9), 134.03, 133.90, 133.62, 133.25, 129.86, 129.81, 129.67, 129.59, 129.46, 128.80, 128.78, 128.66, 128.58, 128.54, 128.37, 128.28, 127.90, 117.46 (C-10), 115.40 (*a*d, *J* = 286 Hz, 3xC*F*$_3$), 98.20 (C-1C), 96.84 (C-1B), 96.64 (C-1A), 72.79 (C-4B), 71.68 (C-4A), 70.98 (C-3A), 70.86 (C-3C), 70.62 (C-3B), 69.80 (C-5C), 69.13 (C-5B), 68.63 (C-4C), 68.24 (C-5A), 67.39 (C-7), 62.32 (C-6C), 61.69 (C-6A), 60.36 (C-6B), 48.51 (C-2), 48.27 (C-2), 33.43 (C-8). HR-MS: Calculated for $C_{63}H_{58}O_{21}N_3F_9$ $[M+Na]^+$: 1386.3317, found: 1386.3311.

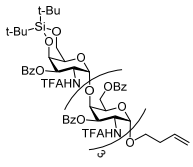
3-Butenyl 3,6-di-*O*-benzoyl-2-deoxy-2-trifluoroacetamido-α-D-galactopyranosyl-(1→4)-3,6-di-*O*-benzoyl-2-deoxy-2-trifluoroacetamido-α-D-galactopyranosyl-(1→4)-3,6-di-*O*-benzoyl-2-deoxy-2-trifluoroacetamido-α-D-galactopyranoside (18)



The reaction was carried out according to the general procedure C using compound **17** (377 mg, 0.28 mmol), PhCOOBt (297 mg, 1.24 mmol) and Et_3N (192 µl, 1.38 mmol). The product was purified by column chromatography (pentane:EtOAc = 3:1). Compound **18** (390 mg, 96% yield) was obtained as white foam. $[\alpha]_D^{25}$ +115.9 (c=1, $CHCl_3$). ^{1}H-NMR ($CDCl_3$, 500 MHz) δ 8.10 – 7.94 (m, 4H, *C*H, Bz), 7.92 – 7.66 (m, 8H, *C*H, Bz), 7.66 – 7.06 (m, 19H), 7.03 – 6.87 (m, 2H), 6.70 (d, *J* = 9.5 Hz, 1H, NH), 5.81 – 5.62 (m, 2H, H-9, 3), 5.59 (d, *J* = 11.2 Hz, 1H, H-3), 5.47 – 5.31 (m, 2H, H-1^{C}, 3), 5.24 – 5.13 (m, 1H, H-2), 5.10 – 5.00 (m, 3H, H-1^{B},

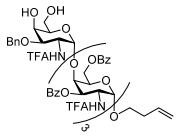
10), 4.95 (td, *J* = 10.4, 3.3 Hz, 1H, H-2), 4.87 (td, *J* = 10.3, 3.6 Hz, 1H, H-2), 4.79 – 4.55 (m, 5H, H-1^{A}, 4^{A}, 4B, 5, 6^{A}), 4.43 (dt, *J* = 33.8, 7.4 Hz, 2H, 2xH-5), 4.28 (s, 1H, H-4^{C}), 4.25 – 4.09 (m, 2H, H-6^{A}, 6^{C}), 3.90 – 3.68 (m, 3H, H-6^{B}, 7), 3.58 – 3.46 (m, 2H, H-6^{C}, 7), 3.39 (bs, 1H, *O*H), 2.31 (t, *J* = 6.5 Hz, 2H, H-8). ^{13}C NMR (125 MHz, $CDCl_3$) δ 166.52, 166.02, 165.92, 165.86, 165.65, 164.50 (6 C=O, Bz), 157.64 (*a*d, *J* = 37 Hz, 3x*CF*$_3$*CO*), 134.20 (C-9), 133.94, 133.61, 133.54, 133.37, 133.24, 129.80, 129.69, 129.62, 129.58, 129.52, 129.41, 129.36, 128.87, 128.78, 128.72, 128.70, 128.54, 128.37, 128.35, 128.31, 128.14, 127.77, 117.45 (C-10), 115.40 (*a*d, *J* = 286 Hz, 3xC*F*$_3$), 97.41 (C-1^{C}), 96.80 (C-1^{B}), 96.45 (C-1^{A}), 71.36 (C-4^{A}), 71.16 (C-4^{B}), 70.82 (C-3), 70.72 (C-3), 70.49 (C-3), 68.80 (C-5), 68.67 (C-5), 68.10 (C-5^{A}), 67.27 (C-7), 65.97 (C-4^{C}), 61.65 (C-6^{C}), 61.26 (C-6^{A}), 60.07 (C-6^{B}), 48.22 (3xC-2), 33.34 (C-8). HR-MS: Calculated for $C_{70}H_{62}O_{22}N_3F_9$ [M+Na]$^{+}$: 1490.3579, found: 1490.3574.

3-Butenyl 3-*O*-benzoyl-2-deoxy-4,6-di-*tert*-butylsilylidene-2-trifluoroacetamido-α-D-galactopyranosyl-(1→4)-3,6-di-*O*-benzoyl-2-deoxy-2-trifluoroacetamido-α-D-galactopyranosyl-(1→4)-3,6-di-*O*-benzoyl-2-deoxy-2-trifluoroacetamido-α-D-galactopyranosyl-(1→4)-3,6-di-*O*-benzoyl-2-deoxy-2-trifluoroacetamido-α-D-galactopyranoside (19)



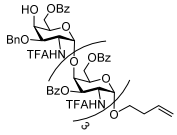
The reaction was carried out according to the general procedure A. The donor **4** (527 mg, 0.76 mmol) and the acceptor **18** (374 mg, 0.26 mmol) were co-evaporated with toluene (three times). The residue was dissolved in 3 ml dry DCM under nitrogen and stirred over fresh flame-dried molecular sieves 4Å. The solution was cooled to 0 °C, after which TfOH (5 µl, 0.05 mmol) was added. The reaction was stirred at 0 °C for 1 h. Then the reaction was quenched with Et_3N, diluted with DCM, washed with saturated $NaHCO_3$ and brine. The organic phase was dried with anhydrous $MgSO_4$, filtered and concentrated *in vacuo*. The product was purified by silica gel column chromatography (pentane:EtOAc = 7:1). Compound **19** (422 mg, 84% yield) was obtained as yellow foam. $[\alpha]_D^{25}$ +106.6 (c=1, $CHCl_3$). ^{1}H-NMR ($CDCl_3$, 400 MHz) δ 8.15 – 7.82 (m, 12H, *C*H, Bz), 7.81 – 7.72 (m, 2H, *C*H, Bz), 7.65 – 7.30 (m, 17H), 7.24 (t, *J* = 7.4 Hz, 1H), 7.17 – 7.04 (m, 3H), 7.03 – 6.90 (m, 2H), 6.77 – 6.65 (m, 2H), 5.87 – 5.62 (m, 3H, H-10, 2xH-3), 5.48 – 5.38 (m, 2H), 5.32 – 5.24 (m, 1H), 5.23 – 4.84 (m, 9H), 4.84 – 4.25 (m, 9H), 4.14 – 3.52 (m, 7H), 3.48 – 3.24 (m, 2H, H-6), 2.38 (q, *J* = 6.5 Hz, 2H, H-8), 0.92 (s, 9H, C*H*$_3$), 0.88 (s, 9H, C*H*$_3$). ^{13}C NMR (100 MHz, $CDCl_3$) δ 166.62, 166.05, 165.91, 165.58, 164.65, 164.43 (C=O, Bz), 157.35 (*a*d, *J* = 37 Hz, 4x*CF*$_3$*CO*), 134.24 (C-9), 134.04, 133.93, 133.61, 133.44, 131.07, 129.84, 129.71, 129.58, 129.56, 129.45, 128.92, 128.88, 128.83, 128.80, 128.78, 128.62, 128.52, 128.48, 128.39, 128.32, 128.05, 127.80, 117.50 (C-10), 115.40 (*a*d, *J* = 286 Hz, 4xC*F*$_3$), 97.87 (C-1), 96.92 (C-1), 96.70 (C-1), 96.64 (C-1^{A}), 72.49, 72.00, 71.14, 70.86, 70.35, 70.21, 70.12, 69.96, 68.95, 68.59, 68.17, 67.98, 67.39 (C-7), 66.10 (C-6), 61.25 (C-6), 60.53 (C-6), 59.94 (C-1), 48.46 (C-2), 48.16 (C-2), 47.98 (C-2), 33.43 (C-8), 27.27 (C*H*$_3$), 26.91 (C*H*$_3$), 23.04 (C-*Si*), 20.42 (C-*Si*). ^{13}C-HMBC ($CDCl_3$, 100 MHz): 97.87 ($J_{C1,H1}$ = 173 Hz), 96.92 ($J_{C1,H1}$ = 171 Hz), 96.70 ($J_{C1,H1}$ = 172 Hz), 96.64 ($J_{C1,H1}$ = 171 Hz). HR-MS: Calculated for $C_{93}H_{92}O_{28}N_4F_{12}Si$ [M+Na]$^{+}$: 1991.5373, found: 1991.5368.

3-Butenyl 3-*O*-benzoyl-2-deoxy-2-trifluoroacetamido-α-D-galactopyranosyl-(1→4)-3,6-di-*O*-benzoyl-2-deoxy-2-trifluoroacetamido-α-D-galactopyranosyl-(1→4)-3,6-di-*O*-benzoyl-2-deoxy-2-trifluoroacetamido-α-D-galactopyranosyl-(1→4)-3,6-di-*O*-benzoyl-2-deoxy-2-trifluoroacetamido-α-D-galactopyranoside (20)



The reaction was carried out according to the general procedure C using compound **19** (407 mg, 0.21 mmol) and HF/pyridine (70%, 86 µl, 3.31 mmol). The product was purified by column chromatography (pentane:EtOAc = 3:2). Compound **20** (335 mg, 88% yield) was obtained as white foam. $[\alpha]_D^{25}$ +108 (c=1, $CHCl_3$). ^{1}H-NMR ($CDCl_3$, 400 MHz) δ 8.02 – 7.86 (m, 10H, *C*H, Bz), 7.84 – 7.78 (m, 2H, *C*H, Bz), 7.76 – 7.67 (m, 2H, *C*H, Bz), 7.65 – 7.21 (m, 19H), 7.19 – 7.04 (m, 4H), 6.98 (t, *J* = 7.6 Hz, 1H), 6.86 (d, *J* = 9.3 Hz, 1H, *N*H), 6.71 (d, *J* = 8.6 Hz, 2H), 5.83 – 5.68 (m, 2H, H-3, 9), 5.60 (d, *J* = 11.4 Hz, 1H, H-3), 5.46 – 5.35 (m, 2H, H-1, 3), 5.30 (d, *J* = 11.4 Hz, 1H, H-3), 5.20 – 4.54 (m, 15H), 4.51 – 4.38 (m, 2H), 4.34 – 4.13 (m, 2H), 4.01 (s, 1H), 3.86 (d, *J* = 9.0 Hz, 4H), 3.75 – 3.53 (m, 3H, H-6, 7), 3.13 – 2.94 (m, 2H, H-6^D), 2.81 (bs, 1H, *O*H), 2.63 (bs, 1H, *O*H), 2.37 (q, *J* = 6.6 Hz, 2H, H-8). ^{13}C NMR (100 MHz, $CDCl_3$) δ 166.68, 166.18, 166.15, 165.70, 164.71, 164.66 (C=O, Bz), 157.50 (*a*d, *J* = 37 Hz, 4x*CF*$_3$*C*O), 134.29 (C-9), 134.07, 133.70, 133.50, 129.86, 129.71, 129.65, 129.57, 129.48, 128.86, 128.65, 128.59, 128.56, 128.50, 128.38, 128.01, 127.82, 117.57 (C-10), 115.48 (*a*d, *J* = 286 Hz, 4xC*F*$_3$), 98.09 (C-1), 96.93 (C-1), 96.74 (C-1), 72.69 (C-4), 72.01 (C-4), 71.14 (C-3), 70.82 (C-3), 70.72 (C-4), 70.44 (C-3), 70.20 (C-4), 69.66, 69.15, 68.75, 68.61, 68.19, 67.48 (C-7), 62.46 (C-6^D), 61.36 (C-6^A), 60.53 (C-6), 60.04 (C-6), 48.43 (C-2), 48.23 (C-2), 48.11 (C-2), 33.49 (C-8). HR-MS: Calculated for $C_{85}H_{76}O_{28}N_4F_{12}$ $[M+Na]^+$: 1851.4352, found: 1851.4346.

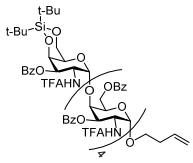
3-Butenyl 3,6-di-*O*-benzoyl-2-deoxy-2-trifluoroacetamido-α-D-galactopyranosyl-(1→4)-3,6-di-*O*-benzoyl-2-deoxy-2-trifluoroacetamido-α-D-galactopyranosyl-(1→4)-3,6-di-*O*-benzoyl-2-deoxy-2-trifluoroacetamido-α-D-galactopyranosyl-(1→4)-3,6-di-*O*-benzoyl-2-deoxy-2-trifluoroacetamido-α-D-galactopyranoside (21)



The reaction was carried out according to the general procedure C using compound **20** (300 mg, 0.16 mmol), PhCOOBt (176 mg, 0.74 mmol) and Et_3N (114 µl, 0.82 mmol). The product was purified by column chromatography (pentane:EtOAc = 3:1). Compound **21** (297 mg, 94% yield) was obtained as white foam. $[\alpha]_D^{25}$ +120.6 (c=1, $CHCl_3$). ^{1}H-NMR ($CDCl_3$, 500 MHz) δ 8.04 – 7.96 (m, 4H, *C*H, Bz), 7.95 – 7.90 (m, 2H, *C*H, Bz), 7.89 – 7.81 (m, 4H, *C*H, Bz), 7.81 – 7.70 (m, 6H, *C*H, Bz), 7.65 – 7.22 (m, 19H), 7.21 – 6.95 (m, 9H), 6.75 (d, *J* = 9.3 Hz, 1H, *N*H), 6.66 (d, *J* = 9.5 Hz, 1H, *N*H), 5.82 – 5.65 (m, 2H, H-9, 3), 5.63 (d, *J* = 11.7 Hz, 1H, H-3), 5.47 (d, *J* = 11.4 Hz, 1H, H-3), 5.40 – 5.33 (m, 1H, H-3), 5.30 (d, *J* = 3.7 Hz, 1H, H-1), 5.20 – 5.08 (m, 2H, H-1, 2), 5.09 – 4.97 (m, 4H), 4.96 – 4.84 (m, 2H), 4.75 (s, 2H), 4.65 (d, *J* = 29.1 Hz, 5H), 4.45 – 4.34 (m, 2H), 4.29 – 4.07 (m, 3H), 3.99 – 3.82 (m, 2H, H-6), 3.79 (dt, *J* = 12.3, 6.3 Hz, 1H, H-7), 3.74 – 3.61 (m, 2H, H-6), 3.51 (dt, *J* = 10.4, 6.5 Hz, 1H, H-7), 3.44 – 3.34 (m, 1H, H-6), 2.37 – 2.26 (m, 2H, H-8). ^{13}C NMR (125 MHz, $CDCl_3$) δ 166.38, 166.06, 165.95, 165.86, 165.61, 164.50 (C=O, Bz), 157.72 (*a*d, *J* = 37 Hz, 4x*CF*$_3$*C*O), 134.21 (C-9), 134.01, 133.62, 133.43, 133.23, 133.00, 129.77, 129.70, 129.63, 129.60, 129.51, 129.38, 128.96, 128.85, 128.76, 128.71, 128.54, 128.33, 128.06, 128.03, 127.87, 127.71, 117.51 (C-10), 115.37 (*a*d, *J* = 286 Hz, 4xC*F*$_3$), 97.51 (C-1), 96.77 (C-1), 96.49 (C-1), 71.61, 71.34, 70.93, 70.67, 70.42, 70.04, 68.76, 68.44,

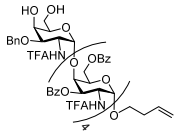
68.14, 67.30 (C-7), 65.82, 61.56 (C-6), 61.27 (C-6), 60.18 (C-6), 59.95 (C-6), 48.41 (C-2), 48.15 (C-2), 48.05 (C-2), 33.37 (C-8). HR-MS: Calculated for $C_{92}H_{80}O_{29}N_4F_{12}$ $[M+Na]^+$: 1955.4614, found: 1955.4609.

Pentasaccharide 22



The reaction was carried out according to the general procedure A. The donor **4** (424 mg, 0.61 mmol) and the acceptor **21** (297 mg, 0.15 mmol) were co-evaporated with toluene (three times). The residue was dissolved in 2 ml dry DCM under nitrogen and stirred over fresh flame-dried molecular sieves 4Å. The solution was cooled to 0 ºC, after which TfOH (3 µl, 0.03 mmol) was added. The reaction was stirred at 0 ºC for 1 h. Then the reaction was quenched with Et_3N, diluted with DCM, washed with saturated $NaHCO_3$ and brine. The organic phase was dried with anhydrous $MgSO_4$, filtered and concentrated *in vacuo*. The product was purified by silica gel column chromatography (pentane:EtOAc = 4:1). Compound **22** (253 mg, 68% yield) was obtained as yellow foam. $[\alpha]_D^{25}$ +143.5 (c=0.2, $CHCl_3$). ^{1}H-NMR ($CDCl_3$, 500 MHz) δ 8.07 – 8.00 (m, 2H, *C*H, Bz), 8.00 – 7.89 (m, 10H, *C*H, Bz), 7.84 – 7.72 (m, 6H, *C*H, Bz), 7.66 – 7.35 (m, 18H), 7.31 – 7.24 (m, 2H), 7.23 – 7.14 (m, 5H), 7.10 – 7.00 (m, 3H), 6.89 (d, *J* = 9.7 Hz, 1H, *N*H), 6.73 (d, *J* = 9.7 Hz, 1H, *N*H), 6.62 (d, *J* = 9.4 Hz, 1H, *N*H), 6.59 (d, *J* = 9.7 Hz, 1H, *N*H), 5.83 – 5.71 (m, 3H), 5.53 (dd, *J* = 11.5, 2.5 Hz, 1H, H-3), 5.44 – 5.41 (m, 1H), 5.40 (d, *J* = 2.8 Hz, 1H, H-1), 5.24 (dd, *J* = 11.2, 2.7 Hz, 1H, H-3), 5.21 – 5.07 (m, 5H), 5.06 (d, *J* = 3.7 Hz, 1H, H-1), 5.00 (qd, *J* = 9.7, 3.7 Hz, 2H, H-2), 4.93 (d, *J* = 3.7 Hz, 1H, H-1), 4.91 – 4.80 (m, 2H, H-2), 4.72 (d, *J* = 2.7 Hz, 1H), 4.70 – 4.54 (m, 7H), 4.49 – 4.42 (m, 2H), 4.27 (dd, *J* = 11.2, 7.6 Hz, 1H, H-6), 3.99 (d, *J* = 2.3 Hz, 1H, H-4), 3.97 – 3.85 (m, 4H), 3.71 (t, *J* = 10.4 Hz, 1H, H-6), 3.67 – 3.52 (m, 3H, H-6, 7), 3.33 (d, *J* = 12.4 Hz, 1H, H-6), 3.24 (d, *J* = 12.2 Hz, 1H, H-6), 2.45 – 2.36 (m, 2H, H-8), 0.88 (s, 9H, *C*H$_3$), 0.85 (s, 9H, *C*H$_3$). ^{13}C NMR (125 MHz, $CDCl_3$) δ 166.70, 166.19, 166.17, 166.09, 165.91, 165.68, 164.68, 164.57, 164.52 (9 C=O, Bz), 157.55 (*a*d, *J* = 37 Hz, 5x*CF$_3$CO*), 134.31 (C-9), 134.14, 134.11, 134.08, 133.76, 133.65, 133.57, 133.52, 129.92, 129.84, 129.73, 129.69, 129.66, 129.60, 129.58, 129.03, 128.96, 128.93, 128.91, 128.89, 128.84, 128.71, 128.65, 128.63, 128.55, 128.54, 128.50, 128.45, 128.40, 128.00, 127.90, 127.89, 117.73 (C-10), 115.46 (*a*d, *J* = 286 Hz, 5x*CF$_3$*), 97.89 (C-1), 97.02 (C-1), 96.84 (C-1), 96.78 (C-1), 96.69 (C-1), 72.35, 72.02, 71.18, 71.01, 70.93, 70.46, 70.27, 70.21, 69.82, 68.98, 68.68, 68.65, 68.23, 68.05, 67.57 (C-7), 66.18, 61.22, 60.50, 60.15, 60.00 (5 C-6), 48.42, 48.28, 48.25, 47.97, 47.90 (5 C-2), 33.58 (C-8), 27.39 (*CH$_3$*), 27.01 (*CH$_3$*), 23.16 (C-*Si*), 20.52 (C-*Si*). ^{13}C-HMBC ($CDCl_3$, 125 MHz): 97.89 ($J_{C1,H1}$ = 173 Hz), 97.02 ($J_{C1,H1}$ = 169 Hz), 96.84 ($J_{C1,H1}$ = 172 Hz), 96.78 ($J_{C1,H1}$ = 172 Hz), 96.69 ($J_{C1,H1}$ = 171 Hz). MALDI-MS: Calculated for $C_{115}H_{110}O_{35}N_5F_{15}Si$ $[M+Na]^+$: 2456.6409, found: 2456.6403.

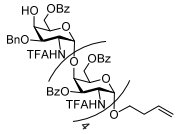
Pentasaccharide 23



The reaction was carried out according to the general procedure B using compound **22** (248 mg, 0.10 mmol) and HF/pyridine (70%, 42 µl, 1.63 mmol). The product was purified by column chromatography (pentane:EtOAc = 2:1). Compound **23** (220 mg, 96% yield) was obtained as white foam. $[\alpha]_D^{25}$ +128.5 (c=0.2, $CHCl_3$). ^{1}H-NMR ($CDCl_3$, 500 MHz) δ 8.05 –

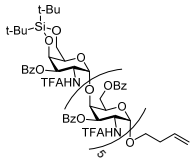
7.98 (m, 2H, *C*H, Bz), 7.97 – 7.88 (m, 10H, *C*H, Bz), 7.80 – 7.70 (m, 6H, *C*H, Bz), 7.63 – 7.52 (m, 5H), 7.51 – 7.32 (m, 13H), 7.23 – 6.95 (m, 10H), 6.81 (d, *J* = 9.6 Hz, 1H, *N*H), 6.68 – 6.55 (m, 3H), 5.85 – 5.63 (m, 3H), 5.47 (dd, *J* = 11.4, 2.4 Hz, 1H), 5.42 – 5.34 (m, 2H), 5.31 – 5.24 (m, 1H), 5.18 – 5.05 (m, 5H), 5.04 – 4.93 (m, 3H), 4.89 (td, *J* = 11.1, 10.5, 6.6 Hz, 1H), 4.84 (d, *J* = 3.6 Hz, 1H), 4.77 (ddd, *J* = 13.0, 9.6, 3.5 Hz, 1H), 4.73 – 4.59 (m, 6H), 4.59 – 4.49 (m, 1H), 4.47 – 4.37 (m, 2H), 4.29 – 4.20 (m, 1H), 4.20 – 4.14 (m, 1H), 3.96 (d, *J* = 4.3 Hz, 1H), 3.94 – 3.81 (m, 3H), 3.78 (q, *J* = 6.4 Hz, 1H), 3.68 (t, *J* = 10.4 Hz, 1H), 3.64 – 3.45 (m, 4H), 3.08 – 2.90 (m, 2H, H-6), 2.57 (bs, 1H, *O*H), 2.38 (q, *J* = 6.8 Hz, 2H, H-8), 2.27 (bs, 1H, *O*H). ^{13}C NMR (125 MHz, $CDCl_3$) δ 166.62, 166.19, 166.16, 166.10, 165.99, 165.69, 164.63, 164.59, 164.53 (9 C=O, Bz), 157.52 (*a*d, *J* = 37 Hz, 5x*CF*$_3$*CO*), 134.31 (C-9), 134.17, 134.12, 134.08, 133.76, 133.67, 133.64, 133.57, 133.50, 129.91, 129.84, 129.75, 129.72, 129.69, 129.64, 129.58, 129.55, 128.95, 128.93, 128.86, 128.81, 128.65, 128.63, 128.59, 128.55, 128.53, 128.45, 127.91, 127.86, 127.83, 117.71 (C-10), 115.46 (*a*d, *J* = 286 Hz, 5xC*F*$_3$), 98.04 (C-1), 97.04 (C-1), 96.80 (C-1), 72.47, 72.11, 71.20, 71.02, 70.80, 70.75, 70.49, 70.27, 70.02, 69.57, 69.06, 68.89, 68.61, 68.17, 67.55 (C-7), 62.60, 61.22, 60.38, 60.11, 59.94 (5 C-6), 48.38 (C-2), 48.26 (C-2), 48.20 (C-2), 47.85 (C-2), 33.56 (C-8). HR-MS: Calculated for $C_{107}H_{94}O_{35}N_5F_{15}$ $[M+Na]^+$: 2316.5388, found: 2316.5382.

Pentasaccharide 24



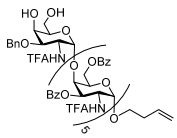
The reaction was carried out according to the general procedure C using compound **23** (220 mg, 0.096 mmol), PhCOOBt (103 mg, 0.43 mmol) and Et_3N (67 µl, 0.48 mmol). The product was purified by column chromatography (pentane:EtOAc = 5:2). Compound **24** (194 mg, 84% yield) was obtained as white power. $[\alpha]_D^{25}$ +131.0 (c=1, $CHCl_3$). ^{1}H-NMR ($CDCl_3$, 500 MHz) δ 8.02 – 7.90 (m, 8H, *C*H, Bz), 7.90 – 7.85 (m, 2H, *C*H, Bz), 7.82 – 7.69 (m, 10H, *C*H, Bz), 7.65 – 7.41 (m, 15H), 7.39 – 7.32 (m, 4H), 7.25 – 6.98 (m, 14H), 6.79 (d, *J* = 9.6 Hz, 1H, *N*H), 6.68 (d, *J* = 9.5 Hz, 1H, *N*H), 6.59 (d, *J* = 9.6 Hz, 1H, *N*H), 5.78 – 5.67 (m, 3H), 5.50 (dd, *J* = 11.4, 2.5 Hz, 1H), 5.43 (dd, *J* = 11.2, 2.5 Hz, 1H), 5.36 (dd, *J* = 11.0, 2.7 Hz, 1H), 5.30 (d, *J* = 3.7 Hz, 1H), 5.17 – 5.02 (m, 5H), 5.02 – 4.81 (m, 6H), 4.74 – 4.54 (m, 8H), 4.44 – 4.31 (m, 2H), 4.26 – 4.15 (m, 2H), 4.11 (t, *J* = 9.8 Hz, 1H), 3.99 – 3.90 (m, 1H), 3.89 – 3.77 (m, 3H), 3.71 – 3.50 (m, 4H), 3.41 – 3.32 (m, 1H, H-6), 3.04 (bs, 1H, *O*H), 2.56 (bs, 1H, *O*H), 2.35 (q, *J* = 6.5 Hz, 2H, H-8). ^{13}C NMR (125 MHz, $CDCl_3$) δ 166.40, 166.13, 166.03, 165.94, 165.90, 165.67, 164.53, 164.51 (C=O, Bz), 157.54 (*a*d, *J* = 37 Hz, 5x*CF*$_3$*CO*), 134.28 (C-9), 134.22, 134.16, 134.08, 133.73, 133.65, 133.60, 133.51, 133.31, 129.87, 129.70, 129.68, 129.64, 129.57, 129.51, 129.37, 129.04, 128.95, 128.88, 128.76, 128.71, 128.66, 128.63, 128.58, 128.55, 128.45, 128.41, 128.07, 127.84, 127.78, 117.67 (C-10), 115.37 (*a*d, *J* = 286 Hz, 5xC*F*$_3$), 97.53, 96.89, 96.78, 96.70, 96.63 (5 C-1), 71.80, 71.38, 71.06, 70.86, 70.72, 70.62, 70.42, 70.10, 69.93, 68.78, 68.72, 68.56, 68.51, 68.20, 67.42 (C-7), 65.93, 61.53 (C-6), 61.27 (C-6), 60.15 (C-6), 59.99 (C-6), 48.38 (C-2), 48.18 (C-2), 48.04 (C-2), 47.85 (C-2), 33.49 (C-8). HR-MS: Calculated for $C_{114}H_{98}O_{36}N_5F_{15}$ $[M+Na]^+$: 2420.5650, found: 2420.5644.

Hexasaccharide (25)



The reaction was carried out according to the general procedure A. The donor **4** (115 mg, 0.17 mmol) and the acceptor **24** (160 mg, 0.07 mmol) were co-evaporated with toluene (three times). The residue was dissolved in 0.33 ml dry DCM under nitrogen and stirred over fresh flame-dried molecular sieves 4Å. The solution was cooled to 0 ºC, after which TfOH (4 µl, 0.04 mmol) was added. The reaction was stirred at 0 ºC for 1 h. Then the reaction was quenched with Et_3N, diluted with DCM, washed with saturated $NaHCO_3$ and brine. The organic phase was dried with anhydrous $MgSO_4$, filtered and concentrated *in vacuo*. The product was purified by silica gel column chromatography (pentane:EtOAc = 3:1). Compound **25** (52 mg, 54% yield) was obtained as white foam, and **24** (78 mg) was recycled. $[\alpha]_D^{25}$ +90.5 (c=0.4, $CHCl_3$). ^{1}H-NMR ($CDCl_3$, 500 MHz) δ 8.04 – 8.01 (m, 2H), 7.99 – 7.91 (m, 10H), 7.90 – 7.87 (m, 2H), 7.82 – 7.74 (m, 8H), 7.64 – 7.37 (m, 24H), 7.25 – 7.00 (m, 13H), 6.93 (d, *J* = 9.7 Hz, 1H, *N*H), 6.77 (d, *J* = 9.8 Hz, 1H, *N*H), 6.61 (d, *J* = 9.9 Hz, 1H, *N*H), 6.59 – 6.52 (m, 3H), 5.85 – 5.75 (m, 1H), 5.75 – 5.70 (m, 1H), 5.68 (dd, *J* = 11.4, 2.7 Hz, 1H), 5.62 (dd, *J* = 11.4, 2.7 Hz, 1H), 5.49 (dd, *J* = 11.5, 2.5 Hz, 1H), 5.43 – 5.37 (m, 2H), 5.22 (dd, *J* = 11.2, 2.7 Hz, 1H), 5.19 – 4.78 (m, 15H), 4.75 – 4.58 (m, 10H), 4.54 (t, *J* = 7.7 Hz, 1H), 4.48 – 4.40 (m, 2H), 4.26 (dd, *J* = 11.2, 7.6 Hz, 1H), 3.98 (d, *J* = 2.2 Hz, 1H), 3.95 – 3.82 (m, 5H), 3.71 (t, *J* = 10.6 Hz, 1H), 3.67 – 3.49 (m, 4H), 3.30 (d, *J* = 12.8 Hz, 1H, H-6), 3.22 (d, *J* = 12.0 Hz, 1H, H-6), 2.45 – 2.37 (m, 2H, H-8), 0.87 (s, 9H), 0.85 (s, 9H). ^{13}C NMR (125 MHz, $CDCl_3$) δ 166.72, 166.24, 166.19, 166.12, 165.98, 165.91, 165.69, 164.65, 164.56, 164.53, 164.47 (11 C=O, Bz), 157.56 (*a*d, *J* = 37 Hz, 6x*CF*$_3$*CO*), 134.33 (C-9), 134.21, 134.17, 134.14, 134.11, 133.81, 133.72, 133.66, 133.61, 133.54, 129.95, 129.87, 129.85, 129.77, 129.72, 129.68, 129.65, 129.62, 129.04, 129.02, 128.95, 128.90, 128.84, 128.69, 128.65, 128.60, 128.57, 128.55, 128.52, 128.49, 128.40, 128.35, 127.93, 127.91, 127.87, 127.80, 117.80 (C-10), 115.43 (*a*d, *J* = 286 Hz, 6xC*F*$_3$), 97.91 (C-1), 97.10 (C-1), 96.87 (C-1), 96.74 (C-1), 72.36, 72.18, 71.28, 71.10, 70.93, 70.50, 70.32, 70.27, 70.24, 70.15, 69.86, 69.00, 68.66, 68.23, 68.06, 67.61 (C-7), 66.20, 61.20, 60.45, 60.06, 59.95 (C-6), 48.41, 48.23, 48.11, 48.06, 47.97, 47.85 (6 C-2), 33.63 (C-8), 27.42 (C*H*$_3$), 27.03 (C*H*$_3$), 23.19 (C-*Si*), 20.55 (C-*Si*). ^{13}C-HMBC ($CDCl_3$, 125 MHz): 97.91 ($J_{C1,H1}$ = 174 Hz), 97.10 ($J_{C1,H1}$ = 172 Hz), 96.87 ($J_{C1,H1}$ = 170 Hz), 96.74 ($J_{C1,H1}$ = 171 Hz). MALDI-MS: Calculated for $C_{137}H_{128}F_{18}N_6O_{42}Si$ $[M+Na]^+$: 2921.7444, found: 2921.6985.

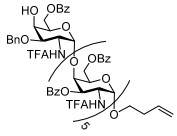
Hexasaccharide 26



The reaction was carried out according to the general procedure A using compound **25** (95 mg, 0.03 mmol) and HF/pyridine (70%, 14 µl, 0.52 mmol). The product was purified by column chromatography (pentane:EtOAc = 3:2). Compound **26** (76 mg, 84% yield) was obtained as yellow syrup. ^{1}H-NMR ($CDCl_3$, 500 MHz) δ 8.03 – 7.98 (m, 2H, *C*H, Bz), 7.96 – 7.85 (m, 12H, *C*H, Bz), 7.78 – 7.71 (m, 8H, *C*H, Bz), 7.60 – 7.32 (m, 22H), 7.20 – 6.99 (m, 13H), 6.87 (d, *J* = 9.7 Hz, 1H, *N*H), 6.74 (d, *J* = 9.7 Hz, 1H, *N*H), 6.66 (d, *J* = 9.7 Hz, 1H, *N*H), 6.61 – 6.54 (m, 2H), 5.87 – 5.64 (m, 3H), 5.57 (dd, *J* = 11.4, 2.7 Hz, 1H), 5.44 (dd, *J* = 11.5, 2.4 Hz, 1H), 5.40 – 5.35 (m, 2H), 5.26 (dd, *J* = 11.2, 2.6 Hz, 1H), 5.17 – 4.85 (m, 12H), 4.82 (d, *J* = 3.8 Hz, 1H), 4.76 (ddd, *J* = 13.1, 9.8, 3.7 Hz, 1H), 4.69 (d, *J* = 2.6 Hz, 1H), 4.68 – 4.54 (m, 7H), 4.48 (d, *J* = 7.7 Hz, 1H), 4.42 (t, *J* = 7.3 Hz, 1H), 4.39 – 4.35 (m, 1H), 4.28 – 4.18 (m, 2H), 3.95 (d,

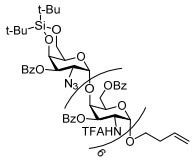
J = 4.4 Hz, 1H), 3.93 – 3.81 (m, 4H), 3.79 – 3.47 (m, 6H), 3.33 (d, *J* = 2.3 Hz, 1H), 3.09 – 2.94 (m, 2H), 2.42 – 2.37 (m, 2H, H-8). ^{13}C NMR (125 MHz, $CDCl_3$) δ 166.57, 166.24, 166.20, 166.12, 166.03, 166.01, 165.73 (C=O, Bz), 157.61 (*a*d, *J* = 37 Hz, 6x*CF*$_3$*CO*), 134.35 (C-9), 134.20, 134.12, 133.81, 133.71, 133.68, 133.62, 133.57, 129.95, 129.90, 129.81, 129.78, 129.73, 129.71, 129.68, 129.65, 129.61, 129.02, 128.95, 128.91, 128.83, 128.70, 128.67, 128.64, 128.60, 128.57, 128.54, 128.49, 127.93, 127.88, 127.82, 124.87, 117.80 (C-10), 115.43 (*a*d, *J* = 286 Hz, 6x*CF*$_3$), 98.05 (C-1), 97.06 (C-1), 96.86 (C-1), 96.75 (C-1), 72.44, 72.10, 71.23, 71.05, 70.96, 70.87, 70.68, 70.52, 70.27, 70.05, 69.99, 69.59, 69.04, 68.93, 68.63, 68.25, 67.61 (C-7), 64.75, 62.69, 61.27, 60.42, 60.13, 59.99 (6 C-6), 48.43, 48.25, 48.19, 48.08, 47.87 (C-2), 33.63 (C-8). MALDI-MS: Calculated for $C_{129}H_{112}F_{18}N_6O_{42}$ $[M+Na]^+$: 2781.6423, found: 2781.5987.

Hexasaccharide 27



The reaction was carried out according to the general procedure B using compound **26** (75 mg, 0.03 mmol), PhCOOBt (29 mg, 0.12 mmol) and Et_3N (19 µl, 0.14 mmol). The product was purified by column chromatography (pentane:EtOAc = 5:2). Compound **27** (71 mg, 91% yield) was obtained as white foam. ^{1}H-NMR ($CDCl_3$, 500 MHz) δ 8.00 – 7.86 (m, 12H), 7.80 – 7.71 (m, 12H), 7.62 – 7.32 (m, 23H), 7.24 – 6.96 (m, 17H), 6.81 (d, *J* = 9.6 Hz, 1H, *N*H), 6.66 (d, *J* = 9.7 Hz, 1H, *N*H), 6.61 (d, *J* = 9.6 Hz, 1H, *N*H), 6.57 – 6.50 (m, 2H), 5.85 – 5.63 (m, 3H), 5.57 (dd, *J* = 11.4, 2.7 Hz, 1H), 5.45 (dd, *J* = 11.4, 2.5 Hz, 1H), 5.42 – 5.28 (m, 3H), 5.18 – 4.77 (m, 15H), 4.72 – 4.49 (m, 11H), 4.40 (t, *J* = 7.2 Hz, 1H), 4.33 (t, *J* = 7.2 Hz, 1H), 4.21 (dd, *J* = 11.2, 7.4 Hz, 1H), 4.15 (d, *J* = 3.3 Hz, 1H), 4.11 – 4.02 (m, 1H), 3.93 – 3.80 (m, 4H), 3.75 (dd, *J* = 11.0, 6.3 Hz, 1H), 3.66 (t, *J* = 10.4 Hz, 1H), 3.62 – 3.48 (m, 4H), 3.46 – 3.36 (m, 1H), 2.71 (s, 1H, *O*H), 2.39 – 2.31 (m, 2H, H-8). ^{13}C NMR (100 MHz, $CDCl_3$) δ 166.39, 166.23, 166.14, 166.11, 166.05, 166.00, 165.91, 165.70 (C=O, Bz), 157.57 (*a*d, *J* = 37 Hz, 6x*CF*$_3$*CO*), 134.32 (C-9), 134.22, 134.14, 133.85, 133.80, 133.70, 133.60, 133.38, 129.94, 129.78, 129.75, 129.73, 129.69, 129.64, 129.61, 129.36, 129.05, 129.00, 128.97, 128.95, 128.78, 128.70, 128.66, 128.60, 128.56, 128.48, 128.46, 128.17, 127.92, 127.87, 127.83, 124.87, 117.79 (C-10), 115.47 (*a*d, *J* = 286 Hz, 6x*CF*$_3$), 97.58 (C-1), 97.05 (C-1), 96.80 (C-1), 72.06, 71.57, 71.21, 71.11, 71.05, 70.75, 70.67, 70.49, 70.30, 70.10, 70.00, 68.87, 68.65, 68.25, 67.57 (C-7), 66.14, 64.75, 61.51, 61.25, 60.22, 60.10, 60.00 (6 C-6), 48.41, 48.24, 48.15, 48.07, 47.89 (C-2), 33.60 (C-8). MALDI-MS: Calculated for $C_{136}H_{116}F_{18}N_6O_{43}$ $[M+Na]^+$: 2885.6685, found: 2885.6282.

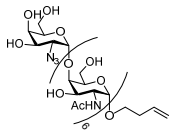
Heptasaccharide 2



The reaction was carried out according to the general procedure C. The donor **3** (46 mg, 0.07 mmol) and the acceptor **27** (70 mg, 0.02 mmol) were co-evaporated with toluene (three times). The residue was dissolved in 0.1 ml dry DCM under nitrogen and stirred over fresh flame-dried molecular sieves 4Å. The solution was cooled to 0 ºC, after which TfOH (1 µl, 7.3 µmol) was added. The reaction was stirred at 0 ºC for 1 h. Then the reaction was quenched with Et_3N, diluted with DCM, washed with saturated $NaHCO_3$ and brine. The organic phase was dried

with anhydrous $MgSO_4$, filtered and concentrated *in vacuo*. The product was purified by silica gel column chromatography (pentane:EtOAc = 5:2). Compound **2** (68 mg, 84% yield) was obtained as white solid. ^{1}H-NMR ($CDCl_3$, 400 MHz) δ 8.09 – 7.87 (m, 16H, *C*H, Bz), 7.84 – 7.71 (m, 10H, *C*H, Bz), 7.68 – 7.37 (m, 25H), 7.25 – 7.14 (m, 11H), 7.12 – 6.95 (m, 7H), 6.71 – 6.53 (m, 2H), 5.86 – 5.69 (m, 3H), 5.63 (dd, *J* = 11.5, 2.7 Hz, 1H), 5.52 (ddd, *J* = 11.5, 7.4, 2.4 Hz, 2H), 5.46 – 5.39 (m, 2H), 5.23 – 4.90 (m, 12H), 4.87 (dd, *J* = 6.8, 3.7 Hz, 2H), 4.81 – 4.50 (m, 12H), 4.49 – 4.42 (m, 2H), 4.32 – 4.24 (m, 2H), 4.11 (t, *J* = 9.9 Hz, 1H), 4.04 (d, *J* = 2.3 Hz, 1H), 3.99 (dd, *J* = 10.8, 3.6 Hz, 1H), 3.96 – 3.51 (m, 13H), 2.42 (q, *J* = 6.5 Hz, 2H, H-8), 0.90 (s, 9H, *C*H$_3$), 0.83 (s, 9H, *C*H$_3$). ^{13}C NMR (100 MHz, $CDCl_3$) δ 166.47, 166.24, 166.22, 166.14, 166.12, 166.05, 165.76, 165.70, 164.95, 164.66, 164.62, 164.59 (C=O, Bz), 157.68 (*a*d, *J* = 37 Hz, 6x*CF$_3$CO*), 134.36 (C-9), 134.19, 134.13, 133.96, 133.81, 133.68, 133.60, 133.28, 133.22, 130.15, 129.85, 129.77, 129.71, 129.66, 129.63, 129.60, 129.40, 129.03, 128.99, 128.96, 128.89, 128.78, 128.76, 128.70, 128.67, 128.60, 128.57, 128.54, 128.48, 128.45, 128.06, 127.99, 127.93, 127.89, 117.80 (C-10), 115.41 (*a*d, *J* = 286 Hz, 6x*CF$_3$*), 99.85 (C-1^G), 97.35 (C-1), 96.99 (C-1), 96.89 (C-1), 96.77 (C-1), 96.65 (C-1), 75.20, 72.68, 71.93, 71.21, 71.17, 70.89, 70.77, 70.56, 70.17, 69.99, 69.87, 69.37, 68.68, 68.59, 68.32, 68.11, 67.62 (C-7), 66.55 (C-6^G), 61.34, 60.93, 60.23, 60.10 (C-6), 58.62 (C-2^G), 48.53, 48.31, 48.24, 48.17, 47.98 (C-2), 33.65 (C-8), 27.46 (C*H$_3$*), 27.19 (C*H$_3$*), 23.14 (C-*Si*), 20.62 (C-*Si*). ^{13}C-HMBC ($CDCl_3$, 100 MHz): 99.85 ($J_{C1,H1}$ = 170 Hz), 97.35 ($J_{C1,H1}$ = 174 Hz), 96.99 ($J_{C1,H1}$ = 171 Hz), 96.89 ($J_{C1,H1}$ = 171 Hz), 96.77 ($J_{C1,H1}$ = 174 Hz), 96.65 ($J_{C1,H1}$ = 172 Hz). MALDI-MS: Calculated for $C_{157}H_{145}F_{18}N_9O_{48}Si$ $[M+Na]^+$: 3316.8562, found: 3316.7918.

Heptasaccharide 1



HF/pyridine (16 eq) solution was added to the solution of **2** in THF at 0 ºC. The reaction was warmed to room temperature and stirred until TLC-analysis indicated full consumption of the starting material (± 1h). Then the mixture was diluted with DCM and washed with saturated $NaHCO_3$ and brine, dried with anhydrous $MgSO_4$, filtered and concentrated *in vacuo*. To the solution of the residue in THF/MeOH (2 ml/0.9 ml), 1 M NaOH solution was added at 0 ºC. The reaction mixture was warmed to room temperature slowly and stirred for overnight. Then the reaction was re-cooled to 0 ºC and neutralized by Amberlite IR120 (H+) resin. After filtration, the filtrate was concentrated *in vacuo* and dissolved in 2 ml water. Then Ac_2O was added at 0 ºC, after which $NaHCO_3$ was added until the pH of the solution was about 9. The mixture was stirred for overnight. After neutralized by Amberlite IR120 (H+) resin and subsequent filtration, the filtrate was concentrated *in vacuo* and purified by gel filtration (HW-40, 0.15M NH_4OAc in H_2O). Compound **1** (5.4 mg, 44% yield) was obtained as white foam. ^{1}H NMR (850 MHz, D_2O) δ 5.91 (ddt, *J* = 17.1, 10.3, 6.6 Hz, 1H, H-9), 5.19 – 5.15 (m, 2H, H-1, 10a), 5.12 (ddt, *J* = 10.3, 2.2, 1.2 Hz, 1H, H-10b), 5.07 – 5.04 (m, 3H, 3xH-1), 5.02 (d, *J* = 3.9 Hz, 1H, H-1), 5.00 (d, *J* = 3.8 Hz, 1H, H-1), 4.98 (d, *J* = 3.7 Hz, 1H, H-1), 4.46 – 4.40 (m, 5H), 4.38 (t, *J* = 6.5 Hz, 1H), 4.34 – 4.28 (m, 5H), 4.23 (dd, *J* = 11.3, 3.7 Hz, 1H), 4.21 – 4.12 (m, 10H), 4.11 (d, *J* = 2.9 Hz, 1H), 4.08 (d, *J* = 3.1 Hz, 1H), 4.06 (d, *J* = 3.0 Hz, 1H), 4.05 – 4.01 (m, 2H), 3.87 (dd, *J* = 11.0, 7.2 Hz, 1H), 3.82 – 3.77 (m, 2H), 3.76 – 3.62 (m, 13H), 3.60 (dt, *J* = 10.2, 6.2 Hz, 1H, H-7), 2.43 – 2.34 (m, 2H, H-8), 2.13 – 2.06 (m, 15H, Ac), 2.04 (s, 3H, Ac). ^{13}C NMR (214 MHz, D_2O) δ 174.63, 174.56, 174.54, 174.49 (C=O, Ac), 135.89 (C-9), 116.45

(C-10), 98.78 (C-1), 98.23 (C-1), 98.20 (C-1), 98.18 (C-1), 98.17 (C-1), 96.70 (C-1), 76.85, 76.33, 76.29, 76.26, 76.21, 71.57, 71.31, 71.26, 71.03, 70.88, 68.67, 67.51, 67.12 (C-7), 67.08, 66.79, 66.62, 66.60, 66.49, 60.52 (C-6), 60.45 (C-6), 60.39, 59.53 (C-6), 59.50 (C-6), 59.47 (C-6), 50.30, 50.27, 50.26, 50.13 (C-2), 33.01 (C-8), 21.92 (CH_3), 21.90 (CH_3), 21.86 (CH_3). HR-MS: Calculated for $C_{58}H_{95}N_9O_{35}$ $[M+H]^+$: 1478.6009, found: 1478.6003.

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Chapter 5

Assembly of a library of Pel oligosaccharides featuring α-glucosamine and α-galactosamine linkages

Introduction

Pseudomonas aeruginosa is an opportunistic Gram-negative pathogen that can cause both acute and chronic infections in immunocompromised patients.[1-6] *P. aeruginosa* can become resistant to antibiotics due to its ability to form biofilm which complicates the treatment of its infections. As part of the biofilm formation three exopolysaccharides are synthesized, alginate, Pel and Psl.[4] Alginate is a negatively charged polymer of mannuronic and guluronic acid,[7] while Psl is a neutral polysaccharide composed of a pentasaccharide repeat containing glucose, rhamnose and mannose.[8] Pel is a positively charged polymer, and although its structure has not been fully characterized it is thought to be composed of α-1,4-linked *N*-acetylgalactosamine (GalNAc) and *N*-acetyl-glucosamine (GlcNAc), both of which also can be de-acetylated to give galactosamine (GalN) and glucosamine (GlcN) residues,

respectively (Figure 1A). The GalN(Ac) : GlcN(Ac) ratio has been reported to be ± 6:1. Pel plays an important role in maintaining cell-cell interactions in biofilms and affords protection to the bacterium by enhancing resistance to aminoglycoside antibiotics.[9] Well-defined fragments of the Pel polymer can serve as powerful research tools in various interconnected fields of research. They may serve as synthetic antigens in the generation of potential Pseudomonas vaccines and they can be used in elucidating biosynthesis pathways and charactering the enzymes involved therein. This may open up avenues to interfere with the biosynthesis and eventually generate anti-bacterial compounds. Because of the seemingly random distribution of monosaccharides in Pel, it is impossible to isolate well defined fragments from natural sources and therefore organic synthesis is the method of choice to provide these.

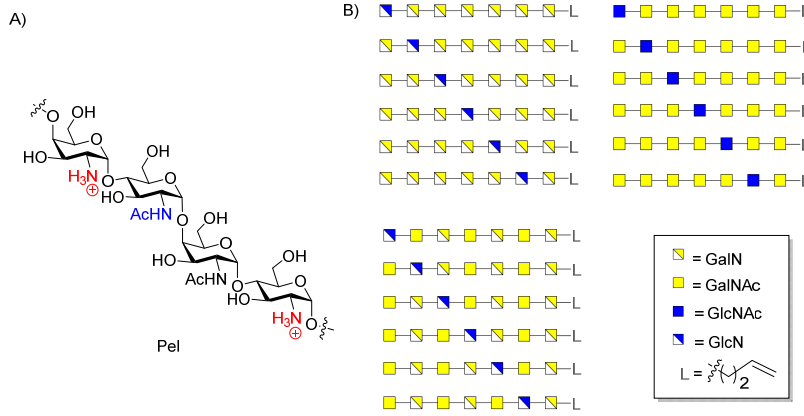


Figure 1. A) Structure of Pel. B) Structures of designed Pel oligomers.

The key to the assembly of Pel fragments is the stereoselective introduction of α-GalN, α-GalNAc, α-GlcN and α-GlcNAc linkages. The Chapters 2, 3 and 4 described the successful application of the 4,6-*O*-DTBS directed α-galactosylation methodology, developed by Kiso's group[10-15], for the synthesis of galactosaminogalactan (GAG) homo- and hetero-oligosaccharides, occurring in the cell wall of *Aspergillus fumigatus*. Application of 4,6-*O*-DTBS protected $GalN_3$ and GalNHTCA donors resulted in glycosylations with high α-stereoselectivity to give a row of GAG fragments, composed of GalN and GalNAc. The high α-stereoselectivity proved to be insensitive with respect to the nature of a C-2-*N*-acyl group, capable of neighboring group participation. On the basis of these results, DTBS-protected GalN donors were chosen as building blocks for the construction of α-GalN and α-GalNAc linkages in Pel.

The formation of similar α-GlcN linkages is more challenging and substantial effort has been expended to develop a procedure for the stereoselective introduction of α-GlcN linkages.[16-26] Recently, Wang *et al.* have reported an effective synthetic strategy to assemble Pel fragments containing 1,4-linked GalNAc and GlcNAc residues.[14] A [2+2+2] strategy was developed for the synthesis of a hexasaccharide in which the α-GlcN linkages were constructed *via* *N*-methyl-*N*-phenylformamide (MPF)-modulated glycosylation methodology. Furthermore, a set of glycosylation reactions between a series of 4,6-tethered glucosazide donors and a panel of acceptors were systematically evaluated by van der Vorm *et al*.[16] They reported that with the increasing reactivity of donors and decreasing nucleophilicity of acceptors, the α-selectivity of the glycosylations increased. Reaction of the most reactive DTBS-protected $GlcN_3$ donor with the acceptor trifluoroethanol (TFE) gave the α-linked product exclusively. As the nucleophilicity of the C-4-OH in GalN moieties is relatively low, the DTBS-$GlcN_3$ donors represent promising building blocks for the construction of α-GlcN-(1→4)-GalN linkages.

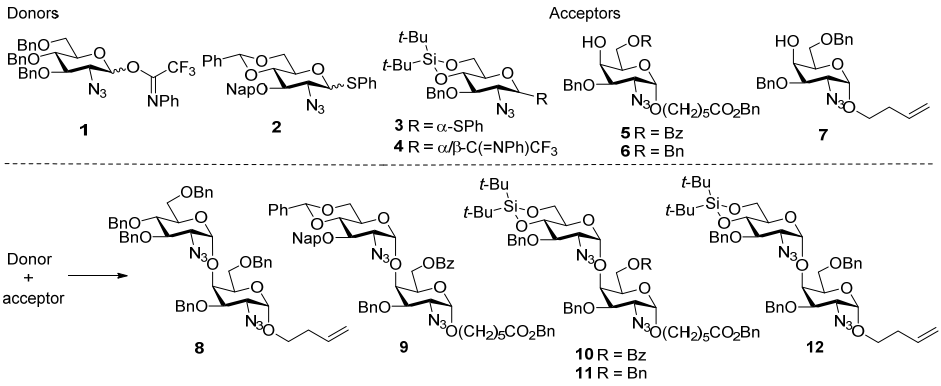
This chapter describes the synthesis of a library of Pel fragments with DTBS-directed glycosylation methodology. A library of hetero-oligomers containing α-GalN/α-GalNAc and α-GlcN/α-GlcNAc residues at predetermined positions, was designed (Figure 1B). A set of heptamers, each of which contains one GlcN/GlcNAc and six GalN/GalNAc residues, was selected because of the ±6:1 GalNAc:GlcNAc ratio that is present in naturally occurring Pel polysaccharides, while some of the residues have been deacetylated.[1] Also a spacer was incorporated at the reducing end of the heptamers for future conjugation purposes.

Results and discussion

As the DTBS-directed α-galactosylation methodology is well established, attention was first paid to the formation of α-$GlcN_3$-(1→4)-$GalN_3$ linkages. A set of glycosylation reactions was investigated using $GlcN_3$ donors **1**-**4** and $GalN_3$ acceptors **5**-**7** (Table 1). First, the additive *N*-methyl-*N*-phenylformamide (MPF) controlled α-glycosylation methodology was attempted to introduce the α-GlcN linkage. With this methodology, glycosylation of benzylated $GlcN_3$ donor **1** with benzylated $GalN_3$ acceptor **7** led to the disaccharide **8** with 7:1 α/β-selectivity, but the yield was only 47% (Table 1, entry 1). Using the same conditions, coupling of 4,6-DTBS-tethered $GlcN_3$ donor **4** with $GalN_3$ **7** afforded the dimer in only 5% yield (entry 2), owing to the low reactivity of C4-OH in $GalN_3$ acceptor. Next, a pre-activation strategy, using thioglucosides **2** and **3** as donors was explored. Benzylidene-protected donor **2** reacted with acceptor **5**, at -78 ^{o}C to -40 ^{o}C to afford disaccharide **9** in 38% yield and with a 3.5/1 α/β ratio (entry 3). When the more reactive DTBS-protected donor **3**

was treated with **5**, a slightly better α-selectivity was obtained (α/β = 5/1, entry 4). Surprisingly, condensation of donor **3** with 6-O-Bn substituted acceptor **6** led to **11** in excellent yield and α-selectivity (entry 5). By contrast, changing the linker of the acceptor to 3-buten-ol, which is more convenient for future conjugation, gave no glycosylation product (entry 6). Condensation of $GlcN_3$ donor **3** and acceptor **7**, promoted by NIS and TfOH at -40 °C, also failed to afford the product (entry 7). To further improve the reaction, the imidate donor **4** was coupled with acceptor **5**, under influence of TBSOTf, giving dimer **10** with moderate α-selectivity (α/β = 3.7/1, entry 8). Gratifyingly, performing the glycosylation of donor **4** and acceptor **7**, at -10 °C with TfOH as promotor, furnished the desired disaccharide **12** in 77% yield and with excellent α-selectivity (>20:1, entry 9). Based on these model reactions, the DTBS-tethered $GlcN_3$ donor **4** was chosen for the construction of α-$GlcN_3$-(1→4)-$GalN_3$ linkages, and the benzyl group was preferred for the protection of C6-OH in GalN acceptors. Of note, the implementation of this strategy would match exceptionally well with the strategy developed for the introduction of the α-GalN linkages in the target compounds.

Table 1. Glycosylation between $GlcN_3$ donors and $GalN_3$ acceptors.



Ent.	Don.	Acc.	Reagents and conditions	Temp.	Pro.	α/β	Yield
1	**1**	**7**	TfOH, MPF, DCM	-78 to 0 °C	**8**	7/1	47%
2	**4**			-78 to 0 °C	**12**	>10/1	5%
3	**2**	**5**	Tf_2O, Ph_2SO, TTBP, DCM	-78 to -40 °C	**9**	3.5/1	38%
4	**3**	**5**		-40 °C	**10**	5/1	65%
5		**6**		-40 °C	**11**	13/1	81%

6		**7**		-40 °C	**12**	-	-
7	**3**	**7**	NIS, TfOH, DCM	-40 °C to 0 °C	**12**	-	-
8	**4**	**5**	TBSOTf, DCM	-78 to -40 °C	**10**	3.7/1	62%
9		**7**	TfOH, DCM	-10 °C	**12**	>20/1	77%

With conditions in hand to construct the required α-GalN and α-GlcN linkages, attention was directed to the assembly of a library of Pel heptamers, consisting of (3x6) members, that can be made available by the synthesis of six protected heptameric precursors and subjecting these to different deprotection procedures. The projected eighteen heptamers contain one GlcN or GlcNAc, differently positioned in the heptameric chain, while the remaining residues are all GalN, all GalNAc or alternating GalN and GalNAc (Figure 1B). The retrosynthesis of Pel heptamers **A-C** with either GlcN or GlcNAc at second position from the reducing end of the heptamer chain is depicted in Figure 2. This retrosynthesis also applies to the remaining members of the projected library that can be accessed using the same strategy. The deprotected heptamers **A**-**C** are derived from protected heptamer **D** through different procedures for the removal of the protecting groups. In path a, the sequence of deprotection steps include DTBS removal, reduction of azido groups, and removal of Bn and TFA groups via Birch reduction to afford compound **A**, containing GalN and GlcN residues. Birch reduction is chosen to avoid reduction of C-C double bond in the linker.[27] Acetylation of free amine groups in **A** can furnish heptamer **B**. In path b, the C2-N-TFA groups are first removed, followed by desilylation and acetylation of the released amino groups, after which reduction the amino and Bn groups should give the heptamer **C**. The common protected heptamer **D** can be constructed with $GlcN_3$ donor **4**, $GalN_3$ donor **13** and GalNHTFA donor **14**, which would serve as precursors for GlcN, GlcNAc, GalN and GalNAc separately.

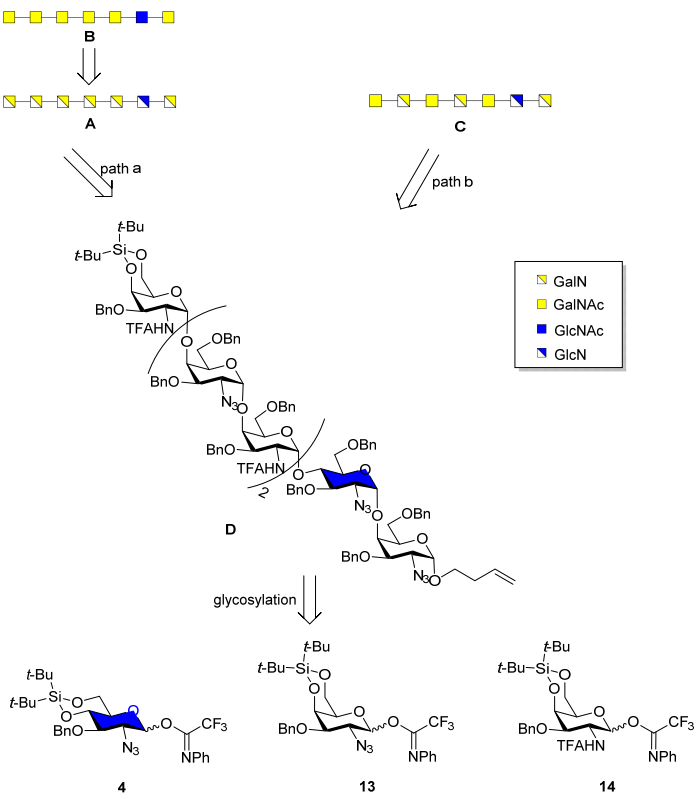


Figure 2. Retrosynthetic analysis of Pel heptasaccharides

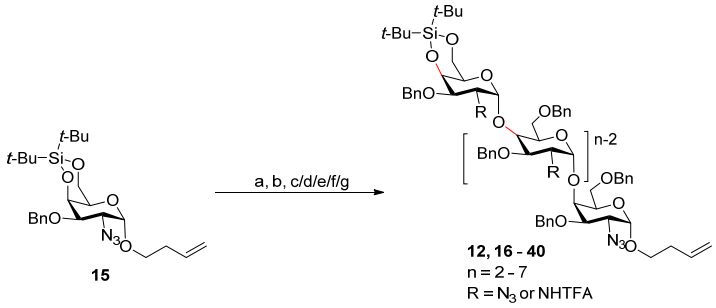
Table 2 summarizes the syntheses of the six fully protected Pel heptasaccharides (**20**, **26**, **31**, **35**, **38**, **40**) with one $GlcN_3$ residue at different positions. The elongation cycle consisted of the following three-steps: 1) glycosylation using the donor of choice, 2) DTBS-removal with HF/pyridine and 3) selective benzylation of the primary alcohol group. The Bn group can be regioselectively introduced under the aegis of Taylor's borinic acid catalyst.[28-30]

As can be seen from the table, the heptasaccharide **20** (or E in Figure 2) with $GlcN_3$ moiety at the second position from the reducing end of the heptamer chain was first synthesized. The acceptor **7** was obtained from **15** through desilylation and regioselective C6-OH benzylation. Condensation of $GlcN_3$ donor **4** and acceptor **7** led to the disaccharide **12** using TfOH promoted condensation at -10 °C, then the DTBS group was cleaved and the liberated 6-OH was benzylated selectively to form the desired 4-OH acceptor, which was reacted with GalNHTFA donor **14** giving the trisaccharide **16** with 73% yield for over three steps. However, the relatively moderate yield of the glycosylation for the tetra- and pentamer (56%

for **17** and 51 % for **18**) was an incentive to optimize the glycosylation reaction conditions. It was found that implementation of a "reverse addition sequence" strategy, in which the acceptor and activator are mixed, after which the donor is slowly added, greatly improved the reaction yields (71% for **17** and 72% for **18**). Elongation of the pentamer with another copy of the $GalN_3$ donor **13** and subsequently the GalNHTFA building block **14**, delivered heptasaccharide **20** in excellent yields.

In an analogous way, the assembly of target heptasaccharides **26**, **31**, **35**, **38** and **40** with $GlcN_3$ moiety at the positions 3-7 was accomplished with building blocks **4**, **13** and **14**. Repetition of the elongation cycle, comprising the same three steps as described above led to all target heptasaccharides. The glycosylation reactions proceeded efficiently providing the intermediate and target oligosaccharides (n = 2-7) with excellent stereoselectivity and good yields (50-79% yields for three steps). The mixed sequence structures were generated uneventfully, showing the chemistry developed to be applicable to any type of Pel-target.

Table 2. Synthesis of Pel oligomers



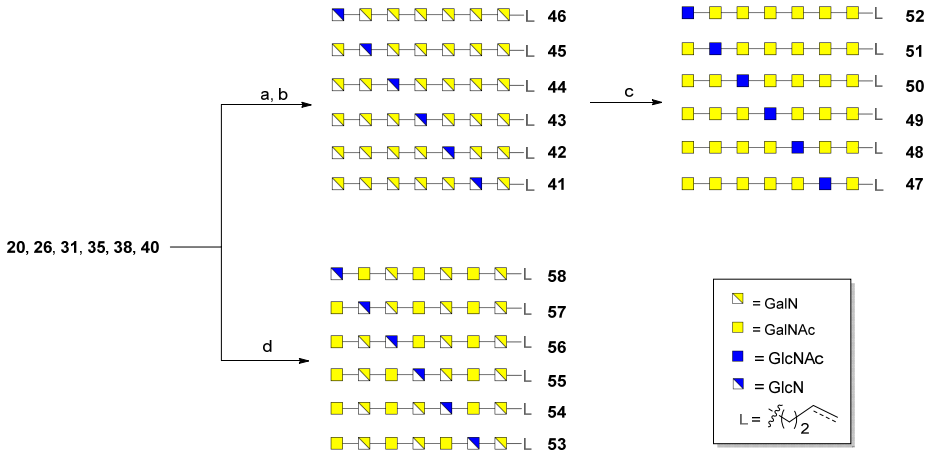
n	$(GluR)_m$ $GalN_3$	Yield[h]
2	$GlcN_3$ $GalN_3$	**12** (71%)[c]
3	GalNHTFA $GlcN_3$ $GalN_3$	**16** (73%)[e]
4	$GalN_3$ GalNHTFA $GlcN_3$ $GalN_3$	**17** (56%)[d] (71%)[f]
5	GalNHTFA $GalN_3$ GalNHTFA $GlcN_3$ $GalN_3$	**18** (51%)[e] (72%)[g]
6	$GalN_3$ GalNHTFA $GalN_3$ GalNHTFA $GlcN_3$ $GalN_3$	**19** (69%)[f]
7	GalNHTFA $GalN_3$ GalNHTFA $GalN_3$ GalNHTFA $GlcN_3$ $GalN_3$	**20** (67%)[g]
2	GalNHTFA $GalN_3$	**21** (79%)[e]
3	$GlcN_3$ GalNHTFA $GalN_3$	**22** (74%)[c]
4	$GalN_3$ $GlcN_3$ GalNHTFA $GalN_3$	**23** (68%)[f]
5	GalNHTFA $GalN_3$ $GlcN_3$ GalNHTFA $GalN_3$	**24** (78%)[g]
6	$GalN_3$ GalNHTFA $GalN_3$ $GlcN_3$ GalNHTFA $GalN_3$	**25** (68%)[f]
7	GalNHTFA $GalN_3$ GalNHTFA $GalN_3$ $GlcN_3$ GalNHTFA $GalN_3$	**26** (76%)[g]

3	$GalN_3$ GalNHTFA $GalN_3$	**27** (79%)[f]
4	$GlcN_3$ $GalN_3$ GalNHTFA $GalN_3$	**28** (73%)[c]
5	GalNHTFA $GlcN_3$ $GalN_3$ GalNHTFA $GalN_3$	**29** (70%)[g]
6	$GalN_3$ GalNHTFA $GlcN_3$ $GalN_3$ GalNHTFA $GalN_3$	**30** (73%)[f]
7	GalNHTFA $GalN_3$ GalNHTFA $GlcN_3$ $GalN_3$ GalNHTFA $GalN_3$	**31** (74%)[g]
4	GalNHTFA $GalN_3$ GalNHTFA $GalN_3$	**32** (66%)[g]
5	$GlcN_3$ GalNHTFA $GalN_3$ GalNHTFA $GalN_3$	**33** (74%)[c]
6	$GalN_3$ $GlcN_3$ GalNHTFA $GalN_3$ GalNHTFA $GalN_3$	**34** (56%)[f]
7	GalNHTFA $GalN_3$ $GlcN_3$ GalNHTFA $GalN_3$ GalNHTFA $GalN_3$	**35** (52%)[g]
5	$GalN_3$ GalNHTFA $GalN_3$ GalNHTFA $GalN_3$	**36** (74%)[f]
6	$GlcN_3$ $GalN_3$ GalNHTFA $GalN_3$ GalNHTFA $GalN_3$	**37** (77%)[c]
7	GalNHTFA $GlcN_3$ $GalN_3$ GalNHTFA $GalN_3$ GalNHTFA $GalN_3$	**38** (50%)[g]
6	GalNHTFA $GalN_3$ GalNHTFA $GalN_3$ GalNHTFA $GalN_3$	**39** (67%)[g]
7	$GlcN_3$ GalNHTFA $GalN_3$ GalNHTFA $GalN_3$ GalNHTFA $GalN_3$	**40** (60%)[c]

a) HF/pyridine, THF, 0 °C to rt. b) $Ph_2BO(CH_2)_2NH_2$, KI, K_2CO_3, BnBr, MeCN, 60 °C. c) **4**, TfOH, 4Å MS, DCM, -10 °C. d) **13**, TfOH, 4Å MS, DCM, 0 °C. e) **14**, TfOH, 4Å MS, DCM, 0 °C. f) TfOH, 4Å MS, DCM, then **13** added in 1h, 0 °C for 3, 4 and 5-mers, -20 °C for 6 and 7-mers. g) TfOH, 4Å MS, DCM, then **14** added in 1h, 0 °C for 4 and 5-mers, -20 °C for 6 and 7-mers. h) yields for over three steps.

With all six protected heptasacharides in hand deprotection conditions were developed to complete the assembly of all projected Pel oligomers (Scheme 1). First, the set of 7-mers containing solely α-GalN and α-GlcN moieties was generated. Removal of the DTBS-group in heptamers **20**, **26**, **31**, **35**, **38** and **40** was performed with HF/pyridine and the azido-groups could be reduced with $HS(CH_2)_3SH$, after which the Bn groups together with the TFA groups were cleaved using sodium in ammonia and THF, affording the 7-mers **41**-**46** in 48%-85% yields. In the Birch reduction, allyl carbinol was used as a scavenger to prevent reduction of the C-C double bond. A portion of the 7-mers **41**-**46** was chemoselectively acetylated to provide the second set of heptamers **47**-**52**, composed of α-GalNAc and α-GlcNAc moieties. Furthermore the heptamers **20**, **26**, **31**, **35**, **38** and **40** were transformed into the third set of GalN-, GalNAc and GlcN- containing heptamers **53**-**58**. Similar to the first series, silylidene groups were first removed. However, the TFA groups could not be cleaved even with strong basic conditions and high temperature (4M NaOH, 80 °C). Also attempts to remove the TFA groups with the assistance of microwave failed (see experimental section table S1). A solution for this problem was found by first removing the benzyl ethers and concomittant reduction of the azido groups, followed by temporily protection of the generated free amino groups with Boc groups. At this stage the TFA groups could be removed with $NH_3{\cdot}H_2O$ at

60 ºC, after which acetylation of generated amines and subsequent removal of Boc groups with 30% TFA provided the heptamers **53**-**58** in 18%-31% yields.



Scheme 1. Deprotection of synthetic Pel heptasaccharides. a) i) HF/pyridine, THF, rt; ii) $HS(CH_2)_3SH$, Et_3N, pyridine/H_2O, rt. b) Na, NH_3 (liq.), THF, t-BuOH, 3-buten-1-ol, -78 ºC, yields for **41**: 69% (12/1 with:without C=C); **42**: 48% (23/1); **43**: 84% (19/1); **44**: 53% (50/1); **45**: 59% (25/1); **46**: 85% (43/1). c) Ac_2O, H_2O, $NaHCO_3$, rt, yields for **47**: 90%; **48**: 91% (11/1); **49**: 91% (32/1); **50**: 90% (32/1); **51**: 89% (21/1); **52**: 88% (12/1). d) i) HF/pyridine, THF, rt; ii) $Pd(OH)_2/C$, H_2, AcOH, THF/t-BuOH/H_2O, rt; iii) Boc_2O, $NaHCO_3$, H_2O, rt; iv) $NH_3 \cdot H_2O$, 60 ºC; v) Ac_2O, $NaHCO_3$, H_2O, rt; vi) 30% TFA in H_2O, L = $(CH_2)_3CH_3$, yields for **53**: 31%; **54**: 25%; **55**: 24%; **56**: 18%; **57**: 30%; **58**: 18%.

In addition to the three sets of heptamers obtained above, another set composed of GalN, GalNAc and GlcNAc residues can be produced by desilylation, reduction of the azides to the amines, chemoselective acetylation of these groups to provide the acetamides, and Birch reduction to remove the banzyl and TFA-groups. Using this strategy, **35** and **38** were brought to the end stage to furnish compounds **59** and **60** containing α-GalN, α-GalNAc and α-GlcNAc moieties (Scheme I).

Scheme I: Synthesis of heptamers **59** and **60**. Reagents and conditions: i) HF/pyridine, THF, rt; ii) $HS(CH_2)_3SH$, Et_3N, pyridine/H_2O, rt; iii) Ac_2O, $NaHCO_3$, H_2O/THF, rt; iv) Na, NH_3 (liq.), THF, t-BuOH, 3-buten-1-ol, -78 ºC, yields for **59**: 62%; **60**: 77%.

Conclusion

In conclusion, synthetic methodology enabling the assembly of Pel fragments has been developed. Key features of the synthetic strategy include the use of DTBS-directed α-glycosylation methodology and a regioselective benzylation procedure. The DTBS-directed glycosylation was not only successfully applied for the construction of α-GalN_3 and α-GalNTFA linkages, as already described in previous Chapters, it also proved applicable for the synthesis of α-GlcN_3 linkages. With the increasing length of the oligosaccharides, the glycosylation yields decreased significantly, owing to the reduced nucleophilicity of the acceptors. Application of a reverse-addition-sequence strategy adequately improved the yields of the glycosylations providing the longer oligosaccharides in good yield. Six protected heptamers with different composition were subjected to different deprotection protocols, providing three sets of heptamers; α-GlcN-α-GalN; α-GlcNAc-α-GalNAc and α-GlcN-α-GalNAc-α-GalN. Unexpectedly, it proved impossible to effectively remove the *N*-TFA groups in the heptamers carrying benzyl protecting groups. Fortunately, a protocol in which the benzyl and azide groups were first reduced, after which the liberated amines were temporarily masked with the use of Boc protection, allowed for removal of the TFA groups, using aqueous ammonia hydroxide. The synthetic Pel heptamers will be valuable for the studies of their biosynthesis and the development of vaccines against *P. aeruginosa*.

Experimental section

General procedure for glycosylation with imidate donors 4, 13 and 14 (procedure A)

The donor (1.5 – 3.0 eq) and acceptor (1.0 eq) were co-evaporated with toluene (three times). The residue was dissolved in dry DCM (0.1 M acceptor in DCM) under nitrogen and stirred over fresh flame-dried molecular sieves 4Å. The solution was cooled to 0 ºC, after which TfOH (0.1 – 0.3 eq) was added. The reaction was stirred at 0 ºC until TLC-analysis showed complete conversion of the acceptor. The reaction was quenched with Et_3N, diluted with DCM, washed with saturated $NaHCO_3$ and brine. The organic phase was dried with anhydrous $MgSO_4$, filtered and concentrated *in vacuo*. The products were purified by silica gel column chromatography (See experimental description below for eluent system).

General procedure for glycosylation with imidate donors 13 and 14 (Reverse-addition sequence, procedure B)

The acceptor (1.0 eq) was co-evaporated with toluene (three times), and the residue was dissolved in dry DCM (0.1 M acceptor in DCM) under nitrogen and stirred over fresh flame-dried molecular sieves 4Å. The solution was cooled to 0 ºC, after which TfOH (0.1 – 0.3 eq) was added. The solution of donor (1.5 -4.0 eq) in dry DCM was added slowly into the reaction mixture within 1 hour. The reaction was stirred at 0 ºC until TLC-analysis showed complete conversion of the acceptor. The reaction was quenched with Et_3N, diluted with DCM, washed with saturated $NaHCO_3$ and brine. The organic phase was dried with anhydrous $MgSO_4$, filtered and concentrated *in vacuo*. The products were purified by silica gel column chromatography (See experimental description below for eluent system).

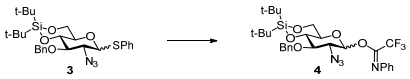
General procedure for the deprotection of di-*tert*-butyl silylidene group (general procedure C)

HF/pyridine (16 eq) solution was added to a solution of starting material in THF at 0 ºC. The reaction was warmed to room temperature and stirred until TLC-analysis indicated full consumption of the starting material (± 1h). Then the mixture was diluted with DCM and washed with saturated $NaHCO_3$ and brine, dried with anhydrous $MgSO_4$, filtered and concentrated *in vacuo*. The product was purified by silica gel column chromatography (See experimental description below for eluent system).

General procedure for selective benzylation of primary alcohol (general procedure D)

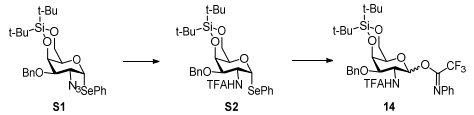
K_2CO_3 (1.1 eq), KI (1.5 eq) and $Ph_2BO(CH_2)_2NH_2$ (0.1-0.2 eq) were added to the solution of starting material in MeCN (0.05 M). Then BnBr was added in the solution. The reaction was allowed to stirred at 60 ºC until TLC-analysis showed complete conversion of the starting material. Then reaction was quenched with H2O after completed checking by TLC, filtered and concentrated *in vacuo*. The product was purified by silica gel column chromatography (See experimental description below for eluent system).

Experimental Procedures and Characterization Data of Products



2-Azido-3-*O*-benzyl-2-deoxy-4,6-di-*tert*-butylsilylidene-1-*O*-(*N*-phenyl-trifluoroacetimidoyl)-α/β-D-glucopyranoside (4)

NIS (525 mg, 2.33 mmol) was added to the solution of compound **3**[16](820 mg, 1.55 mmol) in Acetone/H_2O (16 ml/1.6 ml) at 0 ºC. The reaction was slowly warmed to room temperature and stirred until TLC-analysis indicated full consumption of the starting material (± 1H). Then the mixture was diluted with DCM and washed with saturated $Na_2S_2O_3$ and brine, dried with anhydrous $MgSO_4$, filtered and concentrated *in vacuo*. The product S1 was purified by silica gel column chromatography (pentane:EtOAc = 8:1). Cs_2CO_3 (440 mg, 1.35 mmol) was added to the solution of the residue in 15 ml acetone. The mixture was stirred at 0 ºC for 15 minutes. Then $CF_3C(=NPh)Cl$ (420 mg, 2.03 mmol) was added to the solution. which was slowly warmed to room temperature and stirred overnight. The reaction was quenched with Et_3N and concentrated *in vacuo*. The product **4** was purified by silica gel column chromatography (pentane:Et_2O = 30:1 – 10:1). Compound **4** (828 mg, α:β = 2:1, 88% yield) was obtained as yellow syrup. α-Isomer: ^{1}H NMR ($CDCl_3$, 400 MHz) δ 7.46 – 7.39 (m, 2H), 7.38 – 7.24 (m, 6H), 7.13 – 7.04 (m, 1H), 6.83 (d, *J* = 7.8 Hz, 2H, *aromatic* H), 6.25 (s, 1H, H-1), 5.09 (d, *J* = 10.6 Hz, 1H, *Ph*C*H*HO), 4.84 (d, *J* = 10.6 Hz, 1H, *Ph*C*H*HO), 4.15 (dd, *J* = 9.2, 3.9 Hz, 1H, H-6), 4.07 – 3.82 (m, 4H, H-3, 4, 5, 6), 3.61 – 3.47 (m, 1H, H-2), 1.09 (s, 9H, *C*H_3), 1.04 (s, 9H, *C*H_3). ^{13}C NMR (100 MHz, $CDCl_3$) δ 143.22, 137.92, 129.36, 128.89, 128.55, 128.47, 128.44, 128.09, 126.36, 124.66, 119.44 (*aromatic* C/C*H*), 116.03 (*a*d, *J* = 286 Hz, C*F*$_3$), 93.58 (C-1), 79.42 (C-3), 78.36 (C-4), 75.70 (CH_2*Ph*), 68.96 (C-5), 66.38 (C-6), 61.79 (C-2), 27.46, 26.99 (2 CH_3), 22.74, 20.03 (2 C-*Si*). β-Isomer: ^{1}H NMR ($CDCl_3$, 400 MHz) δ 7.42 (d, *J* = 6.9 Hz, 2H, *aromatic* H), 7.38 – 7.24 (m, 5H, *aromatic* H), 7.11 – 7.05 (m, 1H, *aromatic* H), 6.83 (d, *J* = 7.7 Hz, 2H, *aromatic* H), 5.60 (bs, 1H, H-1), 5.01 (d, *J* = 11.0 Hz, 1H, *Ph*C*H*HO), 4.83 (d, *J* = 11.0 Hz, 1H, *Ph*C*H*HO), 4.24 – 4.09 (m, 1H, H-6), 4.03 – 3.85 (m, 2H, H-4, 6), 3.67 – 3.20 (m, 3H, H-2, 3, 5), 1.08 (s, 9H, *C*H_3), 1.00 (s, 9H, *C*H_3). ^{13}C NMR (100 MHz, $CDCl_3$) δ 143.16, 137.91, 128.86, 128.50, 128.40, 128.07, 124.61, 119.28 (*aromatic* C/C*H*), 116.03 (*a*d, *J* = 286 Hz, C*F*$_3$), 95.54 (C-1), 82.08 (C-3), 77.63 (C-4), 75.37 (CH_2*Ph*), 71.15 (C-5), 66.04 (C-6), 64.47 (C-2), 27.45 (CH_3), 27.05 (CH_3), 22.73, 20.01 (2 C-*Si*). HR-MS: Calculated for $C_{29}H_{37}N_4O_5F_3Si$ $[M+Na]^+$: 629.2383, found: 629.2378.



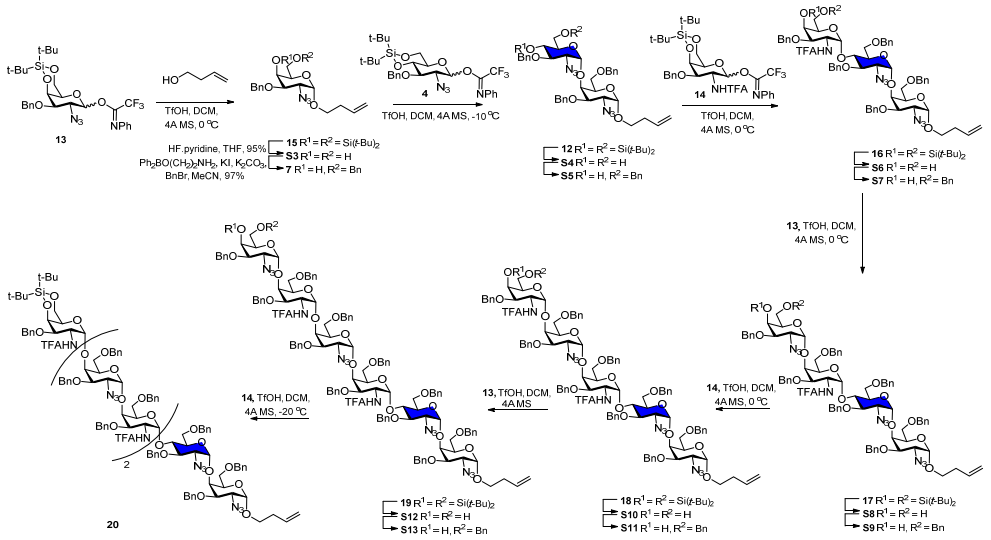
Phenyl 3-*O*-benzyl-2-deoxy-1-seleno-4,6-di-*tert*-butylsilylidene-2-trifluoroacetamido-α-D-galactopyranoside (S2)

1,3-Dithiolpropane (10.1 ml, 100 mmol) and trimethylamine (11.6 ml, 83.5 mmol) were added to the solution of compound **S1** (9.6 g, 16.7 mmol) in pyridine/water (80 ml/20 ml). The mixture was protected from light and stirred at room temperature overnight. The fluent was evaporated and co-evaporated with toluene. The residue was

dissolved in 50 ml pyridine, after which TFA_2O (3.5 ml, 25 mmol) was added at 0 ºC. The reaction was slowly warmed to room temperature and stirred overnight. The reaction was quenched with Methanol and concentrated *in vacuo*. The product was purified by silica gel column chromatography (pentane:EtOAc = 50:1 – 10:1). Compound **S2** (9.58 g, 89% yield) was obtained as yellow syrup. $[\alpha]_D^{25}$ +205.4 (c=1, $CHCl_3$). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.55 – 7.46 (m, 2H), 7.44 – 7.21 (m, 8H, *aromatic* H), 6.59 (d, *J* = 7.0 Hz, 1H, NH), 6.12 (d, *J* = 4.8 Hz, 1H, H-1), 4.83 – 4.73 (m, 2H, H-2, *PhC*H*H*O), 4.71 (d, *J* = 2.7 Hz, 1H, H-5), 4.50 (d, *J* = 11.7 Hz, 1H, *PhC*H*H*O), 4.33 (dd, *J* = 12.7, 2.3 Hz, 1H, H-6), 4.17 (dd, *J* = 12.7, 1.7 Hz, 1H, H-6), 4.05 (d, *J* = 2.3 Hz, 1H, H-4), 3.51 (dd, *J* = 11.0, 2.7 Hz, 1H, H-3), 1.07 (d, *J* = 4.2 Hz, 18H, *C*H$_3$). ^{13}C NMR (100 MHz, $CDCl_3$) δ 157.26 (*a*d, *J* = 37 Hz, *CF$_3$CO*), 149.79, 137.33, 136.16, 134.43, 134.38, 134.33, 129.46, 128.85, 128.59, 128.37, 128.32, 128.24, 127.95, 127.89, 123.86 (*aromatic* C/C*H*), 115.68 (*a*d, *J* = 286 Hz, C*F$_3$*), 88.66 (C-1), 76.06 (C-3), 70.90 (C-4), 69.65 (C*H$_2$Ph*), 68.82 (C-5), 67.23 (C-6), 49.95 (C-2), 27.72, 27.37 (2 C*H$_3$*), 23.50, 20.87 (2 C-*Si*). HR-MS: Calculated for $C_{29}H_{38}NO_5F_3SiSe$ $[M+Na]^+$: 668.1534, found: 668.1529.

3-*O*-benzyl-2-deoxy-4,6-di-*tert*-butylsilylidene-2-trifluoroacetamido-1-*O*-(*N*-phenyl-trifluoroacetimidoyl)-α/β-D-galactopyranoside (14)

NIS (944 mg, 4.19 mmol) was added to the solution of compound **S2** (1.65 g, 2.8 mmol) in Acetone/H_2O (15 ml/3 ml) at 0 ºC. The reaction was slowly warmed to room temperature and stirred until TLC-analysis indicated full consumption of the starting material (± 1H). Then the mixture was diluted with DCM and washed with saturated $Na_2S_2O_3$ and brine, dried with anhydrous $MgSO_4$, filtered and concentrated *in vacuo*. The product was purified by silica gel column chromatography (pentane:EtOAc = 4:1). Cs_2CO_3 (2.77 g, 8.5 mmol) was added to the solution of the hemiacetal (4.3 g, 8.5 mmol) in 45 ml acetone. The mixture was stirred at 0 ºC for 15 minutes. Then $CF_3C(=NPh)Cl$ (2.29 g, 11.06 mmol) was added to the solution. which was slowly warmed to room temperature and stirred overnight. The reaction was quenched with Et_3N and concentrated *in vacuo*. The product **14** was purified by silica gel column chromatography (pentane:Et_2O = 50:1 – 10:1). Compound **14** (5.15 g, α:β = 7:1, 90% yield) was obtained as syrup. α-Isomer: ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.45 – 7.22 (m, 7H), 7.10 (t, *J* = 7.4 Hz, 1H), 6.76 (d, *J* = 7.7 Hz, 2H, *aromatic* H), 6.57 (bs, H-1), 6.11 (d, *J* = 7.3 Hz, 1H, *N*H), 4.80 (d, *J* = 11.8 Hz, 1H, *PhC*H*H*O), 4.72 (s, 2H, H-2, 5), 4.52 (d, *J* = 11.8 Hz, 1H, *PhC*H*H*O), 4.33 – 4.12 (m, 2H, H-6), 3.82 – 3.66 (m, 2H, H-3, 4), 1.14 – 0.97 (m, 18H, *C*H$_3$). ^{13}C NMR (100 MHz, $CDCl_3$) δ 157.53 (*a*d, *J* = 37 Hz, *CF$_3$CO*), 143.09, 137.25, 128.90, 128.44, 128.01, 119.33 (*aromatic* C/C*H*), 115.72(*a*d, *J* = 286 Hz, C*F$_3$*), 96.81 (C-1), 73.91 (C-3), 70.16 (C-4), 69.96 (C*H$_2$Ph*), 68.77 (C-5), 66.87 (C-6), 48.40 (C-2), 27.72, 27.30 (2 C*H$_3$*), 23.51, 20.85 (2 C-*Si*). β-Isomer: ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.48 – 7.27 (m, 7H), 7.20 – 7.08 (m, 1H), 6.84 (d, *J* = 7.7 Hz, 2H, *aromatic* H), 6.56 (d, *J* = 7.2 Hz, 1H, NH), 6.19 (bs, 1H, H-1), 4.73 (d, *J* = 11.6 Hz, 1H, *PhC*H*H*O), 4.64 – 4.47 (m, 2H, *PhC*H*H*O, H-5), 4.42 – 3.90 (m, 5H, H-2, 3, 4, 6), 1.20 – 1.03 (m, 18H, *C*H$_3$). ^{13}C NMR (100 MHz, $CDCl_3$) δ 157.68 (*a*d, *J* = 37 Hz, *CF$_3$CO*), 143.28, 137.42, 128.85, 128.78, 128.33, 128.05, 124.57, 119.38 (*aromatic* C/C*H*), 115.60 (*a*d, *J* = 286 Hz, C*F$_3$*), 93.70 (C-1), 75.46 (C-3), 72.36 (C-4), 70.61 (C*H$_2$Ph*), 68.61 (C-5), 66.90 (C-6), 52.93 (C-2), 27.74, 27.44 (2 C*H$_3$*), 23.54, 20.91 (2 C-*Si*). HR-MS: Calculated for $C_{31}H_{38}N_2O_6F_6Si$ $[M+Na]^+$: 699.2301, found: 699.2296.



3-Butenyl 2-azido-3-*O*-benzyl-2-deoxy-4,6-di-*tert*-butylsilylidene-α-D-galactopyranoside (15)

The reaction was carried out according to the general procedure A. The donor **13** (1.8 g, 2.97 mmol) was co-evaporated with toluene (three times). The the linker alcohol (511 ul, 5.94 mmol) was added, the mixture was dissolved in dry 30 ml DCM under nitrogen and stirred over fresh flame-dried molecular sieves 4Å. The solution was cooled to 0 ºC, after which TfOH (26 µl, 0.23 mmol) was added. The reaction was stirred at 0 ºC for 2 h. Then the reaction was quenched with Et_3N, diluted with DCM, washed with saturated $NaHCO_3$ and brine. The organic phase was dried with anhydrous $MgSO_4$, filtered and concentrated *in vacuo*. The product was purified by silica gel column chromatography (pentane:EtOAc = 50:1). Compound **15** (1.30 g, 89% yield) was obtained as colorless syrup. $[\alpha]_D^{25}$ +146.7 (c=2, $CHCl_3$). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.48 – 7.22 (m, 5H, *aromatic* H), 5.86 – 5.71 (m, 1H, H-9), 5.13 – 5.00 (m, 2H, H-10), 4.93 (d, *J* = 3.5 Hz, 1H, H-1), 4.74 (d, *J* = 11.5 Hz, 1H, *PhCHH*O), 4.65 (d, *J* = 11.5 Hz, 1H, *PhCHH*O), 4.57 (dd, *J* = 2.9, 1.0 Hz, 1H, H-4), 4.24 (dd, *J* = 12.6, 2.1 Hz, 1H, H-6), 4.13 (dd, *J* = 12.5, 1.7 Hz, 1H, H-6), 3.87 (dd, *J* = 10.6, 2.8 Hz, 1H, H-3), 3.77 (dd, *J* = 10.6, 3.5 Hz, 1H, H-2), 3.73 – 3.62 (m, 2H, H-7, 5), 3.59 – 3.48 (m, 1H, H-7), 2.41 – 2.30 (m, 2H, H-8), 1.07 (s, 9H, *CH*$_3$), 1.04 (s, 9H, *CH*$_3$). ^{13}C NMR (100 MHz, $CDCl_3$) δ 137.85 (*aromatic* C), 134.66 (C-9), 128.49, 127.91, 127.83 (*aromatic CH*), 116.89 (C-10), 98.40 (C-1), 75.36 (C-3), 70.40 (C*H*$_2$*Ph*), 69.82 (C-4), 67.67 (C-7), 67.46 (C-5), 67.17 (C-6), 58.23 (C-2), 33.90 (C-8), 27.66, 27.34 (2 C*H*$_3$), 23.42, 20.73 (2 C-*Si*). HR-MS: Calculated for $C_{25}H_{39}N_3O_5Si$ $[M+Na]^+$: 512.2557, found: 512.2551.

3-Butenyl 2-azido-3-*O*-benzyl-2-deoxy-α-D-galactopyranoside (S3)

The reaction was carried out according to the general procedure C using compound **15** (1.27 g, 2.59 mmol) and HF/pyridine (70%, 1.1 ml, 41.5 mmol). The product was purified by column chromatography (pentane:EtOAc = 3:2). Compound **S3** (860 mg, 95% yield) was obtained as white solid. $[\alpha]_D^{25}$ +135.4 (c=1, $CHCl_3$). ^{1}H NMR (400 MHz, Chloroform-*d*) δ 7.47 – 7.26 (m, 5H, *aromatic* H), 5.80 (ddt, *J* = 17.0, 10.2, 6.7 Hz, 1H, H-9), 5.18 – 5.01 (m,

2H, H-10), 4.93 (d, *J* = 3.5 Hz, 1H, H-1), 4.77 – 4.61 (m, 2H, 2x*PhC*H*H*O), 4.10 (d, *J* = 3.1 Hz, 1H, H-4), 3.94 – 3.83 (m, 2H, H-3, 6), 3.83 – 3.68 (m, 3H, H-5, 6, 7), 3.65 (dd, *J* = 10.4, 3.6 Hz, 1H, H-2), 3.52 (dt, *J* = 9.7, 6.6 Hz, 1H, H-7), 2.97 (bs, 1H, OH), 2.71 (bs, 1H, OH), 2.37 (qt, *J* = 6.8, 1.4 Hz, 2H, H-8). ^{13}C NMR (100 MHz, $CDCl_3$) δ 137.12 (*aromatic* C), 134.62 (C-9), 128.73, 128.34, 128.11 (*aromatic* C*H*), 117.03 (C-10), 98.07 (C-1), 75.81 (C-3), 72.02 (CH_2*Ph*), 69.50 (C-5), 67.68 (C-7), 67.50 (C-4), 62.80 (C-6), 58.97 (C-2), 33.87 (C-8). HR-MS: Calculated for $C_{17}H_{23}N_3O_5$ $[M+Na]^+$: 372.1535, found: 372.1530.

3-Butenyl 2-azido-3,6-di-*O*-benzyl-2-deoxy-α-D-galactopyranoside (7)

The reaction was carried out according to the general procedure D using compound **S3** (900 mg, 2.58 mmol), K_2CO_3 (392 mg, 2.84 mmol), KI (428 mg, 2.58 mmol) and $Ph_2BO(CH_2)_2NH_2$ (58 mg, 0.26 mmol). The product was purified by column chromatography (pentane:EtOAc = 7:1). Compound **7** (1.07 g, 94% yield) was obtained as yellow syrup. $[\alpha]_D^{25}$ +75 (c=2, $CHCl_3$). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.43 – 7.26 (m, 10H, *aromatic* H), 5.80 (ddt, *J* = 17.1, 10.2, 6.7 Hz, 1H, H-9), 5.14 – 5.01 (m, 2H, H-10), 4.91 (d, *J* = 3.6 Hz, 1H, H-1), 4.66 (s, 2H, *PhC*H*H*O), 4.58 (d, *J* = 11.9 Hz, 1H, *PhC*H*H*O), 4.56 (d, 1H, *PhC*H*H*O), 4.10 (dd, *J* = 3.2, 1.3 Hz, 1H, H-4), 3.93 (td, *J* = 5.8, 1.3 Hz, 1H, H-5), 3.87 (dd, *J* = 10.4, 3.1 Hz, 1H, H-3), 3.79 – 3.64 (m, 4H, H-2, 6, 7), 3.52 (dt, *J* = 9.7, 6.5 Hz, 1H, H-7), 2.73 (bs, 1H, OH), 2.37 (qt, *J* = 6.8, 1.4 Hz, 2H, H-8). ^{13}C NMR (100 MHz, $CDCl_3$) δ 137.87, 137.24 (*aromatic* C), 134.67 (C-9), 128.97, 128.61, 128.42, 128.15, 128.01, 127.75, 127.66 (*aromatic* C*H*), 116.87 (C-10), 98.00 (C-1), 75.97 (C-3), 73.60, 71.77 (2 CH_2*Ph*), 69.43 (C-6), 68.80 (C-5), 67.58 (C-7), 66.55 (C-4), 58.97 (C-2), 33.84 (C-8). HR-MS: Calculated for $C_{24}H_{29}N_3O_5$ $[M+Na]^+$: 462.2005, found: 462.1999.

3-Butenyl 2-azido-3-*O*-benzyl-2-deoxy-4,6-di-*tert*-butylsilylidene-α-D-glucopyranosyl-(1→4)-2-azido-3,6-di-*O*-benzyl-2-deoxy-α-D-galactopyranoside (12)

The reaction was carried out according to the general procedure A. The donor **4** (808 mg, 1.33 mmol) and acceptor **7** (293 mg, 0.67 mmol) were co-evaporated with toluene (three times). The residue was dissolved in dry 6 ml DCM under nitrogen and stirred over fresh flame-dried molecular sieves 4Å. The solution was cooled to -10 ºC, after which TfOH (12 µl, 0.13 mmol) was added. The reaction was stirred at -10 ºC for 2 h. Then the reaction was quenched with Et_3N, diluted with DCM, washed with saturated $NaHCO_3$ and brine. The organic phase was dried with anhydrous $MgSO_4$, filtered and concentrated *in vacuo*. The product was purified by silica gel column chromatography (pentane:Et_2O = 10:1). Compound **12** (422 mg, 74% yield) was obtained as yellow syrup. $[\alpha]_D^{25}$ +121.5 (c=1, $CHCl_3$). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.58 – 7.33 (m, 15H, *aromatic* H), 5.87 (ddt, *J* = 17.1, 10.2, 6.8 Hz, 1H, H-9), 5.23 – 5.10 (m, 3H, H-10), 5.04 (d, *J* = 3.5 Hz, 1H, H-1^A), 4.92 (d, *J* = 5.4 Hz, 1H, *PhC*H*H*O), 4.91 – 4.87 (m, 2H, H-1^B), 4.76 – 4.63 (m, 2H, *PhC*H*H*O), 4.58 (d, *J* = 11.8 Hz, 1H, *PhC*H*H*O), 4.43 (td, *J* = 9.7, 4.7 Hz, 1H), 4.27 (d, *J* = 2.7 Hz, 1H, H-4^A), 4.12 – 4.03 (m, 1H), 4.03 – 3.88 (m, 5H), 3.86 – 3.71 (m, 3H), 3.67 – 3.56 (m, 2H), 3.37 – 3.27 (m, 1H, H-2^B), 2.43 (qt, *J* = 6.8, 1.4 Hz, 2H, H-8), 1.15 (s, 9H, *C*H$_3$), 1.08 (s, 9H, *C*H$_3$). ^{13}C NMR (100 MHz, $CDCl_3$) δ 138.13, 137.38, 137.26 (*aromatic* C), 134.60 (C-9), 128.50, 128.38, 128.35, 128.32, 128.21, 128.10, 127.88, 127.82, 127.63 (*aromatic* C*H*), 116.88 (C-10), 98.64 (C-1^B), 97.85 (C-1^A), 79.26, 79.17,

75.46, 75.37, 73.59, 73.51, 71.97, 69.02, 67.56, 66.76, 66.74, 66.64, 62.92 (C-2^B), 60.01 (C-2^A), 33.83 (C-8), 27.35, 27.04 (2 C*H*$_3$), 22.55, 19.98 (2 C-*Si*). ^{13}C-HMBC ($CDCl_3$, 100 MHz): 98.64 ($J_{C1,H1}$ = 172 Hz), 97.85 ($J_{C1,H1}$ = 171 Hz). HR-MS: Calculated for $C_{45}H_{60}N_6O_9Si$ $[M+Na]^+$: 879.4089, found: 879.4083.

3-Butenyl 2-azido-3-*O*-benzyl-2-deoxy-α-D-glucopyranosyl-(1→4)-2-azido-3,6-di-*O*-benzyl-2-deoxy-α-D-galactopyranoside (S4)

The reaction was carried out according to the general procedure C using compound **12** (422 mg, 0.49 mmol) and HF/pyridine (70%, 205 µl, 7.88 mmol). The product was purified by column chromatography (pentane:EtOAc = 3:1). Compound **S4** (342 mg, 97% yield) was obtained as white solid. $[\alpha]_D^{25}$ +146.8 (c=1, $CHCl_3$). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.43 – 7.20 (m, 15H, *aromatic* H), 5.78 (ddt, *J* = 17.0, 10.2, 6.8 Hz, 1H, H-9), 5.11 – 5.00 (m, 2H, H-10), 4.93 (d, *J* = 3.5 Hz, 1H, H-1^A), 4.89 – 4.77 (m, 3H, H-1^B, *PhC*H*H*O), 4.72 (d, *J* = 12.0 Hz, 1H, *PhC*H*H*O), 4.61 – 4.46 (m, 3H), 4.21 (d, *J* = 2.7 Hz, 1H, H-4^A), 3.99 – 3.76 (m, 5H), 3.73 – 3.46 (m, 5H), 3.35 (dd, *J* = 12.2, 2.7 Hz, 1H), 3.19 (td, *J* = 11.1, 10.3, 3.5 Hz, 2H), 2.41 – 2.26 (m, 2H, H-8). ^{13}C NMR (101 MHz, $CDCl_3$) δ 138.04, 137.34, 137.26 (*aromatic* C), 134.56 (C-9), 128.42, 128.36, 127.99, 127.97, 127.90, 127.77, 127.73, 127.20 (*aromatic* C*H*), 116.80 (C-10), 98.58 (C-1^B), 98.01 (C-1^A), 79.59, 75.17, 75.00, 73.42, 73.00, 71.57, 71.32, 70.88, 69.01, 67.56, 66.88, 63.35, 61.24, 59.31, 33.77 (C-8). HR-MS: Calculated for $C_{37}H_{44}N_6O_9$ $[M+Na]^+$: 739.3067, found: 739.3062.

3-Butenyl 2-azido-3,6-di-*O*-benzyl-2-deoxy-α-D-glucopyranosyl-(1→4)-2-azido-3,6-di-*O*-benzyl-2-deoxy-α-D-galactopyranoside (S5)

The reaction was carried out according to the general procedure D using compound **S4** (337 mg, 0.47 mmol), K_2CO_3 (71 mg, 0.52 mmol), KI (78 mg, 0.47 mmol) and $Ph_2BO(CH_2)_2NH_2$ (11 mg, 0.047 mmol). The product was purified by column chromatography (pentane:EtOAc = 10:1). Compound **S5** (363 g, 96% yield) was obtained as colorless syrup. $[\alpha]_D^{25}$ +135.8 (c=2, $CHCl_3$). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.58 – 7.28 (m, 20H, *aromatic* H), 5.93 (ddt, *J* = 17.1, 10.2, 6.7 Hz, 1H, H-9), 5.27 – 5.15 (m, 2H, H-10), 5.10 (d, *J* = 3.6 Hz, 1H, H-1^A), 5.06 (d, *J* = 3.7 Hz, 1H, H-1^B), 5.05 – 4.95 (m, 2H, *PhC*H*H*O), 4.90 (d, *J* = 12.0 Hz, 1H, *PhC*H*H*O), 4.74 – 4.62 (m, 3H), 4.44 – 4.35 (m, 2H), 4.33 – 4.20 (m, 2H), 4.17 – 4.05 (m, 2H), 4.04 – 3.79 (m, 5H), 3.75 – 3.61 (m, 3H), 3.40 (dd, *J* = 10.1, 3.6 Hz, 1H), 3.35 (dd, *J* = 10.3, 3.2 Hz, 1H), 3.24 (dd, *J* = 10.4, 4.4 Hz, 1H, H-6^B), 2.84 (bs, 1H, OH), 2.54 – 2.45 (m, 2H, H-8). ^{13}C NMR (100 MHz, $CDCl_3$) δ 138.13, 137.64, 137.49, 137.39 (*aromatic* C), 134.59 (C-9), 128.88, 128.44, 128.39, 128.35, 128.33, 128.26, 128.02, 127.98, 127.95, 127.75, 127.62, 127.56, 127.14, 127.07 (*aromatic* C*H*), 116.82 (C-10), 98.74 (C-1^B), 98.07 (C-1^A), 79.59 (C-3^B), 75.53 (C-3^A), 74.99, 73.46, 73.25 (3 C*H*$_2$*Ph*), 73.20 (C-4^A), 72.45 (C-4^B), 71.66 (C*H*$_2$*Ph*), 69.96 (C-5^B), 69.09 (C-$6^{B)}$, 69.07 (C-5^A), 67.60 (C-7), 66.85 (C-6^A), 63.27 (C-2^B), 59.42 (C-2^A), 33.81 (C-8). HR-MS: Calculated for $C_{44}H_{50}N_6O_9$ $[M+Na]^+$: 829.3537, found: 829.3532.

3-Butenyl 3-*O*-benzyl-2-deoxy-4,6-di-*tert*-butylsilylidene-2-trifluoroacetamido-α-D-galactopyranosyl-(1→4)-2-azido-3,6-di-*O*-benzyl-2-deoxy-α-D-glucopyranosyl-(1→4)-2-azido-3,6-di-*O*-benzyl-2-deoxy-α-D-galactopyranoside (16)

The reaction was carried out according to the general procedure A. The donor **14** (559 mg, 0.83 mmol) and acceptor **S5** (370 mg, 0.46 mmol) were co-evaporated with toluene (three times). The residue was dissolved in dry 4.5 ml DCM under nitrogen and stirred over fresh flame-dried molecular sieves 4Å. The solution was cooled to 0 ºC, after which TfOH (7.5 µl, 0.083 mmol) was added. The reaction was stirred at 0 ºC for 2 h. Then the reaction was quenched with Et_3N, diluted with DCM, washed with saturated $NaHCO_3$ and brine. The organic phase was dried with anhydrous $MgSO_4$, filtered and concentrated *in vacuo*. The product was purified by silica gel column chromatography (pentane:EtOAc = 8:1). Compound **16** (506 mg, 85% yield) was obtained as yellow syrup. $[\alpha]_D^{25}$ +117.9 (c=1, $CHCl_3$). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.42 – 7.22 (m, 23H, *aromatic* H), 7.18 – 7.12 (m, 2H, *aromatic* H), 6.98 (d, *J* = 9.5 Hz, 1H, NH), 5.89 – 5.72 (m, 1H, H-9), 5.45 (d, *J* = 3.5 Hz, 1H, H-1^C), 5.14 – 5.02 (m, 2H, H-10), 5.01 – 4.97 (m, 2H, H-1^A, 1^B), 4.82 – 4.42 (m, 10H), 4.28 (dd, *J* = 18.5, 3.6 Hz, 3H), 4.04 – 3.79 (m, 8H), 3.71 (dt, *J* = 9.8, 6.8 Hz, 1H, H-7), 3.62 (dd, *J* = 10.9, 3.5 Hz, 1H, H-2^A), 3.60 – 3.51 (m, 3H), 3.47 (dd, *J* = 10.9, 2.6 Hz, 1H), 3.31 (dd, *J* = 10.0, 3.6 Hz, 1H, H-2^B), 3.20 (dd, *J* = 11.5, 2.3 Hz, 1H, H-6), 3.08 (dd, *J* = 11.4, 1.8 Hz, 1H, H-6), 2.37 (qt, *J* = 6.7, 1.4 Hz, 2H, H-8), 1.03 (s, 9H, *C*H$_3$), 1.02 (s, 9H, *C*H$_3$). ^{13}C NMR (100 MHz, $CDCl_3$) δ 157.38 (*a*d, *J* = 37 Hz, *CF$_3$CO*), 138.07, 137.59, 137.45, 137.38, 136.35 (*aromatic* C), 134.66 (C-9), 128.67, 128.65, 128.53, 128.51, 128.47, 128.33, 128.24, 128.17, 127.94, 127.91, 127.80, 127.77, 127.45, 127.25 (*aromatic* C*H*), 117.04 (C-10), 115.89 (*a*d, *J* = 287 Hz, C*F$_3$*), 98.53 (C-1^B), 98.22 (C-1^A), 97.45 (C-1^C), 79.79, 75.58, 75.11, 74.69, 73.70, 73.53 (3 C*H$_2$Ph*), 73.21, 72.94, 72.03, 70.86, 69.74, 69.58, 69.13, 68.59, 67.94 (C-6), 67.86 (C-7), 67.12 (C-6), 66.89 (C-6), 64.39 (C-2^B), 59.72 (C-2^A), 48.67 (C-2^C), 33.96 (C-8), 27.67, 27.36 (2 C*H$_3$*), 23.41, 20.81 (2 C-*Si*). HR-MS: Calculated for $C_{67}H_{82}N_7O_{14}F_3Si$ $[M+Na]^+$: 1316.5539, found: 1316.5533.

3-Butenyl 3-*O*-benzyl-2-deoxy-2-trifluoroacetamido-α-D-galactopyranosyl-(1→4)-2-azido-3,6-di-*O*-benzyl-2-deoxy-α-D-glucopyranosyl-(1→4)-2-azido-3,6-di-*O*-benzyl-2-deoxy-α-D-galactopyranoside (S6)

The reaction was carried out according to the general procedure C using compound **16** (417 g, 0.33 mmol) and HF/pyridine (70%, 134 µl, 5.15 mmol). The product was purified by column chromatography (pentane:EtOAc = 3:2). Compound **S6** (341 mg, 92% yield) was obtained as yellow solid. $[\alpha]_D^{25}$ +132.2 (c=1, $CHCl_3$).^{1}H NMR (400 MHz, $CDCl_3$) δ 7.42 – 7.16 (m, 25H, *aromatic* H), 7.08 (d, *J* = 9.9 Hz, 1H, NH), 5.79 (ddt, *J* = 17.0, 10.2, 6.7 Hz, 1H, H-9), 5.25 (d, *J* = 3.6 Hz, 1H, H-1^C), 5.14 – 5.02 (m, 2H, H-10), 5.01 – 4.95 (m, 2H, H-1^A, 1^B), 4.75 (dd, *J* = 14.9, 11.5 Hz, 2H), 4.62 – 4.46 (m, 6H), 4.40 – 4.23 (m, 4H), 4.06 (d, *J* = 2.9 Hz, 1H), 4.03 – 3.93 (m, 2H), 3.93 – 3.80 (m, 4H), 3.76 – 3.50 (m, 7H), 3.44 (dd, *J* = 10.7, 2.9 Hz, 1H), 3.32 – 3.21 (m, 2H), 3.10 (dd, *J* = 11.6, 2.1 Hz, 1H), 2.94 (s, 1H, OH), 2.43 – 2.30 (m, 2H, H-8). ^{13}C NMR (100 MHz, $CDCl_3$) δ 157.38 (*a*d, *J* = 37 Hz, *CF$_3$CO*), 137.55, 137.34, 137.09, 136.49 (*aromatic* C), 134.63 (C-9), 128.60, 128.52, 128.43, 128.23, 128.17, 128.12, 128.09, 127.98, 127.89, 127.88, 127.83, 127.43, 127.24 (*aromatic* C*H*), 116.98 (C-10), 115.89 (*a*d, *J* = 286 Hz, C*F$_3$*), 98.45 (C-1^B), 98.21 (C-1^A), 97.76 (C-1^C), 79.64, 75.81, 75.39, 74.50, 74.38, 73.62, 73.47, 73.04, 71.98, 70.96, 70.92, 70.60, 69.07, 67.79 (C-7), 67.48 (C-6), 66.90 (C-6), 66.22, 64.23 (C-2), 62.52 (C-6), 59.56 (C-2), 49.25 (C-2^C), 33.90 (C-8). HR-MS: Calculated for $C_{59}H_{66}N_7O_{14}F_3$ $[M+Na]^+$: 1176.4518, found: 1176.4512.

3-Butenyl 3,6-di-*O*-benzyl-2-deoxy-2-trifluoroacetamido-α-D-galactopyranosyl-(1→4)-2-azido-3,6-di-*O*-benzyl-2-deoxy-α-D-glucopyranosyl-(1→4)-2-azido-3,6-di-*O*-benzyl-2-deoxy-α-D-galactopyranoside (S7)

The reaction was carried out according to the general procedure D using compound **S6** (286 mg, 0.25 mmol), K_2CO_3 (38 mg, 0.27 mmol), KI (41 mg, 0.25 mmol) and $Ph_2BO(CH_2)_2NH_2$ (5.6 mg, 0.025 mmol). The product was purified by column chromatography (pentane:EtOAc = 4:1). Compound **S7** (279 mg, 90% yield) was obtained as yellow syrup. $[\alpha]_D^{25}$ +118 (c=0.6, $CHCl_3$). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.48 – 7.13 (m, 30H, *aromatic* H), 7.09 (d, *J* = 9.9 Hz, 1H, NH), 5.78 (ddt, *J* = 17.0, 10.2, 6.7 Hz, 1H, H-9), 5.25 (d, *J* = 3.6 Hz, 1H, H-1^C), 5.13 – 5.00 (m, 2H, H-10), 5.00 – 4.96 (m, 2H, H-1^A, 1^B), 4.81 – 4.66 (m, 2H), 4.63 – 4.21 (m, 13H), 4.17 – 3.79 (m, 9H), 3.75 – 3.42 (m, 8H), 3.40 – 3.23 (m, 2H), 3.14 (dd, *J* = 11.3, 2.1 Hz, 1H), 2.62 (s, *O*H), 2.35 (qt, *J* = 6.7, 1.4 Hz, 2H, H-8). ^{13}C NMR (100 MHz, $CDCl_3$) δ 157.34 (*a*d, *J* = 37 Hz, *CF$_3$CO*), 137.90, 137.74, 137.35, 137.32, 137.23, 136.51 (*aromatic* C), 134.63 (C-9), 128.58, 128.54, 128.48, 128.43, 128.36, 128.34, 128.22, 128.14, 128.07, 128.03, 127.94, 127.90, 127.86, 127.82, 127.81, 127.76, 127.72, 127.69, 127.39, 127.33 (*aromatic* C*H*), 116.96 (*a*d, *J* = 286 Hz, C*F$_3$*), 98.49 (C-1^B), 98.18 (C-1^A), 97.91 (C-$^{1C)}$, 79.59, 76.01, 75.13, 74.70, 74.53, 73.70, 73.60, 73.17, 73.03, 71.84, 70.90, 70.87, 69.63, 69.06, 68.81, 67.75, 67.69, 66.93, 65.22, 64.27 (C-2), 59.55 (C-2), 49.40 (C-2^C), 33.89 (C-8). HR-MS: Calculated for $C_{66}H_{72}N_7O_{14}F_3$ $[M+Na]^+$: 1266.4987, found: 1266.4982.

3-Butenyl 2-azido-3-*O*-benzyl-2-deoxy-4,6-di-*tert*-butylsilylidene-α-D-galactopyranosyl-(1→4)-3,6-di-*O*-benzyl-2-deoxy-2-trifluoroacetamido-α-D-galactopyranosyl-(1→4)-2-azido-3,6-di-*O*-benzyl-2-deoxy-α-D-glucopyranosyl-(1→4)-2-azido-3,6-di-*O*-benzyl-2-deoxy-α-D-galactopyranoside (17)

The reaction was carried out according to the general procedure A. The donor **13** (535 mg, 0.88 mmol) and acceptor **S7** (366 mg, 0.29 mmol) were co-evaporated with toluene (three times). The residue was dissolved in dry 3 ml DCM under nitrogen and stirred over fresh flame-dried molecular sieves 4Å. The solution was cooled to 0 ºC, after which TfOH (8 µl, 0.088 mmol) was added. The reaction was stirred at 0 ºC for 2 h. Then the reaction was quenched with Et_3N, diluted with DCM, washed with saturated $NaHCO_3$ and brine. The organic phase was dried with anhydrous $MgSO_4$, filtered and concentrated *in vacuo*. The product was purified by silica gel column chromatography (pentane:EtOAc = 6:1). Compound **17** (343 mg, 70% yield) was obtained as yellow solid. $[\alpha]_D^{25}$ +159.3 (c=1, $CHCl_3$). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.47 – 7.12 (m, 35H, *aromatic* H), 7.05 (d, *J* = 10.0 Hz, 1H, NH), 5.79 (ddt, *J* = 17.0, 10.2, 6.8 Hz, 1H, H-9), 5.36 (d, *J* = 3.6 Hz, 1H, H-1C), 5.13 – 5.02 (m, 2H, H-10), 5.01 – 4.97 (m, 2H, 2xH-1), 4.94 (d, *J* = 3.6 Hz, 1H, H-1), 4.81 – 4.52 (m, 10H), 4.50 (d, *J* = 2.9 Hz, 1H), 4.45 – 4.36 (m, 2H), 4.35 – 4.21 (m, 5H), 4.10 – 3.79 (m, 11H), 3.77 – 3.45 (m, 8H), 3.38 (dd, *J* = 8.3, 5.0 Hz, 1H), 3.34 – 3.25 (m, 2H), 3.14 (dd, *J* = 11.5, 1.9 Hz, 1H), 2.41 – 2.32 (m, 2H, H-8), 1.02 (s, 9H, *C*H$_3$), 0.96 (s, 9H, *C*H$_3$). ^{13}C NMR (100 MHz, $CDCl_3$) δ 157.52 (*a*d, *J* = 37 Hz, *CF$_3$CO*), 137.94, 137.39, 137.35, 137.29, 137.23, 136.42 (*aromatic* C), 134.66 (C-9), 128.65, 128.63, 128.60, 128.55, 128.49, 128.46, 128.30, 128.22, 128.17, 128.14, 127.99, 127.79, 127.76, 127.68, 127.64, 127.33, 126.21, 124.43, 123.56 (*aromatic* C*H*), 117.04 (C-10), 115.94 (*a*d, *J* = 286 Hz, C*F$_3$*), 98.85 (C-1), 98.58 (C-1), 98.28 (C-1), 97.75 (C-1C), 79.78, 76.20, 75.66, 75.39, 74.55, 73.91, 73.69, 73.30, 73.06, 72.00, 71.03, 70.91, 70.64, 70.61, 70.31, 69.61, 69.11, 67.85, 67.57, 67.08, 66.94, 66.63, 64.32, 59.58, 58.51, 49.73

(4 C-2), 33.96 (C-8), 27.64, 27.47 (2 CH_3), 23.31, 20.77 (2 C-*Si*). ^{13}C-HMBC ($CDCl_3$, 100 MHz): 98.85 ($J_{C1,H1}$ = 174 Hz), 98.58 ($J_{C1,H1}$ = 171 Hz), 97.75 ($J_{C1,H1}$ = 171 Hz). HR-MS: Calculated for $C_{87}H_{103}N_{10}O_{18}F_3Si$ $[M+Na]^+$: 1683.7071, found: 1683.7065.

3-Butenyl 2-azido-3-*O*-benzyl-2-deoxy-α-D-galactopyranosyl-(1→4)-3,6-di-*O*-benzyl-2-deoxy-2-trifluoroacetamido-α-D-galactopyranosyl-(1→4)-2-azido-3,6-di-*O*-benzyl-2-deoxy-α-D-glucopyranosyl-(1→4)-2-azido-3,6-di-*O*-benzyl-2-deoxy-α-D-galactopyranoside (S8)

The reaction was carried out according to the general procedure C using compound **17** (112 mg, 0.067 mmol) and HF/pyridine (70%, 28 µl, 1.1 mmol). The product was purified by column chromatography (pentane:EtOAc = 2:1). Compound **S8** (89 mg, 87% yield) was obtained as yellow syrup. $[\alpha]_D^{25}$ +133.7 (c=0.7, $CHCl_3$). ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.63 – 7.27 (m, 35H, *aromatic* H), 7.23 (d, *J* = 9.9 Hz, 1H, NH), 5.89 (ddt, *J* = 17.0, 10.2, 6.8 Hz, 1H, H-9), 5.44 (d, *J* = 3.6 Hz, 1H, H-1^C), 5.23 – 5.12 (m, 2H, H-10), 5.12 – 5.08 (m, 2H, 2xH-1), 5.06 (d, *J* = 3.6 Hz, 1H, H-1), 4.88 (d, *J* = 11.1 Hz, 1H), 4.81 (dd, *J* = 12.1, 4.0 Hz, 2H), 4.76 (s, 2H), 4.75 – 4.69 (m, 1H), 4.68 – 4.59 (m, 4H), 4.53 – 4.44 (m, 3H), 4.43 – 4.37 (m, 2H), 4.37 – 4.30 (m, 2H), 4.30 – 4.24 (m, 1H), 4.24 – 4.18 (m, 1H), 4.15 – 3.92 (m, 9H), 3.85 – 3.75 (m, 2H), 3.71 (dd, *J* = 10.9, 3.5 Hz, 1H), 3.69 – 3.57 (m, 3H), 3.54 – 3.43 (m, 2H), 3.44 – 3.33 (m, 3H), 3.24 (dd, *J* = 11.4, 2.0 Hz, 1H), 3.03 (s, 1H, OH), 2.46 (q, *J* = 6.8 Hz, 2H, H-8). ^{13}C NMR (125 MHz, $CDCl_3$) δ 157.50 (*a*d, *J* = 37 Hz, *C*F_3*C*O), 137.79, 137.34, 137.27, 137.20, 137.11, 136.38 (*aromatic* C), 134.54 (C-9), 128.51, 128.46, 128.44, 128.41, 128.31, 128.20, 128.07, 128.05, 127.99, 127.84, 127.73, 127.71, 127.62, 127.57, 127.19, 126.44 (*aromatic* C*H*), 116.86 (C-10), 115.77 (*a*d, *J* = 286 Hz, CF_3), 99.15 (C-1), 98.43 (C-1), 98.14 (C-1), 97.61 (C-1^C), 79.58, 76.19, 75.93, 75.21, 74.23, 73.91, 73.51, 73.46, 73.15, 72.97, 72.03, 71.84, 71.64, 71.02, 70.73, 70.33, 69.16, 68.96, 67.69, 67.66, 67.33 (C-7), 66.81, 66.63 (2 C-6), 64.13 (C-2), 62.37 (C-6), 59.42, 59.36 (2 C-2), 49.73 (C-2^C), 33.81 (C-8). HR-MS: Calculated for $C_{79}H_{87}N_{10}O_{18}F_3$ $[M+Na]^+$: 1543.6050, found: 1543.6044.

3-Butenyl 2-azido-3,6-di-*O*-benzyl-2-deoxy-α-D-galactopyranosyl-(1→4)-3,6-di-*O*-benzyl-2-deoxy-2-trifluoroacetamido-α-D-galactopyranosyl-(1→4)-2-azido-3,6-di-*O*-benzyl-2-deoxy-α-D-glucopyranosyl-(1→4)-2-azido-3,6-di-*O*-benzyl-2-deoxy-α-D-galactopyranoside (S9)

The reaction was carried out according to the general procedure D using compound **S8** (129 mg, 0.085 mmol), K_2CO_3 (13 mg, 0.09 mmol), KI (14 mg, 0.085 mmol) and $Ph_2BO(CH_2)_2NH_2$ (1.9 mg, 0.0085 mmol). The product was purified by column chromatography (pentane:EtOAc = 4:1). Compound **S9** (129 mg, 94% yield) was obtained as yellow syrup. $[\alpha]_D^{25}$ +136.4 (c=0.5, $CHCl_3$). ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.62 – 7.23 (m, 40H, *aromatic* H), 7.17 (d, *J* = 9.9 Hz, 1H, NH), 5.92 (ddt, *J* = 17.0, 10.3, 6.8 Hz, 1H, H-9), 5.50 (d, *J* = 3.6 Hz, 1H, H-1^C), 5.25 – 5.16 (m, 2H, H-10), 5.15 – 5.10 (m, 3H, 3xH-1), 4.90 (d, *J* = 11.6 Hz, 2H, *PhC*H*H*O), 4.87 – 4.81 (m, 2H, *PhC*H*H*O, H-2^C), 4.81 – 4.74 (m, 2H), 4.72 – 4.61 (m, 5H), 4.57 – 4.47 (m, 3H), 4.46 – 4.39 (m, 4H), 4.37 (d, *J* = 2.9 Hz, 1H), 4.35 – 4.25 (m, 2H), 4.22 – 3.93 (m, 12H), 3.83 (dt, *J* = 9.8, 6.9 Hz, 1H, H-7), 3.76 (dd, *J* = 10.9, 3.5 Hz, 1H, H-2), 3.72 – 3.60 (m, 3H), 3.59 – 3.51 (m, 1H), 3.50 – 3.36 (m, 4H), 3.32 (dd, *J* = 10.0, 3.9 Hz, 1H), 3.29 – 3.22 (m, 1H), 2.48 (q, *J* = 6.9 Hz, 2H, H-8). ^{13}C NMR (125 MHz, $CDCl_3$) δ 157.25 (*a*d, *J* = 37 Hz, *C*F_3*C*O), 137.73, 137.53, 137.45,

137.38, 137.31, 137.22, 137.19, 136.32 (*aromatic* C), 134.50 (C-9), 128.46, 128.42, 128.38, 128.34, 128.32, 128.26, 128.18, 128.16, 128.03, 128.00, 127.98, 127.95, 127.89, 127.76, 127.71, 127.58, 127.56, 127.53, 127.51, 127.45, 127.28, 127.08, 126.71, 126.39 (*aromatic* C*H*), 116.85 (C-10), 115.72 (*a*d, *J* = 286 Hz, C*F*$_3$), 99.35 (C-1), 98.37 (C-1), 98.08 (C-1), 97.48 (C-1^C), 79.52, 76.15, 76.04, 75.20, 74.20 (C*H*$_2$*Ph*), 73.70, 73.45 (C*H*$_2$*Ph*), 73.41 (C*H*$_2$*Ph*), 73.20 (C*H*$_2$*Ph*), 73.10 (C*H*$_2$*Ph*), 72.89, 71.99, 71.75 (C*H*$_2$*Ph*), 71.16 (C*H*$_2$*Ph*), 70.99 (C*H*$_2$*Ph*), 70.69, 70.24, 69.76 (C-6), 68.92, 68.21, 67.63 (C-7), 66.84, 66.76 (C-6), 66.57 (C-6), 64.79 (C-6), 64.07 (C-2), 59.40 (C-2), 59.20 (C-2), 49.60 (C-2^C), 33.77 (C-8). HR-MS: Calculated for $C_{86}H_{93}N_{10}O_{18}F_3$ $[M+Na]^+$: 1633.6519, found: 1633.6514.

Pentasaccharide 18

The reaction was carried out according to the general procedure B using donor **14** (586 mg, 0.87 mmol) and acceptor **S9** (558 mg, 0.35 mmol). The product was purified by column chromatography (pentane:EtOAc = 6:1). Compound **S8** (642 mg, 88% yield) was obtained as yellow syrup. $[\alpha]_D^{25}$ +134.2 (c=0.6, $CHCl_3$). ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.38 – 7.18 (m, 41H, *aromatic* H), 7.17 – 7.15 (m, 2H, *aromatic* H), 7.05 – 7.01 (m, 2H, *aromatic* H), 6.99 (d, *J* = 10.0 Hz, 1H, NH), 6.23 (d, *J* = 9.5 Hz, 1H, NH), 5.79 (ddt, *J* = 17.1, 10.3, 6.8 Hz, 1H, H-9), 5.34 (d, *J* = 3.6 Hz, 1H, H-1), 5.12 – 5.02 (m, 2H, H-10), 4.99 (d, *J* = 3.6 Hz, 3H, 3xH-1), 4.82 (d, *J* = 3.8 Hz, 1H, H-1), 4.80 – 4.68 (m, 5H), 4.65 – 4.33 (m, 13H), 4.32 – 4.17 (m, 5H), 4.05 – 3.80 (m, 11H), 3.76 – 3.53 (m, 7H), 3.50 (dd, *J* = 11.1, 2.5 Hz, 1H), 3.44 (dd, *J* = 12.7, 2.1 Hz, 1H), 3.40 (dd, *J* = 8.3, 4.9 Hz, 1H), 3.37 – 3.28 (m, 2H), 3.26 (dd, *J* = 11.5, 2.1 Hz, 1H), 3.12 (dd, *J* = 11.5, 1.9 Hz, 1H), 2.96 (t, *J* = 9.5 Hz, 1H), 2.86 (dd, *J* = 8.9, 5.4 Hz, 1H), 2.41 – 2.32 (m, 2H, H-8), 1.06 (s, 9H, *C*H$_3$), 0.97 (s, 9H, *C*H$_3$). ^{13}C NMR (125 MHz, $CDCl_3$) δ 157.41 (*a*d, *J* = 37 Hz, *CF*$_3$*CO*), 156.57 (*a*d, *J* = 37 Hz, *CF*$_3$*CO*), 138.03, 137.94, 137.61, 137.56, 137.41, 137.36, 137.28, 136.92, 136.44 (*aromatic* C), 134.67 (C-9), 128.65, 128.62, 128.60, 128.54, 128.49, 128.44, 128.34, 128.22, 128.20, 128.16, 128.14, 128.12, 127.97, 127.93, 127.80, 127.77, 127.74, 127.72, 127.64, 127.34, 126.83, 126.41 (*aromatic* C*H*), 117.04 (C-10), 115.92 (*a*d, *J* = 286 Hz, 2xC*F*$_3$), 99.03 (C-1), 98.56 (C-1), 98.29 (C-1), 97.62 (C-1), 96.74 (C-1), 79.79, 76.46, 75.98, 75.42, 74.90, 74.55, 73.78, 73.69, 73.48, 73.31, 73.11, 73.09, 72.02, 71.95, 71.63, 71.46, 70.90, 70.17, 69.55, 69.51, 69.39, 69.13, 68.79, 67.87 (C-7), 67.79, 67.02, 66.95, 66.76, 65.76, 64.40, 60.27, 59.60, 49.67, 48.25 (5 C-2), 33.96, 27.64 (2 C*H*$_3$), 27.46, 23.35 (2 C-*Si*). ^{13}C-HMBC ($CDCl_3$, 125 MHz): 99.03 ($J_{C1,H1}$ = 171 Hz), 98.56 ($J_{C1,H1}$ = 173 Hz), 98.29 ($J_{C1,H1}$ = 170 Hz), 97.62 ($J_{C1,H1}$ = 176 Hz), 96.74 ($J_{C1,H1}$ = 174 Hz). HR-MS: Calculated for $C_{109}H_{125}N_{11}O_{23}F_6Si$ $[M+Na]^+$: 2120.8521, found: 2120.8517.

Pentasaccharide S10

The reaction was carried out according to the general procedure C using compound **18** (641 mg, 0.31 mmol) and HF/pyridine (70%, 130 µl, 5.0 mmol). The product was purified by column chromatography (pentane:EtOAc = 3:2). Compound **S10** (547 mg, 91% yield) was obtained as white solid. $[\alpha]_D^{25}$ +164.8 (c=0.4, $CHCl_3$). ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.48 – 7.21 (m, 43H, *aromatic* H), 7.14 (dd, *J* = 8.1, 1.6 Hz, 3H), 6.53 (d, *J* = 9.5 Hz, 1H, NH), 5.87 (ddt, *J* = 17.0, 10.3, 6.8 Hz, 1H, H-9), 5.45 (d, *J* = 3.6 Hz, 1H, H-1), 5.21 – 5.10 (m, 2H, H-10), 5.09 – 5.05 (m, 2H, 2xH-1), 5.02 (d, *J* = 3.6 Hz, 1H, H-1), 4.92 (d, *J* = 3.7 Hz, 1H, H-1), 4.88 – 4.76 (m, 3H), 4.76 – 4.58 (m, 8H), 4.52 –

4.41 (m, 5H), 4.41 – 4.34 (m, 4H), 4.31 (d, *J* = 2.4 Hz, 1H), 4.26 (d, *J* = 12.4 Hz, 1H), 4.18 (d, *J* = 1.9 Hz, 1H), 4.12 – 3.89 (m, 12H), 3.82 (d, *J* = 11.8 Hz, 1H), 3.81 – 3.75 (m, 1H), 3.69 (dd, *J* = 10.9, 3.5 Hz, 1H), 3.67 – 3.33 (m, 11H), 3.26 – 3.18 (m, 1H), 3.11 – 2.95 (m, 3H), 2.44 (q, *J* = 6.8 Hz, 2H, H-8). ^{13}C NMR (125 MHz, $CDCl_3$) δ 157.34 (*a*d, *J* = 37 Hz, *CF$_3$CO*), 156.65 (*a*d, *J* = 37 Hz, *CF$_3$CO*), 137.88, 137.56, 137.39, 137.34, 137.26, 137.14, 136.98, 136.38 (*aromatic* C), 134.60 (C-9), 128.58, 128.55, 128.51, 128.46, 128.36, 128.34, 128.14, 128.11, 128.06, 128.03, 128.01, 127.96, 127.89, 127.86, 127.84, 127.82, 127.78, 127.67, 127.56, 127.28, 127.11, 126.48 (*aromatic* C*H*), 116.97 (C-10), 115.88 (*a*d, *J* = 286 Hz, C*F$_3$*), 98.97, 98.52, 98.20, 97.57, 96.90 (5 C-1), 79.75, 76.18, 75.85, 75.25, 75.22, 74.43, 73.63, 73.59, 73.34, 73.23, 73.09, 73.03, 72.02, 71.89, 71.77, 71.37, 70.81, 70.64, 70.52, 70.08, 69.32, 69.04, 68.70, 67.76 (C-7), 67.72, 66.86, 66.67 (3 C-6), 66.30, 65.81 (C-6), 64.29 (C-2), 62.37 (C-6), 60.17, 59.48, 49.58, 48.77 (4 C-2), 33.88 (C-8). HR-MS: Calculated for $C_{101}H_{109}N_{11}O_{23}F_6$ $[M+Na]^+$: 1980.7500, found: 1980.7494.

Pentasaccharide S11

The reaction was carried out according to the general procedure D using compound **S10** (546 mg, 0.28 mmol), K_2CO_3 (42.6 mg), KI (46.5 mg) and $Ph_2BO(CH_2)_2NH_2$ (6.3 mg). The product was purified by column chromatography (pentane:EtOAc = 4:1). Compound **S11** (531 mg, 92% yield) was obtained as white foam. $[\alpha]_D^{25}$ +127 (c=0.3, $CHCl_3$). ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.44 – 7.22 (m, 48H, *aromatic* H), 7.19 – 7.14 (m, 2H, *aromatic* H), 7.10 (d, *J* = 9.9 Hz, 1H, NH), 6.52 (d, *J* = 9.6 Hz, 1H, NH), 5.89 (ddt, *J* = 17.0, 10.2, 6.8 Hz, 1H, H-9), 5.44 (d, *J* = 3.6 Hz, 1H, H-1), 5.22 – 5.12 (m, 2H, H-10), 5.08 (t, *J* = 3.1 Hz, 2H, 2xH-1), 5.04 (d, *J* = 3.7 Hz, 1H, H-1), 4.92 (d, *J* = 3.8 Hz, 1H), 4.90 (d, *J* = 4.5 Hz, 1H), 4.86 (d, *J* = 10.9 Hz, 1H), 4.83 – 4.73 (m, 3H), 4.73 – 4.55 (m, 7H), 4.53 – 4.24 (m, 15H), 4.13 – 3.90 (m, 11H), 3.86 (d, *J* = 11.7 Hz, 1H), 3.80 (dt, *J* = 9.8, 6.9 Hz, 1H), 3.71 (dd, *J* = 10.9, 3.5 Hz, 1H), 3.68 – 3.62 (m, 3H), 3.61 – 3.54 (m, 2H), 3.52 – 3.43 (m, 2H), 3.39 (dd, *J* = 10.2, 3.6 Hz, 1H), 3.35 (dd, *J* = 11.5, 2.1 Hz, 1H), 3.30 (dd, *J* = 9.5, 4.5 Hz, 1H), 3.22 (dd, *J* = 11.4, 1.9 Hz, 1H), 3.12 (t, *J* = 9.5 Hz, 1H), 3.07 – 3.00 (m, 2H), 2.46 (qt, *J* = 6.8, 1.4 Hz, 2H, H-8). ^{13}C NMR (125 MHz, $CDCl_3$) δ 157.28 (*a*d, *J* = 37 Hz, *CF$_3$CO*), 156.60 (*a*d, *J* = 37 Hz, *CF$_3$CO*), 137.85, 137.68, 137.53, 137.41, 137.38, 137.33, 137.28, 137.04, 136.37 (*aromatic* C), 134.60 (C-9), 128.58, 128.52, 128.50, 128.48, 128.46, 128.42, 128.36, 128.33, 128.15, 128.12, 128.06, 128.04, 127.89, 127.87, 127.78, 127.76, 127.74, 127.69, 127.67, 127.61, 127.57, 127.23, 126.50 (*aromatic* C*H*), 116.97 (C-10), 115.89 (*a*d, *J* = 286 Hz, C*F$_3$*), 99.02, 98.48, 98.20, 97.55, 97.08 (5 C-1), 79.70, 76.16, 75.77, 75.44, 75.34, 74.43, 73.67, 73.60, 73.46, 73.35, 73.22, 73.00, 72.96, 71.90, 71.87, 71.79, 71.33, 70.79, 70.57, 70.45, 70.08, 69.09 (C-6), 69.03, 68.79, 68.60, 67.77 (C-7), 67.74, 66.86, 66.66, 65.76 (4 C-6), 65.63, 64.27, 60.00, 59.51, 49.59, 48.86 (5 C-2), 33.88 (C-8). HR-MS: Calculated for $C_{108}H_{115}N_{11}O_{23}F_6$ $[M+Na]^+$: 2070.7969, found: 2070.7964.

Hexasaccharide 19

The reaction was carried out according to the general procedure B using donor **13** (164 mg, 0.27 mmol) and acceptor **S11** (185 mg, 0.09 mmol). The product was purified by column chromatography (pentane:EtOAc = 6:1). Compound **19** (546 mg, 82% yield) was obtained as yellow syrup. $[\alpha]_D^{25}$ +155.0 (c=0.4, $CHCl_3$). ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.57 – 7.52 (m, 4H, *aromatic* H), 7.47 – 7.25 (m, 50H, *aromatic* H), 7.18 – 7.14 (m, 2H, *aromatic*

H), 7.12 (d, *J* = 9.9 Hz, 1H, NH), 6.40 (d, *J* = 9.8 Hz, 1H, NH), 5.90 (ddt, *J* = 17.0, 10.2, 6.8 Hz, 1H, H-9), 5.45 (d, *J* = 3.6 Hz, 1H, H-1), 5.24 – 5.13 (m, 2H, H-10), 5.10 (d, *J* = 3.6 Hz, 2H, 2xH-1), 5.04 (dd, *J* = 7.9, 4.6 Hz, 3H, 2xH-1), 4.91 (d, *J* = 3.8 Hz, 1H, H-1), 4.90 – 4.60 (m, 14H), 4.57 – 4.22 (m, 15H), 4.15 – 3.92 (m, 14H), 3.88 – 3.57 (m, 12H), 3.55 – 3.48 (m, 1H), 3.46 – 3.39 (m, 2H), 3.39 – 3.33 (m, 1H), 3.26 – 3.20 (m, 1H), 3.16 (dd, *J* = 8.3, 5.1 Hz, 1H), 3.08 (t, *J* = 9.4 Hz, 1H), 3.00 (dd, *J* = 9.0, 5.4 Hz, 1H), 2.50 – 2.43 (m, 2H, H-8), 1.13 (s, 9H, *C*H_3), 1.09 (s, 9H, *C*H_3). ^{13}C NMR (125 MHz, $CDCl_3$) δ 157.33 (*a*d, *J* = 37 Hz, *C*F_3*C*O), 156.56 (*a*d, *J* = 37 Hz, *C*F_3*C*O), 137.92, 137.85, 137.61, 137.58, 137.43, 137.33, 137.30, 137.17, 136.92, 136.34 (*aromatic* C), 134.60 (C-9), 128.65, 128.60, 128.54, 128.51, 128.46, 128.44, 128.37, 128.24, 128.17, 128.16, 128.08, 128.06, 128.02, 127.98, 127.96, 127.88, 127.75, 127.69, 127.59, 127.56, 127.23, 126.85, 126.70, 126.46 (*aromatic* C*H*), 117.00 (C-10), 115.88 (*a*d, *J* = 286 Hz, C*F*$_3$), 99.13, 98.50, 98.43, 98.22, 97.64, 97.04 (6 C-1), 79.67, 76.30, 76.23, 75.90, 75.35, 75.24, 74.49, 73.85, 73.62, 73.36, 73.23, 73.09, 73.00, 72.03, 71.92, 71.63, 71.35, 70.83, 70.63, 70.60, 70.30, 70.21, 70.11, 69.64, 69.55, 69.04, 68.77, 67.79 (C-7), 67.71 (C-6), 67.42, 67.14, 66.85, 66.70, 66.38, 65.56 (5 C-6), 64.29, 59.97, 59.53, 58.46, 49.64, 49.11 (6 C-2), 33.90 (C-8), 27.60, 27.43 (2 C*H*$_3$), 23.27, 20.73 (2 C-*Si*). ^{13}C-HMBC ($CDCl_3$, 125 MHz): 99.13 ($J_{C1,H1}$ = 171 Hz), 98.50 ($J_{C1,H1}$ = 173 Hz), 98.43 ($J_{C1,H1}$ = 172 Hz), 98.22 ($J_{C1,H1}$ = 171 Hz), 97.64 ($J_{C1,H1}$ = 174 Hz), 97.04 ($J_{C1,H1}$ = 175 Hz).

Hexasaccharide S12

The reaction was carried out according to the general procedure C using compound **19** (215 mg, 0.087 mmol) and HF/pyridine (70%, 36 µl, 1.39 mmol). The product was purified by column chromatography (pentane:EtOAc = 3:2). Compound **S12** (177 mg, 87% yield) was obtained as white solid. ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.39 – 7.12 (m, 53H, *aromatic* H), 7.08 – 7.02 (m, 3H), 6.42 (d, *J* = 9.7 Hz, 1H, NH), 5.79 (ddt, *J* = 17.1, 10.2, 6.8 Hz, 1H, H-9), 5.33 (d, *J* = 3.6 Hz, 1H, H-1), 5.13 – 5.02 (m, 2H, H-10), 4.98 (t, *J* = 2.8 Hz, 2H, 2xH-1), 4.92 (dd, *J* = 5.7, 3.7 Hz, 2H, 2xH-1), 4.89 (d, *J* = 12.3 Hz, 1H), 4.81 (d, *J* = 3.8 Hz, 1H, H-1), 4.79 – 4.73 (m, 2H), 4.74 – 4.64 (m, 4H), 4.63 – 4.48 (m, 6H), 4.45 – 4.13 (m, 16H), 4.03 – 3.81 (m, 14H), 3.80 – 3.64 (m, 4H), 3.61 (dd, *J* = 10.9, 3.5 Hz, 1H), 3.58 – 3.36 (m, 7H), 3.34 – 3.22 (m, 3H), 3.16 – 3.05 (m, 2H), 2.99 (t, *J* = 9.5 Hz, 1H), 2.90 (dd, *J* = 9.2, 5.4 Hz, 1H), 2.78 (bs, 1H, OH), 2.36 (q, *J* = 6.8 Hz, 2H, H-8), 2.28 (bs, 1H, OH). ^{13}C NMR (125 MHz, $CDCl_3$) δ 157.34 (*a*d, *J* = 37 Hz, *C*F_3*C*O), 156.82 (*a*d, *J* = 37 Hz, *C*F_3*C*O), 137.85, 137.58, 137.52, 137.47, 137.45, 137.42, 137.33, 137.28, 137.16, 137.03, 136.36 (*aromatic* C), 134.61 (C-9), 128.64, 128.60, 128.53, 128.52, 128.50, 128.47, 128.40, 128.38, 128.34, 128.29, 128.17, 128.13, 128.09, 128.03, 127.97, 127.95, 127.90, 127.87, 127.86, 127.77, 127.76, 127.69, 127.63, 127.59, 127.25, 127.13, 126.86, 126.50 (*aromatic* C*H*), 116.99 (C-10), 115.87 (*a*d, *J* = 286 Hz, C*F*$_3$), 99.13, 98.94, 98.50, 98.21, 97.64, 97.05 (6 C-1), 79.69, 76.62, 76.27, 76.12, 75.33, 75.22, 74.47, 73.82, 73.62, 73.36, 73.23, 73.15, 73.03, 72.08, 71.93, 71.89, 71.83, 71.71, 71.37, 70.56, 70.10, 69.71, 69.18, 69.04, 68.74, 67.79 (C-7), 67.72 (C-6), 67.47, 66.86, 66.71, 66.52, 65.64 (4 C-6), 64.28 (C-2), 62.61 (C-6), 59.98, 59.51, 59.48, 49.63, 49.32 (5 C-2), 33.90 (C-8).

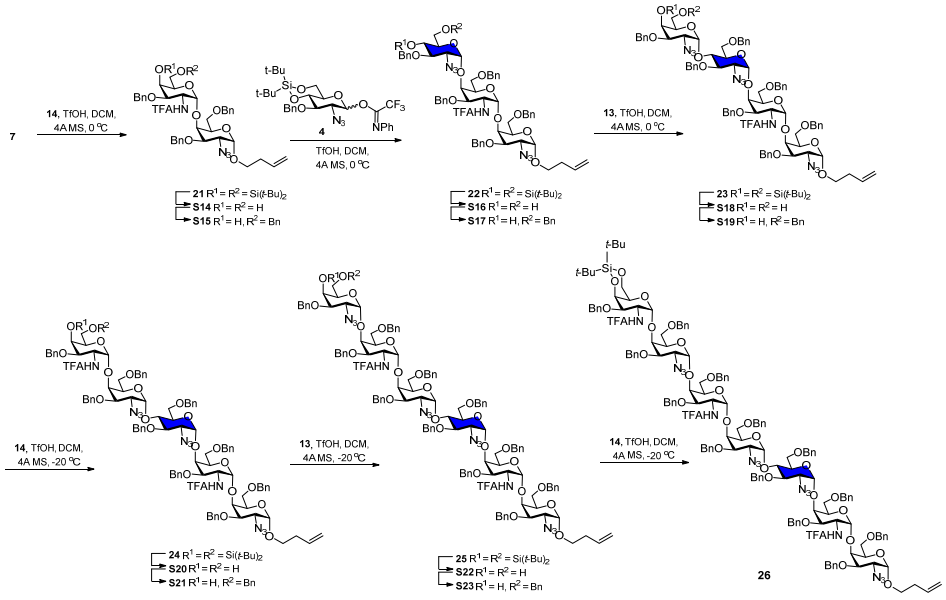
Hexasaccharide S13

The reaction was carried out according to the general procedure D using compound **S12** (173 mg, 0.074 mmol), K_2CO_3 (11 mg, 0.081 mmol), KI (12 mg, 0.074 mmol) and $Ph_2BO(CH_2)_2NH_2$ (1.7 mg, 0.0074 mmol). The product was purified by column chromatography (pentane:EtOAc = 4:1). Compound **S13** (170 mg, 95% yield) was obtained as white foam. ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.46 – 7.39 (m, 4H, *aromatic* H), 7.36 – 7.14 (m, 54H, *aromatic* H), 7.08 – 7.04 (m, 2H, *aromatic* H), 7.02 (d, *J* = 9.9 Hz, 1H, NH), 6.35 (d, *J* = 9.7 Hz, 1H, NH), 5.79 (ddt, *J* = 17.1, 10.2, 6.8 Hz, 1H, H-9), 5.33 (d, *J* = 3.6 Hz, 1H, H-1), 5.12 – 5.02 (m, 2H, H-10), 5.01 – 4.96 (m, 2H), 4.94 (t, *J* = 3.8 Hz, 2H, 2xH-1), 4.89 (d, *J* = 12.3 Hz, 1H, *PhC*H*H*O), 4.80 (d, *J* = 3.8 Hz, 1H, H-1), 4.78 – 4.50 (m, 12H), 4.46 – 4.21 (m, 15H), 4.18 – 4.13 (m, 2H), 4.02 – 3.74 (m, 17H), 3.70 (dt, *J* = 9.8, 6.9 Hz, 1H), 3.62 – 3.37 (m, 7H), 3.33 – 3.21 (m, 4H), 3.15 – 3.04 (m, 3H), 2.99 (t, *J* = 9.4 Hz, 1H), 2.91 (dd, *J* = 9.1, 5.4 Hz, 1H), 2.36 (q, *J* = 6.8 Hz, 2H, H-8). ^{13}C NMR (125 MHz, $CDCl_3$) δ 157.32 (*a*d, *J* = 37 Hz, *CF*$_3$*C*O), 156.61 (*a*d, *J* = 37 Hz, *CF*$_3$*C*O), 137.84, 137.68, 137.60, 137.58, 137.55, 137.47, 137.44, 137.39, 137.32, 137.28, 137.02, 136.35 (*aromatic* C), 134.60 (C-9), 128.58, 128.52, 128.50, 128.48, 128.46, 128.39, 128.36, 128.33, 128.32, 128.31, 128.16, 128.12, 128.07, 128.01, 127.96, 127.94, 127.89, 127.86, 127.75, 127.72, 127.67, 127.65, 127.58, 127.23, 127.16, 126.80, 126.52 (*aromatic* C*H*), 116.98 (C-10), 115.88 (*a*d, *J* = 286 Hz, C*F*$_3$), 99.10, 99.00, 98.48, 98.20, 97.60, 97.11 (6 C-1), 79.67, 76.58, 76.19, 76.16, 75.33, 75.12, 74.45, 73.79, 73.60, 73.38, 73.35, 73.22, 73.13, 73.01, 72.98, 72.00, 71.91, 71.69, 71.59, 71.44, 71.32, 70.81, 70.78, 70.49, 70.09, 69.86, 69.65, 69.03, 68.79, 68.21, 67.78, 67.72, 66.97, 66.85, 66.71, 66.50, 65.65, 64.26, 59.97, 59.51, 59.33, 49.62, 49.23 (6 C-2), 33.89 (C-8).

Heptasaccharide 20

The reaction was carried out according to the general procedure B using donor **14** (142 mg, 0.21 mmol) and acceptor **S13** (170 mg, 0.07 mmol). The product was purified by column chromatography (pentane:EtOAc = 6:1). Compound **20** (165 mg, 81% yield) was obtained as yellow syrup. $[\alpha]_D^{25}$ +176 (c=0.5, $CHCl_3$). ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.47 – 7.18 (m, 61H, *aromatic* H), 7.16 – 7.12 (m, 2H, *aromatic* H), 7.11 – 7.06 (m, 2H, *aromatic* H), 7.05 (d, *J* = 9.7 Hz, 1H, NH), 6.34 (t, *J* = 12.4, 9.6 Hz, 2H, 2xNH), 5.92 – 5.78 (m, 1H, H-9), 5.38 (d, *J* = 3.6 Hz, 1H, H-1), 5.18 – 5.08 (m, 2H, H-10), 5.06 (d, *J* = 3.6 Hz, 1H, H-1), 5.05 – 5.02 (m, 2H, 2xH-1), 4.99 (d, *J* = 3.7 Hz, 1H, H-1), 4.95 (d, *J* = 12.3 Hz, 1H, *PhC*H*H*O), 4.87 (d, *J* = 3.7 Hz, 1H, H-1), 4.85 (d, *J* = 3.7 Hz, 1H, H-1), 4.83 – 4.24 (m, 32H), 4.22 (d, *J* = 12.4 Hz, 1H), 4.09 – 3.42 (m, 31H), 3.40 – 3.27 (m, 4H), 3.21 – 2.92 (m, 6H), 2.42 (qt, *J* = 6.7, 1.4 Hz, 2H, H-8), 1.11 (s, 9H, *C*H$_3$), 1.03 (s, 9H, *C*H$_3$). ^{13}C NMR (125 MHz, $CDCl_3$) δ 157.40 (*a*d, *J* = 37 Hz, *CF*$_3$*C*O), 156.65 (*a*d, *J* = 37 Hz, *CF*$_3$*C*O), 137.97, 137.92, 137.70, 137.68, 137.64, 137.56, 137.46, 137.41, 137.36, 137.29, 137.09, 136.96, 136.43 (*aromatic* C), 134.68 (C-9), 128.67, 128.60, 128.58, 128.55, 128.52, 128.48, 128.44, 128.43, 128.39, 128.36, 128.24, 128.22, 128.16, 128.12, 128.10, 128.02, 127.97, 127.94, 127.92, 127.90, 127.85, 127.83, 127.80, 127.76, 127.66, 127.32, 127.01, 126.83, 126.59 (*aromatic* C*H*), 117.06 (C-10), 115.96 (*a*d, *J* = 286 Hz, 3xC*F*$_3$), 99.19, 98.59, 98.47, 98.29, 97.71, 97.23, 96.77 (7 C-1), 79.77, 76.29, 76.22, 75.43, 75.40, 74.87, 74.57, 73.90, 73.70, 73.43, 73.30, 73.13, 73.11, 73.10, 73.01, 72.07, 72.00, 71.86, 71.77, 71.42, 71.13, 71.05, 70.90, 70.67, 70.17, 69.64, 69.59, 69.42, 69.35, 69.12, 68.86, 68.66, 67.88, 67.80, 67.77, 67.02, 66.94, 66.80, 66.59, 65.85, 65.81, 64.38, 60.23, 60.08, 59.60, 49.70, 49.21, 48.28 (7 C-2), 33.98(C-8), 27.66, 27.47 (2 C*H*$_3$), 23.37, 20.77 (2 C-*Si*).

^{13}C-HMBC ($CDCl_3$, 125 MHz): 99.19 ($J_{C1,H1}$ = 172 Hz), 98.59 ($J_{C1,H1}$ = 172 Hz), 98.47 ($J_{C1,H1}$ = 177 Hz), 98.29 ($J_{C1,H1}$ = 172 Hz), 97.71 ($J_{C1,H1}$ = 175 Hz), 97.23 ($J_{C1,H1}$ = 175 Hz), 96.77 ($J_{C1,H1}$ = 177 Hz).



3-Butenyl 3-*O*-benzyl-2-deoxy-4,6-di-*tert*-butylsilylidene-2-trifluoroacetamido-α-D-galactopyranosyl-(1→4)-2-azido-3,6-di-*O*-benzyl-2-deoxy-α-D-galactopyranoside (21)

The reaction was carried out according to the general procedure A. The donor **14** (2.98 g, 4.4 mmol) and acceptor **7** (1.29 g, 2.94 mmol) were co-evaporated with toluene (three times). The residue was dissolved in dry 29 ml DCM under nitrogen and stirred over fresh flame-dried molecular sieves 4Å. The solution was cooled to 0 °C, after which TfOH (39 µl, 0.44 mmol) was added. The reaction was stirred at 0 °C for 2 h. Then the reaction was quenched with Et_3N, diluted with DCM, washed with saturated $NaHCO_3$ and brine. The organic phase was dried with anhydrous $MgSO_4$, filtered and concentrated *in vacuo*. The product was purified by silica gel column chromatography (pentane:EtOAc = 15:1). Compound **21** (2.34 g, 86% yield) was obtained as yellow syrup. $[\alpha]_D^{25}$ +165.7 (c=0.4, $CHCl_3$). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.38 – 7.25 (m, 15H, *aromatic* H), 6.32 (d, *J* = 9.4 Hz, 1H, NH), 5.77 (ddt, *J* = 17.0, 10.2, 6.7 Hz, 1H, H-9), 5.14 – 5.00 (m, 3H, H-10, 1^B), 4.84 (d, *J* = 3.6 Hz, 1H, H-1^A), 4.75 (d, *J* = 12.0 Hz, 1H, *PhCHH*O), 4.69 (d, *J* = 11.9 Hz, 1H, *PhCHH*O), 4.66 – 4.61 (m, 1H, H-2^B), 4.60 (d, *J* = 11.8 Hz, 1H, *PhCHH*O), 4.49 (d, *J* = 2.4 Hz, 1H, H-4^B), 4.47 (d, *J* = 11.8 Hz, 2H, *PhCHH*O), 4.39 (d, *J* = 11.4 Hz, 1H, *PhCHH*O), 4.36 (d, *J* = 2.7 Hz, 1H, H-4^A), 4.04 (d, *J* = 2.4 Hz, 1H, , H-5^B), 3.91 (dd, *J* = 9.2, 5.8 Hz, 1H, H-5^A), 3.81 (dd, *J* = 10.7, 2.8 Hz, 1H, , H-3^A), 3.76 (dd, *J* = 12.8, 1.6 Hz, 1H, , H-6^B), 3.72 – 3.65 (m, 1H, H-7), 3.65 – 3.56 (m, 2H, H-3^B, 6^B), 3.55 – 3.48 (m, 1H, H-7), 3.45 – 3.30 (m, 3H, , H-2^A, 6^A), 2.34 (qt, *J* = 6.7, 1.3 Hz, 2H, H-8), 1.09 (s, 9H, *CH*$_3$), 1.00 (s, 9H, *CH*$_3$). ^{13}C NMR (100 MHz, $CDCl_3$) δ 156.94 (*ad*, *J* = 37 Hz, *CF*$_3$*CO*), 137.88, 137.12, 136.90 (*aromatic* C), 134.59 (C-9), 128.75, 128.71, 128.68, 128.62, 128.52, 128.43, 128.35, 128.07, 128.01, 127.96, 127.72, 127.67,

127.19, 127.13 (*aromatic* C*H*), 117.08 (C-10), 115.96 (*a*d, *J* = 286 Hz, C*F*$_3$), 98.03 (C-1^A), 97.27 (C-1^B), 75.79 (C-3^A), 74.34 (C-3^B), 73.79 (C*H*$_2$*Ph*), 71.82 (C*H*$_2$*Ph*), 70.33 (C-4^A), 69.65 (C*H*$_2$*Ph*), 69.30 (C-4^B), 68.87 (C-5^A), 68.03 (C-5^B), 67.88 (C-7), 67.05 (C-6^B), 66.63 (C-6^A), 59.81 (C-2^A), 48.45 (C-2^B), 33.93 (C-8), 27.69, 27.47 (2 C*H*$_3$), 23.41, 20.80 (2 C-*Si*). HR-MS: Calculated for $C_{47}H_{61}N_4O_{10}F_3Si$ $[M+Na]^+$: 949.4007, found: 949.4001.

3-Butenyl 3-*O*-benzyl-2-deoxy-2-trifluoroacetamido-α-D-galactopyranosyl-(1→4)-2-azido-3,6-di-*O*-benzyl-2-deoxy-α-D-galactopyranoside (S14)

The reaction was carried out according to the general procedure C using compound **21** (3.6 g, 3.88 mmol) and HF/pyridine (70%, 1.6 ml, 62.1 mmol). The product was purified by column chromatography (pentane:EtOAc = 2:1). Compound **S14** (2.78 g, 91% yield) was obtained as yellow syrup. $[\alpha]_D^{25}$ +128.2 (c=0.4, $CHCl_3$). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.41 – 7.22 (m, 15H), 6.56 (d, *J* = 9.4 Hz, 1H), 5.77 (ddt, *J* = 17.0, 10.2, 6.7 Hz, 1H), 5.11 – 5.01 (m, 2H), 4.98 (d, *J* = 3.6 Hz, 1H), 4.85 (d, *J* = 3.6 Hz, 1H), 4.79 (d, *J* = 11.8 Hz, 1H), 4.66 (d, *J* = 11.9 Hz, 1H), 4.62 (d, *J* = 11.8 Hz, 1H), 4.55 – 4.46 (m, 1H), 4.45 – 4.37 (m, 3H), 4.31 (d, *J* = 2.7 Hz, 1H), 4.15 (dd, *J* = 2.9, 1.4 Hz, 1H), 4.12 – 4.06 (m, 1H), 3.89 (dd, *J* = 8.8, 5.9 Hz, 1H), 3.83 (dd, *J* = 10.8, 2.7 Hz, 1H), 3.71 – 3.28 (m, 8H), 3.13 (s, 1H), 2.34 (qt, *J* = 6.8, 1.4 Hz, 2H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 157.08 (*a*d, *J* = 37 Hz, *CF*$_3$*CO*), 137.21, 137.13, 136.94 (*aromatic* C), 134.53 (C-9), 128.65, 128.63, 128.59, 128.23, 128.15, 128.10, 128.08, 127.94, 127.38 (*aromatic* C*H*), 116.99 (C-10), 115.87 (*a*d, *J* = 286 Hz, C*F*$_3$), 97.99, 97.40, 75.48, 74.70, 73.58, 71.89, 71.18, 70.75, 69.50, 68.93, 67.80, 66.63, 66.60, 62.55, 59.64, 48.93, 33.82. HR-MS: Calculated for $C_{39}H_{45}N_4O_{10}F_3$ $[M+Na]^+$: 809.2986, found: 809.2980.

3-Butenyl 3,6-di-*O*-benzyl-2-deoxy-2-trifluoroacetamido-α-D-galactopyranosyl-(1→4)-2-azido-3,6-di-*O*-benzyl-2-deoxy-α-D-galactopyranoside (S15)

The reaction was carried out according to the general procedure D using compound **S14** (1.83 g, 2.33 mmol), K_2CO_3 (354 mg, 2.56 mmol), KI (387 mg, 2.33 mmol) and $Ph_2BO(CH_2)_2NH_2$ (53 mg, 0.233 mmol). The product was purified by column chromatography (pentane:EtOAc = 5:1). Compound **S15** (1.96 g, 96% yield) was obtained as yellow syrup. $[\alpha]_D^{25}$ +129.9 (c=1, $CHCl_3$). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.40 – 7.18 (m, 20H), 6.44 (d, *J* = 9.4 Hz, 1H), 5.75 (ddt, *J* = 17.0, 10.2, 6.8 Hz, 1H), 5.11 – 5.00 (m, 2H), 4.97 (d, *J* = 3.6 Hz, 1H), 4.83 (d, *J* = 3.6 Hz, 1H), 4.79 (d, *J* = 12.3 Hz, 1H), 4.70 (d, *J* = 12.0 Hz, 1H), 4.62 – 4.50 (m, 2H), 4.45 – 4.38 (m, 3H), 4.37 – 4.23 (m, 4H), 4.22 – 4.17 (m, 1H), 3.87 (dd, *J* = 8.8, 6.0 Hz, 1H), 3.78 (dd, *J* = 10.8, 2.7 Hz, 1H), 3.69 – 3.58 (m, 2H), 3.58 – 3.45 (m, 2H), 3.43 – 3.29 (m, 4H), 2.93 (s, 1H), 2.32 (qt, *J* = 6.8, 1.4 Hz, 2H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 156.99 (*a*d, *J* = 37 Hz, *CF*$_3$*CO*), 137.67, 137.37, 137.31, 137.01 (*aromatic* C), 134.57 (C-9), 129.04, 128.63, 128.56, 128.47, 128.40, 128.25, 128.12, 127.99, 127.94, 127.89, 127.86, 127.79, 127.48 (*aromatic* C*H*), 117.00 (C-10), 115.83 (*a*d, *J* = 286 Hz, C*F*$_3$), 98.06, 97.47, 75.33, 74.88, 73.60, 73.59, 71.74, 71.14, 70.64, 69.23, 68.96, 67.79, 66.68, 65.72, 59.60, 49.02, 33.86. HR-MS: Calculated for $C_{46}H_{51}N_4O_{10}F_3$ $[M+Na]^+$: 899.3455, found: 899.3450.

3-Butenyl 2-azido-3-*O*-benzyl-2-deoxy-4,6-di-*tert*-butylsilylidene-α-D-glucopyranosyl-(1→4)-3,6-di-*O*-benzyl-2-deoxy-2-trifluoroacetamido-α-D-galactopyranosyl-(1→4)-2-azido-3,6-di-*O*-benzyl-2-deoxy-α-D-galactopyranoside (22)

The reaction was carried out according to the general procedure A. The donor **4** (934 mg, 1.54 mmol) and acceptor **S15** (450 mg, 0.51 mmol) were co-evaporated with toluene (three times). The residue was dissolved in dry 5 ml DCM under nitrogen and stirred over fresh flame-dried molecular sieves 4Å. The solution was cooled to -10 °C, after which TfOH (14 µl, 0.15 mmol) was added. The reaction was stirred at -10 °C for overnight. Then the reaction was quenched with Et_3N, diluted with DCM, washed with saturated $NaHCO_3$ and brine. The organic phase was dried with anhydrous $MgSO_4$, filtered and concentrated *in vacuo*. The product was purified by silica gel column chromatography (pentane:EtOAc = 12:1). Compound **22** (583 mg, 85% yield) was obtained as yellow syrup. $[\alpha]_D^{25}$ +114.3 (c=1, $CHCl_3$). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.48 – 7.18 (m, 25H), 6.03 (d, *J* = 9.2 Hz, 1H), 5.75 (ddt, *J* = 17.0, 10.2, 6.7 Hz, 1H), 5.10 (d, *J* = 10.4 Hz, 1H), 5.08 – 5.00 (m, 3H), 4.89 – 4.76 (m, 4H), 4.73 (d, *J* = 3.6 Hz, 1H), 4.60 – 4.41 (m, 4H), 4.40 – 4.28 (m, 3H), 4.25 (d, *J* = 2.6 Hz, 1H), 4.22 (d, *J* = 2.4 Hz, 1H), 4.10 (d, *J* = 11.6 Hz, 1H), 4.00 – 3.73 (m, 8H), 3.68 – 3.57 (m, 2H), 3.48 (dt, *J* = 9.7, 6.5 Hz, 1H), 3.33 (dd, *J* = 9.1, 5.8 Hz, 1H), 3.29 – 3.10 (m, 4H), 2.31 (qt, *J* = 6.8, 1.4 Hz, 2H), 1.05 (s, 9H), 1.02 (s, 9H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 156.62 (*a*d, *J* = 37 Hz, *CF₃CO*), 138.32, 137.51, 137.33, 137.19 (*aromatic* C), 134.62 (C-9), 128.84, 128.67, 128.63, 128.55, 128.52, 128.48, 128.34, 128.29, 128.15, 128.14, 127.98, 127.89, 127.11 (*aromatic* C*H*), 117.02 (C-10), 115.84 (*a*d, *J* = 286 Hz, C*F₃*), 98.20, 98.08, 97.55, 79.40, 79.32, 75.79, 75.76, 73.53, 73.32, 72.59, 71.71, 71.33, 71.14, 70.68, 69.74, 68.99, 67.80, 67.12, 66.79, 66.65, 66.29, 62.90, 59.60, 49.40, 33.92, 27.45, 27.06, 22.74, 20.07. HR-MS: Calculated for $C_{67}H_{82}N_7O_{14}F_3Si$ $[M+Na]^+$: 1316.5539, found: 1316.5533.

3-Butenyl 2-azido-3-*O*-benzyl-2-deoxy-α-D-glucopyranosyl-(1→4)-3,6-di-*O*-benzyl-2-deoxy-2-trifluoroacetamido-α-D-galactopyranosyl-(1→4)-2-azido-3,6-di-*O*-benzyl-2-deoxy-α-D-galactopyranoside (S16)

The reaction was carried out according to the general procedure C using compound **22** (655 mg, 0.51 mmol) and HF/pyridine (70%, 210 µl, 8.1 mmol). The product was purified by column chromatography (pentane:EtOAc = 2:1). Compound **S16** (497 mg, 84% yield) was obtained as white foam. $[\alpha]_D^{25}$ +139.7 (c=1, $CHCl_3$). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.46 – 7.16 (m, 25H), 6.40 (d, *J* = 9.5 Hz, 1H), 5.75 (ddt, *J* = 17.0, 10.2, 6.7 Hz, 1H), 5.11 – 4.96 (m, 3H), 4.93 – 4.79 (m, 4H), 4.78 (d, *J* = 3.7 Hz, 1H), 4.71 (d, *J* = 12.3 Hz, 1H), 4.55 – 4.37 (m, 4H), 4.33 – 4.24 (m, 3H), 4.21 (d, *J* = 2.3 Hz, 1H), 4.09 (s, 3H), 3.94 (dd, *J* = 10.3, 8.8 Hz, 1H), 3.89 – 3.74 (m, 3H), 3.73 – 3.44 (m, 5H), 3.43 – 3.17 (m, 7H), 2.32 (qt, *J* = 6.8, 1.5 Hz, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 157.09 (*a*d, *J* = 37 Hz, *CF₃CO*), 138.30, 137.43, 137.39, 137.24, 136.82 (*aromatic* C), 134.55 (C-9), 128.67, 128.63, 128.62, 128.52, 128.44, 128.38, 128.31, 128.27, 128.19, 128.03, 127.96, 127.89, 127.85, 127.63, 127.15 (*aromatic* C*H*), 117.02 (C-10), 115.83 (*a*d, *J* = 286 Hz, C*F₃*), 98.73, 98.06, 97.25, 80.00, 75.56, 75.22, 74.15, 73.65, 73.28, 72.24, 71.90, 71.59, 71.47, 70.90, 70.61, 69.91, 68.81, 67.83, 66.55, 66.33, 63.53, 62.20, 59.54, 49.49, 33.86. HR-MS: Calculated for $C_{59}H_{66}N_7O_{14}F_3$ $[M+Na]^+$: 1176.4518, found: 1176.4512.

3-Butenyl 2-azido-3,6-di-*O*-benzyl-2-deoxy-α-D-glucopyranosyl-(1→4)-3,6-di-*O*-benzyl-2-deoxy-2-trifluoro-acetamido-α-D-galactopyranosyl-(1→4)-2-azido-3,6-di-*O*-benzyl-2-deoxy-α-D-galactopyranoside (S17)

The reaction was carried out according to the general procedure D using compound **S16** (482 mg, 0.42 mmol), K_2CO_3 (64 mg, 0.46 mmol), KI (70 mg, 0.42 mmol) and $Ph_2BO(CH_2)_2NH_2$ (9.4 mg, 0.042 mmol). The product was purified by column chromatography (pentane:EtOAc = 6:1). Compound **S17** (506 mg, 97% yield) was obtained as colorless syrup. $[\alpha]_D^{25}$ +139.8 (c=1, $CHCl_3$). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.46 – 7.12 (m, 30H), 6.36 (d, *J* = 9.5 Hz, 1H), 5.74 (ddt, *J* = 17.0, 10.2, 6.7 Hz, 1H), 5.10 – 4.97 (m, 3H), 4.95 (d, *J* = 3.6 Hz, 1H), 4.91 (d, *J* = 3.6 Hz, 1H), 4.88 (d, *J* = 11.0 Hz, 1H), 4.84 – 4.73 (m, 2H), 4.67 (d, *J* = 12.4 Hz, 1H), 4.55 (td, *J* = 10.3, 3.6 Hz, 1H), 4.51 – 4.36 (m, 3H), 4.35 – 4.16 (m, 7H), 4.13 – 4.00 (m, 2H), 3.93 (t, *J* = 9.5 Hz, 1H), 3.90 – 3.71 (m, 4H), 3.68 – 3.14 (m, 10H), 2.76 (d, *J* = 4.2 Hz, 1H), 2.30 (q, *J* = 6.8 Hz, 2H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 156.03 (*a*d, *J* = 37 Hz, *CF₃CO*), 138.22, 137.79, 137.33, 137.29, 136.74 (*aromatic* C), 134.41 (C-9), 128.80, 128.49, 128.45, 128.37, 128.34, 128.26, 128.18, 128.16, 128.11, 128.08, 127.99, 127.83, 127.68, 127.64, 127.58, 127.54, 127.48, 127.22, 126.91 (*aromatic* C*H*), 116.83 (C-10), 115.84 (*a*d, *J* = 286 Hz, C*F₃*), 98.67, 97.94, 97.21, 79.77, 75.48, 74.97, 74.24, 73.45, 73.19, 73.07, 72.35, 71.78, 71.43, 70.77, 70.45, 70.36, 69.69, 69.06, 68.70, 67.62, 66.42, 66.23, 63.28, 59.37, 58.71, 58.10, 54.60, 49.25, 33.70. HR-MS: Calculated for $C_{66}H_{72}N_7O_{14}F_3$ $[M+Na]^+$: 1266.4987, found: 1266.4982.

3-Butenyl 2-azido-3-*O*-benzyl-2-deoxy-4,6-di-*tert*-butylsilylidene-α-D-galactopyranosyl-(1→4)-2-azido-3,6-di-*O*-benzyl-2-deoxy-α-D-glucopyranosyl-(1→4)-3,6-di-*O*-benzyl-2-deoxy-2-trifluoroacetamido-α-D-galactopyranosyl-(1→4)-2-azido-3,6-di-*O*-benzyl-2-deoxy-α-D-galactopyranoside (23)

The reaction was carried out according to the general procedure B using donor **13** (722 mg, 1.19 mmol) and acceptor **S17** (494 mg, 0.40 mmol). The product was purified by column chromatography (pentane:EtOAc = 8:1). Compound **23** (547 mg, 83% yield) was obtained as yellow syrup. $[\alpha]_D^{25}$ +126.6 (c=1, $CHCl_3$). ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.46 – 7.17 (m, 35H), 6.39 (d, *J* = 9.6 Hz, 1H), 5.75 (ddt, *J* = 17.1, 10.2, 6.7 Hz, 1H), 5.52 (d, *J* = 3.6 Hz, 1H), 5.10 – 4.99 (m, 3H), 4.99 – 4.90 (m, 3H), 4.84 (d, *J* = 12.4 Hz, 1H), 4.81 (d, *J* = 3.6 Hz, 1H), 4.78 – 4.72 (m, 2H), 4.68 (d, *J* = 11.5 Hz, 1H), 4.63 – 4.56 (m, 1H), 4.53 (d, *J* = 12.4 Hz, 1H), 4.49 – 4.40 (m, 3H), 4.37 – 4.19 (m, 7H), 4.14 (d, *J* = 11.4 Hz, 1H), 4.12 – 4.03 (m, 2H), 4.00 (dd, *J* = 9.7, 8.5 Hz, 1H), 3.96 – 3.76 (m, 7H), 3.68 – 3.55 (m, 3H), 3.53 – 3.44 (m, 2H), 3.43 – 3.32 (m, 4H), 3.23 (dd, *J* = 8.4, 5.2 Hz, 1H), 3.12 (dd, *J* = 11.3, 1.9 Hz, 1H), 2.32 (qt, *J* = 6.7, 1.3 Hz, 2H), 1.02 (s, 9H), 0.97 (s, 9H). ^{13}C NMR (125 MHz, $CDCl_3$) δ 156.64 (*a*d, *J* = 37 Hz, *CF₃CO*), 138.22, 137.87, 137.65, 137.62, 137.46, 137.01 (*aromatic* C), 134.56 (C-9), 128.66, 128.51, 128.48, 128.36, 128.27, 128.20, 128.17, 128.05, 128.01, 127.93, 127.89, 127.78, 127.71, 127.56, 127.49, 127.37, 127.14 (*aromatic* C*H*), 117.02 (C-10), 116.02 (*a*d, *J* = 286 Hz, C*F₃*), 98.98, 98.14, 97.94, 97.58, 80.94, 75.87, 75.64, 74.97, 74.69, 74.31, 73.64, 73.29, 73.16, 72.93, 71.70, 71.16, 70.98, 70.66, 69.99, 69.89, 68.92, 68.86, 67.89, 67.86, 67.04, 66.71, 66.58, 64.81, 59.61, 58.65, 49.49, 33.88, 27.67, 27.36, 23.39, 20.77. HR-MS: Calculated for $C_{87}H_{103}N_{10}O_{18}F_3Si$ $[M+Na]^+$: 1683.7071, found: 1683.7065.

3-Butenyl 2-azido-3-*O*-benzyl-2-deoxy-α-D-galactopyranosyl-(1→4)-2-azido-3,6-di-*O*-benzyl-2-deoxy-α-D-glucopyranosyl-(1→4)-3,6-di-*O*-benzyl-2-deoxy-2-trifluoroacetamido-α-D-galactopyranosyl-(1→4)-2-azido-3,6-di-*O*-benzyl-2-deoxy-α-D-galactopyranoside (S18)

The reaction was carried out according to the general procedure C using compound **23** (530 mg, 0.32 mmol) and HF/pyridine (70%, 133 µl, 5.1 mmol). The product was purified by column chromatography (pentane:EtOAc = 2:1). Compound **S18** (436 mg, 89% yield) was obtained as white foam. $[\alpha]_D^{25}$ +120.5 (c=1, $CHCl_3$). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.48 – 7.12 (m, 35H), 6.46 (d, *J* = 9.6 Hz, 1H), 5.76 (ddt, *J* = 17.0, 10.2, 6.7 Hz, 1H), 5.36 (d, *J* = 3.6 Hz, 1H), 5.12 – 4.99 (m, 3H), 4.94 – 4.87 (m, 3H), 4.84 (d, *J* = 12.4 Hz, 1H), 4.81 (d, *J* = 3.6 Hz, 1H), 4.72 (d, *J* = 12.3 Hz, 1H), 4.68 (s, 2H), 4.57 – 4.39 (m, 4H), 4.37 – 4.19 (m, 7H), 4.18 – 4.01 (m, 5H), 3.97 (dd, *J* = 10.5, 3.0 Hz, 1H), 3.94 – 3.76 (m, 4H), 3.71 (dd, *J* = 10.5, 3.6 Hz, 1H), 3.65 (td, *J* = 6.9, 3.1 Hz, 4H), 3.57 (dd, *J* = 11.0, 2.2 Hz, 1H), 3.50 (dt, *J* = 9.7, 6.5 Hz, 1H), 3.43 – 3.29 (m, 4H), 3.23 (dd, *J* = 8.3, 5.2 Hz, 1H), 3.13 (d, *J* = 11.4 Hz, 1H), 2.67 (d, *J* = 7.1 Hz, 2H), 2.32 (q, *J* = 6.7 Hz, 2H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 156.97 (*a*d, *J* = 37 Hz, *CF*$_3$*CO*), 138.19, 137.97, 137.58, 137.48, 137.40, 137.30, 136.86 (*aromatic* C), 134.53 (C-9), 128.66, 128.65, 128.49, 128.46, 128.33, 128.29, 128.26, 128.17, 128.01, 127.89, 127.84, 127.75, 127.70, 127.55, 127.35, 127.10 (*aromatic* C*H*), 117.03 (C-10), 115.98 (*a*d, *J* = 286 Hz, C*F*$_3$), 99.00, 98.10, 97.99, 97.34, 80.15, 76.36, 75.94, 75.60, 75.05, 74.66, 73.63, 73.27, 73.20, 73.00, 71.81, 71.65, 71.08, 70.96, 70.71, 70.32, 69.92, 68.76, 68.47, 67.86, 67.02, 66.65, 66.31, 64.54, 62.51, 59.61, 59.56, 49.47, 33.85. HR-MS: Calculated for $C_{79}H_{87}N_{10}O_{18}F_3$ $[M+Na]^+$: 1543.6050, found: 1543.6044.

3-Butenyl 2-azido-3,6-di-*O*-benzyl-2-deoxy-α-D-galactopyranosyl-(1→4)-2-azido-3,6-di-*O*-benzyl-2-deoxy-α-D-glucopyranosyl-(1→4)-3,6-di-*O*-benzyl-2-deoxy-2-trifluoroacetamido-α-D-galactopyranosyl-(1→4)-2-azido-3,6-di-*O*-benzyl-2-deoxy-α-D-galactopyranoside (S19)

The reaction was carried out according to the general procedure D using compound **S18** (421 mg, 0.28 mmol), K_2CO_3 (42 mg, 0.30 mmol), KI (46 mg, 0.28 mmol) and $Ph_2BO(CH_2)_2NH_2$ (6.2 mg, 0.028 mmol). The product was purified by column chromatography (pentane:EtOAc = 4:1). Compound **S19** (436 mg, 98% yield) was obtained as white foam. $[\alpha]_D^{25}$ +136.2 (c=1, $CHCl_3$). ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.56 – 7.26 (m, 40H), 6.46 (d, *J* = 9.5 Hz, 1H), 5.87 (ddt, *J* = 17.0, 10.2, 6.7 Hz, 1H), 5.69 (d, *J* = 3.7 Hz, 1H), 5.22 – 5.12 (m, 3H), 5.12 – 5.04 (m, 3H), 4.96 (d, *J* = 12.4 Hz, 1H), 4.91 (d, *J* = 3.6 Hz, 1H), 4.82 (d, *J* = 12.0 Hz, 3H), 4.70 (ddd, *J* = 13.2, 9.7, 3.6 Hz, 1H), 4.64 (d, *J* = 12.4 Hz, 1H), 4.59 – 4.51 (m, 2H), 4.51 – 4.33 (m, 9H), 4.30 – 4.22 (m, 3H), 4.21 – 4.13 (m, 3H), 4.07 – 3.96 (m, 3H), 3.91 (dd, *J* = 10.8, 2.6 Hz, 1H), 3.86 (dd, *J* = 10.6, 3.6 Hz, 1H), 3.79 – 3.41 (m, 11H), 3.39 – 3.31 (m, 2H), 2.88 (s, 1H), 2.49 – 2.38 (m, 2H). ^{13}C NMR (125 MHz, $CDCl_3$) δ 156.52 (*a*d, *J* = 37 Hz, *CF*$_3$*CO*), 138.47, 137.92, 137.79, 137.65, 137.56, 137.40, 136.89 (*aromatic* C), 134.51 (C-9), 128.97, 128.60, 128.58, 128.53, 128.43, 128.41, 128.32, 128.25, 128.21, 128.17, 128.14, 128.12, 127.95, 127.91, 127.83, 127.82, 127.71, 127.67, 127.49, 127.34, 127.30, 127.07 (*aromatic* C*H*), 116.95 (C-10), 116.02 (*a*d, *J* = 286 Hz, C*F*$_3$), 98.89, 98.05, 98.03, 97.42, 80.62, 76.17, 75.57, 74.61, 74.57, 74.44, 73.57, 73.56, 73.23, 72.95, 72.70, 71.69, 71.58, 70.94, 70.82, 70.48, 69.90, 69.42, 68.86, 68.83, 67.77, 66.70, 66.67, 66.43, 64.86, 59.53, 59.21, 58.60, 58.19, 54.74, 49.39, 33.81. HR-MS: Calculated for $C_{86}H_{93}N_{10}O_{18}F_3$ $[M+Na]^+$: 1633.6519, found: 1633.6514.

Pentasaccharide 24

The reaction was carried out according to the general procedure B using donor **14** (542 mg, 0.80 mmol) and acceptor **S19** (430 mg, 0.27 mmol). The product was purified by column chromatography (pentane:EtOAc = 7:1). Compound **24** (501 mg, 89% yield) was obtained as yellow foam. $[\alpha]_D^{25}$ +150.6 (c=0.5, $CHCl_3$). ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.63 – 7.21 (m, 45H), 6.42 (d, *J* = 9.6 Hz, 2H), 5.86 (ddt, *J* = 17.0, 10.3, 6.7 Hz, 1H), 5.59 (d, *J* = 3.7 Hz, 1H), 5.22 – 5.02 (m, 7H), 4.94 (d, *J* = 12.4 Hz, 1H), 4.90 (d, *J* = 3.6 Hz, 1H), 4.86 – 4.71 (m, 5H), 4.70 – 4.33 (m, 14H), 4.32 – 4.15 (m, 6H), 4.15 – 4.04 (m, 3H), 4.04 – 3.93 (m, 2H), 3.90 (dd, *J* = 10.7, 2.5 Hz, 1H), 3.81 (d, *J* = 12.6 Hz, 1H), 3.78 – 3.66 (m, 3H), 3.65 – 3.56 (m, 4H), 3.54 (dd, *J* = 10.1, 3.3 Hz, 1H), 3.51 – 3.40 (m, 3H), 3.40 – 3.33 (m, 2H), 3.32 – 3.23 (m, 2H), 2.48 – 2.37 (m, 2H), 1.20 (s, 10H), 1.10 (s, 9H). ^{13}C NMR (125 MHz, $CDCl_3$) δ 156.71 (*a*d, *J* = 37 Hz, 2x*CF*$_3$*CO*), 138.38, 138.17, 137.85, 137.52, 137.45, 137.39, 136.96, 136.78 (*aromatic* C), 134.51 (C-9), 128.61, 128.55, 128.53, 128.50, 128.47, 128.44, 128.27, 128.25, 128.15, 128.07, 127.99, 127.85, 127.78, 127.76, 127.68, 127.66, 127.48, 127.42, 127.20, 127.08, 126.63 (*aromatic* C*H*), 116.97 (C-10), 115.89 (*a*d, *J* = 286 Hz, 2xC*F*$_3$), 98.82, 98.06, 97.47, 97.39, 96.90, 79.98, 76.10, 75.59, 74.63, 74.29, 73.90, 73.49, 73.27, 73.03, 72.51, 71.77, 71.62, 70.97, 70.62, 70.60, 69.87, 69.54, 69.34, 69.22, 68.81, 68.73, 67.78, 67.75, 66.99, 66.65, 66.44, 66.17, 64.72, 60.20, 59.56, 49.37, 48.29, 33.83, 27.59, 27.41, 23.30, 20.72. HR-MS: Calculated for $C_{109}H_{125}N_{11}O_{23}F_6Si$ $[M+Na]^+$: 2120.8521, found: 2120.8516.

Pentasaccharide S20

The reaction was carried out according to the general procedure C using compound **24** (490 mg, 0.23 mmol) and HF/pyridine (70%, 97 µl, 3.7 mmol). The product was purified by column chromatography (pentane:EtOAc = 3:2). Compound **S20** (395 mg, 86% yield) was obtained as white foam. $[\alpha]_D^{25}$ +117.6 (c=0.5, $CHCl_3$). ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.46 (d, *J* = 7.2 Hz, 2H), 7.43 – 7.09 (m, 43H), 6.44 (d, *J* = 9.5 Hz, 1H), 6.40 (d, *J* = 9.6 Hz, 1H), 5.74 (ddt, *J* = 17.1, 10.2, 6.7 Hz, 1H), 5.48 (d, *J* = 3.7 Hz, 1H), 5.09 – 4.90 (m, 7H), 4.87 – 4.74 (m, 3H), 4.72 – 4.48 (m, 5H), 4.46 – 4.20 (m, 12H), 4.19 – 4.01 (m, 8H), 3.99 – 3.91 (m, 2H), 3.90 – 3.82 (m, 2H), 3.78 (dd, *J* = 10.7, 2.6 Hz, 1H), 3.66 – 3.52 (m, 3H), 3.52 – 3.39 (m, 5H), 3.39 – 3.27 (m, 4H), 3.27 – 3.19 (m, 2H), 3.19 – 3.09 (m, 2H), 2.90 (s, 1H), 2.36 – 2.25 (m, 2H), 2.02 (s, 1H). ^{13}C NMR (125 MHz, $CDCl_3$) δ 156.78 (*a*d, *J* = 37 Hz, 2x*CF*$_3$*CO*), 138.34, 138.16, 137.60, 137.55, 137.42, 137.40, 137.05, 136.98, 136.84 (*aromatic* C), 134.53 (C-9), 128.59, 128.58, 128.54, 128.49, 128.47, 128.42, 128.22, 128.17, 128.14, 128.12, 128.05, 127.96, 127.88, 127.85, 127.75, 127.67, 127.46, 127.42, 127.25, 127.10, 126.99 (*aromatic* C*H*), 116.95 (C-10), 115.93 (*a*d, *J* = 286 Hz, C*F*$_3$), 98.80, 98.05, 97.53, 97.43, 97.13, 80.03, 75.92, 75.58, 74.84, 74.58, 74.24, 73.82, 73.48, 73.45, 73.25, 73.05, 72.58, 71.97, 71.65, 71.07, 70.84, 70.60, 70.58, 69.86, 69.29, 69.24, 68.84, 68.71, 67.79, 66.67, 66.24, 64.71, 62.45, 60.11, 59.56, 49.41, 48.83, 33.81. HR-MS: Calculated for $C_{101}H_{109}N_{11}O_{23}F_6$ $[M+Na]^+$: 1980.7500, found: 1980.7494.

Pentasaccharide S21

The reaction was carried out according to the general procedure D using compound **S20** (389 mg, 0.2 mmol), K_2CO_3 (30 mg, 0.22 mmol), KI (33 mg, 0.2 mmol) and $Ph_2BO(CH_2)_2NH_2$ (4.5 mg, 0.02 mmol). The product was

purified by column chromatography (pentane:EtOAc = 4:1). Compound **S21** (369 mg, 90% yield) was obtained as yellow syrup. $[\alpha]_D^{25}$ +143.7 (c=0.5, $CHCl_3$). ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.45 (d, *J* = 7.6 Hz, 2H), 7.41 – 7.06 (m, 48H), 6.44 (dd, *J* = 14.6, 9.5 Hz, 2H), 5.73 (ddt, *J* = 17.0, 10.2, 6.7 Hz, 1H), 5.47 (d, *J* = 3.7 Hz, 1H), 5.08 – 4.90 (m, 7H), 4.86 – 4.76 (m, 3H), 4.57 (ddd, *J* = 53.0, 25.7, 12.7 Hz, 6H), 4.42 – 4.00 (m, 21H), 3.98 – 3.82 (m, 4H), 3.78 (dd, *J* = 10.6, 2.5 Hz, 1H), 3.60 (dq, *J* = 13.3, 6.6 Hz, 3H), 3.55 – 3.29 (m, 9H), 3.29 – 3.09 (m, 5H), 2.95 (s, 1H), 2.29 (q, *J* = 6.8 Hz, 2H). ^{13}C NMR (125 MHz, $CDCl_3$) δ 156.55 (*a*d, *J* = 37 Hz, 2x*CF*$_3$*CO*), 138.29, 138.07, 137.72, 137.66, 137.48, 137.34, 137.33, 137.24, 136.90 (*aromatic* C), 134.44 (C-9), 128.86, 128.49, 128.45, 128.40, 128.37, 128.36, 128.33, 128.31, 128.29, 128.21, 128.11, 128.05, 128.02, 127.99, 127.87, 127.85, 127.73, 127.66, 127.62, 127.57, 127.55, 127.49, 127.41, 127.36, 127.30, 127.15, 127.09, 126.99 (*aromatic* C*H*), 116.84 (C-10), 115.83 (*a*d, *J* = 286 Hz, 2xC*F*$_3$), 98.70, 97.98, 97.48, 97.33, 97.22, 79.87, 75.75, 75.52, 74.83, 74.49, 74.18, 73.72, 73.37, 73.24, 73.14, 72.93, 72.47, 71.75, 71.54, 70.98, 70.86, 70.52, 70.49, 70.47, 69.77, 69.25, 69.07, 68.78, 68.70, 68.61, 67.68, 66.60, 66.41, 66.19, 65.56, 64.58, 59.95, 59.47, 58.61, 58.12, 54.68, 49.34, 48.89, 33.72. HR-MS: Calculated for $C_{108}H_{115}N_{11}O_{23}F_6$ $[M+Na]^+$: 2070.7969, found: 2070.7964.

Hexasaccharide 25

The reaction was carried out according to the general procedure B using donor **13** (346 mg, 0.57 mmol) and acceptor **S21** (390 mg, 0.19 mmol). The product was purified by column chromatography (pentane:EtOAc = 6:1). Compound **25** (415 mg, 88% yield) was obtained as white foam. $[\alpha]_D^{25}$ +130.6 (c=0.5, $CHCl_3$). ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.50 – 7.09 (m, 57H), 7.03 – 6.96 (m, 1H), 6.31 (d, *J* = 9.5 Hz, 1H), 6.25 (d, *J* = 9.7 Hz, 1H), 5.73 (ddt, *J* = 17.0, 10.2, 6.7 Hz, 1H), 5.41 (d, *J* = 3.7 Hz, 1H), 5.08 – 4.89 (m, 9H), 4.85 – 4.72 (m, 3H), 4.70 – 4.43 (m, 8H), 4.37 – 4.18 (m, 14H), 4.17 – 3.93 (m, 10H), 3.92 – 3.82 (m, 3H), 3.81 – 3.52 (m, 8H), 3.50 – 3.19 (m, 9H), 3.18 – 3.06 (m, 3H), 2.29 (q, *J* = 6.6 Hz, 2H), 1.03 (s, 10H), 0.98 (s, 9H). ^{13}C NMR (125 MHz, $CDCl_3$) δ 156.60 (*a*d, *J* = 37 Hz, 2x*CF*$_3$*CO*), 138.34, 138.10, 137.89, 137.82, 137.51, 137.39, 137.35, 137.14, 137.06, 136.87, 136.71 (*aromatic* C), 134.45 (C-9), 128.55, 128.50, 128.48, 128.42, 128.40, 128.37, 128.29, 128.16, 128.14, 128.08, 128.01, 127.91, 127.79, 127.69, 127.66, 127.62, 127.48, 127.36, 127.34, 127.12, 127.00, 126.49 (*aromatic* C*H*), 116.92 (C-10), 115.84 (*a*d, *J* = 286 Hz, C*F*$_3$), 98.85, 98.34, 98.03, 97.77, 97.34, 97.29, 80.22, 76.19, 75.76, 75.55, 74.73, 74.42, 74.37, 74.01, 73.44, 73.42, 73.18, 72.91, 72.70, 71.64, 71.56, 70.91, 70.75, 70.68, 70.56, 70.52, 70.14, 69.83, 69.61, 69.56, 69.21, 68.75, 68.65, 67.73, 67.36, 67.07, 66.63, 66.34, 65.97, 64.78, 59.87, 59.50, 58.44, 49.33, 49.10, 33.78, 27.55, 27.39, 23.20, 20.67.

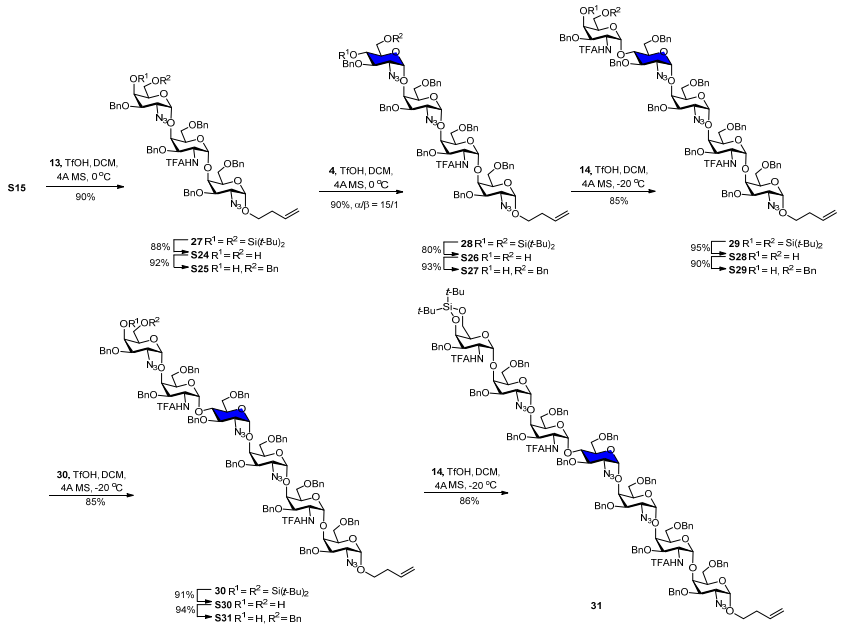
Hexasaccharide S22

The reaction was carried out according to the general procedure C using compound **25** (409 mg, 0.17 mmol) and HF/pyridine (70%, 69 µl, 2.65 mmol). The product was purified by column chromatography (pentane:EtOAc = 3:2). Compound **S22** (347 mg, 90% yield) was obtained as white foam. $[\alpha]_D^{25}$ +147 (c=0.5, $CHCl_3$). ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.52 – 7.09 (m, 55H), 7.02 (td, *J* = 6.3, 2.9 Hz, 1H), 6.39 (t, *J* = 11.1 Hz, 2H), 5.81 – 5.68 (m, 1H), 5.42 (d, *J* = 3.7 Hz, 1H), 5.09 – 4.76 (m, 11H), 4.73 – 4.61 (m, 4H), 4.61 – 4.48 (m, 3H), 4.44 (td, *J* = 10.4, 3.6 Hz, 1H),

4.40 – 4.24 (m, 9H), 4.23 – 4.08 (m, 10H), 4.08 – 4.01 (m, 2H), 4.01 – 3.91 (m, 5H), 3.90 – 3.82 (m, 2H), 3.81 – 3.73 (m, 2H), 3.68 – 3.53 (m, 4H), 3.51 – 3.27 (m, 9H), 3.27 – 3.19 (m, 2H), 3.18 – 3.05 (m, 3H), 2.84 (s, 1H), 2.35 – 2.24 (m, 2H). ^{13}C NMR (125 MHz, $CDCl_3$) δ 156.77 (*a*d, *J* = 37 Hz, *CF*$_3$*CO*), 138.36, 138.13, 137.75, 137.56, 137.46, 137.45, 137.38, 137.22, 136.95, 136.87 (*aromatic* C), 134.49 (C-9), 128.59, 128.56, 128.53, 128.49, 128.46, 128.44, 128.41, 128.39, 128.34, 128.20, 128.18, 128.14, 128.08, 128.04, 127.92, 127.88, 127.81, 127.67, 127.65, 127.58, 127.39, 127.35, 127.30, 127.16, 127.07, 126.71 (*aromatic* C*H*), 116.92 (C-10), 115.87 (*a*d, *J* = 286 Hz, C*F*$_3$), 98.84, 98.75, 98.05, 97.80, 97.41, 97.31, 80.24, 76.38, 76.02, 75.55, 74.70, 74.37, 74.34, 74.01, 73.45, 73.38, 73.21, 73.13, 72.97, 72.72, 71.76, 71.73, 71.63, 71.59, 71.04, 70.81, 70.69, 70.59, 69.84, 69.73, 69.20, 69.08, 68.83, 68.64, 67.76, 67.45, 66.67, 66.54, 66.45, 66.09, 64.79, 62.60, 59.91, 59.53, 59.41, 49.40, 49.32, 33.79.

Heptasaccharide 26

The reaction was carried out according to the general procedure B using donor **14** (381 mg, 0.56 mmol) and acceptor **S23** (340 mg, 0.14 mmol). The product was purified by column chromatography (pentane:EtOAc = 6:1). Compound **26** (358 mg, 88% yield) was obtained as yellow foam. $[\alpha]_D^{25}$ +157.6 (c=0.5, $CHCl_3$). ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.52 – 7.02 (m, 69H), 6.42 – 6.34 (m, 2H), 6.31 (d, *J* = 9.4 Hz, 1H), 5.73 (ddt, *J* = 17.0, 10.2, 6.7 Hz, 1H), 5.43 (d, *J* = 3.6 Hz, 1H), 5.08 – 4.87 (m, 9H), 4.86 – 4.76 (m, 3H), 4.72 (dd, *J* = 12.0, 7.2 Hz, 2H), 4.68 – 4.42 (m, 10H), 4.41 – 4.19 (m, 15H), 4.12 (d, *J* = 11.1 Hz, 4H), 4.09 – 3.82 (m, 12H), 3.81 – 3.72 (m, 2H), 3.71 – 3.53 (m, 5H), 3.50 – 2.96 (m, 16H), 2.35 – 2.26 (m, 2H), 1.07 (s, 9H), 0.98 (s, 9H). ^{13}C NMR (125 MHz, $CDCl_3$) δ 156.69 (*a*d, *J* = 37 Hz, 3x*CF*$_3$C*O*), 138.32, 138.13, 137.87, 137.80, 137.62, 137.52, 137.41, 137.37, 137.29, 137.21, 136.90, 136.84 (*aromatic* C), 134.47 (C-9), 128.56, 128.52, 128.49, 128.46, 128.44, 128.41, 128.39, 128.31, 128.28, 128.17, 128.16, 128.11, 128.09, 128.05, 127.97, 127.93, 127.81, 127.79, 127.74, 127.72, 127.67, 127.64, 127.39, 127.36, 127.16, 127.09, 127.02, 126.73, 126.57 (*aromatic* C*H*), 116.94 (C-10), 115.83 (*a*d, *J* = 286 Hz, C*F*$_3$), 98.83, 98.31, 98.05, 97.75, 97.49, 97.40, 96.73, 80.24, 76.20, 76.05, 75.57, 74.70, 74.51, 74.31, 73.97, 73.44, 73.39, 73.20, 73.05, 72.94, 72.90, 72.68, 71.85, 71.61, 71.19, 71.06, 70.99, 70.95, 70.64, 70.58, 69.83, 69.57, 69.49, 69.36, 69.27, 68.79, 68.56, 67.76, 67.72, 66.91, 66.63, 66.49, 66.36, 66.14, 65.74, 64.78, 60.15, 59.92, 59.51, 49.37, 49.20, 48.21, 33.80, 27.56, 27.38, 23.25, 20.67.



3-Butenyl 2-azido-3-*O*-benzyl-2-deoxy-4,6-di-*tert*-butylsilylidene-α-D-galactopyranosyl-(1→4)-3,6-di-*O*-benzyl-2-deoxy-2-trifluoroacetamido-α-D-galactopyranosyl-(1→4)-2-azido-3,6-di-*O*-benzyl-2-deoxy-α-D-galactopyranoside (27)

The reaction was carried out according to the general procedure B using donor **13** (1.07 g, 1.77 mmol) and acceptor **S15** (620 mg, 0.71 mmol). The product was purified by column chromatography (pentane:EtOAc = 10:1). Compound **27** (828 mg, 90% yield) was obtained as white foam. $[\alpha]_D^{25}$ +176.3 (c=1, $CHCl_3$). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.50 – 7.14 (m, 26H), 6.31 (d, *J* = 9.7 Hz, 1H), 5.76 (ddt, *J* = 17.0, 10.2, 6.8 Hz, 1H), 5.12 – 4.99 (m, 2H), 4.95 (dd, *J* = 5.6, 3.6 Hz, 2H), 4.87 (d, *J* = 12.3 Hz, 1H), 4.81 – 4.62 (m, 4H), 4.59 – 4.23 (m, 9H), 4.20 – 4.06 (m, 2H), 4.02 – 3.92 (m, 2H), 3.87 (dd, *J* = 9.0, 5.9 Hz, 1H), 3.85 – 3.60 (m, 6H), 3.57 (dd, *J* = 11.1, 2.4 Hz, 1H), 3.55 – 3.45 (m, 1H), 3.43 – 3.26 (m, 3H), 3.16 (dd, *J* = 8.4, 5.2 Hz, 1H), 2.33 (qt, *J* = 6.8, 1.4 Hz, 2H), 1.03 (s, 9H), 1.00 (s, 9H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 156.96 (*a*d, *J* = 37 Hz, *C*F_3*CO*), 137.99, 137.49, 137.24, 137.20, 136.89 (*aromatic* C), 134.58 (C-9), 128.70, 128.69, 128.65, 128.54, 128.36, 128.29, 128.20, 128.13, 127.90, 127.87, 127.83, 127.28, 127.06 (*aromatic* C*H*), 117.06 (C-10), 115.95 (*a*d, *J* = 286 Hz, CF_3), 98.55, 98.14, 97.51, 76.02, 75.80, 74.48, 73.76, 73.41, 71.68, 70.94, 70.69, 70.64, 70.37, 69.88, 69.67, 68.89, 67.89, 67.55, 67.23, 66.50, 66.44, 59.55, 58.60, 49.27, 33.91, 27.68, 27.50, 23.36, 20.80. HR-MS: Calculated for $C_{67}H_{82}N_7O_{14}F_3Si$ $[M+Na]^+$: 1316.5539, found: 1316.5533.

3-Butenyl 2-azido-3-*O*-benzyl-2-deoxy-α-D-galactopyranosyl-(1→4)-3,6-di-*O*-benzyl-2-deoxy-2-trifluoro-acetamido-α-D-galactopyranosyl-(1→4)-2-azido-3,6-di-*O*-benzyl-2-deoxy-α-D-galactopyranoside (S24)

The reaction was carried out according to the general procedure C using compound **27** (910 mg, 0.70 mmol) and HF/pyridine (70%, 292 µl, 11.2 mmol). The product was purified by column chromatography (pentane:EtOAc = 2:1). Compound **S24** (710 mg, 88% yield) was obtained as white foam. $[\alpha]_D^{25}$ +155.4 (c=1, $CHCl_3$). ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.54 – 7.20 (m, 25H), 6.54 (d, *J* = 10.3, 3.9 Hz, 1H), 5.82 (ddt, *J* = 17.0, 10.4, 6.7 Hz, 1H), 5.18 – 5.06 (m, 2H), 5.04 (d, *J* = 3.6 Hz, 1H), 5.01 (d, *J* = 3.6 Hz, 1H), 4.93 – 4.73 (m, 5H), 4.62 – 4.54 (m, 2H), 4.49 (s, 2H), 4.42 – 4.27 (m, 5H), 4.27 – 4.22 (m, 1H), 4.20 – 4.12 (m, 2H), 4.06 (dd, *J* = 10.5, 3.0 Hz, 1H), 3.97 – 3.81 (m, 3H), 3.76 (dd, *J* = 10.5, 3.5 Hz, 1H), 3.73 – 3.64 (m, 2H), 3.63 – 3.49 (m, 3H), 3.48 – 3.34 (m, 3H), 3.28 (dd, *J* = 8.6, 5.3 Hz, 1H), 2.95 (d, *J* = 8.1 Hz, 1H), 2.44 (s, 1H), 2.38 (q, *J* = 6.7 Hz, 2H). ^{13}C NMR (125 MHz, $CDCl_3$) δ 157.11 (*a*d, *J* = 37 Hz, *CF*$_3$*CO*), 137.38, 137.37, 137.35, 137.20, 136.91 (*aromatic* C), 134.52 (C-9), 128.65, 128.61, 128.41, 128.27, 128.22, 128.17, 128.14, 128.09, 128.00, 127.95, 127.87, 127.44, 127.14 (*aromatic* C*H*), 116.98 (C-10), 115.81 (*a*d, *J* = 286 Hz, C*F*$_3$), 98.86, 98.07, 97.42, 76.53, 75.51, 74.37, 73.62, 73.26, 71.84, 71.69, 71.65, 71.10, 70.81, 69.94, 69.16, 68.82, 67.81, 67.56, 66.53, 66.49, 62.71, 59.51, 59.47, 49.40, 33.83. HR-MS: Calculated for $C_{59}H_{66}N_7O_{14}F_3$ $[M+Na]^+$: 1176.4518, found: 1176.4512.

3-Butenyl 2-azido-3,6-di-*O*-benzyl-2-deoxy-α-D-galactopyranosyl-(1→4)-3,6-di-*O*-benzyl-2-deoxy-2-trifluoroacetamido-α-D-galactopyranosyl-(1→4)-2-azido-3,6-di-*O*-benzyl-2-deoxy-α-D-galactopyranoside (S25)

The reaction was carried out according to the general procedure D using compound **S24** (983 mg, 0.85 mmol), K_2CO_3 (129 mg, 0.94 mmol), KI (141 mg, 0.85 mmol) and $Ph_2BO(CH_2)_2NH_2$ (19 mg, 0.085 mmol). The product was purified by column chromatography (pentane:EtOAc = 4:1). Compound **S25** (973 mg, 92% yield) was obtained as white foam. $[\alpha]_D^{25}$ +141.7 (c=1, $CHCl_3$). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.48 – 7.14 (m, 32H), 6.32 (d, *J* = 9.5 Hz, 1H), 5.75 (ddt, *J* = 17.0, 10.2, 6.8 Hz, 1H), 5.10 – 5.00 (m, 2H), 4.98 (d, *J* = 3.7 Hz, 1H), 4.95 (d, *J* = 3.7 Hz, 1H), 4.82 (d, *J* = 12.4 Hz, 1H), 4.79 – 4.66 (m, 4H), 4.52 (t, *J* = 12.7 Hz, 2H), 4.42 (s, 2H), 4.37 (q, *J* = 5.3, 3.9 Hz, 1H), 4.34 – 4.17 (m, 7H), 4.07 (d, *J* = 1.5 Hz, 2H), 4.00 (dd, *J* = 10.5, 2.9 Hz, 1H), 3.90 – 3.80 (m, 2H), 3.77 (dd, *J* = 10.6, 3.1 Hz, 2H), 3.67 – 3.55 (m, 2H), 3.53 – 3.43 (m, 2H), 3.40 – 3.25 (m, 4H), 3.19 (dd, *J* = 8.5, 5.2 Hz, 1H), 3.09 (s, 1H), 2.31 (q, *J* = 6.7 Hz, 2H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 156.86 (*a*d, *J* = 37 Hz, *CF*$_3$*CO*), 137.61, 137.55, 137.47, 137.39, 137.37, 136.93 (*aromatic* C), 134.53 (C-9), 128.98, 128.61, 128.55, 128.52, 128.44, 128.42, 128.35, 128.31, 128.22, 128.14, 128.03, 128.01, 127.94, 127.85, 127.78, 127.72, 127.53, 127.24, 127.08 (*aromatic* C*H*), 116.98 (C-10), 115.92 (*a*d, *J* = 286 Hz, C*F*$_3$), 98.94, 98.04, 97.42, 76.56, 75.62, 74.20, 73.61, 73.46, 73.25, 71.62, 71.50, 71.41, 71.00, 70.74, 69.89, 69.77, 68.84, 68.32, 67.78, 66.88, 66.50, 59.52, 59.36, 49.33, 33.84. HR-MS: Calculated for $C_{66}H_{72}N_7O_{14}F_3$ $[M+Na]^+$: 1266.4987, found: 1266.4982.

3-Butenyl 2-azido-3-*O*-benzyl-2-deoxy-4,6-di-*tert*-butylsilylidene-α-D-glucopyranosyl-(1→4)-2-azido-3,6-di-*O*-benzyl-2-deoxy-α-D-galactopyranosyl-(1→4)-3,6-di-*O*-benzyl-2-deoxy-2-trifluoroacetamido-α-D-galactopyranosyl-(1→4)-2-azido-3,6-di-*O*-benzyl-2-deoxy-α-D-galactopyranoside (28)

The reaction was carried out according to the general procedure A. The donor **4** (585 mg, 0.96 mmol) and acceptor **S25** (400 mg, 0.32 mmol) were co-evaporated with toluene (three times). The residue was dissolved in dry 4 ml

DCM under nitrogen and stirred over fresh flame-dried molecular sieves 4Å. The solution was cooled to -10 ºC, after which TfOH (9 µl, 0.01 mmol) was added. The reaction was stirred at -10 ºC for overnight. Then the reaction was quenched with Et_3N, diluted with DCM, washed with saturated $NaHCO_3$ and brine. The organic phase was dried with anhydrous $MgSO_4$, filtered and concentrated *in vacuo*. The product was purified by silica gel column chromatography (pentane:EtOAc = 8:1). Compound **28** (487 mg, 90% yield) was obtained as yellow syrup. $[\alpha]_D^{25}$ +134.9 (c=1, $CHCl_3$). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.47 – 7.16 (m, 39H), 6.28 (d, *J* = 9.6 Hz, 1H), 5.75 (ddt, *J* = 17.0, 10.2, 6.7 Hz, 1H), 5.13 – 4.98 (m, 3H), 4.96 (d, *J* = 3.8 Hz, 1H), 4.94 (d, *J* = 3.7 Hz, 1H), 4.88 – 4.70 (m, 6H), 4.61 (d, *J* = 12.0 Hz, 1H), 4.55 – 4.19 (m, 12H), 4.17 – 4.02 (m, 3H), 3.94 (dd, *J* = 11.7, 3.3 Hz, 3H), 3.88 – 3.74 (m, 6H), 3.72 – 3.56 (m, 5H), 3.48 (dt, *J* = 9.7, 6.5 Hz, 1H), 3.42 – 3.25 (m, 3H), 3.22 – 3.13 (m, 2H), 3.08 (dd, *J* = 8.7, 5.2 Hz, 1H), 2.36 – 2.26 (m, 2H), 1.03 (s, 9H), 0.98 (s, 9H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 156.79 (*a*d, *J* = 37 Hz, *CF$_3$CO*), 138.23, 137.72, 137.60, 137.44, 137.32, 136.98 (*aromatic* C), 134.57 (C-9), 128.70, 128.64, 128.56, 128.50, 128.46, 128.44, 128.38, 128.34, 128.30, 128.27, 128.25, 128.19, 128.15, 128.10, 127.98, 127.90, 127.87, 127.79, 127.76, 127.66, 127.62, 127.24, 127.15, 127.11 (*aromatic* C*H*), 117.02 (C-10), 115.86 (*a*d, *J* = 286 Hz, C*F$_3$*), 98.64, 98.47, 98.11, 97.53, 79.33, 79.24, 76.28, 75.60, 75.51, 74.59, 73.66, 73.28, 73.06, 72.99, 72.24, 71.64, 71.16, 71.10, 70.74, 69.91, 69.07, 68.91, 67.82, 66.77, 66.71, 66.59, 66.38, 66.07, 62.99, 60.27, 59.54, 49.33, 33.89, 27.45, 27.19, 22.64, 20.04. HR-MS: Calculated for $C_{87}H_{103}N_{10}O_{18}F_3Si$ $[M+Na]^+$: 1683.7071, found: 1683.7065.

3-Butenyl 2-azido-3-*O*-benzyl-2-deoxy-α-D-glucopyranosyl-(1→4)-2-azido-3,6-di-*O*-benzyl-2-deoxy-α-D-galactopyranosyl-(1→4)-3,6-di-*O*-benzyl-2-deoxy-2-trifluoroacetamido-α-D-galactopyranosyl-(1→4)-2-azido-3,6-di-*O*-benzyl-2-deoxy-α-D-galactopyranoside (S26)

The reaction was carried out according to the general procedure C using compound **28** (638 mg, 0.38 mmol) and HF/pyridine (70%, 160 µl, 6.14 mmol). The product was purified by column chromatography (pentane:EtOAc = 3:1). Compound **S26** (469 mg, 80% yield) was obtained as white foam. $[\alpha]_D^{25}$ +187.5 (c=1, $CHCl_3$). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.44 – 7.14 (m, 37H), 6.52 (d, *J* = 9.6 Hz, 1H), 5.74 (ddt, *J* = 17.1, 10.2, 6.7 Hz, 1H), 5.10 – 4.98 (m, 3H), 4.95 (d, *J* = 3.7 Hz, 1H), 4.90 (d, *J* = 3.7 Hz, 1H), 4.87 (s, 2H), 4.82 (d, *J* = 4.3 Hz, 1H), 4.81 – 4.76 (m, 2H), 4.72 (d, *J* = 12.7 Hz, 1H), 4.65 (d, *J* = 11.9 Hz, 1H), 4.56 (td, *J* = 10.4, 3.6 Hz, 1H), 4.49 (d, *J* = 12.4 Hz, 1H), 4.46 – 4.37 (m, 3H), 4.34 – 4.23 (m, 5H), 4.14 – 3.97 (m, 5H), 3.95 – 3.71 (m, 6H), 3.69 – 3.57 (m, 4H), 3.48 (dt, *J* = 9.7, 6.5 Hz, 1H), 3.41 – 3.26 (m, 3H), 3.20 (dq, *J* = 8.4, 5.0, 4.6 Hz, 2H), 3.15 – 3.02 (m, 4H), 2.31 (q, *J* = 6.7 Hz, 2H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 156.94 (*a*d, *J* = 37 Hz, *CF$_3$CO*), 138.21, 137.63, 137.59, 137.39, 137.34, 136.93 (*aromatic* C), 134.53 (C-9), 128.61, 128.54, 128.49, 128.45, 128.37, 128.35, 128.21, 128.14, 128.02, 128.00, 127.92, 127.87, 127.86, 127.78, 127.69, 127.22, 127.12, 126.90 (*aromatic* C*H*), 117.00 (C-10), 115.95 (*a*d, *J* = 286 Hz, C*F$_3$*), 98.79, 98.28, 98.08, 97.61, 79.64, 76.04, 75.55, 75.06, 74.52, 73.61, 73.27, 72.97, 72.15, 71.71, 71.68, 71.63, 71.21, 71.18, 70.81, 70.75, 69.82, 68.98, 68.92, 67.81, 66.54, 66.44, 66.23, 63.34, 61.97, 59.99, 59.48, 49.36, 33.84. HR-MS: Calculated for $C_{79}H_{87}N_{10}O_{18}F_3$ $[M+Na]^+$: 1543.6050, found: 1543.6044.

3-Butenyl 2-azido-3,6-di-*O*-benzyl-2-deoxy-α-D-glucopyranosyl-(1→4)-2-azido-3,6-di-*O*-benzyl-2-deoxy-α-D-galactopyranosyl-(1→4)-3,6-di-*O*-benzyl-2-deoxy-2-trifluoroacetamido-α-D-galactopyranosyl-(1→4)-2-azido-3,6-di-*O*-benzyl-2-deoxy-α-D-galactopyranoside (S27)

The reaction was carried out according to the general procedure D using compound **S26** (452 mg, 0.30 mmol), K_2CO_3 (45 mg, 0.33 mmol), KI (49 mg, 0.30 mmol) and $Ph_2BO(CH_2)_2NH_2$ (6.7 mg, 0.03 mmol). The product was purified by column chromatography (pentane:EtOAc = 5:1). Compound **S27** (445 mg, 93% yield) was obtained as white foam. $[\alpha]_D^{25}$ +147.6 (c=0.5, $CHCl_3$). ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.42 – 7.11 (m, 43H), 6.36 (d, *J* = 9.6 Hz, 1H), 5.80 – 5.69 (m, 1H), 5.09 – 4.99 (m, 3H), 4.96 (d, *J* = 3.7 Hz, 2H), 4.92 (d, *J* = 10.9 Hz, 1H), 4.88 – 4.83 (m, 2H), 4.80 (d, *J* = 12.4 Hz, 1H), 4.76 (d, *J* = 3.6 Hz, 1H), 4.72 (d, *J* = 12.7 Hz, 1H), 4.62 (d, *J* = 11.8 Hz, 1H), 4.56 (ddd, *J* = 13.3, 9.8, 3.7 Hz, 1H), 4.48 (d, *J* = 12.4 Hz, 1H), 4.45 – 4.36 (m, 3H), 4.36 – 4.23 (m, 5H), 4.18 (d, *J* = 12.0 Hz, 1H), 4.13 – 4.03 (m, 6H), 4.01 (dd, *J* = 11.0, 2.6 Hz, 1H), 3.88 – 3.70 (m, 6H), 3.67 (dd, *J* = 11.0, 3.6 Hz, 1H), 3.65 – 3.56 (m, 2H), 3.47 (dt, *J* = 9.7, 6.5 Hz, 1H), 3.39 – 3.25 (m, 3H), 3.25 – 3.18 (m, 2H), 3.15 (dd, *J* = 8.7, 5.2 Hz, 1H), 3.09 (dd, *J* = 10.3, 3.3 Hz, 1H), 3.00 (dd, *J* = 10.3, 4.8 Hz, 1H), 2.68 (d, *J* = 2.8 Hz, 1H), 2.38 – 2.25 (m, 2H). ^{13}C NMR (125 MHz, $CDCl_3$) δ 156.82 (*a*d, *J* = 37 Hz, *CF*$_3$*CO*), 138.27, 137.74, 137.73, 137.72, 137.54, 137.37, 137.33, 136.91 (*aromatic* C), 134.51 (C-9), 128.57, 128.53, 128.47, 128.43, 128.37, 128.35, 128.32, 128.17, 128.12, 128.07, 128.02, 127.97, 127.82, 127.78, 127.76, 127.70, 127.65, 127.43, 127.27, 127.10, 126.88 (*aromatic* C*H*), 116.95 (C-10), 115.89 (*a*d, *J* = 286 Hz, C*F*$_3$), 98.78, 98.59, 98.04, 97.49, 79.66, 76.27, 75.54, 75.04, 74.40, 73.59, 73.28, 73.26, 72.95, 72.93, 72.75, 71.79, 71.59, 71.10, 71.05, 70.68, 69.81, 69.67, 69.38, 69.08, 68.87, 67.76, 66.53, 66.44, 66.27, 63.32, 59.96, 59.49, 49.32. HR-MS: Calculated for $C_{86}H_{93}N_{10}O_{18}F_3$ $[M+Na]^+$: 1633.6519, found: 1633.6514.

Pentasaccharide 29

The reaction was carried out according to the general procedure B using donor **14** (550 mg, 0.81 mmol) and acceptor **S27** (437 mg, 0.27 mmol). The product was purified by column chromatography (pentane:EtOAc = 7:1). Compound **29** (488 mg, 85% yield) was obtained as yellow foam. $[\alpha]_D^{25}$ +157.8 (c=0.5, $CHCl_3$). ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.45 – 7.16 (m, 47H), 7.15 – 7.09 (m, 2H), 6.89 (d, *J* = 9.5 Hz, 1H), 6.31 (d, *J* = 9.6 Hz, 1H), 5.75 (ddt, *J* = 17.1, 10.2, 6.8 Hz, 1H), 5.48 (d, *J* = 3.5 Hz, 1H), 5.11 – 4.99 (m, 4H), 4.96 (d, *J* = 3.6 Hz, 1H), 4.86 – 4.63 (m, 8H), 4.61 – 4.37 (m, 10H), 4.37 – 4.17 (m, 7H), 4.16 – 4.01 (m, 5H), 4.00 – 3.58 (m, 13H), 3.54 – 3.41 (m, 3H), 3.40 – 3.14 (m, 6H), 3.07 – 3.01 (m, 1H), 2.97 (d, *J* = 10.7 Hz, 1H), 2.31 (qt, *J* = 6.7, 1.4 Hz, 2H), 1.03 (d, *J* = 4.7 Hz, 18H). ^{13}C NMR (125 MHz, $CDCl_3$) δ 157.08 (*a*d, *J* = 37 Hz, 2x*CF*$_3$*CO*), 138.07, 137.63, 137.55, 137.45, 137.38, 136.92, 136.42 (*aromatic* C), 134.51 (C-9), 128.61, 128.59, 128.49, 128.44, 128.42, 128.38, 128.33, 128.22, 128.19, 128.13, 128.08, 127.93, 127.89, 127.86, 127.84, 127.83, 127.74, 127.72, 127.33, 127.10, 126.83 (*aromatic* C*H*), 116.98 (C-10), 115.96 (*a*d, *J* = 286 Hz, 2xC*F*$_3$), 98.75, 98.07, 98.01, 97.48, 97.04, 76.12, 75.57, 75.26, 74.39, 74.20, 73.62, 73.49, 73.27, 73.00, 72.40, 71.90, 71.88, 71.64, 71.20, 71.06, 70.75, 70.61, 69.79, 69.68, 69.57, 68.98, 68.81, 68.44, 67.80, 67.05, 66.55, 66.52, 66.23, 63.95, 60.35, 59.52, 49.30, 48.57, 33.84, 27.62, 27.32. HR-MS: Calculated for $C_{109}H_{125}N_{11}O_{23}F_6Si$ $[M+Na]^+$: 2120.8521, found: 2120.8516.

Pentasaccharide S28

The reaction was carried out according to the general procedure C using compound **29** (478 mg, 0.23 mmol) and HF/pyridine (70%, 95 µl, 3.64 mmol). The product was purified by column chromatography (pentane:EtOAc = 3:2). Compound **S28** (423 mg, 95% yield) was obtained as white foam. $[\alpha]_D^{25}$ +135.4 (c=0.5, $CHCl_3$). ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.43 – 7.14 (m, 46H), 7.08 (d, *J* = 9.8 Hz, 1H), 6.40 (d, *J* = 9.6 Hz, 1H), 5.74 (ddt, *J* = 17.0, 10.2, 6.7 Hz, 1H), 5.26 (d, *J* = 3.6 Hz, 1H), 5.11 – 4.98 (m, 4H), 4.95 (d, *J* = 3.6 Hz, 1H), 4.85 – 4.74 (m, 4H), 4.69 (d, *J* = 12.6 Hz, 1H), 4.63 (d, *J* = 11.8 Hz, 1H), 4.59 – 4.43 (m, 6H), 4.39 (d, *J* = 12.5 Hz, 3H), 4.35 – 4.22 (m, 7H), 4.15 – 4.01 (m, 6H), 3.97 (d, *J* = 9.0 Hz, 1H), 3.92 – 3.82 (m, 3H), 3.78 (dq, *J* = 9.4, 2.7 Hz, 2H), 3.73 – 3.58 (m, 7H), 3.48 (dt, *J* = 9.7, 6.5 Hz, 1H), 3.42 (dd, *J* = 10.6, 2.8 Hz, 1H), 3.39 – 3.26 (m, 3H), 3.25 – 3.14 (m, 3H), 3.11 (d, *J* = 10.4 Hz, 1H), 3.00 (d, *J* = 11.0 Hz, 1H), 2.35 – 2.24 (m, 2H). ^{13}C NMR (125 MHz, $CDCl_3$) δ 157.08 (*a*d, *J* = 37 Hz, 2x*CF*$_3$*CO*), 137.60, 137.54, 137.46, 137.43, 137.36, 137.14, 136.88, 136.55 (*aromatic* C), 134.49 (C-9), 128.55, 128.54, 128.37, 128.33, 128.17, 128.14, 128.09, 128.03, 127.99, 127.92, 127.86, 127.82, 127.79, 127.59, 127.34, 127.25, 127.05, 126.92 (*aromatic* C*H*), 116.91 (C-10), 115.89 (*a*d, *J* = 286 Hz, 2xC*F*$_3$), 98.73, 98.03, 97.96, 97.49, 97.46, 79.52, 75.91, 75.56, 74.39, 74.05, 73.87, 73.58, 73.38, 73.21, 72.94, 72.05, 71.90, 71.61, 71.12, 71.08, 70.87, 70.74, 70.71, 70.57, 69.72, 68.93, 68.82, 67.76, 67.32, 66.55, 66.52, 66.26, 66.10, 63.81, 62.38, 60.18, 59.48, 49.28, 49.20, 33.79. HR-MS: Calculated for $C_{101}H_{109}N_{11}O_{23}F_6$ $[M+Na]^+$: 1980.7500, found: 1980.7494.

Pentasaccharide S29

The reaction was carried out according to the general procedure D using compound **S28** (416 mg, 0.21 mmol), K_2CO_3 (32 mg, 0.23 mmol), KI (35 mg, 0.21 mmol) and $Ph_2BO(CH_2)_2NH_2$ (4.8 mg, 0.021 mmol). The product was purified by column chromatography (pentane:EtOAc = 4:1). Compound **S29** (391 mg, 90% yield) was obtained as yellow syrup. $[\alpha]_D^{25}$ +169 (c=0.5, $CHCl_3$). ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.47 – 7.05 (m, 54H), 6.42 (d, *J* = 9.5 Hz, 1H), 5.74 (ddt, *J* = 17.0, 10.2, 6.7 Hz, 1H), 5.28 (d, *J* = 3.6 Hz, 1H), 5.10 – 4.99 (m, 4H), 4.95 (d, *J* = 3.6 Hz, 1H), 4.85 – 4.72 (m, 4H), 4.67 (d, *J* = 12.6 Hz, 1H), 4.63 – 4.19 (m, 20H), 4.16 – 3.96 (m, 7H), 3.94 – 3.83 (m, 4H), 3.82 – 3.74 (m, 2H), 3.73 – 3.57 (m, 5H), 3.56 – 3.41 (m, 3H), 3.33 (ddt, *J* = 26.5, 10.2, 4.8 Hz, 3H), 3.24 – 3.11 (m, 4H), 3.04 (d, *J* = 10.8 Hz, 1H), 2.76 (s, 1H), 2.29 (q, *J* = 6.8 Hz, 2H). ^{13}C NMR (125 MHz, $CDCl_3$) δ 156.93 (*a*d, *J* = 37 Hz, 2x*CF*$_3$*CO*), 137.88, 137.74, 137.49, 137.37, 137.31, 137.29, 137.23, 136.83, 136.53 (*aromatic* C), 134.43 (C-9), 128.46, 128.43, 128.41, 128.30, 128.29, 128.24, 128.19, 128.13, 128.06, 128.02, 127.90, 127.86, 127.78, 127.71, 127.68, 127.65, 127.59, 127.53, 127.49, 127.24, 127.22, 126.96 (*aromatic* C*H*), 116.82 (C-10), 115.77 (*a*d, *J* = 286 Hz, C*F*$_3$), 98.62, 97.97, 97.94, 97.46, 97.38, 79.38, 75.98, 75.71, 75.51, 74.25, 73.88, 73.53, 73.49, 73.14, 73.04, 72.84, 72.01, 71.74, 71.52, 70.99, 70.69, 70.65, 70.60, 69.67, 69.49, 68.85, 68.76, 68.69, 67.67, 67.55, 66.46, 66.22, 65.10, 63.71, 60.08, 59.41, 49.25, 49.21, 33.71. HR-MS: Calculated for $C_{108}H_{115}N_{11}O_{23}F_6$ $[M+Na]^+$: 2070.7969, found: 2070.7964.

Hexasaccharide 30

The reaction was carried out according to the general procedure B using donor **13** (344 mg, 0.57 mmol) and acceptor **S29** (388 mg, 0.19 mmol). The product was purified by column chromatography (pentane:EtOAc = 6:1). Compound **30** (401 mg, 85% yield) was obtained as white foam. $[\alpha]_D^{25}$ +150 (c=0.5, $CHCl_3$). ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.49 – 7.41 (m, 2H), 7.40 – 7.12 (m, 55H), 7.01 (d, *J* = 9.8 Hz, 1H), 6.28 (d, *J* = 9.6 Hz, 1H), 5.80 – 5.68 (m, 1H), 5.38 (d, *J* = 3.5 Hz, 1H), 5.11 – 4.99 (m, 4H), 4.96 (dd, *J* = 5.9, 3.6 Hz, 2H), 4.84 – 4.21 (m, 29H), 4.15 – 3.95 (m, 9H), 3.94 – 3.44 (m, 16H), 3.40 – 3.09 (m, 8H), 3.03 (d, *J* = 11.0 Hz, 1H), 2.30 (q, *J* = 6.7 Hz, 2H), 1.03 (s, 9H), 0.96 (s, 9H). ^{13}C NMR (125 MHz, $CDCl_3$) δ 157.05 (*a*d, *J* = 37 Hz, 2x*CF*$_3$*CO*), 137.90, 137.84, 137.50, 137.41, 137.37, 137.31, 137.29, 137.23, 137.14, 136.81, 136.39 (*aromatic* C), 134.44 (C-9), 128.53, 128.51, 128.47, 128.44, 128.37, 128.34, 128.31, 128.29, 128.18, 128.15, 128.09, 128.05, 127.98, 127.89, 127.86, 127.81, 127.78, 127.76, 127.67, 127.62, 127.57, 127.51, 127.26, 126.99, 126.84, 126.04 (*aromatic* C*H*), 116.92 (C-10), 115.81 (*a*d, *J* = 286 Hz, 2xC*F*$_3$), 98.74, 98.68, 98.01, 97.40, 97.37, 79.54, 76.28, 75.88, 75.53, 74.31, 73.98, 73.56, 73.30, 73.20, 73.17, 72.91, 71.96, 71.82, 71.55, 71.01, 70.95, 70.91, 70.64, 70.53, 70.50, 70.10, 69.70, 69.55, 68.90, 68.73, 67.72, 67.51, 67.46, 66.96, 66.48, 66.41, 66.21, 63.78, 60.12, 59.44, 58.42, 49.60, 49.20, 33.77, 27.52, 27.37, 23.17.

Hexasaccharide S30

The reaction was carried out according to the general procedure C using compound **30** (394 mg, 0.16 mmol) and HF/pyridine (70%, 66 µl, 2.56 mmol). The product was purified by column chromatography (pentane:EtOAc = 3:2). Compound **S30** (340 mg, 91% yield) was obtained as white foam. $[\alpha]_D^{25}$ +149.2 (c=0.5, $CHCl_3$). ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.42 – 7.12 (m, 63H), 7.08 (d, *J* = 9.8 Hz, 1H), 6.42 (d, *J* = 9.6 Hz, 1H), 5.74 (ddt, *J* = 17.0, 10.3, 6.7 Hz, 1H), 5.34 (d, *J* = 3.5 Hz, 1H), 5.11 – 4.91 (m, 7H), 4.85 – 4.74 (m, 4H), 4.72 – 4.52 (m, 9H), 4.52 – 3.57 (m, 41H), 3.52 – 3.43 (m, 2H), 3.43 – 3.07 (m, 11H), 3.01 (d, *J* = 10.9 Hz, 1H), 2.90 (s, 1H), 2.30 (q, *J* = 6.7 Hz, 2H). ^{13}C NMR (125 MHz, $CDCl_3$) δ 157.11 (*a*d, *J* = 37 Hz, 2x*CF*$_3$*CO*), 137.88, 137.54, 137.44, 137.42, 137.39, 137.33, 137.15, 136.86, 136.49 (*aromatic* C), 134.46 (C-9), 128.52, 128.47, 128.44, 128.33, 128.29, 128.19, 128.14, 128.11, 128.06, 128.04, 127.92, 127.83, 127.77, 127.73, 127.72, 127.60, 127.58, 127.20, 127.02, 126.88, 126.40 (*aromatic* C*H*), 116.88 (C-10), 115.84 (*a*d, *J* = 286 Hz, 2xC*F*$_3$), 99.15, 98.69, 98.02, 97.41, 79.47, 76.15, 75.84, 75.51, 74.35, 73.82, 73.54, 73.47, 73.18, 73.16, 72.89, 72.10, 72.04, 71.85, 71.66, 71.58, 71.09, 71.05, 71.01, 70.65, 70.27, 69.68, 69.17, 68.89, 68.77, 67.72, 67.49, 67.43, 66.65, 66.53, 66.48, 63.76, 62.43, 60.13, 59.44, 59.40, 49.76, 49.24, 33.76.

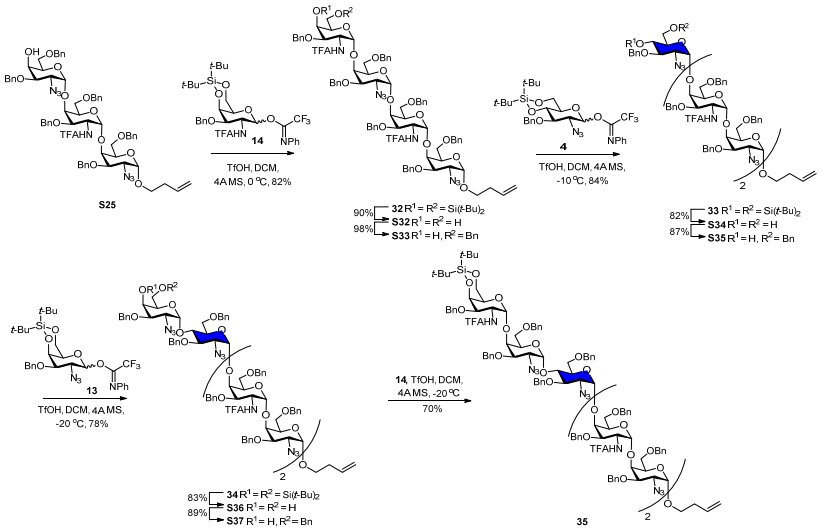
Hexasaccharide S31

The reaction was carried out according to the general procedure D using compound **S30** (333 mg, 0.14 mmol), K_2CO_3 (22 mg, 0.16 mmol), KI (24 mg, 0.14 mmol) and $Ph_2BO(CH_2)_2NH_2$ (6.4 mg, 0.029 mmol). The product was purified by column chromatography (pentane:EtOAc = 7:2). Compound **S31** (325 mg, 94% yield) was obtained as white foam. $[\alpha]_D^{25}$ +146.2 (c=0.5, $CHCl_3$). ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.45 – 7.09 (m, 62H), 6.99 (d, *J* = 9.7 Hz, 1H), 6.32 (d, *J* = 9.5 Hz, 1H), 5.80 – 5.67 (m, 1H), 5.37 (d, *J* = 3.5 Hz, 1H), 5.09 – 5.00 (m, 4H), 4.99 (d, *J* = 3.7 Hz, 1H), 4.95 (d, *J* = 3.6 Hz, 1H), 4.83 – 4.73 (m, 5H), 4.72 – 4.52 (m, 7H), 4.51 – 4.43 (m, 2H), 4.43 – 4.17 (m, 15H), 4.16 – 3.57 (m, 21H), 3.50 – 3.42 (m, 2H), 3.42 – 3.07 (m, 11H), 3.01 (d, *J* = 11.0 Hz, 1H), 2.29 (q, *J* = 6.7

Hz, 2H). ^{13}C NMR (125 MHz, $CDCl_3$) δ 156.99 (*a*d, *J* = 37 Hz, 2x*CF*$_3$*CO*), 137.82, 137.61, 137.51, 137.46, 137.40, 137.37, 137.35, 137.28, 137.25, 136.77, 136.42 (*aromatic* C), 134.41 (C-9), 128.48, 128.44, 128.40, 128.34, 128.29, 128.28, 128.26, 128.23, 128.19, 128.17, 128.14, 128.10, 128.04, 128.00, 127.98, 127.91, 127.81, 127.75, 127.73, 127.70, 127.56, 127.50, 127.45, 127.19, 126.94, 126.77, 126.37 (*aromatic* C*H*), 116.86 (C-10), 115.83 (*a*d, *J* = 286 Hz, C*F*$_3$), 99.39, 98.63, 97.97, 97.34, 97.27, 79.45, 76.26, 76.16, 75.83, 75.49, 74.27, 73.82, 73.50, 73.42, 73.21, 73.14, 73.11, 72.85, 72.02, 71.94, 71.75, 71.50, 71.19, 71.07, 70.96, 70.89, 70.59, 70.17, 69.78, 69.65, 68.84, 68.69, 68.24, 67.67, 67.42, 66.86, 66.56, 66.44, 66.37, 66.17, 63.71, 60.06, 59.39, 59.25, 58.09, 49.60, 49.17, 33.72.

Heptasaccharide 31

The reaction was carried out according to the general procedure B using donor **14** (381 mg, 0.56 mmol) and acceptor **S31** (330 mg, 0.14 mmol). The product was purified by column chromatography (pentane:EtOAc = 6:1). Compound **31** (341 mg, 86% yield) was obtained as yellow foam. $[\alpha]_D^{25}$ +149.8 (c=0.5, $CHCl_3$). ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.45 – 7.09 (m, 67H), 7.08 – 7.02 (m, 2H), 7.00 (d, *J* = 9.7 Hz, 1H), 6.37 (d, *J* = 9.5 Hz, 1H), 6.27 (d, *J* = 9.4 Hz, 1H), 5.74 (ddt, *J* = 17.0, 10.3, 6.7 Hz, 1H), 5.36 (d, *J* = 3.5 Hz, 1H), 5.10 – 4.98 (m, 5H), 4.97 – 4.93 (m, 1H), 4.86 – 4.66 (m, 9H), 4.66 – 4.52 (m, 6H), 4.52 – 4.19 (m, 20H), 4.14 – 3.83 (m, 15H), 3.81 – 3.55 (m, 9H), 3.53 – 3.26 (m, 8H), 3.26 – 3.08 (m, 4H), 3.06 – 2.93 (m, 2H), 2.92 – 2.85 (m, 1H), 2.30 (q, *J* = 6.8 Hz, 2H), 1.07 (s, 9H), 0.98 (s, 9H). ^{13}C NMR (125 MHz, $CDCl_3$) δ 156.80 (*a*d, *J* = 37 Hz, *CF*$_3$*CO*), 137.89, 137.51, 137.50, 137.42, 137.39, 137.33, 137.31, 137.15, 136.84, 136.80, 136.39 (*aromatic* C), 134.45 (C-9), 128.60, 128.53, 128.50, 128.47, 128.42, 128.37, 128.34, 128.32, 128.28, 128.23, 128.18, 128.14, 128.08, 128.06, 128.01, 127.98, 127.86, 127.83, 127.81, 127.79, 127.76, 127.70, 127.67, 127.63, 127.61, 127.57, 127.53, 127.24, 127.00, 126.84, 126.72, 126.21 (*aromatic* C*H*), 116.91 (C-10), 115.83 (*a*d, *J* = 286 Hz, C*F*$_3$), 98.89, 98.68, 98.03, 97.97, 97.43, 97.28, 96.59, 79.56, 76.55, 75.91, 75.84, 75.55, 74.74, 74.35, 74.02, 73.55, 73.34, 73.19, 73.17, 72.98, 72.91, 71.95, 71.83, 71.58, 71.46, 71.38, 71.05, 70.99, 70.68, 70.61, 69.95, 69.69, 69.42, 69.34, 69.23, 68.89, 68.75, 68.65, 67.74, 67.67, 67.53, 66.89, 66.58, 66.42, 66.20, 65.64, 63.86, 60.16, 60.12, 59.44, 53.44, 49.54, 49.23, 48.13, 33.77, 27.52, 27.35, 23.21, 20.64.



3-Butenyl 3-*O*-benzyl-2-deoxy-4,6-di-*tert*-butylsilylidene-2-trifluoroacetamido-α-D-galactopyranosyl-(1→4)-2-azido-3,6-di-*O*-benzyl-2-deoxy-α-D-galactopyranosyl-(1→4)-3,6-di-*O*-benzyl-2-deoxy-2-trifluoro-acetamido-α-D-galactopyranosyl-(1→4)-2-azido-3,6-di-*O*-benzyl-2-deoxy-α-D-galactopyranoside (32)

The reaction was carried out according to the general procedure B using donor **14** (2.44 g, 3.61 mmol) and acceptor **S25** (1.5 g, 1.2 mmol). The product was purified by column chromatography (pentane:EtOAc = 8:1). Compound **32** (1.70 g, 82% yield) was obtained as yellow foam. ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.44 – 7.10 (m, 37H), 6.28 (dd, *J* = 9.7, 3.6 Hz, 2H), 5.75 (ddt, *J* = 17.1, 10.2, 6.8 Hz, 1H), 5.09 – 5.00 (m, 3H), 4.95 (d, *J* = 3.6 Hz, 1H), 4.87 – 4.83 (m, 1H), 4.82 (s, 1H), 4.79 (d, *J* = 3.6 Hz, 1H), 4.75 (d, *J* = 3.5 Hz, 1H), 4.73 (d, *J* = 3.3 Hz, 1H), 4.67 – 4.62 (m, 2H), 4.62 – 4.56 (m, 1H), 4.55 – 4.44 (m, 4H), 4.44 – 4.34 (m, 4H), 4.31 (dd, *J* = 9.9, 5.3 Hz, 1H), 4.27 (d, *J* = 2.9 Hz, 2H), 4.25 – 4.22 (m, 1H), 4.11 (d, *J* = 11.6 Hz, 1H), 4.06 (d, *J* = 11.6 Hz, 1H), 4.02 (d, *J* = 11.5 Hz, 1H), 3.98 – 3.89 (m, 3H), 3.85 (dd, *J* = 9.0, 5.8 Hz, 1H), 3.83 – 3.76 (m, 2H), 3.70 – 3.57 (m, 4H), 3.53 – 3.43 (m, 2H), 3.40 – 3.28 (m, 4H), 3.21 (dd, *J* = 8.6, 5.2 Hz, 1H), 3.12 – 3.01 (m, 2H), 2.32 (qt, *J* = 6.7, 1.3 Hz, 2H), 1.07 (s, 9H), 0.98 (s, 9H). ^{13}C NMR (125 MHz, $CDCl_3$) δ 156.81 (*a*d, *J* = 37 Hz, 2x*CF$_3$CO*), 137.98, 137.61, 137.45, 137.40, 137.29, 136.97, 136.94 (*aromatic* C), 134.57 (C-9), 128.69, 128.66, 128.65, 128.57, 128.52, 128.50, 128.45, 128.37, 128.25, 128.19, 128.17, 128.10, 127.97, 127.90, 127.83, 127.81, 127.75, 127.37, 127.11, 126.80 (*aromatic* C*H*), 117.02 (C-10), 115.87 (*a*d, *J* = 286 Hz, 2xC*F$_3$*), 98.47, 98.12, 97.54, 96.85, 76.25, 75.76, 74.77, 74.53, 73.67, 73.18, 73.12, 71.79, 71.77, 71.21, 71.14, 70.97, 69.68, 69.65, 69.56, 69.36, 68.88, 68.73, 67.87, 67.83, 67.00, 66.58, 65.86, 60.29, 59.60, 49.31, 48.30, 33.89, 27.64, 27.45, 23.34, 20.75. HR-MS: Calculated for $C_{89}H_{104}N_8O_{19}F_6Si$ $[M+Na]^+$: 1753.6989, found: 1753.6983.

3-Butenyl 3-*O*-benzyl-2-deoxy-2-trifluoroacetamido-α-D-galactopyranosyl-(1→4)-2-azido-3,6-di-*O*-benzyl-2-deoxy-α-D-galactopyranosyl-(1→4)-3,6-di-*O*-benzyl-2-deoxy-2-trifluoroacetamido-α-D-galactopyranosyl-(1→4)-2-azido-3,6-di-*O*-benzyl-2-deoxy-α-D-galactopyranoside (S32)

The reaction was carried out according to the general procedure C using compound **32** (2.33 g, 1.35 mmol) and HF/pyridine (70%, 560 µl, 21.5 mmol). The product was purified by column chromatography (pentane:EtOAc = 2:1). Compound **S32** (1.9 g, 90% yield) was obtained as white foam. $[\alpha]_D^{25}$ +179.4 (c=1, $CHCl_3$). ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.50 – 7.10 (m, 37H), 6.52 (d, *J* = 9.5 Hz, 1H), 6.33 (d, *J* = 9.7 Hz, 1H), 5.75 (ddt, *J* = 17.0, 10.2, 6.7 Hz, 1H), 5.09 – 5.00 (m, 2H), 4.99 (d, *J* = 3.7 Hz, 1H), 4.93 (d, *J* = 3.6 Hz, 1H), 4.87 (d, *J* = 3.7 Hz, 1H), 4.84 – 4.75 (m, 3H), 4.65 (dd, *J* = 11.8, 3.1 Hz, 2H), 4.51 (dp, *J* = 13.4, 3.6, 3.1 Hz, 3H), 4.47 – 4.35 (m, 5H), 4.33 (d, *J* = 2.6 Hz, 1H), 4.30 (dd, *J* = 9.9, 5.4 Hz, 1H), 4.26 (d, *J* = 2.6 Hz, 1H), 4.23 – 4.17 (m, 2H), 4.14 – 3.98 (m, 6H), 3.96 (dd, *J* = 10.9, 2.6 Hz, 1H), 3.85 (dd, *J* = 9.0, 5.8 Hz, 1H), 3.82 – 3.75 (m, 2H), 3.67 – 3.53 (m, 3H), 3.53 – 3.43 (m, 2H), 3.40 – 3.32 (m, 3H), 3.32 – 3.23 (m, 2H), 3.20 (dd, *J* = 8.6, 5.2 Hz, 1H), 3.09 (d, *J* = 7.5 Hz, 2H), 2.90 (s, 1H), 2.32 (qt, *J* = 6.7, 1.4 Hz, 2H). ^{13}C NMR (125 MHz, $CDCl_3$) δ 156.88 (*a*d, *J* = 37 Hz, 2x*CF*$_3$*CO*), 137.63, 137.42, 137.29, 137.15, 137.03, 136.95 (*aromatic* C), 134.56 (C-9), 128.66, 128.64, 128.46, 128.42, 128.24, 128.22, 128.16, 128.11, 128.02, 127.99, 127.96, 127.92, 127.87, 127.63, 127.18, 127.08 (*aromatic* C*H*), 117.00 (C-10), 115.87 (*a*d, *J* = 286 Hz, 2xC*F*$_3$), 98.49, 98.07, 97.51, 97.12, 76.14, 75.74, 75.20, 74.06, 73.65, 73.12, 73.05, 72.02, 71.74, 71.26, 71.14, 70.89, 70.84, 70.76, 69.63, 69.42, 68.86, 68.70, 67.84, 66.60, 66.55, 66.40, 65.86, 62.44, 60.21, 59.57, 49.26, 48.89, 33.86. HR-MS: Calculated for $C_{81}H_{88}N_8O_{19}F_6$ $[M+Na]^+$: 1613.5968, found: 1613.5962.

3-Butenyl 3,6-di-*O*-benzyl-2-deoxy-2-trifluoroacetamido-α-D-galactopyranosyl-(1→4)-2-azido-3,6-di-*O*-benzyl-2-deoxy-α-D-galactopyranosyl-(1→4)-3,6-di-*O*-benzyl-2-deoxy-2-trifluoroacetamido-α-D-galactopyranosyl-(1→4)-2-azido-3,6-di-*O*-benzyl-2-deoxy-α-D-galactopyranoside (S33)

The reaction was carried out according to the general procedure D using compound **S32** (1.84 g, 1.16 mmol), K_2CO_3 (240 mg, 1.73 mmol), KI (249 mg, 1.5 mmol) and $Ph_2BO(CH_2)_2NH_2$ (53 mg, 0.23 mmol). The product was purified by column chromatography (pentane:EtOAc = 4:1). Compound **S33** (1.90 g, 98% yield) was obtained as yellow syrup. $[\alpha]_D^{25}$ +77.4 (c=3, $CHCl_3$). ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.43 – 7.11 (m, 46H), 6.42 (d, *J* = 9.5 Hz, 1H), 6.24 (d, *J* = 9.7 Hz, 1H), 5.75 (ddt, *J* = 17.0, 10.2, 6.7 Hz, 1H), 5.09 – 5.00 (m, 2H), 4.99 (d, *J* = 3.8 Hz, 1H), 4.91 (d, *J* = 3.6 Hz, 1H), 4.87 – 4.78 (m, 3H), 4.76 (d, *J* = 3.6 Hz, 1H), 4.71 (d, *J* = 12.1 Hz, 1H), 4.58 (d, *J* = 12.0 Hz, 1H), 4.56 – 4.32 (m, 10H), 4.31 – 4.16 (m, 9H), 4.10 (d, *J* = 11.6 Hz, 1H), 4.07 – 4.01 (m, 3H), 3.94 (dd, *J* = 10.9, 2.6 Hz, 1H), 3.84 (dd, *J* = 9.0, 5.8 Hz, 1H), 3.80 – 3.73 (m, 2H), 3.66 – 3.53 (m, 4H), 3.48 (dq, *J* = 9.5, 6.4 Hz, 2H), 3.39 – 3.31 (m, 2H), 3.31 – 3.17 (m, 4H), 3.15 – 3.05 (m, 2H), 2.91 (s, 1H), 2.32 (qt, *J* = 6.7, 1.4 Hz, 2H). ^{13}C NMR (125 MHz, $CDCl_3$) δ 156.85 (*a*d, *J* = 37 Hz, 2x*CF*$_3$*CO*), 137.76, 137.62, 137.55, 137.44, 137.31, 137.12, 136.96 (*aromatic* C), 134.59 (C-9), 128.68, 128.66, 128.60, 128.54, 128.51, 128.49, 128.44, 128.43, 128.28, 128.22, 128.07, 128.04, 127.96, 127.90, 127.87, 127.83, 127.79, 127.73, 127.71, 127.28, 127.11 (*aromatic* C*H*), 117.03 (C-10), 115.92 (*a*d, *J* = 286 Hz, C*F*$_3$), 98.57, 98.09, 97.50, 97.30, 76.12, 75.77, 75.44, 74.03, 73.68, 73.57, 73.11, 72.03, 71.74, 71.13, 71.07, 70.88, 70.86, 70.59, 69.68, 69.23, 68.87, 68.81, 68.70, 67.87, 66.61, 66.57, 65.85, 65.78, 60.09, 59.60, 49.26, 48.99, 33.89. HR-MS: Calculated for $C_{88}H_{94}N_8O_{19}F_6$ $[M+Na]^+$: 1703.6437, found: 1703.6432.

Pentasaccharide 33

The reaction was carried out according to the general procedure A. The donor **4** (713 mg, 0.36 mmol) and acceptor **S33** (495 mg, 0.089 mmol) were co-evaporated with toluene (three times). The residue was dissolved in dry 5 ml DCM under nitrogen and stirred over fresh flame-dried molecular sieves 4Å. The solution was cooled to -10 °C, after which TfOH (10 µl, 0.036 mmol) was added. The reaction was stirred at -10 °C for overnight. Then the reaction was quenched with Et_3N, diluted with DCM, washed with saturated $NaHCO_3$ and brine. The organic phase was dried with anhydrous $MgSO_4$, filtered and concentrated *in vacuo*. The product was purified by silica gel column chromatography (pentane:EtOAc = 8:1). Compound **33** (676 mg, 84% yield) was obtained as white foam. $[\alpha]_D^{25}$ +119.6 (c=1, $CHCl_3$). ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.50 – 7.11 (m, 48H), 7.07 (h, *J* = 4.2 Hz, 1H), 6.13 (d, *J* = 9.6 Hz, 1H), 6.08 (d, *J* = 9.4 Hz, 1H), 5.74 (ddt, *J* = 17.0, 10.2, 6.8 Hz, 1H), 5.12 – 4.99 (m, 4H), 4.97 – 4.89 (m, 2H), 4.87 – 4.77 (m, 4H), 4.76 (d, *J* = 3.7 Hz, 1H), 4.74 (d, *J* = 3.7 Hz, 1H), 4.62 – 4.31 (m, 11H), 4.30 – 4.09 (m, 8H), 4.06 – 3.70 (m, 13H), 3.65 – 3.57 (m, 2H), 3.53 (dd, *J* = 11.1, 2.4 Hz, 1H), 3.51 – 3.44 (m, 1H), 3.34 (dd, *J* = 9.3, 5.8 Hz, 1H), 3.29 – 3.17 (m, 4H), 3.16 – 3.01 (m, 4H), 2.31 (qt, *J* = 6.7, 1.3 Hz, 2H), 1.04 (s, 9H), 1.01 (s, 9H). ^{13}C NMR (125 MHz, $CDCl_3$) δ 156.61 (*a*d, *J* = 37 Hz, 2x*CF*$_3$*CO*), 138.33, 137.71, 137.69, 137.41, 137.38, 137.25, 136.94 (*aromatic* C), 134.56 (C-9), 128.67, 128.64, 128.59, 128.54, 128.50, 128.46, 128.44, 128.41, 128.34, 128.28, 128.26, 128.24, 128.23, 128.18, 128.12, 128.10, 128.05, 127.94, 127.91, 127.89, 127.84, 127.81, 127.64, 127.12, 126.81 (*aromatic* C*H*), 117.01 (C-10), 115.93 (*a*d, *J* = 286 Hz, 2xC*F*$_3$), 98.57, 98.11, 98.06, 97.40, 79.41, 79.29, 76.46, 75.73, 75.73, 75.71, 73.65, 73.55, 73.21, 73.17, 73.05, 73.01, 71.93, 71.69, 71.30, 70.95, 70.79, 70.66, 69.62, 69.53, 68.88, 68.84, 67.82, 67.09, 66.78, 66.73, 66.54, 66.26, 65.75, 62.90, 60.02, 59.58, 49.31, 49.22, 33.87, 27.43, 27.05, 22.69, 20.02. HR-MS: Calculated for $C_{109}H_{125}N_{11}O_{23}F_6Si$ $[M+Na]^+$: 2120.8521, found: 2120.8516.

Pentasaccharide S34

The reaction was carried out according to the general procedure C using compound **33** (740 mg, 0.35 mmol) and HF/pyridine (70%, 146 µl, 5.64 mmol). The product was purified by column chromatography (pentane:EtOAc = 2:1). Compound **S34** (568 mg, 82% yield) was obtained as white foam. $[\alpha]_D^{25}$ +144.6 (c=1, $CHCl_3$). ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.49 – 7.10 (m, 46H), 7.06 (dd, *J* = 8.1, 6.4 Hz, 1H), 6.40 (d, *J* = 9.5 Hz, 1H), 6.36 (d, *J* = 9.5 Hz, 1H), 5.74 (ddt, *J* = 17.1, 10.3, 6.7 Hz, 1H), 5.10 – 4.97 (m, 3H), 4.97 – 4.76 (m, 8H), 4.67 (d, *J* = 12.4 Hz, 1H), 4.61 – 4.46 (m, 4H), 4.45 – 4.32 (m, 5H), 4.32 – 3.89 (m, 16H), 3.88 – 3.73 (m, 4H), 3.72 – 3.44 (m, 6H), 3.40 – 2.97 (m, 11H), 2.41 (s, 1H), 2.30 (q, *J* = 6.7 Hz, 2H). ^{13}C NMR (125 MHz, $CDCl_3$) δ 156.80 (*a*d, *J* = 37 Hz, 2x*CF*$_3$*CO*), 138.30, 137.57, 137.53, 137.47, 137.36, 137.31, 137.24, 136.87, 136.84 (*aromatic* C), 134.49 (C-9), 128.56, 128.52, 128.49, 128.45, 128.42, 128.36, 128.34, 128.31, 128.29, 128.28, 128.17, 128.13, 128.11, 127.94, 127.89, 127.87, 127.83, 127.81, 127.76, 127.73, 127.61, 127.42, 127.32, 127.01, 126.82 (*aromatic* C*H*), 116.93 (C-10), 115.79 (*a*d, *J* = 286 Hz, 2xC*F*$_3$), 98.68, 98.51, 98.03, 97.50, 96.88, 79.97, 76.28, 75.67, 75.12, 74.66, 74.21, 73.57, 73.15, 73.07, 72.98, 72.17, 71.88, 71.73, 71.68, 71.43, 71.17, 71.12, 70.84, 70.50, 70.41, 69.67, 69.54, 68.81, 68.63, 67.78, 66.56, 66.45, 65.44, 63.47, 62.03, 59.95, 59.51, 49.38, 49.22, 33.79. HR-MS: Calculated for $C_{101}H_{109}N_{11}O_{23}F_6$ $[M+Na]^+$: 1980.7500, found: 1980.7494.

Pentasaccharide S35

The reaction was carried out according to the general procedure D using compound **S34** (552 mg, 0.28 mmol), K_2CO_3 (58 mg, 0.42 mmol), KI (60 mg, 0.36 mmol) and $Ph_2BO(CH_2)_2NH_2$ (12.7 mg, 0.056 mmol). The product was purified by column chromatography (pentane:EtOAc = 4:1). Compound **S35** (501 mg, 87% yield) was obtained as white foam. $[\alpha]_D^{25}$ +144 (c=1, $CHCl_3$). ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.54 – 6.99 (m, 64H), 6.45 – 6.25 (m, 2H), 5.80 – 5.65 (m, 1H), 5.12 – 4.63 (m, 14H), 4.60 – 3.70 (m, 38H), 3.66 – 2.98 (m, 19H), 2.78 (d, *J* = 4.7 Hz, 1H), 2.51 (d, *J* = 5.8 Hz, 1H), 2.28 (q, *J* = 6.7 Hz, 2H). ^{13}C NMR (125 MHz, $CDCl_3$) δ 156.53 (*a*d, *J* = 37 Hz, 2x*CF*$_3$*CO*), 138.70, 138.24, 137.84, 137.44, 137.42, 137.38, 137.24, 137.13, 136.81, 136.71 (*aromatic* C), 134.37 (C-9), 128.75, 128.43, 128.38, 128.28, 128.25, 128.22, 128.18, 128.15, 128.12, 128.10, 128.05, 128.00, 127.97, 127.94, 127.79, 127.76, 127.68, 127.65, 127.57, 127.48, 127.44, 127.40, 127.01, 126.97, 126.89, 126.81, 126.69 (*aromatic* C*H*), 116.79 (C-10), 115.74 (*a*d, *J* = 286 Hz, C*F*$_3$), 98.67, 98.38, 97.92, 97.26, 96.96, 79.83, 76.11, 75.58, 74.92, 74.86, 73.92, 73.43, 73.11, 72.97, 72.92, 72.83, 72.35, 71.88, 71.58, 71.48, 70.91, 70.80, 70.61, 70.47, 70.37, 69.52, 69.42, 69.04, 68.65, 68.56, 67.61, 66.44, 66.27, 65.41, 63.30, 59.78, 59.37, 58.71, 58.07, 54.59, 49.19, 49.06, 33.66. HR-MS: Calculated for $C_{108}H_{115}N_{11}O_{23}F_6$ $[M+Na]^+$: 2070.7969, found: 2070.7964.

Hexasaccharide 34

The reaction was carried out according to the general procedure B using donor **13** (568 mg, 0.94 mmol) and acceptor **S35** (480 mg, 0.23 mmol). The product was purified by column chromatography (pentane:EtOAc = 6:1). Compound **34** (450 mg, 78% yield) was obtained as white foam. $[\alpha]_D^{25}$ +140.9 (c=1, $CHCl_3$). ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.50 – 7.06 (m, 59H), 6.41 (d, *J* = 9.5 Hz, 1H), 6.21 (d, *J* = 9.6 Hz, 1H), 5.74 (ddt, *J* = 17.1, 10.3, 6.7 Hz, 1H), 5.51 (d, *J* = 3.6 Hz, 1H), 5.09 – 4.98 (m, 4H), 4.97 – 4.88 (m, 4H), 4.84 (d, *J* = 3.7 Hz, 1H), 4.82 – 4.72 (m, 4H), 4.69 (d, *J* = 11.5 Hz, 1H), 4.63 – 4.53 (m, 2H), 4.53 – 4.35 (m, 8H), 4.29 (td, *J* = 14.0, 13.3, 8.9 Hz, 5H), 4.23 – 4.13 (m, 5H), 4.13 – 3.73 (m, 18H), 3.66 – 3.53 (m, 4H), 3.47 (q, *J* = 6.3 Hz, 2H), 3.42 – 3.05 (m, 10H), 2.30 (q, *J* = 6.7 Hz, 2H), 1.03 (s, 10H), 0.97 (d, *J* = 1.5 Hz, 10H). ^{13}C NMR (125 MHz, $CDCl_3$) δ 156.55 (*a*d, *J* = 37 Hz, 2x*CF*$_3$*CO*), 138.18, 138.16, 137.82, 137.65, 137.58, 137.52, 137.33, 137.20, 137.02, 136.82 (*aromatic* C), 134.46 (C-9), 128.55, 128.52, 128.45, 128.41, 128.39, 128.38, 128.33, 128.30, 128.25, 128.18, 128.13, 128.11, 127.99, 127.96, 127.92, 127.89, 127.86, 127.81, 127.78, 127.68, 127.66, 127.59, 127.51, 127.43, 127.39, 127.04, 126.97, 126.77 (*aromatic* C*H*), 116.93 (C-10), 115.90 (*a*d, *J* = 286 Hz, C*F*$_3$), 98.93, 98.48, 98.01, 97.90, 97.34, 97.25, 80.90, 76.30, 75.83, 75.67, 75.53, 74.67, 74.47, 73.88, 73.57, 73.10, 73.04, 73.00, 72.95, 71.78, 71.61, 70.99, 70.90, 70.87, 70.72, 70.64, 70.61, 70.58, 69.84, 69.71, 69.57, 68.78, 68.73, 68.67, 67.79, 67.74, 66.96, 66.66, 66.51, 66.41, 65.63, 64.78, 59.91, 59.50, 49.36, 49.15, 33.79, 27.58, 27.28, 23.28, 20.67.

Hexasaccharide S36

The reaction was carried out according to the general procedure C using compound **34** (440 mg, 0.18 mmol) and HF/pyridine (70%, 74 µl, 2.85 mmol). The product was purified by column chromatography (pentane:EtOAc = 2:1). Compound **S36** (346 mg, 83% yield) was obtained as white foam. $[\alpha]_D^{25}$ +118.6 (c=0.5, $CHCl_3$). ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.61 – 7.01 (m, 59H), 6.44 (d, *J* = 9.5 Hz, 1H), 6.31 (d, *J* = 9.6 Hz, 1H), 5.74 (ddt, *J* = 17.0, 10.3, 6.7 Hz,

1H), 5.32 (d, *J* = 3.6 Hz, 1H), 5.10 – 4.98 (m, 3H), 4.96 – 4.85 (m, 5H), 4.83 (d, *J* = 3.7 Hz, 1H), 4.80 (d, *J* = 12.3 Hz, 1H), 4.77 (d, *J* = 3.6 Hz, 1H), 4.73 (d, *J* = 12.3 Hz, 1H), 4.66 (s, 2H), 4.61 – 4.47 (m, 4H), 4.47 – 4.34 (m, 5H), 4.34 – 4.00 (m, 18H), 4.01 – 3.75 (m, 10H), 3.74 – 3.42 (m, 9H), 3.42 – 3.02 (m, 11H), 2.88 – 2.64 (m, 2H), 2.30 (q, *J* = 6.7 Hz, 2H). ^{13}C NMR (125 MHz, $CDCl_3$) δ 156.73 (*a*d, *J* = 37 Hz, 2x*CF*$_3$*CO*), 138.15, 137.94, 137.61, 137.49, 137.45, 137.31, 137.23, 137.22, 136.90, 136.80 (*aromatic* C), 134.46 (C-9), 128.52, 128.49, 128.38, 128.36, 128.33, 128.32, 128.27, 128.16, 128.14, 128.08, 128.02, 128.01, 127.91, 127.86, 127.78, 127.76, 127.58, 127.55, 127.44, 127.40, 127.01, 126.94, 126.72 (*aromatic* C*H*), 116.89 (C-10), 115.81 (*a*d, *J* = 286 Hz, 2xC*F*$_3$), 98.94, 98.47, 97.98, 97.36, 96.90, 80.07, 76.25, 76.19, 75.64, 75.59, 74.68, 74.15, 73.54, 73.08, 73.00, 72.96, 71.69, 71.61, 71.12, 71.02, 70.96, 70.79, 70.63, 70.40, 70.26, 69.63, 69.51, 68.72, 68.53, 68.40, 67.72, 66.80, 66.62, 66.46, 66.39, 65.37, 64.49, 62.27, 59.89, 59.60, 59.46, 49.35, 49.15, 33.75.

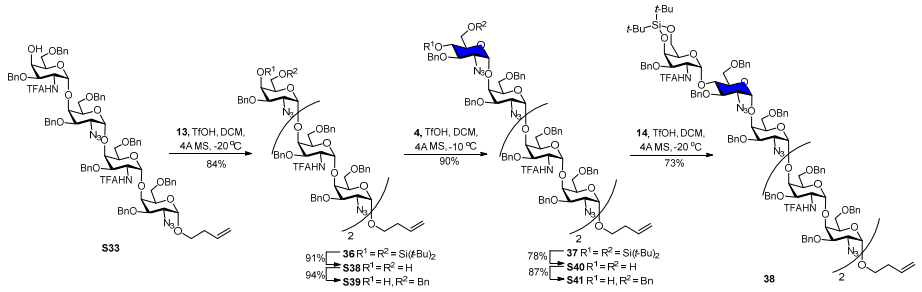
Hexasaccharide S37

The reaction was carried out according to the general procedure D using compound **S36** (340 mg, 0.15 mmol), K_2CO_3 (30 mg, 0.22 mmol), KI (32 mg, 0.19 mmol) and $Ph_2BO(CH_2)_2NH_2$ (6.6 mg, 0.029 mmol). The product was purified by column chromatography (pentane:EtOAc = 4:1). Compound **S37** (309 g, 88% yield) was obtained as white foam. $[\alpha]_D^{25}$ +128 (c=0.2, $CHCl_3$). ^{1}H NMR (500 MHz, Chloroform-*d*) δ 7.52 – 7.03 (m, 65H), 6.37 (d, *J* = 9.5 Hz, 1H), 6.26 (d, *J* = 9.6 Hz, 1H), 5.74 (ddt, *J* = 17.0, 10.3, 6.7 Hz, 1H), 5.55 (d, *J* = 3.7 Hz, 1H), 5.10 – 4.89 (m, 8H), 4.83 (d, *J* = 3.7 Hz, 1H), 4.80 (d, *J* = 12.3 Hz, 1H), 4.77 – 4.68 (m, ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.52 – 7.03 (m, 65H), 6.37 (d, *J* = 9.5 Hz, 1H), 6.26 (d, *J* = 9.6 Hz, 1H), 5.74 (ddt, *J* = 17.0, 10.3, 6.7 Hz, 1H), 5.55 (d, *J* = 3.7 Hz, 1H), 5.10 – 4.89 (m, 8H), 4.83 (d, *J* = 3.7 Hz, 1H), 4.80 (d, *J* = 12.3 Hz, 1H), 4.77 – 4.68 (m, 4H), 4.62 – 4.45 (m, 5H), 4.43 – 4.00 (m, 26H), 4.00 – 3.70 (m, 9H), 3.66 – 3.03 (m, 18H), 2.78 (s, 1H), 2.30 (q, *J* = 6.8 Hz, 2H).^{13}C NMR (125 MHz, $CDCl_3$) δ 156.52 (*a*d, *J* = 37 Hz, 2x*CF*$_3$C*O*), 138.48, 137.90, 137.78, 137.65, 137.62, 137.56, 137.51, 137.32, 137.20, 136.93, 136.81 (*aromatic* C), 134.46 (C-9), 128.53, 128.49, 128.47, 128.37, 128.36, 128.29, 128.27, 128.20, 128.15, 128.09, 128.02, 127.93, 127.88, 127.85, 127.81, 127.79, 127.76, 127.65, 127.60, 127.56, 127.50, 127.28, 127.22, 127.18, 126.95, 126.75 (*aromatic* C*H*), 116.90 (C-10), 115.85 (*a*d, *J* = 286 Hz, C*F*$_3$), 98.89, 98.45, 97.99, 97.35, 97.15, 80.62, 76.27, 76.14, 75.66, 75.22, 74.63, 74.42, 73.89, 73.55, 73.50, 73.09, 73.01, 72.97, 72.85, 72.76, 71.72, 71.63, 71.60, 70.98, 70.91, 70.78, 70.70, 70.46, 69.66, 69.54, 69.37, 68.80, 68.74, 68.65, 67.72, 66.69, 66.64, 66.50, 66.40, 65.53, 64.87, 59.89, 59.48, 59.19, 58.14, 49.31, 49.15, 33.76.

Heptasaccharide 35

The reaction was carried out according to the general procedure B using donor **14** (338 mg, 0.50 mmol) and acceptor **S37** (302 mg, 0.13 mmol). The product was purified by column chromatography (pentane:EtOAc = 6:1). Compound **35** (276 mg, 76% yield) was obtained as yellow syrup. $[\alpha]_D^{25}$ +110.5 (c=0.2, $CHCl_3$). ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.50 – 7.41 (m, 4H), 7.40 – 7.07 (m, 64H), 6.36 (d, *J* = 9.6 Hz, 1H), 6.30 (d, *J* = 9.3 Hz, 1H), 6.19 (d, *J* = 9.6 Hz, 1H), 5.83 – 5.67 (m, 1H), 5.44 (d, *J* = 3.6 Hz, 1H), 5.09 – 4.89 (m, 9H), 4.84 – 4.78 (m, 2H), 4.75 (d, *J* = 3.6 Hz, 1H), 4.73 – 4.67 (m, 3H), 4.66 – 4.55 (m, 3H), 4.54 – 4.43 (m, 6H), 4.42 – 3.91 (m, 30H), 3.89 – 3.72

(m, 4H), 3.73 – 3.31 (m, 11H), 3.30 – 3.04 (m, 10H), 2.31 (qt, *J* = 6.7, 1.4 Hz, 2H), 1.07 (s, 9H), 0.97 (s, 9H). ^{13}C NMR (125 MHz, $CDCl_3$) δ 156.73 (*a*d, *J* = 37 Hz, 3x*CF$_3$CO*), 138.50, 138.24, 137.92, 137.71, 137.68, 137.64, 137.59, 137.53, 137.44, 137.29, 137.13, 136.97, 136.89 (*aromatic* C), 134.59 (C-9), 128.68, 128.64, 128.61, 128.58, 128.56, 128.52, 128.51, 128.46, 128.44, 128.34, 128.31, 128.28, 128.25, 128.23, 128.21, 128.06, 128.03, 127.94, 127.92, 127.88, 127.82, 127.75, 127.72, 127.70, 127.56, 127.47, 127.24, 127.21, 127.14, 126.87, 126.72 (*aromatic* C*H*), 117.04 (C-10), 116.00 (*a*d, *J* = 286 Hz, 3xC*F$_3$*), 98.90, 98.59, 98.10, 97.68, 97.47, 97.29, 97.02, 80.37, 76.46, 76.18, 75.76, 75.43, 74.37, 74.22, 73.91, 73.70, 73.55, 73.24, 73.11, 73.06, 73.02, 72.72, 71.92, 71.89, 71.75, 71.15, 71.04, 70.84, 70.77, 70.75, 70.70, 70.03, 69.74, 69.68, 69.65, 69.43, 69.27, 68.87, 68.76, 68.70, 67.88, 67.83, 67.06, 66.76, 66.64, 66.58, 66.23, 65.68, 64.94, 60.23, 60.04, 59.62, 49.44, 49.26, 48.35, 33.91, 27.66, 27.47, 23.38, 20.79.



Pentasaccharide 36

The reaction was carried out according to the general procedure B using donor **13** (1.33 g, 2.19 mmol) and acceptor **S33** (1.23 g, 0.73 mmol). The product was purified by column chromatography (pentane:EtOAc = 8:1). Compound **36** (1.29 g, 84% yield) was obtained as white foam. $[\alpha]_D^{25}$ +144 (c=1, $CHCl_3$). ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.50 – 7.08 (m, 50H), 6.32 (d, *J* = 9.8 Hz, 1H), 6.22 (d, *J* = 9.7 Hz, 1H), 5.75 (ddt, *J* = 17.1, 10.3, 6.8 Hz, 1H), 5.09 – 5.00 (m, 2H), 4.98 (d, *J* = 3.7 Hz, 1H), 4.97 – 4.91 (m, 3H), 4.85 – 4.81 (m, 1H), 4.80 – 4.71 (m, 3H), 4.71 – 4.55 (m, 3H), 4.54 – 4.45 (m, 5H), 4.42 – 4.32 (m, 5H), 4.32 – 4.18 (m, 6H), 4.16 – 4.02 (m, 4H), 4.00 (s, 1H), 3.98 (s, 1H), 3.96 (dd, *J* = 10.7, 2.6 Hz, 2H), 3.88 – 3.59 (m, 9H), 3.55 (ddd, *J* = 10.7, 7.9, 2.4 Hz, 2H), 3.49 (dt, *J* = 9.7, 6.5 Hz, 1H), 3.35 (dd, *J* = 9.2, 5.8 Hz, 1H), 3.31 – 3.19 (m, 4H), 3.13 – 3.03 (m, 3H), 2.31 (qt, *J* = 6.7, 1.4 Hz, 2H), 1.02 (s, 9H), 0.98 (s, 9H). ^{13}C NMR (125 MHz, $CDCl_3$) δ 156.81 (*a*d, *J* = 37 Hz, 2x*CF$_3$CO*), 138.02, 137.70, 137.66, 137.42, 137.33, 137.31, 137.26, 137.00, 136.95 (*aromatic* C), 134.58 (C-9), 128.71, 128.69, 128.67, 128.62, 128.55, 128.51, 128.43, 128.35, 128.28, 128.21, 128.16, 128.13, 128.12, 128.02, 127.96, 127.91, 127.80, 127.72, 127.66, 127.64, 127.13, 126.96, 126.77 (*aromatic* C*H*), 117.03 (C-10), 115.95 (*a*d, *J* = 286 Hz, 2xC*F$_3$*), 98.65, 98.49, 98.10, 97.48, 97.28, 76.51, 76.07, 75.73, 75.16, 74.20, 73.69, 73.32, 73.23, 73.09, 71.85, 71.74, 71.21, 71.06, 70.88, 70.71, 70.69, 70.64, 70.34, 69.69, 69.66, 68.86, 68.79, 67.87, 67.50, 67.22, 66.66, 66.56, 66.45, 65.70, 60.01, 59.61, 58.60, 49.27, 49.25, 33.89, 27.66, 27.49, 23.33, 20.79. HR-MS: Calculated for $C_{109}H_{125}N_{11}O_{23}F_6Si$ $[M+Na]^+$: 2120.8521, found: 2120.8516.

Pentasaccharide S38

The reaction was carried out according to the general procedure C using compound **36** (1.20 g, 0.57 mmol) and HF/pyridine (70%, 238 µl, 9.14 mmol). The product was purified by column chromatography (pentane:EtOAc = 2:1). Compound **S38** (1.02 g, 91% yield) was obtained as white foam. $[\alpha]_D^{25}$ +158.2 (c=1, $CHCl_3$). ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.49 – 7.09 (m, 48H), 6.47 (d, *J* = 9.7 Hz, 1H), 6.36 (d, *J* = 9.6 Hz, 1H), 5.75 (ddt, *J* = 17.0, 10.2, 6.7 Hz, 1H), 5.09 – 4.96 (m, 3H), 4.96 – 4.89 (m, 3H), 4.85 (d, *J* = 3.7 Hz, 1H), 4.80 (d, *J* = 12.4 Hz, 1H), 4.77 (d, *J* = 3.6 Hz, 1H), 4.75 – 4.65 (m, 3H), 4.58 (d, *J* = 12.2 Hz, 1H), 4.54 – 4.43 (m, 4H), 4.41 – 4.34 (m, 4H), 4.34 – 4.23 (m, 4H), 4.23 – 4.04 (m, 8H), 4.03 – 3.94 (m, 5H), 3.87 – 3.75 (m, 4H), 3.67 (dd, *J* = 10.5, 3.5 Hz, 1H), 3.65 – 3.54 (m, 3H), 3.47 (dq, *J* = 8.4, 5.9, 5.3 Hz, 2H), 3.43 – 3.24 (m, 5H), 3.21 (dd, *J* = 8.7, 5.2 Hz, 1H), 3.15 – 3.02 (m, 3H), 2.84 (s, 1H), 2.37 – 2.29 (m, 3H). ^{13}C NMR (125 MHz, $CDCl_3$) δ 156.86 (*a*d, *J* = 37 Hz, 2x*CF*$_3$*CO*), 137.58, 137.54, 137.45, 137.38, 137.35, 137.29, 137.19, 137.00, 136.87 (*aromatic* C), 134.50 (C-9), 128.61, 128.57, 128.54, 128.49, 128.39, 128.38, 128.34, 128.31, 128.28, 128.18, 128.12, 128.05, 127.96, 127.94, 127.90, 127.86, 127.83, 127.81, 127.64, 127.52, 127.17, 127.03, 126.85 (*aromatic* C*H*), 116.95 (C-10), 115.85 (*a*d, *J* = 286 Hz, 2xC*F*$_3$), 98.85, 98.56, 98.04, 97.45, 97.17, 76.58, 76.29, 75.65, 74.97, 74.13, 73.60, 73.16, 73.06, 72.98, 71.84, 71.79, 71.68, 71.18, 71.06, 70.81, 70.79, 70.75, 69.74, 69.55, 69.12, 68.81, 68.67, 67.78, 67.50, 66.58, 66.54, 66.48, 65.66, 62.63, 59.95, 59.51, 59.48, 49.36, 49.21, 33.81. HR-MS: Calculated for $C_{101}H_{109}N_{11}O_{23}F_6$ $[M+Na]^+$: 1980.7500, found: 1980.7494.

Pentasaccharide S39

The reaction was carried out according to the general procedure D using compound **S38** (1.06 g, 0.54 mmol), K_2CO_3 (112 mg, 0.81 mmol), KI (117 mg, 0.7 mmol) and $Ph_2BO(CH_2)_2NH_2$ (24 mg, 0.11 mmol). The product was purified by column chromatography (pentane:EtOAc = 4:1). Compound **S39** (1.05 g, 94% yield) was obtained as white foam. $[\alpha]_D^{25}$ +162.6 (c=1, $CHCl_3$). ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.49 – 7.07 (m, 57H), 6.34 (d, *J* = 9.7 Hz, 1H), 6.23 (d, *J* = 9.6 Hz, 1H), 5.74 (ddt, *J* = 17.1, 10.2, 6.7 Hz, 1H), 5.09 – 4.98 (m, 3H), 4.96 (d, *J* = 3.7 Hz, 1H), 4.94 – 4.90 (m, 2H), 4.83 (d, *J* = 3.7 Hz, 1H), 4.80 (d, *J* = 12.3 Hz, 1H), 4.77 – 4.65 (m, 4H), 4.57 (d, *J* = 12.3 Hz, 1H), 4.54 – 4.45 (m, 4H), 4.42 – 4.33 (m, 5H), 4.32 – 4.23 (m, 7H), 4.22 – 4.11 (m, 4H), 4.10 – 4.02 (m, 3H), 4.01 – 3.94 (m, 4H), 3.87 – 3.74 (m, 5H), 3.66 – 3.54 (m, 3H), 3.51 – 3.41 (m, 2H), 3.39 – 3.18 (m, 6H), 3.14 – 3.05 (m, 4H), 2.30 (qt, *J* = 6.8, 1.4 Hz, 2H). ^{13}C NMR (125 MHz, $CDCl_3$) δ 156.69 (*a*d, *J* = 37 Hz, 2x*CF*$_3$*CO*), 137.62, 137.59, 137.57, 137.56, 137.47, 137.44, 137.33, 137.22, 137.00, 136.84 (*aromatic* C), 134.49 (C-9), 128.56, 128.52, 128.46, 128.41, 128.38, 128.33, 128.29, 128.18, 128.11, 127.98, 127.95, 127.93, 127.86, 127.81, 127.70, 127.62, 127.61, 127.21, 127.01, 126.78 (*aromatic* C*H*), 116.94 (C-10), 115.75 (*a*d, *J* = 286 Hz, 2xC*F*$_3$), 98.94, 98.53, 98.00, 97.37, 97.20, 77.36, 76.61, 76.33, 75.65, 74.89, 73.97, 73.58, 73.36, 73.13, 73.06, 72.98, 71.81, 71.63, 71.55, 71.44, 71.08, 70.95, 70.77, 70.75, 70.66, 69.78, 69.69, 69.57, 68.77, 68.70, 68.24, 67.76, 66.89, 66.58, 66.50, 66.45, 65.65, 59.92, 59.51, 59.36, 49.27, 49.17, 33.80. HR-MS: Calculated for $C_{108}H_{115}N_{11}O_{23}F_6$ $[M+Na]^+$: 2070.7969, found: 2070.7964.

Hexasaccharide 37

The reaction was carried out according to the general procedure A. The donor **4** (178 mg, 0.29 mmol) and acceptor **S39** (150 mg, 0.073 mmol) were co-evaporated with toluene (three times). The residue was dissolved in dry 2 ml DCM under nitrogen and stirred over fresh flame-dried molecular sieves 4Å. The solution was cooled to -10 ºC, after which TfOH (2.6 µl, 0.03 mmol) was added. The reaction was stirred at -10 ºC for overnight. Then the reaction was quenched with Et_3N, diluted with DCM, washed with saturated $NaHCO_3$ and brine. The organic phase was dried with anhydrous $MgSO_4$, filtered and concentrated *in vacuo*. The product was purified by silica gel column chromatography (pentane:EtOAc = 6:1). Compound **37** (162 mg, 90% yield) was obtained as white foam. $[\alpha]_D^{25}$ +135.6 (c=1, $CHCl_3$). ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.47 – 7.08 (m, 64H), 6.31 (d, *J* = 9.7 Hz, 1H), 6.17 (d, *J* = 9.7 Hz, 1H), 5.75 (ddt, *J* = 17.0, 10.3, 6.7 Hz, 1H), 5.12 – 5.00 (m, 3H), 4.98 (d, *J* = 3.7 Hz, 1H), 4.95 – 4.89 (m, 3H), 4.86 – 4.73 (m, 7H), 4.58 (dd, *J* = 14.7, 12.1 Hz, 2H), 4.53 – 4.44 (m, 4H), 4.41 – 4.18 (m, 15H), 4.18 – 3.87 (m, 13H), 3.86 – 3.73 (m, 8H), 3.70 – 3.52 (m, 7H), 3.49 (dt, *J* = 9.7, 6.5 Hz, 1H), 3.34 (dd, *J* = 9.2, 5.8 Hz, 1H), 3.31 – 3.18 (m, 4H), 3.16 – 3.00 (m, 5H), 2.31 (qt, *J* = 6.8, 1.4 Hz, 2H), 1.02 (s, 10H), 0.97 (s, 10H). ^{13}C NMR (125 MHz, $CDCl_3$) δ 156.77 (*a*d, *J* = 37 Hz, 2x*CF*$_3$*CO*), 138.29, 137.84, 137.74, 137.68, 137.58, 137.43, 137.35, 137.32, 137.12, 136.97 (*aromatic* C), 134.59 (C-9), 128.68, 128.62, 128.57, 128.52, 128.48, 128.46, 128.45, 128.37, 128.32, 128.29, 128.25, 128.22, 128.14, 128.05, 127.97, 127.95, 127.92, 127.85, 127.83, 127.79, 127.73, 127.67, 127.50, 127.15, 126.98, 126.91, 119.42, 119.33 (*aromatic* C*H*), 117.05 (C-10), 116.00 (*a*d, *J* = 286 Hz, 2xC*F*$_3$), 98.68, 98.66, 98.48, 98.11, 97.47, 97.42, 79.36, 79.27, 76.41, 76.36, 75.73, 75.53, 75.36, 73.98, 73.71, 73.22, 73.19, 73.11, 72.97, 72.30, 71.93, 71.74, 71.31, 71.14, 71.03, 70.87, 70.84, 69.77, 69.69, 69.06, 68.89, 68.85, 67.88, 66.79, 66.72, 66.60, 66.43, 66.13, 65.82, 63.04, 60.34, 60.00, 59.63, 49.34, 49.28, 33.92, 27.48, 27.22, 22.67, 20.07.

Hexasaccharide S40

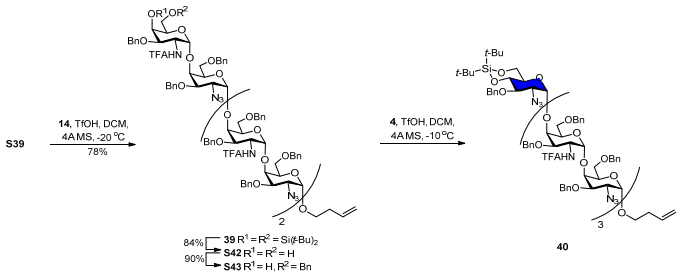
The reaction was carried out according to the general procedure C using compound **37** (555 mg, 0.23 mmol) and HF/pyridine (70%, 94 µl, 3.6 mmol). The product was purified by column chromatography (pentane:EtOAc = 2:1). Compound **S40** (463 mg, 88% yield) was obtained as white foam. $[\alpha]_D^{25}$ +148.5 (c=1, $CHCl_3$). ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.43 – 7.11 (m, 59H), 6.45 (d, *J* = 9.0 Hz, 2H), 5.73 (ddd, *J* = 16.9, 10.6, 5.1 Hz, 1H), 5.12 – 4.62 (m, 16H), 4.62 – 3.69 (m, 40H), 3.60 (dq, *J* = 30.8, 12.9, 11.5 Hz, 6H), 3.44 (q, *J* = 7.2 Hz, 1H), 3.38 – 2.91 (m, 13H), 2.28 (q, *J* = 6.9 Hz, 2H), 1.91 (s, 1H). ^{13}C NMR (125 MHz, $CDCl_3$) δ 156.57 (*a*d, *J* = 37 Hz, 2x*CF*$_3$*CO*), 138.14, 137.55, 137.50, 137.44, 137.27, 137.22, 137.19, 136.85, 136.73 (*aromatic* C), 134.37 (C-9), 128.63, 128.44, 128.39, 128.32, 128.27, 128.24, 128.21, 128.15, 128.06, 127.99, 127.97, 127.88, 127.82, 127.79, 127.75, 127.69, 127.65, 127.62, 127.52, 127.46, 127.28, 126.88, 126.84, 126.70 (*aromatic* C*H*), 116.84 (C-10), 115.78 (*a*d, *J* = 286 Hz, 2xC*F*$_3$), 98.58, 98.41, 98.15, 97.93, 97.39, 97.12, 79.37, 76.11, 75.77, 75.53, 74.71, 74.02, 73.43, 73.01, 72.92, 72.83, 72.79, 71.98, 71.57, 71.38, 70.99, 70.64, 70.46, 69.48, 69.39, 68.73, 68.72, 67.64, 66.51, 66.28, 65.58, 63.15, 61.33, 59.78, 59.37, 49.12, 49.10, 33.66.

Hexasaccharide S41

The reaction was carried out according to the general procedure D using compound **S40** (450 mg, 0.19 mmol), K_2CO_3 (40 mg, 0.29 mmol), KI (42 mg, 0.25 mmol) and $Ph_2BO(CH_2)_2NH_2$ (8.7 mg, 0.039 mmol). The product was purified by column chromatography (pentane:EtOAc = 4:1). Compound **S41** (402 mg, 97% yield) was obtained as white foam. $[\alpha]_D^{25}$ +148.6 (c=0.5, $CHCl_3$). ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.46 – 7.13 (m, 62H), 6.40 (d, *J* = 9.4 Hz, 1H), 6.32 (d, *J* = 9.4 Hz, 1H), 5.73 (ddt, *J* = 17.0, 10.3, 6.7 Hz, 1H), 5.10 – 4.70 (m, 15H), 4.63 – 3.93 (m, 35H), 3.89 – 3.70 (m, 7H), 3.69 – 3.41 (m, 7H), 3.38 – 2.95 (m, 13H), 2.76 (s, 1H), 2.28 (q, *J* = 6.8 Hz, 2H). ^{13}C NMR (125 MHz, $CDCl_3$) δ 156.55 (*a*d, *J* = 37 Hz, *CF*$_3$*C**O***), 138.20, 137.67, 137.65, 137.58, 137.48, 137.43, 137.27, 137.24, 137.14, 136.86, 136.71 (*aromatic* C), 134.37 (C-9), 128.79, 128.45, 128.40, 128.34, 128.30, 128.28, 128.26, 128.22, 128.20, 128.15, 128.08, 128.02, 127.91, 127.87, 127.83, 127.81, 127.78, 127.74, 127.70, 127.68, 127.64, 127.59, 127.54, 127.50, 127.46, 127.28, 127.07, 126.89, 126.85, 126.78, 126.72 (*aromatic* C***H***), 116.83 (C-10), 115.79 (*a*d, *J* = 286 Hz, C*F*$_3$), 98.62, 98.44, 97.93, 97.28, 97.15, 79.46, 76.13, 75.58, 74.90, 74.83, 73.88, 73.46, 73.12, 73.04, 72.94, 72.85, 72.75, 72.61, 71.63, 71.51, 70.95, 70.82, 70.62, 70.55, 69.60, 69.51, 69.44, 69.23, 68.91, 68.67, 68.61, 67.64, 66.49, 66.29, 66.17, 65.57, 63.18, 59.84, 59.78, 59.39, 58.56, 58.04, 54.55, 49.15, 49.08, 33.68.

Heptasaccharide 38

The reaction was carried out according to the general procedure B using donor **14** (442 mg, 0.65 mmol) and acceptor **S41** (395 mg, 0.16 mmol). The product was purified by column chromatography (pentane:EtOAc = 6:1). Compound **38** (380 mg, 80% yield) was obtained as white foam. $[\alpha]_D^{25}$ +120 (c=0.3, $CHCl_3$). ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.46 – 7.42 (m, 2H), 7.39 – 7.11 (m, 69H), 6.89 (d, *J* = 9.5 Hz, 1H), 6.36 (d, *J* = 9.7 Hz, 1H), 6.22 (d, *J* = 9.6 Hz, 1H), 5.75 (ddt, *J* = 17.0, 10.2, 6.7 Hz, 1H), 5.45 (d, *J* = 3.5 Hz, 1H), 5.10 – 4.97 (m, 5H), 4.95 – 4.89 (m, 2H), 4.84 (d, *J* = 3.7 Hz, 1H), 4.83 – 4.62 (m, 8H), 4.61 – 4.33 (m, 15H), 4.33 – 4.13 (m, 11H), 4.11 – 3.87 (m, 14H), 3.87 – 3.74 (m, 5H), 3.72 – 3.41 (m, 9H), 3.35 (dd, *J* = 9.2, 5.8 Hz, 1H), 3.31 – 3.18 (m, 5H), 3.15 – 3.06 (m, 4H), 3.05 – 2.99 (m, 1H), 2.95 (d, *J* = 10.5 Hz, 1H), 2.31 (qt, *J* = 6.7, 1.3 Hz, 2H), 1.02 (d, *J* = 6.0 Hz, 17H). ^{13}C NMR (125 MHz, $CDCl_3$) δ 156.99 (*a*d, *J* = 37 Hz, 3x*CF*$_3$*C**O***), 138.12, 137.68, 137.66, 137.62, 137.59, 137.52, 137.39, 137.29, 137.08, 136.92, 136.46 (*aromatic* C), 134.55 (C-9), 128.64, 128.60, 128.56, 128.53, 128.48, 128.44, 128.42, 128.38, 128.36, 128.26, 128.22, 128.19, 128.07, 128.01, 128.00, 127.91, 127.89, 127.86, 127.78, 127.75, 127.74, 127.69, 127.62, 127.37, 127.11, 127.04, 126.87 (*aromatic* C***H***), 117.03 (C-10), 115.97 (*a*d, *J* = 286 Hz, 3xC*F*$_3$), 98.80, 98.63, 98.08, 98.01, 97.45, 97.38, 97.13, 79.80, 76.38, 76.22, 75.70, 75.31, 75.19, 74.27, 74.06, 73.67, 73.52, 73.21, 73.14, 73.06, 72.99, 72.52, 71.95, 71.92, 71.71, 71.35, 71.19, 71.02, 70.87, 70.84, 70.62, 69.74, 69.65, 69.61, 68.98, 68.84, 68.77, 68.48, 67.85, 67.80, 67.10, 66.68, 66.62, 66.54, 66.30, 65.79, 63.99, 60.43, 59.99, 59.59, 49.31, 49.24, 48.61, 33.88, 27.66, 27.36, 23.39, 20.80.



Hexasaccharide 39

The reaction was carried out according to the general procedure B using donor **14** (597 mg, 0.94 mmol) and acceptor **S39** (480 mg, 0.23 mmol). The product was purified by column chromatography (pentane:EtOAc = 6:1). Compound **39** (462 mg, 78% yield) was obtained as white foam. $[\alpha]_D^{25}$ +149.7 (c=1, $CHCl_3$). ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.44 (d, *J* = 7.6 Hz, 2H), 7.37 – 7.10 (m, 56H), 6.34 (d, *J* = 9.5 Hz, 1H), 6.26 (dd, *J* = 15.4, 9.4 Hz, 2H), 5.81 – 5.67 (m, 1H), 5.08 – 4.98 (m, 4H), 4.96 – 4.89 (m, 2H), 4.89 – 4.55 (m, 11H), 4.54 – 4.42 (m, 7H), 4.42 – 4.33 (m, 6H), 4.33 – 4.09 (m, 9H), 4.06 – 3.91 (m, 9H), 3.88 – 3.74 (m, 5H), 3.71 – 3.53 (m, 5H), 3.46 (dt, *J* = 14.0, 8.6 Hz, 2H), 3.38 – 3.17 (m, 6H), 3.16 – 2.96 (m, 5H), 2.30 (q, *J* = 6.8 Hz, 2H), 1.07 (s, 11H), 0.98 (s, 10H). ^{13}C NMR (125 MHz, $CDCl_3$) δ 156.59 (*a*d, *J* = 37 Hz, 3x*CF*$_3$*CO*), 137.84, 137.59, 137.57, 137.52, 137.36, 137.31, 137.18, 137.17, 136.95, 136.84, 136.80 (*aromatic* C), 134.44 (C-9), 128.60, 128.53, 128.48, 128.43, 128.39, 128.35, 128.33, 128.30, 128.24, 128.15, 128.13, 128.08, 128.04, 128.01, 127.90, 127.88, 127.81, 127.79, 127.77, 127.71, 127.70, 127.62, 127.56, 126.98, 126.94, 126.71 (*aromatic* C*H*), 116.90 (C-10), 115.81 (*a*d, *J* = 286 Hz, 3xC*F*$_3$), 98.49, 98.31, 98.01, 97.33, 97.22, 96.65, 76.35, 76.14, 75.66, 75.07, 74.65, 73.97, 73.55, 73.02, 72.94, 72.91, 71.83, 71.60, 71.05, 70.93, 70.88, 70.72, 69.52, 69.44, 69.38, 69.22, 68.72, 68.66, 68.56, 67.73, 67.69, 66.87, 66.57, 66.48, 66.38, 65.73, 65.66, 60.20, 59.94, 59.49, 49.15, 48.19, 33.77, 27.52, 27.35, 23.21, 20.63.

Hexasaccharide S42

The reaction was carried out according to the general procedure C using compound **39** (445 mg, 0.18 mmol) and HF/pyridine (70%, 73 µl, 2.8 mmol). The product was purified by column chromatography (pentane:EtOAc = 3:2). Compound **S42** (353 mg, 84% yield) was obtained as white foam. $[\alpha]_D^{25}$ +141.8 (c=0.5, $CHCl_3$). ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.46 – 7.11 (m, 64H), 6.46 (d, *J* = 9.5 Hz, 1H), 6.33 (d, *J* = 9.6 Hz, 1H), 6.30 (d, *J* = 9.6 Hz, 1H), 5.83 – 5.67 (m, 1H), 5.09 – 5.00 (m, 2H), 4.99 (d, *J* = 3.6 Hz, 1H), 4.97 (d, *J* = 3.7 Hz, 1H), 4.95 – 4.89 (m, 2H), 4.86 (d, *J* = 3.7 Hz, 1H), 4.84 (d, *J* = 3.7 Hz, 1H), 4.80 (d, *J* = 12.3 Hz, 1H), 4.77 (d, *J* = 3.6 Hz, 1H), 4.73 (d, *J* = 11.8 Hz, 1H), 4.65 – 4.46 (m, 9H), 4.45 – 4.33 (m, 8H), 4.32 – 4.12 (m, 10H), 4.07 – 3.90 (m, 12H), 3.87 – 3.70 (m, 5H), 3.65 – 3.42 (m, 7H), 3.39 – 3.20 (m, 8H), 3.14 – 3.02 (m, 5H), 2.90 (s, 1H), 2.31 (q, *J* = 6.7 Hz, 2H). ^{13}C NMR (125 MHz, $CDCl_3$) δ 156.73 (*a*d, *J* = 37 Hz, 3x*CF*$_3$*CO*), 137.67, 137.63, 137.57, 137.37, 137.31, 137.28, 137.10, 137.01, 136.89 (*aromatic* C), 134.52 (C-9), 128.58, 128.53, 128.51, 128.39, 128.37, 128.34, 128.18, 128.13, 128.11, 128.03, 127.95, 127.88, 127.84, 127.81, 127.60, 127.53, 127.29, 127.12, 127.05, 126.75 (*aromatic* C*H*), 116.95 (C-10),

115.86 (*a*d, *J* = 286 Hz, 3x*CF*$_3$), 98.53, 98.40, 98.04, 97.43, 97.24, 96.93, 76.42, 76.09, 75.68, 75.14, 74.71, 74.08, 73.60, 73.08, 73.06, 72.97, 72.91, 71.92, 71.90, 71.68, 71.20, 71.11, 71.06, 70.93, 70.78, 70.71, 70.67, 69.53, 69.42, 69.29, 68.80, 68.70, 68.59, 67.78, 66.64, 66.58, 66.51, 66.39, 65.86, 65.73, 62.44, 60.18, 60.00, 59.53, 49.22, 49.18, 48.82, 33.82.

Hexasaccharide S43

The reaction was carried out according to the general procedure D using compound **S42** (347 mg, 0.15 mmol), K_2CO_3 (30 mg, 0.22 mmol), KI (31 mg, 0.19 mmol) and $Ph_2BO(CH_2)_2NH_2$ (6.5 g, 0.03 mmol). The product was purified by column chromatography (pentane:EtOAc = 4:1). Compound **S43** (330 mg, 92% yield) was obtained as white foam. $[\alpha]_D^{25}$ +145.6 (c=0.5, $CHCl_3$). ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.46 – 7.08 (m, 66H), 6.43 (d, *J* = 9.5 Hz, 1H), 6.31 (t, *J* = 8.8 Hz, 2H), 5.74 (ddt, *J* = 17.0, 10.3, 6.7 Hz, 1H), 5.08 – 4.87 (m, 6H), 4.86 – 4.78 (m, 4H), 4.76 (d, *J* = 3.6 Hz, 1H), 4.66 (d, *J* = 12.1 Hz, 1H), 4.60 – 4.43 (m, 8H), 4.42 – 4.12 (m, 20H), 4.07 – 3.90 (m, 9H), 3.89 – 3.71 (m, 4H), 3.68 – 3.43 (m, 7H), 3.40 – 3.18 (m, 7H), 3.15 – 3.02 (m, 5H), 2.96 (s, 1H), 2.30 (q, *J* = 6.7 Hz, 2H). ^{13}C NMR (125 MHz, $CDCl_3$) δ 156.62 (*a*d, *J* = 37 Hz, 3x*CF*$_3$*CO*), 137.68, 137.59, 137.51, 137.40, 137.32, 137.25, 137.22, 137.05, 136.93, 136.83 (*aromatic* C), 134.46 (C-9), 128.89, 128.52, 128.46, 128.44, 128.38, 128.34, 128.32, 128.31, 128.27, 128.14, 128.07, 128.05, 127.96, 127.91, 127.89, 127.86, 127.78, 127.76, 127.72, 127.62, 127.58, 127.54, 127.50, 127.31, 127.20, 126.96, 126.70 (*aromatic* C*H*), 116.89 (C-10), 115.87 (*a*d, *J* = 286 Hz, C*F*$_3$), 98.49, 98.41, 97.99, 97.39, 97.16, 97.09, 76.35, 75.97, 75.65, 75.25, 74.55, 74.05, 73.54, 73.41, 73.02, 72.93, 72.91, 72.87, 71.85, 71.79, 71.13, 71.04, 71.01, 70.81, 70.75, 70.69, 70.59, 70.38, 69.52, 69.38, 69.08, 68.76, 68.65, 68.62, 67.73, 66.58, 66.50, 66.43, 65.75, 65.65, 65.58, 59.95, 59.48, 58.14, 49.17, 49.11, 48.88, 33.76.

Heptasaccharide 40

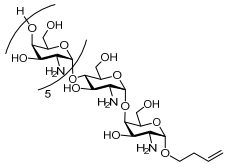
The reaction was carried out according to the general procedure A. The donor **4** (312 mg, 0.51 mmol) and acceptor **S43** (320 mg, 0.13 mmol) were co-evaporated with toluene (three times). The residue was dissolved in dry 3 ml DCM under nitrogen and stirred over fresh flame-dried molecular sieves 4Å. The solution was cooled to -10 °C, after which TfOH (7.7 µl, 0.05 mmol) was added. The reaction was stirred at -10 °C for overnight. Then the reaction was quenched with Et_3N, diluted with DCM, washed with saturated $NaHCO_3$ and brine. The organic phase was dried with anhydrous $MgSO_4$, filtered and concentrated *in vacuo*. The product was purified by silica gel column chromatography (pentane:EtOAc = 6:1). Compound **40** (320 mg, 85% yield) was obtained as white foam. $[\alpha]_D^{25}$ +131.6 (c=0.5, $CHCl_3$). ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.47 – 7.03 (m, 81H), 6.19 (d, *J* = 9.6 Hz, 2H), 6.07 (d, *J* = 9.4 Hz, 1H), 5.82 – 5.67 (m, 1H), 5.12 – 4.99 (m, 5H), 4.96 (d, *J* = 3.6 Hz, 1H), 4.94 – 4.88 (m, 4H), 4.85 – 4.73 (m, 8H), 4.61 – 4.11 (m, 32H), 4.10 – 3.97 (m, 6H), 3.96 – 3.71 (m, 17H), 3.66 – 3.44 (m, 6H), 3.35 (dd, *J* = 9.2, 5.8 Hz, 1H), 3.30 – 3.19 (m, 6H), 3.17 – 3.00 (m, 8H), 2.31 (qt, *J* = 6.8, 1.4 Hz, 2H), 1.04 (s, 9H), 1.01 (s, 10H). ^{13}C NMR (125 MHz, $CDCl_3$) δ 156.69 (*a*d, *J* = 37 Hz, 3x*CF*$_3$*CO*), 138.33, 137.81, 137.71, 137.68, 137.61, 137.40, 137.32, 137.29, 137.28, 137.22, 137.04, 136.93 (*aromatic* C), 134.56 (C-9), 128.65, 128.58, 128.53, 128.44, 128.38, 128.32, 128.26, 128.24, 128.18, 128.10, 128.08, 128.02, 128.00, 127.92, 127.90, 127.87, 127.84, 127.79, 127.75,

127.72, 127.69, 127.67, 127.63, 127.11, 126.84, 126.82 (*aromatic* C*H*), 117.03 (C-10), 115.96 (*a*d, *J* = 286 Hz, 3xCF_3), 98.60, 98.54, 98.11, 98.08, 97.45, 97.34, 97.24, 79.40, 79.29, 76.50, 76.45, 75.74, 74.28, 74.04, 73.67, 73.23, 73.20, 73.13, 73.06, 72.98, 72.93, 71.93, 71.73, 71.28, 71.16, 71.04, 71.02, 70.83, 70.78, 70.76, 70.67, 69.64, 69.49, 69.44, 68.84, 68.77, 67.85, 67.10, 66.81, 66.55, 66.27, 65.76, 62.89, 60.04, 59.59, 49.30, 49.24, 49.19, 33.88, 27.44, 27.06, 22.70.

General procedure for desilylation and Birch reduction of the oligosaccharides towards 41 - 46 (general procedure E)

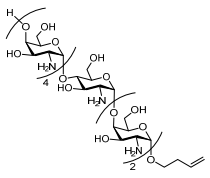
HF/pyridine (16 eq) solution was added to a solution of starting material in THF at 0 ºC. The reaction was warmed to room temperature and stirred until TLC-analysis indicated full consumption of the starting material (± 1h). Then the mixture was diluted with DCM and washed with saturated $NaHCO_3$ and brine, dried with anhydrous $MgSO_4$, filtered and concentrated *in vacuo*. The residue was purified by silica gel column chromatography. Ammonia (10 ml) was condensed at -78 oC, the residue was dissolved in THF (2 ml) and tert-butanol (0.8 ml) and slowly added to the flask containing ammonia. Allyl carbinol (200 ul) was added to the reaction mixture. Small pieces of sodium was added to the reaction mixture one by one to keep deep blue for 15 min. Then ammonia acetate (100 mg) was added. The solution was allowed to warm to room temperature and stirred until all of the ammonia was evaporated. The solution was concentrated *in vacuo* and purified by gel filtration (HW-40, 0.15M NH_4OAc in H_2O). The product containing fractions were pooled and lyophilized (4x) to yield the final products as a white solid.

Heptasaccharide (41)



(69% yield, 12/1 with:without C=C). The reaction was carried out according to the general procedure E. ^{1}H NMR (500 MHz, Deuterium Oxide) δ 5.88 (ddt, *J* = 17.1, 10.3, 6.6 Hz, 1H), 5.67 (d, *J* = 4.0 Hz, 1H), 5.33 – 5.23 (m, 4H), 5.19 – 5.12 (m, 3H), 5.11 – 5.07 (m, 1H), 4.48 (q, *J* = 5.4 Hz, 3H), 4.41 (t, *J* = 6.4 Hz, 1H), 4.31 – 4.20 (m, 5H), 4.19 – 4.00 (m, 11H), 3.86 – 3.71 (m, 16H), 3.66 – 3.53 (m, 6H), 3.49 (dd, *J* = 10.9, 3.8 Hz, 1H), 3.19 (dd, *J* = 10.8, 3.6 Hz, 1H), 2.42 – 2.35 (m, 2H). ^{13}C NMR (125 MHz, D_2O) δ 135.71, 116.71, 97.36, 97.19, 96.91, 96.79, 96.53, 95.49, 76.54, 76.28, 76.23, 76.15, 75.34, 71.53, 71.44, 70.98, 70.90, 70.72, 67.90, 67.65, 66.76, 66.68, 66.52, 60.56, 60.47, 60.26, 60.10, 54.77, 50.98, 50.91, 33.10.

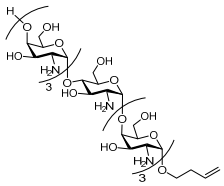
Heptasaccharide (42)



(48% yield, 25/1 with:without C=C). The reaction was carried out according to the general procedure E. ^{1}H NMR (500 MHz, Deuterium Oxide) δ 5.88 (ddt, *J* = 17.1, 10.4, 6.6 Hz, 1H), 5.70 (d, *J* = 3.9 Hz, 1H), 5.32 (d, *J* = 3.8 Hz, 1H), 5.29 (dd, *J* = 5.7, 3.9 Hz, 2H), 5.26 (d, *J* = 3.8 Hz, 1H), 5.22 (d, *J* = 3.8 Hz, 1H), 5.19 (d, *J* = 3.8 Hz, 1H), 5.18 – 5.13 (m, 1H), 5.09 (ddt, *J* = 10.4, 2.3, 1.3 Hz, 1H), 4.53 – 4.46 (m, 3H), 4.42 (t, *J* = 6.4 Hz, 1H), 4.33 – 4.00 (m, 19H), 3.87 – 3.69 (m, 18H), 3.67 – 3.59 (m, 5H), 3.59 – 3.50 (m, 3H), 3.26 (dd, *J* = 11.0,

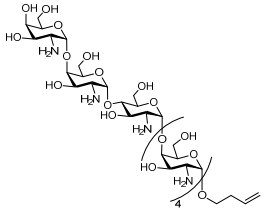
3.5 Hz, 1H), 2.39 (q, *J* = 6.6 Hz, 2H). ^{13}C NMR (125 MHz, D_2O) δ 135.70, 116.72, 97.13, 96.81, 96.65, 96.48, 96.31, 95.33, 76.50, 76.30, 76.19, 76.13, 75.17, 71.44, 71.22, 70.97, 70.72, 70.66, 67.87, 67.67, 66.59, 66.40, 60.58, 60.54, 60.47, 60.26, 60.13, 60.01, 54.67, 51.00, 50.91, 50.85, 33.11. HR-MS: Calculated for $C_{46}H_{85}N_7O_{29}$ $[M+2H]^{2+}$: 600.7774, found: 600.7769.

Heptasaccharide (43)



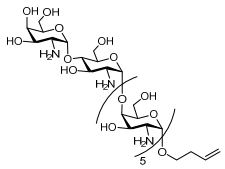
(84% yield, 19/1). The reaction was carried out according to the general procedure E. ^{1}H NMR (500 MHz, Chloroform-*d*) δ 5.88 (ddt, *J* = 17.0, 10.3, 6.6 Hz, 1H), 5.71 (d, *J* = 3.9 Hz, 1H), 5.31 (q, *J* = 4.2, 3.5 Hz, 3H), 5.28 (d, *J* = 3.8 Hz, 1H), 5.24 (d, *J* = 3.7 Hz, 1H), 5.19 (d, *J* = 3.8 Hz, 1H), 5.15 (dq, *J* = 17.3, 1.7 Hz, 1H), 5.09 (ddt, *J* = 10.3, 2.4, 1.3 Hz, 1H), 4.49 (t, *J* = 5.7 Hz, 3H), 4.42 (t, *J* = 6.4 Hz, 1H), 4.33 – 4.00 (m, 18H), 3.90 – 3.70 (m, 18H), 3.69 – 3.58 (m, 7H), 3.53 (dd, *J* = 11.0, 3.8 Hz, 1H), 3.32 (dd, *J* = 10.6, 3.6 Hz, 1H), 2.38 (q, *J* = 6.6 Hz, 2H). ^{13}C NMR (125 MHz, $CDCl_3$) δ 138.23, 119.25, 99.41, 98.91, 98.75, 98.71, 97.82, 78.92, 78.80, 78.70, 78.61, 77.47, 73.94, 73.49, 73.36, 73.13, 73.11, 73.05, 70.39, 70.20, 69.01, 68.85, 68.76, 68.62, 68.56, 63.11, 63.05, 63.01, 62.76, 62.60, 57.09, 53.52, 53.40, 53.37, 53.32, 35.64. HR-MS: Calculated for $C_{46}H_{85}N_7O_{29}$ $[M+2H]^{2+}$: 600.7774, found: 600.7769.

Heptasaccharide (44)



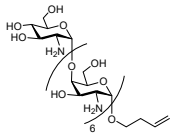
(53% yield, 50/1). The reaction was carried out according to the general procedure E. ^{1}H NMR (850 MHz, Deuterium Oxide) δ 5.85 (ddt, *J* = 17.1, 10.3, 6.7 Hz, 1H), 5.64 (d, *J* = 4.0 Hz, 1H), 5.23 (d, *J* = 3.9 Hz, 1H), 5.22 (d, *J* = 3.9 Hz, 1H), 5.20 (d, *J* = 3.9 Hz, 1H), 5.18 (d, *J* = 3.9 Hz, 1H), 5.15 (d, *J* = 3.8 Hz, 1H), 5.14 – 5.11 (m, 1H), 5.10 (d, *J* = 3.7 Hz, 1H), 5.06 (d, *J* = 10.3 Hz, 1H), 4.44 (p, *J* = 6.5, 6.1 Hz, 3H), 4.37 (t, *J* = 6.4 Hz, 1H), 4.25 (dt, *J* = 10.1, 3.2 Hz, 1H), 4.19 (dd, *J* = 9.3, 2.9 Hz, 3H), 4.15 (t, *J* = 3.6 Hz, 2H), 4.11 – 4.06 (m, 5H), 4.05 (t, *J* = 5.7 Hz, 1H), 4.03 – 3.97 (m, 5H), 3.82 – 3.72 (m, 15H), 3.70 – 3.67 (m, 2H), 3.62 – 3.52 (m, 4H), 3.51 – 3.45 (m, 3H), 3.41 (dd, *J* = 10.9, 3.8 Hz, 1H), 3.09 (dd, *J* = 10.6, 3.7 Hz, 1H), 2.36 (q, *J* = 7.2 Hz, 2H). ^{13}C NMR (214 MHz, D_2O) δ 135.63, 116.60, 97.66, 97.35, 97.12, 96.79, 95.47, 76.44, 76.41, 76.34, 76.25, 76.22, 75.43, 71.97, 71.48, 71.32, 71.04, 70.85, 70.84, 70.78, 70.74, 67.85, 67.51, 67.22, 66.98, 66.66, 66.62, 60.54, 60.52, 60.49, 60.06, 60.01, 59.96, 54.82, 50.94, 50.92, 50.89, 50.88, 50.76, 33.02. HR-MS: Calculated for $C_{46}H_{85}N_7O_{29}$ $[M+H]^+$: 1200.5470, found: 1200.5464. HR-MS: Calculated for $C_{46}H_{85}N_7O_{29}$ $[M+2H]^{2+}$: 600.7774, found: 600.7769.

Heptasaccharide (45)



(59% yield, 25/1). The reaction was carried out according to the general procedure E. ^{1}H NMR (500 MHz, Deuterium Oxide) δ 5.91 (ddt, *J* = 17.1, 10.3, 6.6 Hz, 1H), 5.44 (d, *J* = 4.0 Hz, 1H), 5.17 (dq, *J* = 17.3, 1.7 Hz, 1H), 5.12 – 5.08 (m, 1H), 5.06 – 4.93 (m, 6H), 4.41 – 4.33 (m, 4H), 4.21 – 3.95 (m, 11H), 3.87 – 3.72 (m, 23H), 3.67 – 3.58 (m, 2H), 3.18 – 3.09 (m, 6H), 2.85 – 2.79 (m, 1H), 2.42 – 2.35 (m, 2H). ^{13}C NMR (214 MHz, D_2O) δ 135.78, 116.48, 100.11, 100.09, 99.97, 99.65, 98.56, 77.46, 77.45, 77.40, 77.34, 76.84, 76.57, 73.88, 72.00, 71.94, 71.92, 71.80, 71.79, 71.61, 71.09, 70.10, 69.83, 69.76, 69.65, 68.41, 68.39, 67.45, 61.20, 61.18, 60.67, 60.32, 60.23, 60.18, 60.14, 55.19, 51.41, 51.39, 51.32, 51.05, 50.75, 33.09. HR-MS: Calculated for $C_{46}H_{85}N_7O_{29}$ $[M+2H]^{2+}$: 600.7774, found: 600.7769.

Heptasaccharide (46)

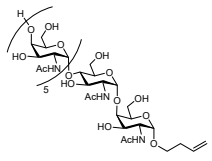


(85% yield, 43/1). The reaction was carried out according to the general procedure E. ^{1}H NMR (850 MHz, Deuterium Oxide) δ 5.90 – 5.82 (m, 1H), 5.28 – 5.23 (m, 4H), 5.23 – 5.14 (m, 3H), 5.14 – 5.11 (m, 1H), 5.06 (d, *J* = 10.3 Hz, 1H), 4.45 (q, *J* = 5.7, 4.9 Hz, 5H), 4.24 – 4.08 (m, 13H), 4.01 (t, *J* = 5.8 Hz, 1H), 3.84 – 3.72 (m, 15H), 3.59 (dt, *J* = 9.9, 6.3 Hz, 1H), 3.58 – 3.52 (m, 6H), 3.51 – 3.45 (m, 1H), 3.20 (dd, *J* = 10.7, 3.6 Hz, 1H), 2.36 (q, *J* = 7.2 Hz, 2H). ^{13}C NMR (214 MHz, D_2O) δ 135.63, 116.61, 96.85, 96.74, 95.37, 76.36, 76.30, 76.28, 76.21, 72.36, 70.78, 70.70, 70.65, 70.30, 69.15, 67.52, 66.71, 66.58, 66.50, 60.53, 60.09, 60.07, 60.06, 60.02, 59.95, 54.34, 50.84, 50.74, 33.02. HR-MS: Calculated for $C_{46}H_{85}N_7O_{29}$ $[M+2H]^{2+}$: 600.7774, found: 600.7769.

General procedure for acetylation of the oligosaccharides towards 47 - 52 (general procedure F)

To a solution of starting material in H_2O (1 ml) was added Ac_2O at 0 °C. Then $NaHCO_3$ was added to the solution until the pH is 8~9. The reaction was warmed to room temperature and stirred for 3h. Then the mixture was neutralized with AcOH and then concentrated *in vacuo*, which was purified by gel filtration (HW-40, 0.15M NH_4OAc in H_2O). The product containing fractions were pooled and lyophilized (4x) to yield the final products as a white solid.

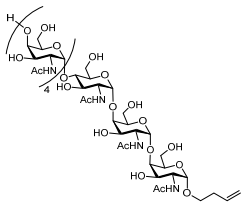
Heptasaccharide (47)



(90% yield). The reaction was carried out according to the general procedure F. ^{1}H NMR (850 MHz, Deuterium Oxide) δ 5.85 (ddt, *J* = 17.1, 10.3, 6.7 Hz, 1H), 5.42 (d, *J* = 3.9 Hz, 1H), 5.13 – 5.04 (m, 2H), 5.02 – 4.98 (m, 2H), 4.97 – 4.92 (m, 3H), 4.86 (d, *J* = 3.7 Hz, 1H), 4.40 – 4.35 (m, 3H), 4.33 (t, *J* = 6.6 Hz, 1H), 4.29 – 4.23 (m, 4H), 4.22 – 4.16 (m, 3H), 4.14 – 3.96 (m, 16H), 3.94 – 3.88 (m, 1H), 3.83 (dd, *J* = 12.4, 3.2 Hz, 1H), 3.77 – 3.72 (m, 2H), 3.71 – 3.53 (m, 15H), 2.38 – 2.29 (m, 2H), 2.07 – 1.97 (m, 21H). ^{13}C NMR (214 MHz, D_2O) δ 174.64, 174.52, 174.49, 174.48, 174.42, 174.34, 135.78, 116.39, 98.23, 98.15, 98.12, 98.07, 98.01, 97.98, 96.67, 77.18, 76.66, 76.33, 76.16, 76.07, 75.29, 72.24, 71.52, 71.22, 71.17, 71.13, 70.59, 70.53, 68.09, 67.10, 67.07, 66.94,

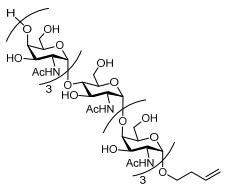
66.80, 66.60, 66.53, 66.40, 60.36, 60.21, 59.90, 59.47, 59.35, 54.33, 50.19, 50.03, 49.91, 32.96, 21.93, 21.82, 21.78, 21.77. HR-MS: Calculated for $C_{60}H_{99}N_7O_{36}$ $[M+2H]^{2+}$: 747.8144, found: 747.8138.

Heptasaccharide (48)



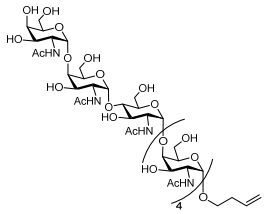
(91% yield, 7/1). The reaction was carried out according to the general procedure F. ^{1}H NMR (850 MHz, Deuterium Oxide) δ 5.85 (ddt, *J* = 17.1, 10.4, 6.7 Hz, 1H), 5.43 (d, *J* = 3.9 Hz, 1H), 5.13 – 5.04 (m, 2H), 5.00 (d, *J* = 3.8 Hz, 1H), 4.97 – 4.95 (m, 2H), 4.94 (d, *J* = 3.8 Hz, 1H), 4.93 (d, *J* = 3.8 Hz, 1H), 4.92 (d, *J* = 3.7 Hz, 1H), 4.40 – 4.36 (m, 3H), 4.33 (t, *J* = 6.5 Hz, 1H), 4.29 – 4.23 (m, 4H), 4.21 – 4.16 (m, 3H), 4.15 – 3.96 (m, 16H), 3.92 (dd, *J* = 10.8, 3.7 Hz, 1H), 3.84 (dd, *J* = 12.5, 3.2 Hz, 1H), 3.77 – 3.72 (m, 2H), 3.71 – 3.57 (m, 14H), 3.54 (dt, *J* = 10.4, 6.2 Hz, 1H), 2.39 – 2.27 (m, 2H), 2.05 – 1.98 (m, 21H). ^{13}C NMR (214 MHz, D_2O) δ 174.63, 174.56, 174.48, 174.42, 174.35, 135.78, 116.38, 98.24, 98.17, 98.10, 98.08, 97.98, 96.61, 76.68, 76.53, 76.36, 76.08, 75.27, 72.23, 71.47, 71.29, 71.22, 71.16, 70.60, 70.54, 68.11, 68.09, 67.10, 67.04, 66.96, 66.82, 66.61, 66.40, 60.35, 60.21, 59.92, 59.47, 59.38, 59.34, 54.28, 50.21, 50.08, 50.03, 49.94, 32.95, 21.93, 21.82, 21.77. HR-MS: Calculated for $C_{60}H_{99}N_7O_{36}$ $[M+2H]^{2+}$: 747.8144, found: 747.8138.

Heptasaccharide (49)



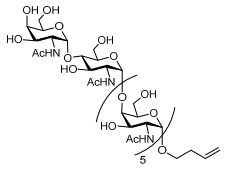
(91% yield, 32/1). The reaction was carried out according to the general procedure F. ^{1}H NMR (850 MHz, Deuterium Oxide) δ 5.85 (ddt, *J* = 17.0, 10.4, 6.6 Hz, 1H), 5.43 (d, *J* = 3.9 Hz, 1H), 5.13 – 5.08 (m, 1H), 5.07 – 5.04 (m, 1H), 5.00 (d, *J* = 3.8 Hz, 1H), 4.97 – 4.90 (m, 5H), 4.40 – 4.36 (m, 3H), 4.34 – 4.31 (m, 1H), 4.30 – 4.22 (m, 4H), 4.22 – 4.15 (m, 3H), 4.14 – 4.10 (m, 3H), 4.09 – 3.96 (m, 12H), 3.92 (dd, *J* = 10.8, 3.6 Hz, 1H), 3.84 (dd, *J* = 12.4, 3.2 Hz, 1H), 3.78 – 3.71 (m, 2H), 3.71 – 3.56 (m, 14H), 3.54 (dt, *J* = 10.4, 6.2 Hz, 1H), 2.37 – 2.28 (m, 2H), 2.05 – 1.99 (m, 21H). ^{13}C NMR (214 MHz, D_2O) δ 174.63, 174.56, 174.48, 174.46, 174.43, 174.41, 174.36, 135.79, 116.38, 98.19, 98.17, 98.12, 98.08, 98.03, 97.97, 96.61, 76.77, 76.68, 76.24, 76.02, 75.27, 72.23, 71.49, 71.28, 71.23, 71.16, 71.12, 70.59, 70.58, 68.11, 68.09, 67.11, 67.04, 66.98, 66.82, 66.53, 66.48, 66.38, 60.36, 60.35, 60.23, 59.93, 59.50, 59.32, 54.29, 50.23, 50.20, 50.03, 49.95, 32.95, 21.82, 21.81, 21.78. HR-MS: Calculated for $C_{60}H_{99}N_7O_{36}$ $[M+2H]^{2+}$: 747.8144, found: 747.8139.

Heptasaccharide (50)



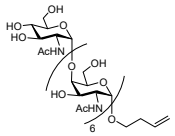
(90% yield, 32/1). The reaction was carried out according to the general procedure F. ^{1}H NMR (850 MHz, Deuterium Oxide) δ 5.85 (ddt, *J* = 17.0, 10.4, 6.6 Hz, 1H), 5.43 (d, *J* = 4.0 Hz, 1H), 5.13 – 5.08 (m, 1H), 5.08 – 5.04 (m, 1H), 5.01 (d, *J* = 3.8 Hz, 1H), 5.00 (d, *J* = 3.8 Hz, 1H), 4.95 – 4.90 (m, 4H), 4.40 – 4.36 (m, 3H), 4.33 (t, *J* = 6.6 Hz, 1H), 4.30 – 4.22 (m, 4H), 4.22 – 4.14 (m, 3H), 4.14 – 4.10 (m, 3H), 4.09 – 3.95 (m, 13H), 3.92 (dd, *J* = 10.9, 3.6 Hz, 1H), 3.84 (dd, *J* = 12.6, 3.2 Hz, 1H), 3.77 – 3.56 (m, 17H), 3.54 (dt, *J* = 10.4, 6.1 Hz, 1H), 2.36 – 2.29 (m, 2H), 2.06 – 2.02 (m, 15H), 2.02 – 2.00 (m, 6H). ^{13}C NMR (214 MHz, D_2O) δ 174.64, 174.55, 174.47, 174.46, 174.44, 174.42, 174.35, 135.79, 116.38, 98.28, 98.15, 98.08, 98.02, 97.98, 96.61, 76.87, 76.75, 76.74, 76.65, 76.09, 75.25, 72.33, 71.49, 71.29, 71.15, 71.10, 70.60, 70.58, 70.55, 68.09, 68.07, 67.03, 66.97, 66.90, 66.51, 66.40, 60.39, 60.37, 60.34, 59.91, 59.34, 59.30, 54.29, 50.20, 50.16, 50.07, 50.04, 49.97, 32.95, 21.94, 21.93, 21.84, 21.83, 21.82, 21.81, 21.79, 21.78, 21.77. HR-MS: Calculated for $C_{60}H_{99}N_7O_{36}$ $[M+2H]^{2+}$: 747.8144, found: 747.8138.

Heptasaccharide (51)



(89% yield, 13/1). The reaction was carried out according to the general procedure F. ^{1}H NMR (850 MHz, Deuterium Oxide) δ 5.76 (ddt, *J* = 17.1, 10.4, 6.7 Hz, 1H), 5.27 (d, *J* = 4.0 Hz, 1H), 5.04 – 4.99 (m, 1H), 4.98 – 4.95 (m, 1H), 4.93 – 4.89 (m, 3H), 4.86 – 4.82 (m, 3H), 4.31 – 4.26 (m, 4H), 4.22 – 4.13 (m, 4H), 4.13 – 4.05 (m, 3H), 4.05 – 3.96 (m, 8H), 3.93 – 3.87 (m, 6H), 3.84 – 3.80 (m, 1H), 3.79 – 3.76 (m, 2H), 3.67 – 3.47 (m, 16H), 3.45 (dt, *J* = 10.4, 6.2 Hz, 1H), 2.29 – 2.19 (m, 2H), 1.97 – 1.93 (m, 15H), 1.91 (s, 3H), 1.90 (s, 3H). ^{13}C NMR (214 MHz, D_2O) δ 174.56, 174.51, 174.49, 174.46, 174.44, 174.35, 135.79, 116.38, 98.16, 98.12, 98.09, 98.07, 98.00, 96.61, 76.74, 76.61, 76.17, 76.08, 75.54, 71.54, 71.49, 71.15, 70.61, 68.34, 68.33, 67.48, 67.03, 66.97, 66.52, 66.39, 61.05, 60.37, 59.93, 59.33, 54.28, 50.20, 50.16, 50.04, 49.84, 32.95, 21.96, 21.83, 21.78, 21.77. HR-MS: Calculated for $C_{60}H_{99}N_7O_{36}$ $[M+2H]^{2+}$: 747.8144, found: 747.8138.

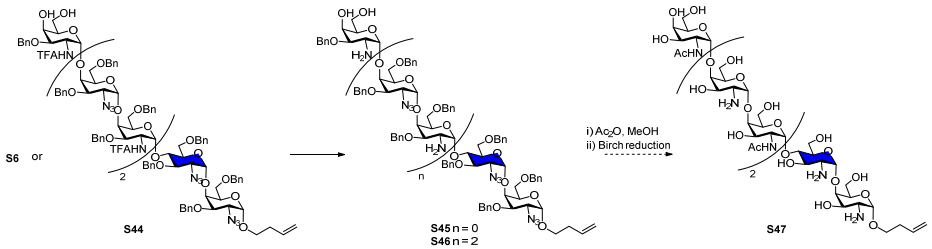
Heptasaccharide (52)



(88% yield, 12/1). The reaction was carried out according to the general procedure F. ^{1}H NMR (850 MHz, Deuterium Oxide) δ 5.85 (ddt, *J* = 17.1, 10.3, 6.7 Hz, 1H), 5.13 – 5.08 (m, 1H), 5.07 – 5.04 (m, 1H), 5.01 – 4.98 (m, 4H), 4.95 – 4.92 (m, 3H), 4.40 – 4.35 (m, 5H), 4.28 – 4.22 (m, 5H), 4.18 (dd, *J* = 11.2, 3.7 Hz, 1H), 4.14 – 4.04 (m, 10H), 4.01 – 3.95 (m, 3H), 3.89 (dd, *J* = 10.9, 3.6 Hz, 1H), 3.83 – 3.77 (m, 2H), 3.76 – 3.71 (m, 1H), 3.70 – 3.49 (m, 15H), 2.37 – 2.28 (m, 2H), 2.05 – 2.02 (m, 17H), 1.99 (s, 7H). ^{13}C NMR (214 MHz, D_2O) δ 174.55, 174.48, 174.45, 174.41, 174.23, 135.79, 116.39, 98.23, 98.11, 98.08, 96.61, 76.76, 76.74, 76.63, 76.61, 76.15, 76.08, 71.87, 71.49, 71.15, 71.13, 70.38, 69.47, 67.03, 66.97, 66.52, 66.40, 60.37, 59.75, 59.34, 53.96, 50.20, 50.17, 50.11, 50.03, 32.95, 21.84, 21.83, 21.78, 21.77, 21.73, 21.72. HR-MS: Calculated for $C_{60}H_{99}N_7O_{36}$ $[M+2H]^{2+}$: 747.8144, found: 747.8138.

Removal of TFA group was first attempted on trisaccharide **S6** in 1 M NaOH solution at 40 ºC, giving S45 in 92% yield (Table S1, entry 1). However, the TFA groups in heptamer **S44** could not be cleaved even with strong basic conditions and high temperature (4M KOH, 80 ºC, entry 2). Also attempts to remove the TFA groups with the assistance of microwave failed (entry 3). Considering the possible solubility problem of the intermediates, ammonia in methanol and 1,4-dioxane was applied, but only afforded a mixture of incompletely deprotected products (entries 4 and 5). Another attempt by the combination of KOH and H_2O_2 in 37 ºC led to a mixture (entry 6). When the reaction was proceed at 100 ºC with ammonium salt and ethylenediamine as reagents, which could be used for the deacylation of unactivated amides to generate amines[31], still failed to give the target **S46** (entry 7).

Table S1. Attempts of N-TFA removal of heptasaccharide **S44**



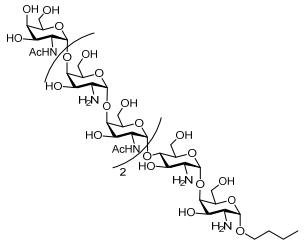
Entry	RN-TFA	Reagents and conditions	Yield
1	**S6**	1M NaOH, THF, MeOH, 40 ºC, 24h	92% (**S45**)
2	**S44**	4M KOH, THF, MeOH, 80 ºC, 5d	mixture
3	**S44**	4M KOH, THF, MeOH, 60 ºC, microwave, 6h	mixture
4	**S44**	NH_3 in MeOH, 65 ºC, 7d	mixture
5	**S44**	$NH_3.H_2O$, 1,4-dioxane, 60 ºC, 4d	mixture
6	**S44**	KOH, H_2O_2, H_2O, THF, 37 ºC, 2d	mixture
7	**S44**	$H_2N(CH_2)_2NH_2$, NH_4Br, 100 ºC, 24h	mixture

General procedure for heptasaccharides 53 - 58 (general procedure G)

HF/pyridine (16 eq) solution was added to a solution of starting material in THF at 0 ºC. The reaction was warmed to room temperature and stirred until TLC-analysis indicated full consumption of the starting material (± 1h). Then the mixture was diluted with DCM and washed with saturated $NaHCO_3$ and brine, dried with anhydrous $MgSO_4$, filtered and concentrated *in vacuo*. The residue was purified by silica gel column chromatography. The residue was dissolved in THF/H_2O/*tert*-BuOH (2 ml/2 ml/0.8 ml) before a catalytic amount of $Pd(OH)_2$/C was added. The reaction mixture was stirred for 3 days under a H_2 atmosphere, filtered and concentrated *in vacuo*. Then Boc_2O and Et_3N were added to the solution of the residue in methanol at 0 ºC. The reaction was slowly warmed to room temperature and stirred for overnight. The reaction was concentrated *in vacuo* and co-evaporated with toluene for 3 times. The residue was dissolved in $NH_3{\cdot}H_2O$ (2 ml), which was warmed to 60 ºC and stirred for overnight. The

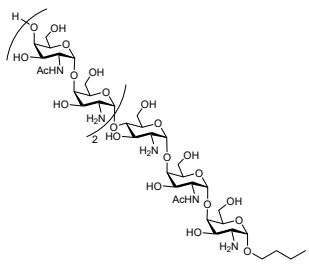
solution was concentrated *in vacuo* and then dissolved in H_2O. Ac_2O was added at 0 ºC and $NaHCO_3$ was added to the solution until the pH is 8~9. The reaction was warmed to room temperature and stirred for 3h. Then the mixture was neutralized with AcOH and then concentrated *in vacuo*. The residue was dissolved in 30% TFA in H_2O, and allowed to stirred at rt for overnight. The solution was concentrated *in vacuo*, which was purified by gel filtration (HW-40, 0.15M NH_4OAc in H_2O). The product containing fractions were pooled and lyophilized (4x) to yield the final products as a white solid.

Heptasaccharide (53)



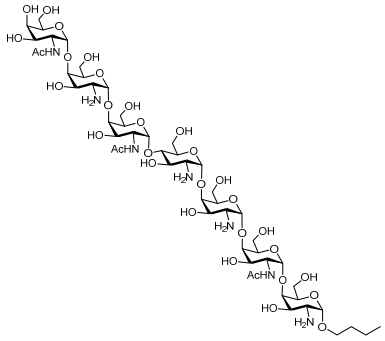
(31% yield). The reaction was carried out according to the general procedure G. ^{1}H NMR (500 MHz, Deuterium Oxide) δ 5.44 (d, *J* = 3.9 Hz, 1H), 5.28 (d, *J* = 3.9 Hz, 1H), 5.20 (d, *J* = 3.8 Hz, 1H), 5.13 (d, *J* = 3.8 Hz, 1H), 5.05 (d, *J* = 3.6 Hz, 1H), 5.00 (d, *J* = 3.8 Hz, 1H), 4.96 (d, *J* = 3.9 Hz, 1H), 4.42 (q, *J* = 4.4, 2.8 Hz, 3H), 4.36 (t, *J* = 6.4 Hz, 1H), 4.31 – 4.22 (m, 4H), 4.21 – 3.91 (m, 17H), 3.84 – 3.58 (m, 18H), 3.58 – 3.43 (m, 5H), 3.01 (d, *J* = 10.6 Hz, 1H), 2.09 – 1.98 (m, 9H), 1.64 – 1.53 (m, 2H), 1.41 – 1.28 (m, 2H), 0.87 (t, *J* = 7.4 Hz, 3H). ^{13}C NMR (214 MHz, D_2O) δ 175.70, 175.48, 175.39, 99.27, 99.08, 98.38, 96.38, 96.29, 77.50, 77.13, 76.71, 75.78, 72.70, 72.58, 72.39, 71.84, 71.21, 70.09, 69.30, 69.04, 68.07, 67.75, 67.64, 67.51, 61.59, 61.49, 61.43, 61.14, 61.07, 60.61, 60.39, 56.02, 52.07, 51.99, 51.79, 51.02, 50.98, 50.81, 31.62, 22.93, 22.79, 22.74, 19.66, 13.95. HR-MS: Calculated for $C_{52}H_{93}N_7O_{32}$ $[M+2H]^{2+}$: 664.8011, found: 664.8005.

Heptasaccharide (54)



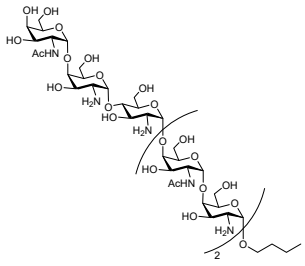
(25% yield). The reaction was carried out according to the general procedure G. ^{1}H NMR (850 MHz, Deuterium Oxide) δ 5.46 (d, *J* = 4.0 Hz, 1H), 5.03 (d, *J* = 3.7 Hz, 1H), 4.95 – 4.92 (m, 4H), 4.90 (d, *J* = 3.8 Hz, 1H), 4.40 – 4.33 (m, 4H), 4.30 (t, *J* = 6.4 Hz, 1H), 4.26 – 4.20 (m, 3H), 4.17 – 4.11 (m, 4H), 4.10 (d, *J* = 2.8 Hz, 1H), 4.04 – 4.00 (m, 5H), 3.99 – 3.95 (m, 5H), 3.93 – 3.90 (m, 2H), 3.89 – 3.86 (m, 2H), 3.82 – 3.62 (m, 25H), 3.48 (dt, *J* = 9.8, 6.4 Hz, 1H), 2.04 – 2.01 (m, 9H), 1.58 – 1.52 (m, 2H), 1.37 – 1.32 (m, 2H), 0.86 (t, *J* = 7.4 Hz, 3H). ^{13}C NMR (214 MHz, D_2O) δ 175.45, 175.41, 100.99, 100.94, 100.59, 99.30, 99.22, 99.15, 78.43, 77.93, 77.82, 76.95, 74.73, 73.37, 72.84, 72.64, 72.24, 72.17, 72.04, 71.92, 70.62, 70.42, 69.24, 69.14, 68.09, 67.76, 67.73, 61.56, 61.45, 61.36, 60.98, 60.83, 56.17, 52.33, 52.00, 51.91, 51.32, 51.17, 51.06, 31.66, 22.79, 22.74, 19.72, 13.99. HR-MS: Calculated for $C_{52}H_{93}N_7O_{32}$ $[M+2H]^{2+}$: 664.8011, found: 664.8005.

Heptasaccharide (55)



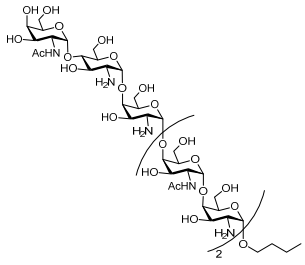
(24% yield). The reaction was carried out according to the general procedure G. ^{1}H NMR (850 MHz, Deuterium Oxide) δ 5.43 (d, *J* = 3.9 Hz, 1H), 5.21 – 5.14 (m, 2H), 5.09 (d, *J* = 3.8 Hz, 1H), 5.06 – 5.02 (m, 1H), 4.95 (d, *J* = 4.0 Hz, 1H), 4.93 (d, *J* = 3.9 Hz, 1H), 4.40 (dt, *J* = 11.4, 5.6 Hz, 3H), 4.33 (t, *J* = 6.4 Hz, 1H), 4.28 – 4.20 (m, 4H), 4.20 – 4.11 (m, 5H), 4.10 – 3.95 (m, 13H), 3.95 – 3.87 (m, 3H), 3.84 – 3.59 (m, 21H), 3.50 (dt, *J* = 9.7, 6.4 Hz, 1H), 3.47 – 3.32 (m, 3H), 2.95 (s, 1H), 2.05 – 1.99 (m, 11H), 1.60 – 1.52 (m, 2H), 1.37 – 1.29 (m, 2H), 0.86 (t, *J* = 7.4 Hz, 3H). ^{13}C NMR (214 MHz, D_2O) δ 174.64, 174.45, 174.39, 98.26, 98.13, 97.35, 76.72, 76.63, 76.34, 74.96, 71.74, 71.59, 71.06, 70.88, 70.81, 70.63, 68.23, 68.07, 67.08, 66.88, 66.55, 60.57, 60.47, 60.23, 60.16, 59.91, 59.82, 59.69, 51.16, 51.08, 50.89, 50.04, 49.89, 30.62, 18.67, 12.96. HR-MS: Calculated for $C_{52}H_{93}N_7O_{32}$ $[M+2H]^{2+}$: 664.8011, found: 664.8005.

Heptasaccharide (56)



(18% yield). The reaction was carried out according to the general procedure G. ^{1}H NMR (500 MHz, Deuterium Oxide) δ 5.53 (d, *J* = 4.0 Hz, 1H), 5.08 (d, *J* = 3.9 Hz, 1H), 5.03 – 4.93 (m, 5H), 4.45 – 4.37 (m, 3H), 4.34 (t, *J* = 6.4 Hz, 1H), 4.32 – 4.24 (m, 2H), 4.22 – 4.14 (m, 4H), 4.11 – 3.65 (m, 34H), 3.53 (dt, *J* = 9.8, 6.3 Hz, 1H), 3.26 (dd, *J* = 11.1, 3.9 Hz, 1H), 3.21 – 3.14 (m, 2H), 2.85 (dd, *J* = 10.5, 3.6 Hz, 1H), 2.11 – 2.02 (m, 9H), 1.64 – 1.56 (m, 2H), 1.43 – 1.34 (m, 2H), 0.90 (t, *J* = 7.4 Hz, 3H). ^{13}C NMR (214 MHz, D_2O) δ 174.44, 174.41, 100.08, 99.72, 98.54, 98.24, 98.23, 98.12, 77.56, 77.09, 76.92, 76.55, 75.95, 73.77, 72.46, 71.75, 71.67, 71.31, 71.23, 71.07, 70.87, 70.86, 69.89, 69.44, 69.38, 68.39, 68.23, 68.13, 68.11, 67.00, 66.89, 66.73, 60.53, 60.52, 60.00, 59.84, 59.68, 55.18, 51.27, 51.07, 50.93, 50.33, 50.17, 50.09, 30.67, 21.80, 21.75, 19.95, 18.73, 13.00. HR-MS: Calculated for $C_{52}H_{93}N_7O_{32}$ $[M+2H]^{2+}$: 664.8011, found: 664.8005.

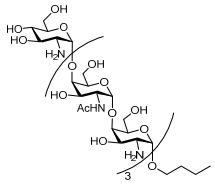
Heptasaccharide (57)



(30% yield). The reaction was carried out according to the general procedure G. ^{1}H NMR (850 MHz, Deuterium Oxide) δ 5.26 (d, *J* = 3.9 Hz, 1H), 5.20 – 5.14 (m, 2H), 5.06 (s, 1H), 5.03 (d, *J* = 3.8 Hz, 1H), 4.89 (d, *J* = 3.9 Hz, 1H), 4.84 (d, *J* = 3.9 Hz, 1H), 4.36 – 4.29 (m, 4H), 4.26 – 4.21 (m, 1H), 4.19 – 4.14 (m, 2H), 4.13 – 4.08 (m, 5H), 4.05 (dd, *J* = 11.2, 3.9 Hz, 2H), 4.01 – 3.95 (m, 6H), 3.94 (t, *J* = 6.3 Hz, 1H), 3.92 – 3.88 (m, 2H), 3.87 (d, *J* = 3.2 Hz, 1H), 3.79 (dd, *J* = 11.2, 3.2 Hz, 1H), 3.74 (dd, *J* = 12.3, 4.0 Hz, 1H), 3.70 – 3.59 (m, 13H), 3.59 – 3.52 (m, 4H), 3.50 (dd, *J* = 10.9, 6.3 Hz, 1H), 3.47 – 3.38 (m, 4H), 1.96 – 1.89 (m, 9H), 1.51 – 1.43 (m, 2H), 1.28 – 1.22 (m, 2H), 0.77 (t, *J* = 7.4 Hz, 3H). ^{13}C NMR (214 MHz, D_2O) δ 174.47, 98.10, 96.60, 95.30,

76.73, 76.51, 76.16, 75.97, 75.70, 75.13, 71.60, 71.56, 70.66, 70.54, 70.32, 70.26, 68.23, 67.21, 66.56, 66.46, 61.09, 60.16, 60.04, 59.90, 59.37, 54.83, 50.99, 50.87, 50.00, 49.95, 49.88, 30.61, 23.13, 23.12, 21.91, 21.74, 18.66, 12.95. HR-MS: Calculated for $C_{52}H_{93}N_7O_{32}$ $[M+2H]^{2+}$: 664.8011, found: 664.8005.

Heptasaccharide (58)

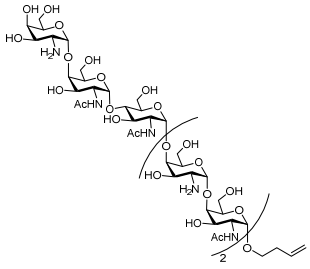


(18% yield). The reaction was carried out according to the general procedure G. ^{1}H NMR (850 MHz, Deuterium Oxide) δ 5.29 – 5.22 (m, 2H), 5.20 (d, *J* = 4.0 Hz, 1H), 5.12 (d, *J* = 3.8 Hz, 1H), 4.99 (d, *J* = 4.1 Hz, 2H), 4.94 (d, *J* = 3.9 Hz, 1H), 4.44 – 4.38 (m, 5H), 4.29 – 4.23 (m, 3H), 4.23 – 4.17 (m, 3H), 4.15 – 4.03 (m, 10H), 4.02 – 3.96 (m, 3H), 3.86 (t, *J* = 9.9 Hz, 1H), 3.81 – 3.56 (m, 19H), 3.54 – 3.46 (m, 5H), 3.20 (d, *J* = 10.3 Hz, 1H), 2.05 – 1.99 (m, 11H), 1.60 – 1.52 (m, 2H), 1.36 – 1.29 (m, 2H), 0.86 (t, *J* = 7.5, 3.2 Hz, 3H). ^{13}C NMR (214 MHz, D_2O) δ 174.49, 174.48, 174.43, 98.11, 95.39, 95.13, 77.01, 76.60, 76.55, 76.20, 75.77, 72.39, 71.58, 71.02, 70.36, 69.04, 68.24, 66.85, 66.58, 66.48, 61.04, 60.44, 60.19, 60.08, 59.65, 59.41, 54.41, 51.01, 50.89, 50.02, 49.95, 30.62, 21.75, 18.67, 12.96. HR-MS: Calculated for $C_{52}H_{93}N_7O_{32}$ $[M+2H]^{2+}$: 664.8011, found: 664.8002.

General procedure for desilylation, reduction, acetylation and Birch reduction of the oligosaccharides towards 59 and 60 (general procedure H)

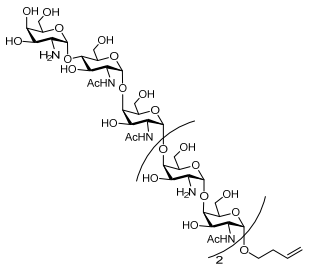
HF/pyridine (16 eq) solution was added to a solution of starting material in THF at 0 ºC. The reaction was warmed to room temperature and stirred until TLC-analysis indicated full consumption of the starting material (± 1h). Then the mixture was diluted with DCM and washed with saturated $NaHCO_3$ and brine, dried with anhydrous $MgSO_4$, filtered and concentrated *in vacuo*. The residue was purified by silica gel column chromatography. 1,3-Dithiolpropane and trimethylamine were added to the solution of the residue in pyridine/water. The mixture was protected from light and stirred at room temperature for overnight. The fluent was evaporated and co-evaporated with toluene. The residue was dissolved in THF/H_2O (2 ml, 2/1), after which Ac_2O and $NaHCO_3$ were added (pH~8). The reaction was allowed to stir at rt for 2 days. The reaction was concentrated *in vacuo* and the residue was purified by silica gel column chromatography. Ammonia (10 ml) was condensed at -78 ºC, the residue was dissolved in THF (2 ml) and tert-butanol (0.8 ml) and slowly added to the flask containing ammonia. Allyl carbinol (200 ul) was added to the reaction mixture. Small pieces of sodium was added to the reaction mixture one by one to keep deep blue for 15 min. Then ammonia acetate (100 mg) was added. The solution was allowed to warm to room temperature and stirred until all of the ammonia was evaporated. The solution was concentrated *in vacuo* and purified by gel filtration (HW-40, 0.15M NH_4OAc in H_2O). The product containing fractions were pooled and lyophilized (4x) to yield the final products as a white solid.

Heptasaccharide 59



(77% yield, 9/1). The reaction was carried out according to the general procedure H. ^{1}H NMR (850 MHz, Deuterium Oxide) δ 5.82 (ddt, *J* = 17.1, 10.3, 6.6 Hz, 1H), 5.37 (d, *J* = 3.9 Hz, 1H), 5.10 – 5.06 (m, 1H), 5.05 – 5.01 (m, 2H), 4.99 – 4.97 (m, 2H), 4.94 (d, *J* = 3.9 Hz, 1H), 4.89 (d, *J* = 3.8 Hz, 1H), 4.85 (d, *J* = 3.7 Hz, 1H), 4.37 – 4.31 (m, 4H), 4.28 – 4.25 (m, 1H), 4.24 – 4.17 (m, 4H), 4.14 (dd, *J* = 11.3, 3.8 Hz, 1H), 4.12 – 4.08 (m, 3H), 4.07 – 3.86 (m, 20H), 3.85 – 3.67 (m, 18H), 3.66 – 3.56 (m, 10H), 3.51 (dt, *J* = 10.2, 6.2 Hz, 1H), 3.15 – 3.07 (m, 4H), 2.34 – 2.26 (m, 2H), 2.01 – 1.95 (m, 12H). ^{13}C NMR (214 MHz, D_2O) δ 174.70, 174.62, 174.54, 174.41, 135.87, 116.45, 99.71, 98.21, 97.95, 97.85, 96.72, 77.45, 77.22, 77.04, 76.57, 76.29, 75.69, 72.05, 71.80, 71.66, 71.35, 71.21, 71.06, 70.46, 69.14, 68.23, 67.33, 67.28, 67.14, 66.88, 60.71, 60.66, 60.17, 59.97, 59.75, 59.63, 54.26, 51.36, 51.26, 51.01, 50.35, 50.20, 50.15, 33.00, 21.99, 21.91, 21.84. HR-MS: Calculated for $C_{54}H_{93}N_7O_{33}$ $[M+2H]^{2+}$: 684.7986, found: 684.7980.

Heptasaccharide 60



(69% yield, 23/1). The reaction was carried out according to the general procedure H. ^{1}H NMR (850 MHz, Deuterium Oxide) δ 5.82 (ddt, *J* = 17.1, 10.3, 6.6 Hz, 1H), 5.36 (d, *J* = 4.1 Hz, 1H), 5.09 – 5.05 (m, 1H), 5.04 – 5.01 (m, 1H), 4.99 (d, *J* = 3.8 Hz, 1H), 4.97 – 4.92 (m, 3H), 4.90 – 4.87 (m, 2H), 4.36 – 4.30 (m, 4H), 4.24 – 4.19 (m, 3H), 4.17 – 4.12 (m, 2H), 4.09 (d, *J* = 2.8 Hz, 1H), 4.06 – 3.91 (m, 12H), 3.91 – 3.87 (m, 3H), 3.86 – 3.83 (m, 2H), 3.81 – 3.77 (m, 2H), 3.75 – 3.56 (m, 18H), 3.51 (dt, *J* = 10.3, 6.1 Hz, 1H), 3.11 – 3.04 (m, 3H), 2.34 – 2.25 (m, 2H), 2.02 – 1.95 (m, 12H). ^{13}C NMR (214 MHz, D_2O) δ 174.61, 174.54, 174.51, 174.33, 135.88, 116.46, 100.13, 100.06, 98.24, 98.22, 98.08, 96.71, 77.32, 77.11, 76.95, 76.93, 76.67, 71.85, 71.84, 71.59, 71.43, 71.33, 70.86, 70.62, 69.52, 69.44, 68.48, 68.46, 67.37, 67.13, 66.93, 66.64, 61.22, 60.66, 59.97, 59.80, 59.73, 53.78, 51.40, 51.38, 50.88, 50.38, 50.23, 50.15, 33.00, 21.84, 21.81, 21.80. Calculated for $C_{54}H_{93}N_7O_{33}$ $[M+2H]^{2+}$: 684.7986, found: 684.7980.

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Chapter 6

Summary and Future Prospects

The work described in this Thesis is focused on the assembly of oligosaccharide fragments derived from a fungal polysaccharide, galactosaminogalactan (GAG) and fragments of the exopolysaccharide Pel, generated by *Pseudomonas aeruginosa*. Both polysaccharides are characterized by the presence of α-galactosamine linkages and the occurrence of both *N*-acetyl galactosamine (GalNAc) and galactosamine (GalN) residues makes these complex linear polysaccharides polycationic. In addition, GAG-polysaccharides can contain α-galactose (Gal) residues, while the Pel polysaccharide can contain α-glucosamine (GlcN) and α-*N*-acetyl glucosamine (GlcNAc) monosaccharides. To assemble the corresponding oligosaccharides as effectively as possible, synthetic methodologies, enabling the stereoselective construction of the required *cis*-glycosidic linkages has to be developed. These synthetic fragments will be valuable tools to elucidate the biosynthesis of GAG and

Pel, and characterize the enzymes involved therein. These fragments may also enable avenues to generate potential vaccines.

Aspergillus fumigatus and *Pseudomonas aeruginosa* are biofilm-forming microorganisms, which complicates the treatment of their infections. The polysaccharides GAG and Pel both play important roles in biofilm formation and thus are potential targets in the development of anti-inflammatory therapies. In **Chapter 1** recent knowledge on the plausible biosynthetic pathways and the chemical syntheses of fragments of both polysaccharides are described. Key to the assembly of oligosaccharide fragments is the stereoselective introduction of α-GalN and α-GlcN linkages. An overview of the developed methods for stereoselective synthesis of α-galactosamine and α-glucosamine is described.

Synthesis of GAG oligosaccharides

Chapter 2, **3** and **4** describe the synthesis of GAG oligosaccharides, including homo- and hetero-oligosaccharides as well as an azido-GAG fragment. **Chapter 2** deals with the synthesis of GAG homo-oligomers up to 9- or 12-mers and composed of either Gal, GalN or GalNAc, moieties using effective synthetic methodology. The key feature of the strategy is a three-step chain-elongation cycle: 1) di-*tert*-butylsilylidene (DTBS)-directed α-galactosylation; 2) DTBS-removal with HF/pyridine; and 3) regioselective benzoylation of the primary alcohol group, using benzoyl-hydroxybenzotriazole (BzOBt) as a mild acylating agent. In the deprotection process, the homo-oligomers of Gal (8- and 9-mer) were unexpectedly found to have poor solubility in water, while the homo-oligomers of GalN and GalNAc both proved to be well soluble in water. To investigate the conformation and spatial presentation of the synthetic GAGs, their structural properties were studied by a combination of NMR and computational methods. The oligomers were shown to adopt an elongated, almost straight, structure, stabilized by inter-residue H-bonds, one of which is a non-conventional C-H⋯O hydrogen bond between H5 of the residue (i+1) and O3 of the residue (i). This is the first time that this type of non-conventional C-H⋯O HB is reported for linear oligosaccharide structures, which was revealed by a significant downfield chemical shift for the non-reducing-end H5 protons in the NMR spectra. The structures place the groups at C-2 to the outside of the structure and can readily interact with binding partners, such as biosynthesis enzymes and antibodies.

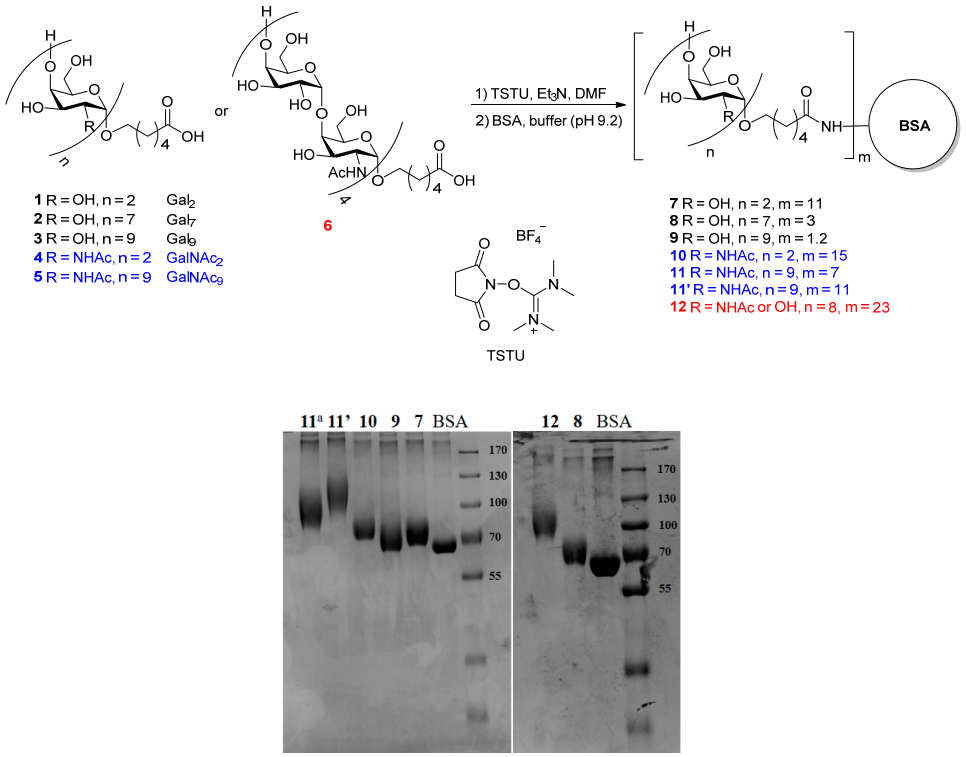
Chapter 3 reports the assembly of four sets of GAG hetero-oligomers, including the hetero-oligomers of α-GalN and α-GalNAc; hetero-oligomers of α-Gal, α-GalN and α-GalNAc; hetero-oligomers of α-Gal and α-GalN; hetero-oligomers of α-Gal and α-GalNAc. To enable the assembly of these hetero-oligosaccharides, the same methodology as described

in Chapter 2 was used. The Gal donor and $GalN_3$ donor served as precursors for Gal and GalN, respectively and a GalNTCA donor served as precursor for the GalNAc moieties. Even though the GalNTCA donor is equipped with a C-2-trichloroacetamide group, intrinsically capable of neighboring group participation, the α-selectivity of the glycosylations of this donor was excellent. Even with a reactive linker alcohol the selectivity was good (α:β=8:1) when the glycosylation was performed at 0 °C, and lowering the temperature to -20 °C further increased the selectivity to 14:1 (α:β ratio). The mixed sequence structures were produced uneventfully, showing the developed chemistry to be applicable to any GAG-target. Some of the synthetic fragments were applied for the investigations of the glycosidases Sph3, Ega3 and the *N*-acetyl hydrolase Agd3 involved in GAG biosynthesis. Treatment of GalNAc heptasaccharides with the hydrolase Sph3 resulted in the rapid hydrolysis and accumulation of pentasaccharides, while the hexamer could not be hydrolyzed, indicating that the minimum substrate size of Sph3 is seven and that the enzyme functions as an endo-acting glycoside hydrolase. The hydrolase Ega3 was found to be an endoglycosidase, degrading the non-acetylated α-1,4-$(GalN)_9$ into trisaccharide products. Furthermore, comparative deacetylation experiments with the deacetylase Agd3 suggested that Agd3 is specific for regions of the GAG polymer that are GalNAc/GalN rich and has higher affinity to partially deacetylated polymers.

In recent years, carbohydrate-based vaccines have been widely explored and identified as one of the most effective ways of preventing bacterial and fungal infections.[1-11] Conjugation of a saccharide antigen to a carrier protein converts the saccharide to a T-dependent antigen, increasing immunogenicity from infancy and enabling the development of immunological memory. Although most of the carbohydrate-based vaccines are produced from isolated polysaccharides, the use of synthetic oligosaccharides presents a promising alternative approach. Well-defined oligosaccharides allow more controlled conjugation chemistry compared to native polysaccharides and can be used to study detailed structure-activity relationships.

As depicted in Scheme 1, the synthetic GAG oligomers **1-6** have been successfully conjugated to the carrier protein bovine serum albumin (BSA). The hexanoic acid spacer was first converted to its *N*-hydroxysuccinimide (OSu) ester by using *N*,*N*,*N*',*N*'-tetramethyl-O-(*N*-succinimidyl)-uronium tetrafluoroborate (TSTU).[2] After removal of the solvent, the sugar-OSu esters were directly used without purification to react with the amino groups of BSA in a buffer solution The obtained BSA glycoconjugates were purified by filtration against sodium phosphate buffer. The conjugates were analyzed by SDS-PAGE and mass

spectrometry analysis to estimate the oligomer/BSA molar ratio. Immunization studies of these conjugates are currently ongoing.



Scheme 1: SDS-PAGE of GAG oligomers conjugated to BSA. a) 40 equivents of $(GalNAc)_9$ was used in conjugation reaction. b) 70 Equivents of oligomers were used for the other conjugation reactions.

To explore more details and the dynamics of GAG biosynthesis *in vivo*, the synthesis of an azido-GAG heptamer with a C-2-N_3 group at the non-reducing end is discussed in **Chapter 4**. The DTBS-directed α-galactosaminylation methodology was used to construct α-$GalN_3$ and α-GalNTFA linkages, again with excellent α-stereoselectivity. The reactivity of the used benzoylated GalNTFA donors and acceptors proved to be relatively low, giving moderate or low glycosylation yields. Increasing the concontration of the reaction from 0.05 M to 0.2 M greatly improved the yields of the coupling reactions. The assembled N_3-GAG heptamer is currently being evaluated for cell surface labeling of *A. fumigatus*. Sph3 is expected to have trans-glycosylase activity and may transfer the N_3-GAG to cell surface bound GAG polymers. The azide groups will then be used to visualize the labeled GAG polymers on the cell surface.

Synthesis of Pel heptasaccharides

Chapter 5 covers the synthesis of a library of Pel fragments, containing six α-GalN and α-GalNAc residues and one α-GlcN/GlcNAc moiety at different positions in the saccharide chain. First, a glycosylation study was conducted, using different $GlcN_3$ donors and $GalN_3$ acceptors for the formation of α-$GlcN_3$-(1→4)-$GalN_3$ linkages. Both the MPF-modulated glycosylation method, previously specifically developed to introduce α-glucosamine linkages, and a pre-activation strategy failed to effectively construct the desired 1,2-*cis* linkages. Also, a benzoyl group at the C6-OH of the acceptor did not prove to be beneficial for the wanted stereoselectivity. Thus, a DTBS protected $GlcN_3$ donor and a benzyl group for the protection of C-6-OH in GalN acceptors were chosen for the construction of α-$GlcN_3$-(1→4)-$GalN_3$ linkages. The Bn group was regioselectively introduced under the aegis of Taylor's borinic acid catalyst $Ph_2BO(CH_2)_2NH_2$. With the DTBS-protected $GlcN_3$, $GalN_3$ and GalNHTFA imidate donors and TfOH as promotor, the required 1,2-*cis* GalN and GlcN linkages were stereoselectively formed. Nevertheless, with the elongation of the chains, coupling reaction yields decreased significantly, owing to the low nucleophilicity of the acceptors. Fortunately, the yields of the glycosylation reactions towards the longer chains were optimized using a reverse-addition-sequence strategy, in which the acceptor was pre-mixed with the activator, prior to the addition of the donor glycoside. To generate the final compounds, six synthetic heptasaccharides were deprotected with four different strategies, giving three sets of heptamers: α-GlcN-α-GalN; α-GlcNAc-α-GalNAc and α-GlcN-α-GalNAc-α-GalN. The Bn groups were removed using a Birch reduction to avoid the reduction of C-C double bond in linker part. Unexpectedly, it was found difficult to cleave the TFA groups of fully-protected heptamers in the deprotection protocol. Starting the deprotection procedure with removal of the Bn groups by hydrogenolysis and the intermediate use of a Boc group, to mask the concommitantly released amino groups, the TFA groups could be effectively removed using ammonia hydroxide solution at 60 °C.

The synthetic Pel structures will allow for detailed structural studies by a combination of NMR and computational methods. Comparison of their structural properties with GAG oligomers can be done at the same time, as they only differ in a GlcN/GlcNAc moiety. What's more, these heptasaccharides will be valuable tools for the study of enzymes involved in Pel biosynthesis. Conjugation of heptamers with carrier proteins may produce carbohydrate-based vaccines, which will benefit the development of vaccines against *P. aeruginosa*.

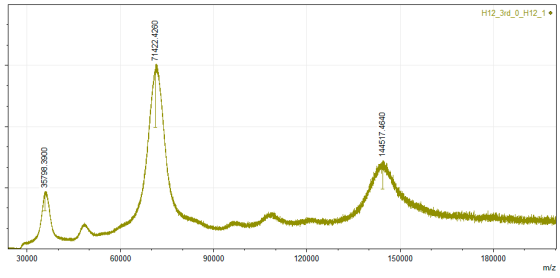
Experimental section

General procedure for conjugation reactions with BSA

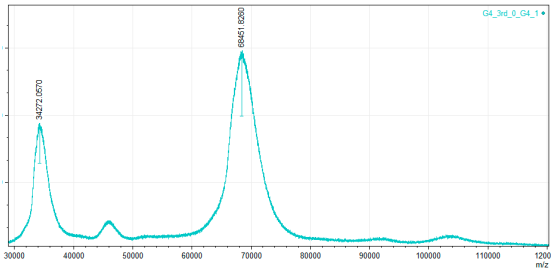
To the solution of carboxylic acid (1.0 eq) in dry DMF (0.01 M), TSTU (1.1 eq) and Et_3N (1.0 eq) were added, which was allowed to stir at rt for 2h. The reaction mixture was concentrated in vacuo and dissolved in butter ($Na_2B_4O_7$ and $NaHCO_3$, pH 9.2). BSA solution (10 mg/ml) was added to the NHS ester solution, which was allowed to stir for 2h at rt. The mixture was diluted to 4 mL with the buffer in a centrifugal filter (5 mL, 10K). After five minutes of centrifugation, the residue was diluted with 4 mL of the buffer. Repeating centrifugation and dilution for another 19 times. Then the BSA-conjugation solution was diluted with sodium phosphate buffer (NaH_2PO_4-Na_2HPO_4, 0.01M, pH 7.4) to 4 mL. After five minutes of centrifugation, the residue was diluted and centrifuged for another 9 times. The BSA-conjugation was finally diluted to 0.5 mg/mL with sodium phosphate buffer and kept at 4 °C.

MALDI-TOF data of BSA-conjugations 7-12:

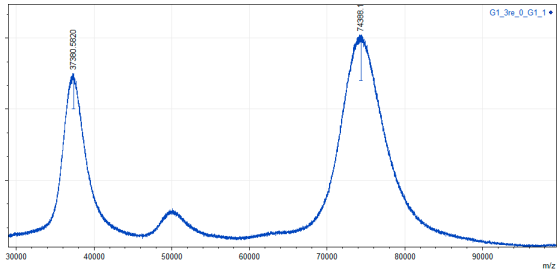
$(Gal_2)_{11}$-BSA **7**



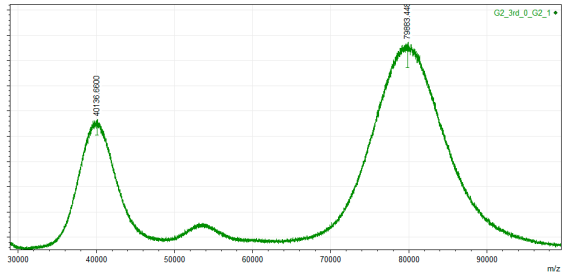
$(Gal_9)_{1.2}$-BSA **9**



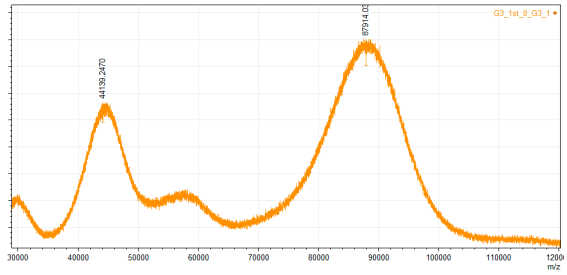
$(GalNAc_2)_{15}$-BSA **10**



$(GalNAc_9)_7$-BSA **11**



$(GalNAc_9)_{11}$-BSA **11'**



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Chinese Summary

中文小结

Chemical Synthesis of Fragments of Galactosaminogalactan and Pel Polysaccharides

半乳糖胺半乳聚糖和 Pel 多糖片段的化学合成研究

本论文描述了烟曲霉细胞壁中的半乳糖胺半乳聚糖 (Galactosaminogalactan, GAG) 和铜绿假单胞菌中的 Pel 多糖片段的合成设计。两种多糖均包含α-1,4 连接的半乳糖胺 (GalN) 和乙酰半乳糖胺 (GalNAc)单糖片段，其中 GAG 多糖中还有半乳糖 (Gal)片段，而 Pel 多糖的具体结构仍有待确认，该糖链的组成中可能包含了葡萄糖胺 (GlcN) 和乙酰葡萄糖胺 (GlcNAc)单糖片段。通过 4,6-位连接的二叔丁基亚甲硅烷基 (DTBS) 介导的糖苷化反应，所需的不同的α-糖苷键都可以立体选择性的构建。另外，合成的多糖分子的还原端都引入了一个连接位点，用来进行蛋白质或其它活性分子的结合修饰，为相关微生物糖疫苗的开发奠定了基础。

第一章先简要介绍了糖在生物体内的生物活性以及近年来糖化学领域发展的 1,2-顺式糖苷键的合成研究，然后对 GAG 和 Pel 多糖在微生物细胞内的生物合成途径及其多糖片段的化学合成方法进行了重点介绍。由于两种多糖均由α-连接的半乳糖胺或葡萄糖胺片段组成，本章列举了不同的立体选择性构建α-GalN 和α-GlcN 糖苷键的研究方法，以及这些方法在不同的糖缀合物合成中的应用。

第二章描述了三类 GAG 寡糖均聚体的合成，其糖链组成分别为 Gal、GalN 和 GalNAc，且糖链最长可达十二糖（图 1）。α-糖苷键可通过 DTBS-介导的糖苷化反应构建，糖链的延长以三步为一个循环。第一步为糖苷化反应，给体 **1** 和 **2** 分别用来构建α-Gal、α-GalN 或α-GalNAc 糖苷键。第二步将 DTBS 保护基脱除，然后在第三步中选择性的将裸露的 6-位羟基用 Bz 保护起来。6-位选择性苯甲酰化反应可以用温和的酰化试剂 BzOBt 实现。在脱除保护基后发现由 Gal 组成的八糖和九糖在水中的溶解性较差，而 GalN 和 GalNAc 组成的九糖及十二糖均没有溶解性问题。结合寡糖的 NMR 谱图及计算化学研究， Jesús Jiménez-Barber 课题组发现 GAG 寡糖为细长的且几乎直线型的结构，该结构由分子间的氢键稳定，其中一个是残基 H5（i+1）和残基 O3（i）之间的非常规 C-H···O 氢键。在这样的结构中，C-2 上的基团被放置在结构的外部，从而可以很容易地与其它的生物活性分子（如生物合成酶和抗体）相互作用。

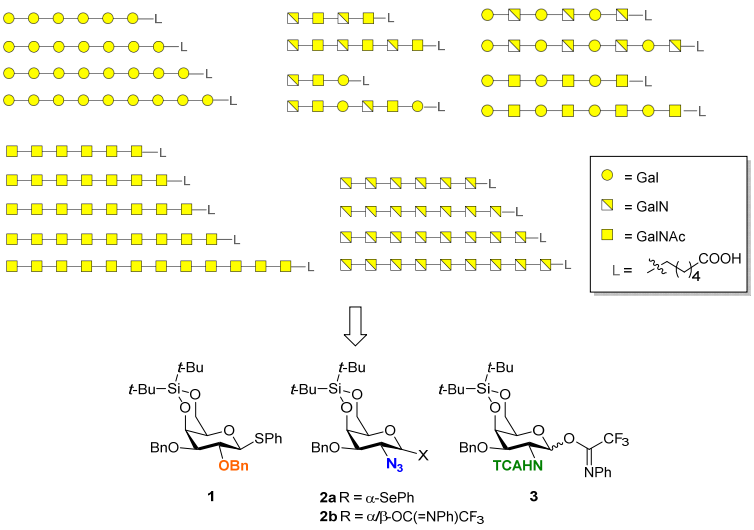

图 1. GAG 寡糖的合成及合成中的糖基给体

第三章描述了四类 GAG 寡糖非均聚体的合成（图 1），分别由不同的单糖单元组成。与第二章一样，糖苷键也是通过 DTBS-介导的糖苷化反应立体选择性地构建，糖链的延长以三步为一个循环有效延伸。其中给体 **3** 的 2-位胺基由三氯乙酰基（TCA）保护，TCA 是一个在糖苷化反应中具有邻基参与功能的保护基，但在 DTBS 基团的参与下，给体 **3** 的在糖苷化反应中仍可选择性地构建α-糖苷键。合成的所有 GAG 寡糖已被用于其生物合成途径的体外探索研究。

第四章描述了非还原末端糖基的 2-位为叠氮基团的 GAG 七糖的合成（图 2）。合成的 N_3-GAG 将作为探针用于探测细胞内水平 Sph3 对于 GAG 多糖生物合成的转糖基化活性。为了在脱保护过程中保留叠氮基团，给体的 3 位和受体的 3，6-位保护基均为苯甲酰基。三氟乙酰基（TFA）和叠氮保护的 4，6-DTBS 糖基给体分别用于构建α-GalNAc 和α-$GalN_3$ 糖苷键。由于 Bz 保护的受体和给体活性较低，在合成五糖和六糖时糖苷化产率偏低，在增加了反应液的浓度后，收率有了较大提升。

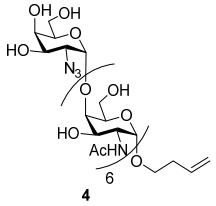

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图 2. N_3-GAG 的结构

第五章描述了一系列 Pel 寡糖片段的合成（图 3）。通过优化和筛选不同的糖苷化反应条件，DTBS-介导的糖苷化反应被成功地用于α-GalN 和α-GlcN 糖苷键的构建。糖链延长的方法与第二章类似，第一步为 DTBS-引导的糖苷化反应，在第二步中脱除该保护基后，裸露的 6-位羟基选择性地用苄基保护起来而成为下一个循环中的受体。随着糖链的延长，糖苷化反应的收率会逐渐降低，而反加法成功地解决了这个问题。在反应中受体和促进剂首先加入，然后缓慢地将糖基给体的溶液滴加入反应液中。最终通过不同的脱保护基策略，一个全保护的七糖可转化为三个不同的 Pel 片段，从而得到了三个系列的终产物。这些合成的寡糖片段将用于 Pel 的生物合成路线和糖疫苗的研究中。

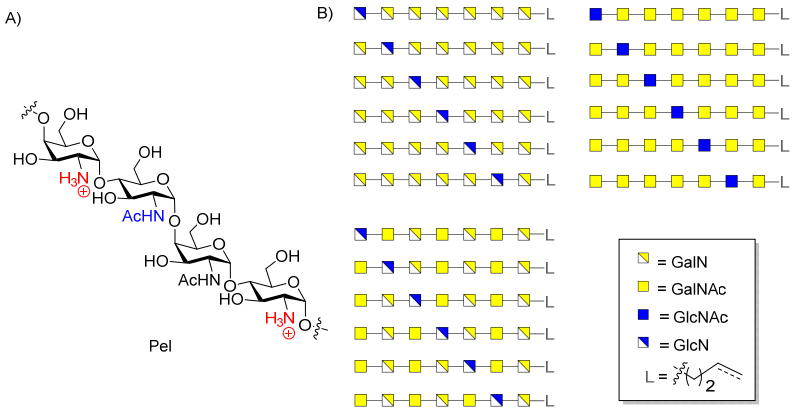

图 3. A）Pel 多糖的结构；B）合成的 Pel 寡糖片段。

第六章对本论文进行了总结，并对未来的工作进行展望。介绍了 GAG 寡糖与 BSA 蛋白的共价结合，这些糖蛋白将有利于糖疫苗的开发和发展。

Curriculum Vitae

Yongzhen Zhang was born on 6th Oct. 1989 in Feixian, Shandong province, China. After finishing his high school education in Feixian, he was enrolled in Yantai University in 2007, majoring in Pharmacy. He obtained his Bachelor of Science in 2011 and joined in Ocean University of China in the same year, majoring in Medicinal Chemistry. In 2014, he received his Master of Science degree after finishing the thesis "Studies on the Glycosylations of Glycosyl 4,5-Allenoates and Stereoselective Synthesis of β-D-Mannuronic Acid Oligosaccharides" under the supervision of Prof. dr. Ming Li. Then he moved to Marine Biomedical Research Institute of Qingdao as a researcher to do some synthesis work foucusing on Plinabulin and other new drugs development until Mar. 2016.

He started his Ph.D. study on "Chemical Synthesis of Fragments of Galactosaminogalactan and Pel Polysaccharides", presenting in this thesis, in the bio-organic synthesis group of Leiden University from May 2017. His doctoral studies were under the supervision of Prof. dr. Jeroen Codée and Prof. dr. Gijs van der Marel. Parts of his research were presented as poster at the annual Dutch chemistry conference "Chains" (2017). A poster was presented at the 20th European Carbohydrate Symposium 2019 in Leiden, the Netherlands. The poster at 20th European Carbohydrate Symposium won third poster prize.

From Oct. 2021, he will start his postdoctoral career at University of Florida.

List of Publications

1. Bamford, N.C.; Mauff F.; Van Loon, J. C.; Ostapska, H.; Snarr, B. D.; Zhang, Y.; Kitova, E. N.; Klassen, J. S.; Codée, J. D. C.; Sheppard, D. C., Howell, P. L. Structural and biochemical characterization of the exopolysaccharide deacetylase Agd3 required for *Aspergillus fumigatus* biofilm formation. *Nat. Commun*. **2020**, *11*: 2450.
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5. Bamford, N.; Mauff, F.; Subramanian, A.; Yip, P.; Millan, C.; Zhang, Y.; Zacharias, C.; Forman, A.; Nitz, M.; Codée, J. D. C.; Uson, I.; Sheppard, D.; Howell, P. L. Ega3 from the fungal pathogen *Aspergillus fumigatus* is an endo-α-1,4-galactosaminidase that disrupts microbial biofilms. *J. Biol. Chem*. **2019**, *294*, 13833-13849.
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Sept. 2021, Linyi

Yongzhen