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Toward the Solid-Phase Synthesis of Heparan Sulfate Oligosaccharides: Evaluation of Iduronic Acid and Idose Building Blocks

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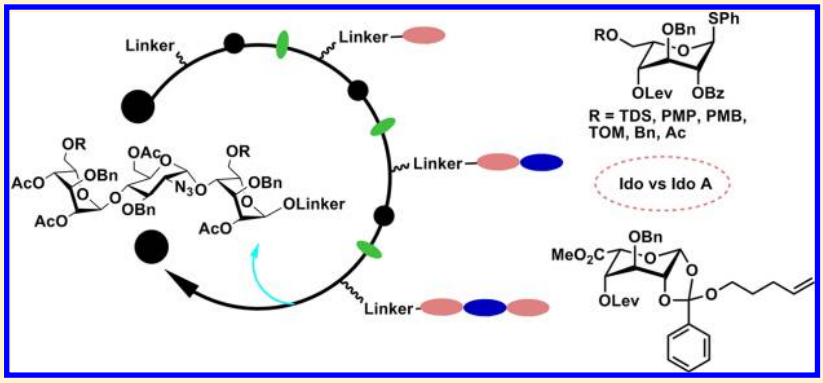
Supporting Information



ABSTRACT: Glycan arrays have been established as the premier technical platform for assessing the specificity of carbohydrate binding proteins, an important step in functional glycomics research. Access to large libraries of well-characterized oligosaccharides remains a major bottleneck of glycan array research, and this is particularly true for glycosaminoglycans (GAGs), a class of linear sulfated polysaccharides which are present on most animal cells. Solid-supported synthesis is a potentially powerful tool for the accelerated synthesis of relevant GAG libraries with variations in glycan sequence and sulfation pattern. We have evaluated a series of iduronic acid and idose donors, including a couple of novel *n*-pentenyl orthoester donors in the sequential assembly of heparan sulfate precursors from monosaccharide building blocks in solution and on a polystyrene resin. The systematic study of donor and acceptor performance up to the trisaccharide stage in solution and on the solid support have resulted in a general strategy for the solid-phase assembly of this important class of glycans.

INTRODUCTION

Glycosaminoglycans (GAGs) are highly charged and linear polysaccharides composed of (2-amino-2-deoxyhexopyranosyl)pyranuronic acid disaccharide repeating units (with the exception of keratan sulfate), which are further classified according to their monosaccharide composition and glycosidic linkage (Figure 1). Heparan sulfates (HSs) are composed of 1−4-linked hexuronic acid (*β*-D-glucuronic or *α*-L-iduronic) and glucosamine disaccharide repeating units with a variable degree of *O*- and *N*-sulfation (Figure 1). Expressed on serine residues of proteoglycans, they are present on most animal cell surfaces and in the extracellular matrix, where they engage through ionic interactions with a large number of proteins, including growth factors and their receptors. HS biosynthesis is performed by the orchestrated action of two polymerases, a glucuronyl C-5-epimerase, various *N*-deacetylases/*N*-sulfotransferases, and *O*-sulfotransferases in the ER/Golgi, and further modifications are then produced by extracellular sulfatases.[1] The very large structural heterogeneity of HS with nonrandom differences in chain length, monosaccharide sequence, and sulfation pattern is a result of the sequential action and specificity of these enzymes involved in HS biosynthesis.[1,2]

The degree of specificity in HS−protein interactions is still a matter of debate, but a growing body of scientific evidence has demonstrated that GAG expression is strictly regulated, resulting in a species- and tissue-specific polysaccharide composition, and specific epitopes are recognized by some receptors, while others show far more relaxed structural requirements for binding to HS.[2]

HS−protein interactions are implicated in many biological processes, such as angiogenesis, blood coagulation, viral entry, etc.,[3] but SAR studies have been hampered by the high heterogeneity of the biological material and the associated problems in isolating pure samples. Therefore, considerable efforts have been invested in the development of synthetic

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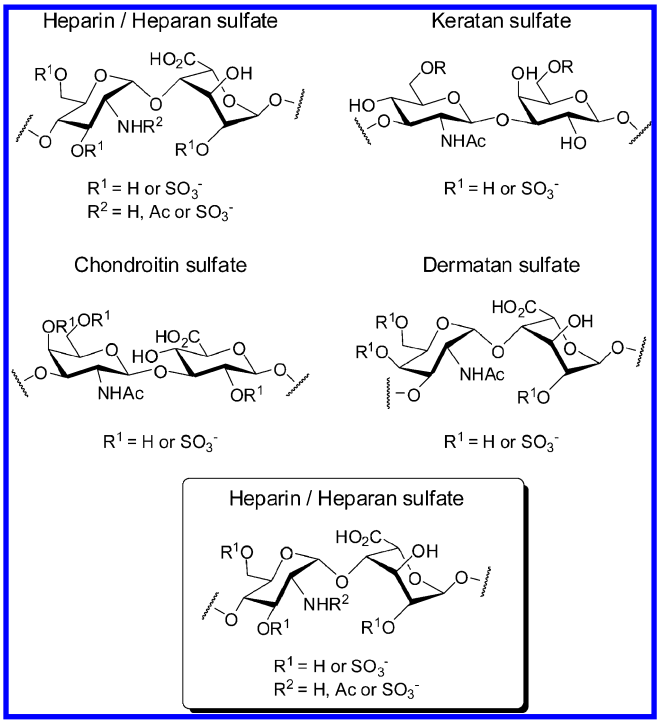

Figure 1. Disaccharide repeating units of different classes of GAGs.

strategies for the preparation of HS oligosaccharides with defined sequence and sulfation patterns.[4−14] (Automated) solid-phase synthesis is especially suited for the preparation of linear biopolymers such as oligonucleotides and oligopeptides, and efforts toward its extension to oligosaccharides and particularly GAGs[15−18] are currently under way, although accompanied by a number of additional challenges.

Unlike peptides or oligonucleotides, common sugar monomers have up to five hydroxyl groups of similar reactivity which require adequate differentiation and protection throughout the synthesis. In addition, reliable strategies and experimental setups for the stereoselective,[5] high-yielding coupling reactions between monomers have to be developed. The need for moisture-free and low-temperature coupling conditions has further implications for the design of specialized automated synthesizers.[19] As a result, only very few studies related to the solid-phase synthesis of GAGs have been reported to date.[15−17,20,18]

The solid-phase synthesis of neutral oligosaccharides has been more straightforward, and various biologically important glycan structures have been prepared even in an automated fashion.[21−23]

We have recently described a synthetic strategy for the solid-phase synthesis of HS precursors based on the sequential assembly of idose and glucosamine monosaccharide building blocks.[15] As an excess of reagents is usually employed for solid-phase reactions to proceed with high conversion, the use of monosaccharide building blocks is generally preferred over that of more elaborate disaccharide building blocks. In spite of employing a substantial donor excess in this preliminary investigation, we did not obtain the high coupling yields required for the preparation of larger HS oligomers. Therefore, we decided to study in more detail the requirements for an efficient solid-phase assembly of HS oligosaccharides from monosaccharide building blocks.

In general terms, the main criteria to assess the efficiency of a solid-phase synthesis of HS oligosaccharides can be summarized as follows: (1) the assembly of glycosyl donors and glycosyl acceptors must occur with high yield and complete stereoselectivity; (2) only a low number of glycosylation cycles must be needed to achieve the above yield and stereoselectivity; (3) the reaction conditions and the experimental prcedure may allow automation of the entire synthetic process at a later stage.

In this context we present here the results of a systematic evaluation of iduronic acid (IdoA) and idose (Ido) glycosyl donors, among them new highly reactive *n*-pentenyl orthoesters (NPOEs), with variations in the protecting group pattern and the leaving group, for the sequential solution- and solid-phase synthesis of HS precursors. The direct use of IdoA donors for the oligomer assembly directly reduces the steric hindrance exerted by a voluminous protecting group at C-6 of Ido donors and avoids additional deprotection and oxidation steps to produce the natural structure. Uronic acid donors due to their electron-withdrawing ester function, however, are known to be less reactive than their nonoxidized analogues,[24] and our study was intended to clarify whether their direct use in the solid-phase assembly is viable and justified.

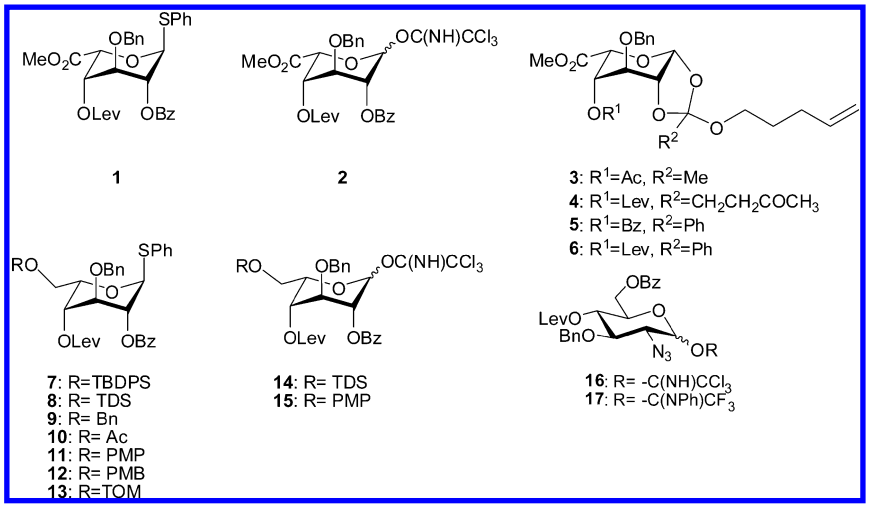

Figure 2. Ido, IdoA, and azidoglucose donors employed in this study. TBDPS = *tert*-butyldiphenylsilyl, TDS = thexyldimethylsilyl, PMP = *p*-methoxyphenyl, PMB = *p*-methoxybenzyl, and TOM = [(triisopropylsilyl)oxy]methyl.

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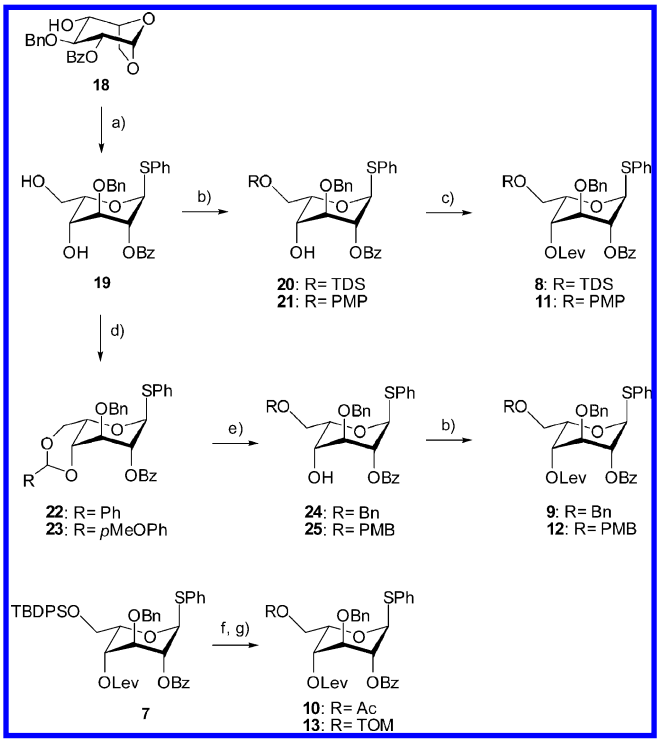
RESULTS AND DISCUSSION

All Ido and IdoA donors studied were prepared under the following constraints: Acyl groups were chosen for anchimeric assistance in the 1,2-*trans*-selective glycosylation reactions and as temporary protection of sulfated hydroxyl positions in the final molecule, while hydroxyl functions unchanged during the assembly and sulfation were protected as benzyl ethers.

With this in mind, IdoA donors **1**[25]**–6**, Ido thioglycosides **7**[9]**–13**, trichloroacetimidates **14** and **15** with protecting groups of varying size at C-6, and azidoglucose donors **16** and **17** were prepared and evaluated as building blocks in the solid-phase assembly of HS precursors (Figure 2).

All Ido donors were prepared from 1,6-anhydro compound **18**, which was synthesized from diacetone glucose in seven steps with an overall yield of 20% (Scheme 1).[26] Thioglycoside

Scheme 1. Synthesis of the Thiophenyl Idopyranoside Donors 8–13[a]



[a]Reagents and conditions: (a) Me_3SiSPh, ZnI_2, rt, o/n, 77%; (b) for **20**, (TDS)Cl, cat. DMAP, pyridine, rt, o/n, 85%; for **21**, (PMP)OH, PPh_3, DIAD, THF, 2 h, 80 °C, 70%; (c) LevOH, EDC·HCl, cat. DMAP, CH_2Cl_2, 5 h, 65% (**8**), 94% (**9**), 90% (**11**), 90% (**12**); (d) $PhCH(OMe)_2$ (for **22**), *p*-methoxybenzaldehyde (for **23**), CSA, DMF, 80 °C, 5 h, 79% (**22**), 84% (**23**); (e) TES, TFA, 0 °C to rt, 2 h, 70% (**24**), I_2, $NaCNBH_3$, −20 °C, CH_2Cl_2, 61% (**25**); (f, g) HF–pyridine, THF, 0 °C to rt, 50%; for **10**, Ac_2O, pyridine, CH_2Cl_2, quant; for **13**, (TOM)Cl, DIPEA, CH_2Cl_2, 0 °C to rt, 64%.

19 was accessible via thiolysis of **18** with trimethyl(phenylthio)-silane and zinc iodide (Scheme 1).[27] Selective protection of HO-6 with a thexyldimethylsilyl chloride or *p*-methoxyphenol by Mitsunobu reaction[28] afforded **20** and **21**, respectively. Levulination of the free HO-4 afforded intermediates **8** and **11**, which after hydrolysis of the thiophenyl group, were treated with trichloroacetonitrile and DBU to afford imidates **14** and **15**. Acid-catalyzed acetalization of diol **19** with dimethoxybenzylidene acetal or *p*-methoxybenzaldehyde afforded thioglycosides **22** and **23**, respectively, which, after selective reductive ring-opening with triethylsilane and trifluoracetic acid,[29] furnished compounds **24** and **25**. These compounds were further levulinated to obtain donors **9** and **12**, respectively. Finally, exchange of the *tert*-butyldiphenylsilyl ether in **7** for an acetate or [(triisopropylsilyl)oxy]methyl (TOM) group afforded the thioglycosides **10** and **13**.

Imidates **16** and **17** were obtained in a five-step sequence from known 2-azidoglucose derivative **26**.[30] Thiol-mediated transacetalization furnished diol **27**; selective benzoylation[31] with benzoyl cyanide at low temperature afforded alcohol **28**, which was levulinated under standard conditions to give intermediate **29**. Hydrolysis of the anomeric silyl group with buffered TBAF afforded the corresponding hemiacetal, which was activated either with trichloroacetonitrile to the trichloro-**16** or with *N*-phenyltrifluoroacetimidoyl chloride[32] to the *N*-phenyltrifluoroacetimidate **17** (Scheme 2).

NPOEs have been described by Fraser-Reid et al. as potent glycosyl donors of mannose,[33] glucose,[33] and galactose.[34] Depending on the monosaccharide configuration, *n*-pentenyl glycosides (NPGs) and NPOEs can react via distinct intermediates, and the mannose-NPOE, with a 1,2-*cis*-diol configuration found also in the stable L-idose-NPOE $^1C_4$ conformer, was found to be more reactive than the corresponding 2-*O*-acyl NPG.[35,32] NPOEs hold an activated anomeric position as a glycosyl donor and differentiated positions C-2 and C-4 at the same time, a feat that would require multiple additional steps for other glycosyl donor types. A further hallmark of NPOEs is their facile preparation from peracylated anomeric bromides by treatment with a soft base in the presence of 1-pentanol.[29]

Surprisingly, in spite of these obvious advantages, NPOEs have not been evaluated to date as potential glycosyl donors for the synthesis of HS oligosaccharides, while NPGs have been investigated previously.[25,36]

We synthesized orthoesters **3–6** via the bromosugars from triol **30**[37] as shown in Scheme 3. Briefly, triol **30** was acylated with acetic anhydride, levulinic acid, or benzoyl chloride to afford the corresponding triacyl compounds **31**,[38] **32**, and **33** respectively. Tribenzoate **33** was most readily obtained and easily crystallized, while acetate **31** and levulinate **32** required very careful adjustment of the reaction conditions to suppress the competing furanoside formation.[38] Formation of 1-bromosugars was achieved in high yield by treatment with either HBr/AcOH or $TiBr_4$, which were rapidly reacted with 1-pentenol to the mixed orthoesters **3–5** (Scheme 3)[25]

Orthoester **6** was prepared from **5** through replacement of the benzoate ester at C-4 by a temporary levulinic ester protecting group. Unfortunately, the hydrolysis of the benzoate group under harsh conditions using sodium methoxide was accompanied by extensive elimination to the alkene **34**. Mild ester hydrolysis of compound **5** with trimethyltin hydroxide,[39] however, allowed debenzoylation without any elimination. Carbodiimide-mediated re-esterification of the acid function cleanly produced the free alcohol **35**, although care had to be taken in the workup to avoid the cleavage of the acid-labile orthoester function. Final levulination of the 4-hydroxy function produced the fully differentiated orthoester glycosyl donor **6**.

The conformation of the pyranoid ring in all Ido and IdoA glyosyl donors described so far, including NPOEs **3–6**, was unambigously established as $^1C_4$, and the stereochemistry of the

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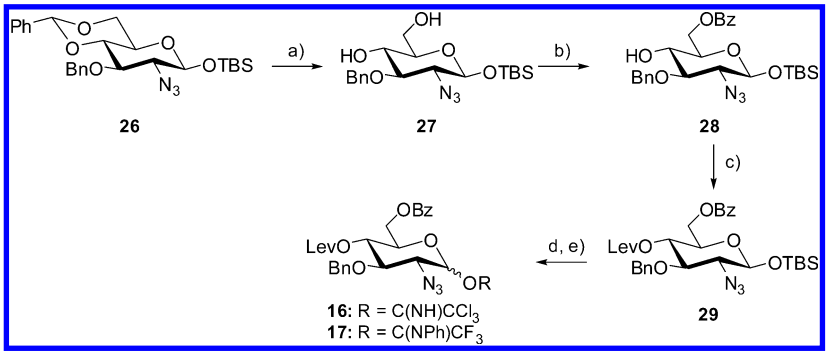
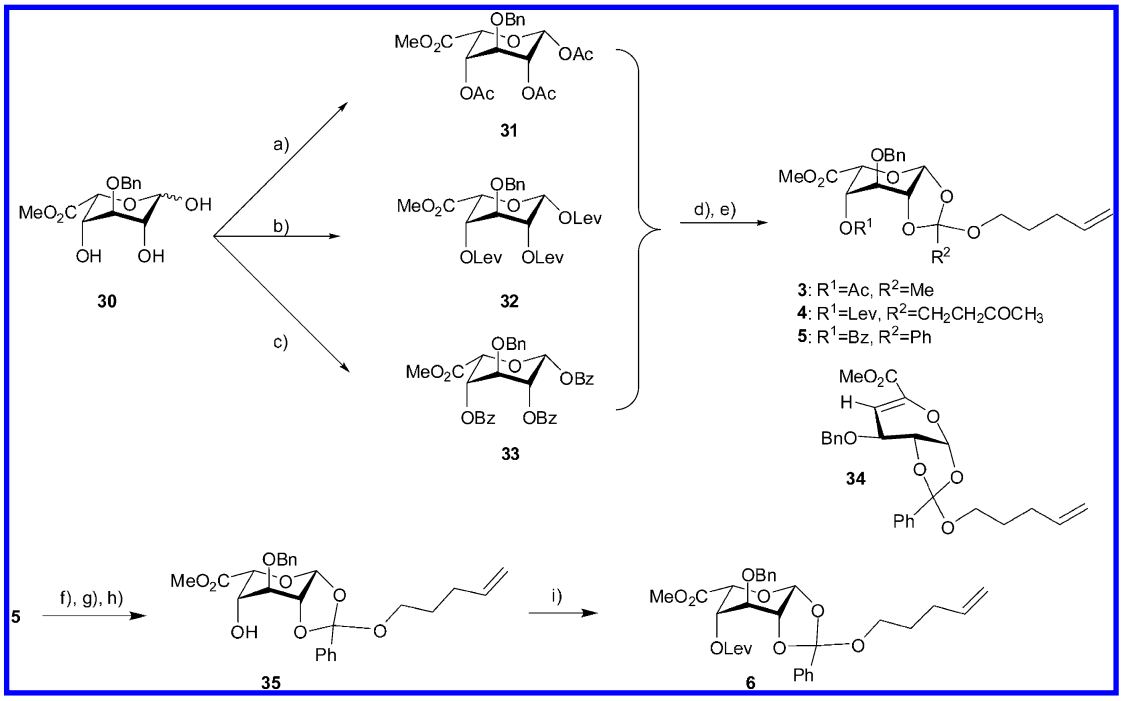
Scheme 2. Synthesis of Trichloroacetimidates 16 and 17[a]



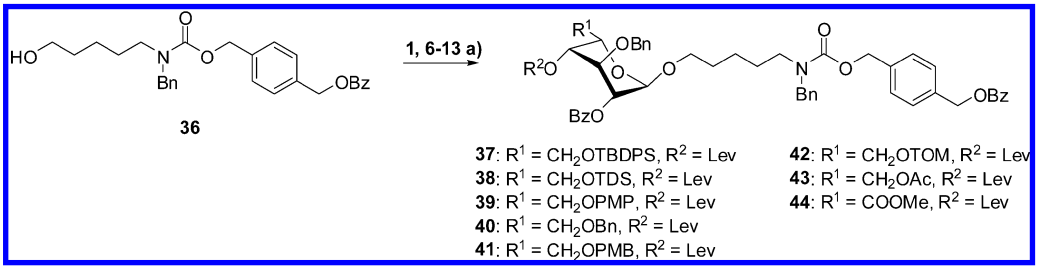
[a]Reagents and conditions: (a) EtSH, pTSA, CH_2Cl_2, 3 h, rt, 89%; (b) BzCN, cat. Et_3N, AcCN, 7 h, −40 °C, 90%; (c) EDC·HCl, LevOH, cat. DMAP, CH_2Cl_2, rt, 91%; (d) TBAF, AcOH, THF, 0 °C, 3 h; (e) for **16**, trichloroacetonitrile, DBU, CH_2Cl_2, 0 °C, 2 h, 85% over two steps; for **17**, *N*-phenyltrifluoroacetimidoyl chloride, K_2CO_3, acetone, rt, o/n, 91% over two steps.

Scheme 3. Synthesis of Orthoesters with Increasing Steric Bulk at the Exocyclic Carbon[a]



[a]Reagents and conditions: (a) AcCl, pyridine, DMAP, CH_2Cl_2, −40 °C to rt, 78%; (b) LevOH, EDC·HCl, DMAP, −25 °C to rt, 80%; (c) BzCl, pyridine, CH_2Cl_2, −40 °C to rt, 91%; (d) HBr/AcOH, CH_2Cl_2; (e) 4-pentenol, 2,6-lutidine, CH_2Cl_2; (f) trimethyltin hydroxide, toluene, microwave, 100 °C; (g) NaOMe/MeOH, microwave, 60 °C; (h) MeOH, EDC·HCl, DMAP, 60% over three steps; (i) LevOH, EDC·HCl, DMAP, CH_2Cl_2, 90%.

Scheme 4. Glycosylation of Linker 36 with Different Ido and IdoA Donors[a]



[a]Reagents and conditions: (a) NIS, (TMS)OTf or TfOH; for yields and details see Table 1.

orthoesters was determined to be *exo*, in both cases using NMR spectroscopy.

With all donors in hand, their performance in key glycosylation reactions involved in the assembly of HS oligosaccharides was investigated. First we looked at the

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glycosylation of the carbamate spacer linker **36**,[15] which had been specially designed for the release of oligosaccharides as 5-aminopentyl glycosides for facile attachment to glycan array surfaces (Scheme 4). Linker **36** also bears a benzoyl group to mimic the ester linkage toward a polystyrene resin.

The glycosylation reactions involving donors **1** and **6**−**13** and acceptor **36** are shown in Table 1. All reactions were carried out at −20 °C after temperature optimization in a series of test glycosylations employing the 6-*O*-*tert*-butyldiphenylsilyl (TBDPS) derivative **7** (entries 1−3, **37**[15]). Thioglycoside donors (**1**, **7**−**13**) reacted in good to excellent yields with the primary hydroxyl function of the benzoylated linker **36** independent of the size of the substituent at C-6. Donors **1**, **6**, and **10** with electron-withdrawing substituents at position C-6 performed less well unless stronger activation conditions were employed (entry 11). In general, the glycosylation of the primary linker hydroxyl functional group proved to be straightforward for all glycosyl donors evaluated, and orthoester derivative **6** (entry 12) performed equally well as the corresponding phenyl thioglycoside **1** (entry 11).

Table 1. Test Glycosylations of Linker 36 in Solution Using Glycosyl Donors 1 and 6−13

entry	donor	temp	product	yield[a] (%)
1	**7**	−20 °C to rt[b]	**37**	82
2	**7**	0 °C to rt[b]	**37**	60
3	**7**	−45 °C to rt[b]	**37**	63
4	**8**	−20 °C to rt[b]	**38**	80
5	**11**	−20 °C to rt[b]	**39**	79
6	**9**	−20 °C to rt[b]	**40**	82
7	**12**	−20 °C to rt[b]	**41**	70
8	**13**	−20 °C to rt[c]	**42**	90
9	**10**	−20 °C to rt[c]	**43**	52
10	**1**	0 °C to rt[b]	**44**	55
11	**1**	rt[d]	**44**	66
12	**6**	0 °C to rt[d]	**44**	69

[a]Only the α-anomer formed. [b]A 1.5 equiv sample of donor, 1.5 equiv of NIS, and 0.25 equiv of (TMS)OTf were used. [c]A 1.2 equiv sample of donor, 1.5 equiv of NIS, and 0.1 equiv of TfOH were used. [d]A 1.5 equiv sample of donor, 3 equiv of NIS, and 0.25 equiv of (TMS)OTf were used.

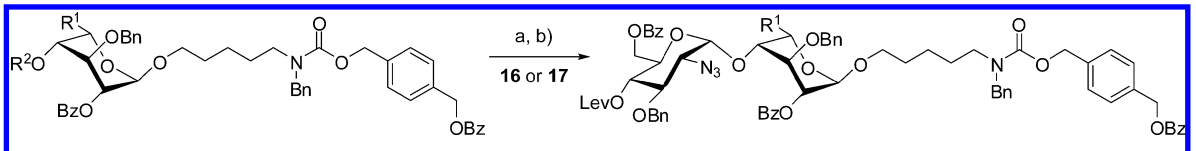
Stronger differences between the derivatives with different protecting group regimes were expected in the following glycosylation of Ido/IdoA acceptors with donors **16** and **17**. Deprotection of the 4-*O*-levulinic ester in glycosides **37**[15]−**44** with hydrazine acetate provided the glycosyl acceptors (with a broad variation of the protecting group at position C-6) that were submitted to glycosylation with glycosyl donors **16** and **17** (Scheme 5). As a general trend, the glycosylation yields increased with a reduced steric demand of the protecting group at C-6 (Table 2). Substitution of the TBDPS group (entries 1 and 2) with a TOM group (entry 7), used extensively in nucleic acid chemistry, did not improve the accessibility to the acceptor site substantially, and the disaccharide **50** was formed in 50% yield. A change from the bulky TBDPS group to the smaller thexyldimethylsilyl (TDS) group (entry 3) led to a slight increase in the formation of the corresponding disaccharide **46**. A more pronounced effect was observed for 6-*O*-*p*-methoxyphenyl (PMP), -Bn, and -*p*-methoxybenzyl (PMB) protected Ido acceptors (entries 4−6), which demonstrated higher accessibility of the axial acceptor function to the azidoglucose donor and gave rise to the disaccharides **47**−**49** in good yields. This effect was reversed, however, when small but electron-withdrawing groups were employed for protection of C-6. Both the 6-*O*-acetate (entry 8) and the IdoA derivative (entries 9 and 10) were poorer acceptors in this comparison, with yields for the corresponding disaccharides **51** and **52** below 50%, probably as a result of decreased nucleophilicity of the axial HO-4 acceptor. Furthermore, as a further consequence of this

Table 2. Glycosylations of Different Ido and IdoA Acceptors with Azidoglucose Donors 16 and 17 in Solution

entry	donor	temp	amt of (TMS)OTf (equiv)	product	yield (%)
1	**16**	−20 °C to rt	0.25	**45**	42
2	**17**	−20 °C to rt	0.25	**45**	32[a]
3	**16**	−20 °C to rt	0.25	**46**	51
4	**16**	−20 °C to rt	0.25	**47**	65
5	**16**	−20 °C to rt	0.25	**48**	58
6	**16**	−20 °C to rt	0.25	**49**	61
7	**16**	−20 °C to rt	0.10	**50**	50
8	**16**	−20 °C to rt	0.10	**51**	15[b]
9	**17**	0 °C to rt	0.05	**52**	32
10	**16**	0 °C to rt	0.05	**52**	48

[a]Conversion determined by LC−MS analysis. [b]Obtained as an α/β mixture.

Scheme 5. Glycosylation of Different Ido/IdoA Acceptors with Azidoglucose Trichloroacetimidate 16 and Trifluoroacetimidate 17[a]



37: R^1 = $CH_2OTBDPS$, R^2 = Lev
38: R^1 = CH_2OTDS, R^2 = Lev
39: R^1 = CH_2OPMP, R^2 = Lev
40: R^1 = CH_2OBn, R^2 = Lev
41: R^1 = CH_2OPMB, R^2 = Lev
42: R^1 = CH_2OTOM, R^2 = Lev
43: R^1 = CH_2OAc, R^2 = Lev
44: R^1 = COOMe, R^2 = Lev

45: R^1 = $CH_2OTBDPS$
46: R^1 = CH_2OTDS
47: R^1 = CH_2OPMP
48: R^1 = CH_2OBn
49: R^1 = CH_2OPMB
50: R^1 = CH_2OTOM
51: R^1 = CH_2OAc
52: R^1 = COOMe

[a]Reagents and conditions: (a) hydrazine acetate, CH_2Cl_2; (b) (TMS)OTf, CH_2Cl_2, 1.2−1.4 equiv of donor; for yields see Table 2.

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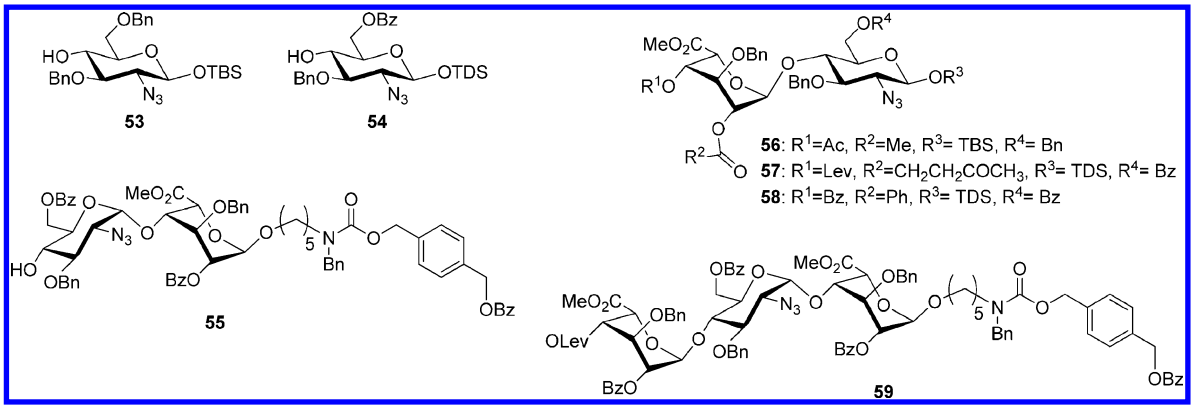

Figure 3. Glycosylation of azidoglucose acceptors **53**−**55** with Ido *n*-pentenyl orthoesters.

decreased reactivity, an α/β mixture which could not be separated was obtained in the case of the 6-*O*-acetate derivative **51**.

In a direct comparison of the imidate donors **16** and **17** (entries 1, 2 and 9, 10), the trichloroacetimidate **16** performed with both Ido and IdoA acceptors consistently better than the corresponding *N*-phenyltrifluorocetimidate **17**.

A particular challenge in the chemical synthesis of HS oligosaccharides is the efficient glycosylation of HO-4 of glucosamine residues.[40] While little difference between Ido and IdoA donors was found for the glycosylation of the primary hydroxy group of the anomeric aminopentyl linker, we were intrigued to investigate the performance of the IdoA orthoesters and thioglycosides in the notoriously difficult glycosylation of the azidoglucose acceptors **53**[41]−**55**. The *n*-pent-4-enyl orthoacetate **3**, ortholevulinoate **4**, and orthobenzoate **5** were activated with NIS and a catalytic amount of (TMS)OTf and reacted with the azidoglucose acceptors **53** and **55** (Figure 3). Glycosylations involving the orthoacetate **3** and ortholevulinoate **5** produced the disaccharides **56** and **57** in 30% and 36% yield, respectively (Table 3). These compounds were accompanied by up to 30% of a disaccharide with undetermined stereochemistry lacking the HO-2 protecting group, which had presumably formed via an orthoester exchange mechanism after attack on the exocyclic carbon.[42,43] We reasoned that the increase of the bulk of the orthoester alkyl substituent from methyl to phenyl (compounds **3** and **5**, Scheme 3) should favor the attack of the nucleophile at the anomeric rather than the exocyclic carbon, leading to a stronger stereocontrol in the glycosylation, and indeed, after activation of the orthobenzoate **5** with NIS/(TMS)OTf, the disaccharide **58** was produced in an excellent 85% yield as the pure α-anomer (Table 3). After this promising result, we compared IdoA thioglycoside and *n*-pent-4-enyl orthobenzoate donors in the glycosylation of the disaccharide acceptor **55**.

Table 3. Comparison of Thioglycoside 1 and *n*-Pentenyl Orthoesters 3−6 in the Key Glycosylation with Azidoglucose Acceptors 53−55[a]

entry	donor	acceptor	conditions	product	yield (%)
1	**3**	**53**	a, 0 °C to rt	**56**	30
2	**4**	**54**	a, 0 °C to rt	**57**	36
3	**5**	**54**	b, 0 °C to rt	**58**	85
4	**1**	**55**	b, rt	**59**	34
5	**6**	**55**	b, 0 °C to rt	**59**	45

[a]Reagents and conditions: (a) 1.2 equiv of donor, 1.2 equiv of NIS, 0.2 equiv of (TMS)OTf; (b) 1.2−1.5 equiv of donor, 3.0 equiv of NIS, 0.2 equiv of (TMS)OTf.

Both reactions involving thioglycoside **1** and orthoester **6** proceeded less well than expected from the previous results, with a less than 50% yield of trisaccharide **59** being obtained after workup (Table 3). In any case, the orthoester **6** performed slightly better than the thioglycoside **1** derivative in this trial, and we moved on to evaluate the orthoester and thioglycoside donors in the solid-phase assembly of building blocks with the possibility of increasing conversion by use of a donor excess and various cycles of glycosylation.

Solid-phase trials were performed on a polystyrene resin functionalized with the carbamate-type linker **60** at 0.2 or 0.4 mmol/g prepared as described recently[15] (Scheme 6). After methylation of the unreacted carboxylic acid functions using diazomethane, the resin-bound linker **SP-61**[15] was deprotected with HF−pyridine, affording the acceptor **SP-62**.[15] Glycosylation with 3 equiv of the IdoA trichloroacetimidate **2** under (TMS)OTf catalysis at −40 °C afforded resin-bound monosaccharide **SP-63**. LC−MS analysis of a cleaved aliquot of the resin afforded compound **64** in a conversion of 84% (Table 4). Similar yields were achieved employing 5 equiv of either thioglycoside donor **1** or orthoester **6** under conventional NIS/(TMS)OTf activation, thus reproducing the high yields of the solution-phase experiments for this reaction. The following deprotection of the levulinic ester at C-4 in **SP-63** with 3 equiv of hydrazine acetate to the resin-bound acceptor **SP-65** was monitored by a dibutyltin oxide-mediated[39] cleavage of an analytical sample from the resin. Subsequent glycosylation of **SP-65** with 3 equiv of azidoglucose donor **16** at −40 °C afforded resin **SP-66**. Cleavage of a resin aliquot with sodium methoxide suggested a low conversion to disaccharide **67**, 21% after one cycle (Table 4). However, after four cycles the conversion of the analogue disaccharide **68** (cleaved with dibutyltin oxide (DBTO)) was increased to 86%. Again hydrazinolysis of the levulinic acid afforded resin-bound acceptor **SP-69**, which was condensed with the *n*-pent-4-enyl orthoester donor **6** with NIS and (TMS)OTf at 0 °C. The glycosylation was repeated twice, affording resin **SP-70**, and LC−MS analysis of a cleaved sample, **71**, suggested conversion of around 76% after three cycles (Table 4). Preparative cleavage of the trisaccharide **71** from the resin using DBTO to avoid elimination was less effective than expected from the analytical run and had to be repeated several times until no further compound was cleaved.[44] Employing lithium peroxide to hydrolyze the ester groups prior to the methoxide-mediated

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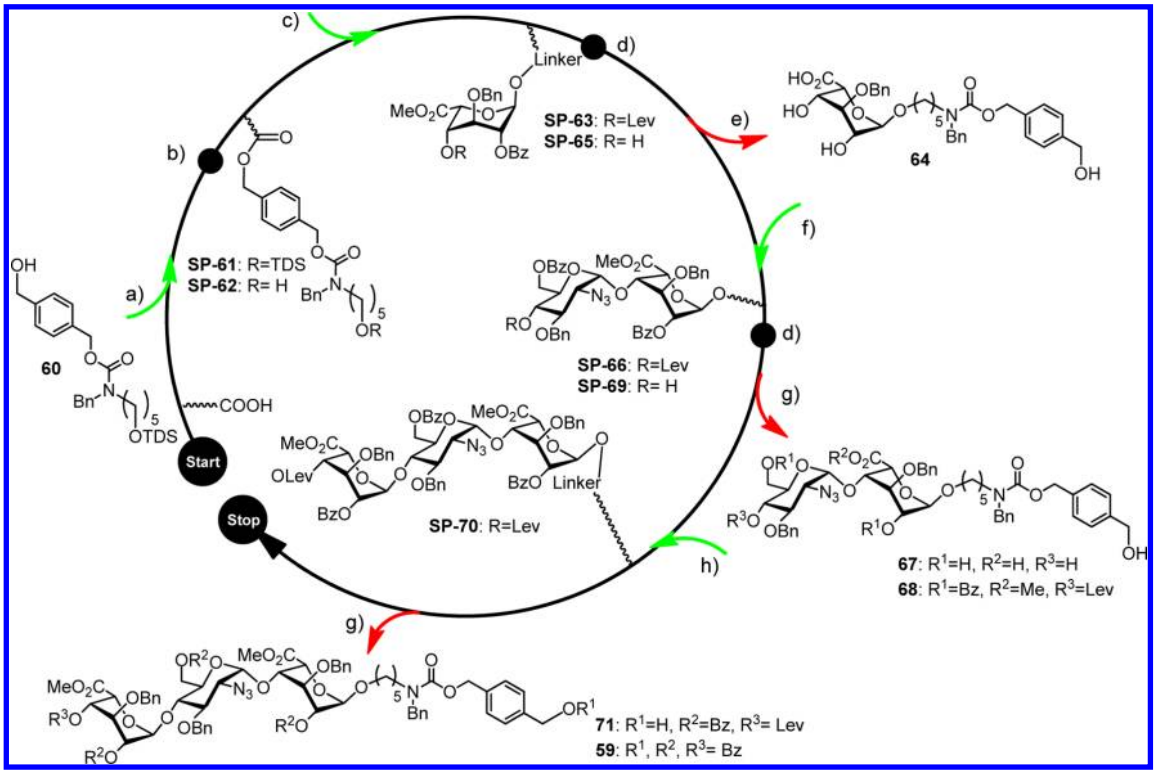
Scheme 6. Solid-Phase Synthesis of a Trisaccharide Employing IdoA Donors[a]



[a]Reagents and conditions: (a) carboxypolystyrene resin, DIC, DMAP, CH_2Cl_2, then Me_3SiCHN_2, THF, MeOH; (b) HF−pyridine, THF; (c) **1**, **2**, or **6**, NIS, (TMS)OTf, CH_2Cl_2; (d) hydrazine acetate, CH_2Cl_2; (e) NaOMe, MeOH; (f) **16**, (TMS)OTf, CH_2Cl_2; (g) Bu_2SnO, MeOH, CH_2Cl_2; (h) **6**, NIS, (TMS)OTf, CH_2Cl_2; for conversions see Table 4.

Table 4. Evaluation of Iduronic Acid Derivatives 1, 2, and 6 in the Solid-Phase Synthesis of HS Trisaccharide Precursors

entry	donor	acceptor	conditions	product	conversion[a] (%)
1	**2**	**SP-62**	1 × 3 equiv, −40 °C to rt, 10% (TMS)OTf	**64**	84
2	**1**	**SP-62**	1 × 5 equiv, rt, NIS (3.5 equiv), 15% (TMS)OTf	**64**	87
3	**6**	**SP-62**	1 × 5 equiv, 0 °C to rt, NIS (3.5 equiv), 15% (TMS)OTf	**64**	85
4	**16**	**SP-65**	1 × 3 equiv, −20 °C to rt, 15% (TMS)OTf	**67**	21
5	**16**	**SP-65**	4 × 3 equiv, −20 °C to rt, 15% (TMS)OTf	**68**	84
6	**6**	**SP-70**	3 × 3 equiv, 0 °C to rt, 15% (TMS)OTf	**71**	76

[a]Conversion was determined by LC−MS analysis after cleavage from the resin.

cleavage from the resin was hampered by the low swelling of the hydrophilic resin in the aqueous reagent solution. After rebenzoylation and purification by preparative TLC, the protected trisaccharide **59** was isolated in 8% overall yield over eight steps.

Both low reactivity of IdoA donors and their incompatibility with the effective methoxide-promoted linker cleavage led us to study idose donors instead for the solid-phase assembly of HS oligosaccharides. First, resin-bound glycoside **SP-72** was synthesized in near-quantitative yield as the analysis of the methoxide cleavage product **73** suggested employing the 6-*O*-acetate-protected thioglycoside donor **10** (Scheme 7). Hydrazinolysis afforded the acceptor **SP-74**, which was reacted with the azidoglucose derivative **16** to produce the disaccharide **SP-75**, albeit in only 22% yield as seen by LC−MS analysis of the cleaved compound **76** (Table 5). Apparently, the electronic effect of the 6-*O*-acetate group on the nucleophilicity of the OH-4 acceptor compensated any favorable reduction of the steric bulk at C-6, leading to an overall poor yield in the glycosylation, confirming the results of the solution-phase glycosylation (Table 2, entry 8), albeit with complete α-selectivity.

Next, employing the TDS-protected thioglycoside **8**, we prepared resin **SP-77** in near-quantitative yield (**78**). Hydrazinolysis to **SP-79** was followed by treatment with 3 × 3 equiv of the imidate **16**, giving rise to the resin-bound disaccharide **SP-80** with excellent conversion (77%, **81**) (Table 5). Delevulination to **SP-82** and coupling with the imidate **14** in four cycles afforded trisaccharide **SP-83** in 70% yield (**84**) (Table 5), a result comparable to the one obtained with the orthoester IdoA donor **6**.

When we scaled up the reaction, these promising results were however undermined by the (TMS)OTf-promoted partial loss of the silyl group and subsequent overglycosylation at C-6, so we decided to abandon the TDS-protected donors. We turned our attention to the 6-*O*-PMP-protected derivative **11** offering high stability under Lewis acid conditions and excellent acceptor properties in the solution-based glycosylation trials (Table 2, entry 4). Preparation of resin-bound glycoside **SP-85** proceeded in excellent conversion (**86**) (Table 5). Depro-

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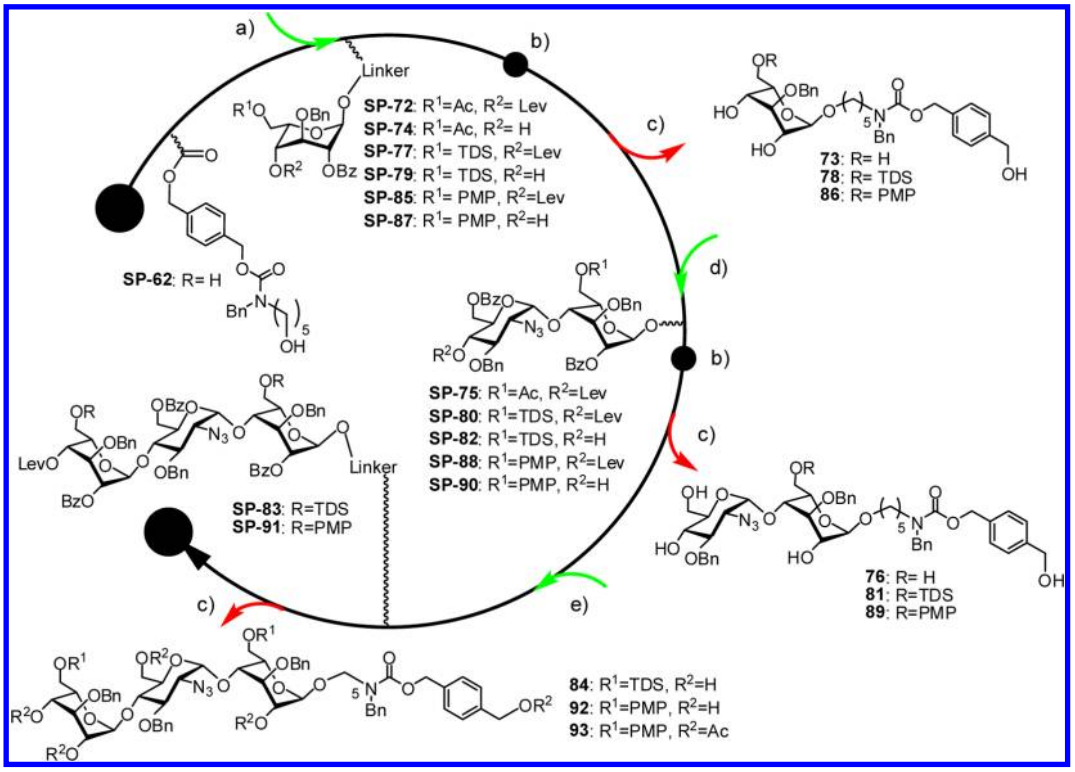
Scheme 7. Solid-Phase Synthesis of Trisaccharide Precursors Involving Idose Donors[a]



[a]Reagents and conditions: (a) **8**, **11**, or **10**, NIS, (TMS)OTf; (b) hydrazine acetate, CH_2Cl_2; (c) NaOMe, MeOH; (d) **16** or **17**, (TMS)OTf, CH_2Cl_2; (e) **14** or **15**, NIS, (TMS)OTf, CH_2Cl_2; for conversions see Table 5.

Table 5. Evaluation of Idose Derivatives 8, 10, and 11 in the Solid-Phase Synthesis of HS Trisaccharide Precursors

entry	donor	acceptor	conditions	product	conversion[a] (%)
1	**10**	**SP-62**	1 × 5 equiv, −20 °C to rt, NIS (6.5 equiv), 10% (TMS)OTf	**73**	96
2	**16**	**SP-74**	1 × 3 equiv, −20 to rt, 10% (TMS)OTf	**76**	22
3	**8**	**SP-62**	1 × 5 equiv, −20 °C to rt, NIS (6.5 equiv), 10% (TMS)OTf	**78**	>95
4	**16**	**SP-79**	3 × 3 equiv, −20 °C to rt, 10% (TMS)OTf	**81**	77
5	**14**	**SP-82**	4 × 3 equiv, −20 °C to rt, 10% (TMS)OTf	**84**	70
6	**11**	**SP-62**	1 × 5 equiv, −20 °C to rt, NIS (6.5 equiv), 10% (TMS)OTf	**86**	>95
7	**17**	**SP-87**	2 × 6 equiv, −20 °C to rt, 10% (TMS)OTf	**89**	71
8	**16**	**SP-87**	4 × 3 equiv, −20 °C to rt, 10% (TMS)OTf	**89**	80
9	**16**	**SP-87**	2 × 6 equiv, −20 °C to rt, 10% (TMS)OTf	**89**	85
10	**16**	**SP-87**	1 × 12 equiv, −20 °C to rt, 10% (TMS)OTf	**89**	68
11	**16**	**SP-87**	1 × 12 equiv + 1 × 6 equiv, −20 °C to rt, 10% (TMS)OTf	**89**	85
12	**16**	**SP-87**	3 × 6 equiv, −20 °C to rt, 10% (TMS)OTf	**89**	90
13	**15**	**SP-90**	2 × 6 equiv, −20 °C to rt, 10% (TMS)OTf	**92**	94

[a]Conversion was determined by LC−MS analysis after cleavage from the resin.

tection of the levulinuic ester (**SP-87**) and glycosylation with trifluoroacetimidate **17** produced resin-bound disaccharide **SP-88** in 71% yield (**89**, entry 7).

Coupling with imidate **16** in four cycles of 3 equiv raised the yield of **SP-88** to 80% (**89,** entry 8). A larger donor excess of 6 equiv improved the yield slightly after only two cycles to 85%, while a single cycle of 12 equiv resulted in a slightly lower yield (Table 5, entries 9 and 10). A conversion of 90% was achieved with three cycles of 6 equiv of donor **16** (entry 12). Finally, after removal of the levulinic ester, acceptor **SP-90** was coupled in two cycles with imidate **15** to afford the resin-bound trisaccharide **SP-91** with 94% conversion (**92**, entry 13).

Then the previously established full solid-phase glycosylation procedure consisting of mono-, di-, and trisaccharide formation was applied to linker resin **SP-62** to obtain 39 mg of the crude heparin sulfate precursor **92** (for the complete synthesis see the Supporting Information). For purification purposes cleaved crude trisaccharide **92** was acetylated, providing **93** in 72% overall yield over eight steps with an average yield of 95% per step (Scheme 7). Measurement of the three C,H heteronuclear anomeric coupling constants confirmed a 1,2-*cis* configuration for all glycosidic linkages (idose $J_{C,H}$ = 169 and 170 Hz and azidoglucose $J_{C,H}$ = 172 Hz, Figure 4).[45]

CONCLUSIONS

In conclusion, we have investigated the donor and acceptor properties of a range of idose and iduronic acid donors with particular focus on the steric bulk around the C-4 acceptor

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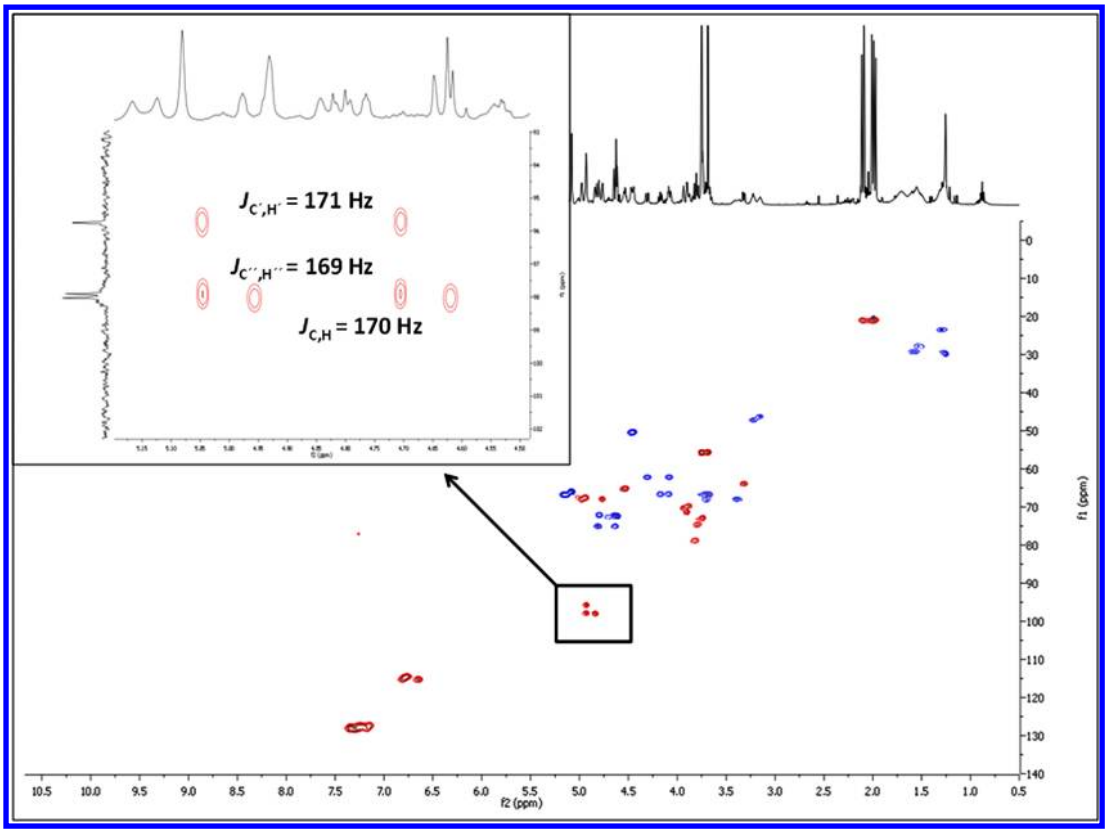

Figure 4. HSQC NMR spectra of heparin trisaccharide precursor **93**. $J_{C,H}$ coupling values (~170 Hz) confirmed α-selectivity of the glycosylation reactions.

position, which had been found to compromise yields in glycosylation on the sterically demanding TBDPS derivative **7**. For the first time a series of iduronic acid *n*-pentenyl orthoester donors have been prepared and evaluated in the solution- and solid-phase synthesis of trisaccharide heparin sulfate precursors including all major structural features of larger HS chains. We have found that the use of IdoA donors for the solid-phase heparin sulfate synthesis was not compatible with the strong basic conditions required to cleave our ester linker, and considerable elimination of IdoA ester residues to the alkene was observed. A change to base-labile linkers cleaved under less harsh conditions or to orthogonal photolinkers[18] in the future could permit the direct use of IdoA donors.

Our results also demonstrate that idose donors with less bulky electron-donating groups at C-6 outperform iduronic acid as glycosyl donors and acceptors in the glycosylation with azidoglucose derivatives **16**, **17**, **53**, and **54** even though additional off-bead oxidation is required to arrive at the natural products. In particular, the solution- and solid-phase synthesis involving the 6-*O*-PMP-protected idose derivatives **11** and **15** showed promisingly high yields for all conversions studied, suggesting a viable and robust route which is currently being employed in our laboratory for the synthesis of larger heparan sulfate fragments, related glycosaminoglycan oligosaccharides, and simpler heparin mimetics. In future studies we will investigate the possibility of including idose deprotection and oxidation into the solid-phase protocol.

EXPERIMENTAL SECTION

General Methods. All anhydrous reactions were performed in flame-dried or oven-dried glassware under a positive pressure of dry argon. Air- or moisture-sensitive reagents and anhydrous solvents were transferred with oven-dried syringes or cannulae. Purification of compounds was performed on a automated flash chromatography system or by conventional flash chromatography using silica gel 60 (63−200 mesh). Size exclusion chromatography was performed on Sephadex LG-20. All solution-phase reactions were monitored using analytical thin-layer chromatography (TLC) with 0.2 mm precoated silica gel 60 F254 aluminum plates. Components were visualized by illumination with a short-wavelength (254 nm) ultraviolet light and/or by charring with vanillin, ceric ammonium molybdate, potassium permanganate, or phosphomolybdate staining solution. All solvents used for anhydrous reactions were distilled. Tetrahydrofuran (THF) was distilled from sodium/benzophenone under argon. Dichloromethane and acetonitrile were distilled from calcium hydride. Methanol was distilled from calcium sulfate. *N*,*N*-dimethylformamide (DMF) was stored over activated 4 Å molecular sieves under argon. Solid-phase reactions were performed either in a Schlenk tube fitted with a cooling jacket or in a normal Schlenk tube under an argon atmosphere.

^{1}H, DQF-COSY, HSQC, and ^{13}C NMR spectra were recorded at ambient temperature on a 500 MHz NMR spectrometer to confirm the NMR peak assigments. Deuterated chloroform ($CDCl_3$), methanol (CD_3OD), or water (D_2O) was used as the solvent for NMR experiments, unless otherwise stated. Chemical shifts are reported in parts per million downfield from TMS and corrected using the solvent residual peak or TMS as an internal standard. Splitting patterns are designated as follows: s, singlet; d, doublet; t, triplet; q, quartet; m, multiplet; br, broad. Low-resolution mass spectrometry (LRMS) was performed on an electrospray ionization time of flight mass spectrometer equipped with an electrospray source with a pump rate of 5 μL/min using electrospray ionization (ESI) or a matrix-assisted desorption ionization time of flight (MALDI-TOF) mass spectrometer operated in the reflectron/positive ion mode with DHB in MeOH as the MALDI matrix. High-resolution mass spectrometry (HRMS) data were acquired on a time of flight mass spectrometer. Samples in CH_2Cl_2/MeOH (1:1) were mixed with ES tuning mix for internal

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calibration and infused into the mass spectrometer at 5 μL/min. For microwave heating of reactions a monomode oven was used.

Procedure A (Levulination). To a solution of 4-hydroxy acceptor (1 equiv) in dry CH_2Cl_2 (~10 mL/mmol) was added a catalytic amount of DMAP at room temperature, followed by addition of levulinic acid (1.5−5 equiv) and EDC·HCl (1.5−5 equiv). After 5 h, the TLC control (hexane/ethyl acetate, 2:1 or 3:1) indicated full conversion of the starting material. The reaction mixture was diluted with CH_2Cl_2 (~150 mL) and subsequently washed with saturated $NaHCO_3$ aq solution (2 × ~200 mL), 1 M HCl (~200 mL), water (~200 mL), and brine (~200 mL). After being dried over $MgSO_4$ and concentrated, the crude reaction mixuture was purified by column chromatography on silica using a hexane/ethyl acetate gradient (100% → 50% hexane).

Procedure B (Glycosylation with Thiophenyl Idose Derivatives and *n*-Pentenyl Orthoester Derivatives). The linker acceptor and thiophenyl donor (1.2−1.5 equiv) were dissolved in dry CH_2Cl_2 (2 mL) under argon and then cooled to the desired temperature. *N*-Iodosuccinimide and a catalytic amount of trimethylsilyl triflate ((TMS)OTf) or triflic acid (TfOH) were added, and the reaction mixture was allowed to warm to room temperature. After 1.5−3 h, the crude reaction mixture was quenched with saturated $NaHCO_3$ aq solution and solid $Na_2S_2O_3$. The mixture was filtered and washed with saturated $NaHCO_3$ aq solution, water, and brine. The crude reaction mixture was purified by column chromatography.

Procedure C (Glycosylation with Azidoglucose Trichloroacetimidate Donor, Disaccharide Synthesis). The idose acceptor and azidoglucose donor were dissolved in dry CH_2Cl_2 (15 mL/mmol) under argon and then cooled to −20 °C (0 °C for iduronic acid). After addition of (TMS)OTf, the reaction mixture was allowed to warm slowly to room temperature. After 2 h, the reaction mixture was quenched with triethylamine. The crude reaction mixture was diluted with CH_2Cl_2 and washed with saturated $NaHCO_3$ aq solution, water, and brine. The concentrated crude reaction was purified by column chromatography.

Procedure D (Solid-Phase Glycosylation). Solid-phase glycosylations were performed in either a Schlenk tube fitted with a cooling jacket or a normal Schlenk tube under an argon atmosphere. Unless otherwise noted, the resin was swollen with the glycosyl donor (thioglycoside or trichloroacetimidate) in dry CH_2Cl_2 (750 μL/100 mg of resin). The reaction mixture was shaken for 10 min on a vortex or an orbital shaker. Then the Schlenk tube with a cooling jacket was connected to a cryostat and cooled to the specified temperature. The normal Schlenk tube was cooled in a Dewar flask containing acetone at the specified temperature. After additional shaking for 10 min the activator (NIS, (TMS)OTf/TfOH for thioglycosides or (TMS)OTf for trichloroacetimidates) was added. The mixture was shaken for 10 min at the specified temperature. Then the mixture was allowed to warm to room temperature and was shaken for 1−1.5 h. The resin was washed with THF (5 × 3 mL/100 mg of resin), CH_2Cl_2 (5 × 3 mL/100 mg of resin), and dry diethyl ether (2 × 3 mL/100 mg of resin) and dried in high vacuum. The THF washings were collected for possible recovery of the donor. The conversion was analyzed by LC−MS after NaOMe cleavage: A 5 mg sample of resin was placed into a small microwave vial (0.2−0.5 mL) equipped with a magnetic stir bar. After the resin was swollen with 250 μL of anhydrous CH_2Cl_2, 50 μL of a 0.2 M sodium methoxide solution was added. The mixture was irradiated in a microwave oven for 5 min at 55 °C with prestirring for 30 s. After the mixture was cooled to room temperature, the supernatant was transferred to an Eppendorf vial, and the solution was concentrated to dryness by an air stream. The residue was redissolved in 100 μL of methanol (HPLC grade). A 1:10 dilution of this solution was used for LC−MS analysis. For iduronic acid donors the conversion was analyzed by LC−MS after dibutyltin oxide cleavage: A 5 mg sample of resin and 4 mg of dibutyltin oxide were placed into a small microwave vial (0.2−0.5 mL) equipped with a magnetic stir bar. After the resin was swollen with 200 μL of anhydrous dichloromethane, 100 μL of MeOH was added. The mixture was irradiated in a microwave oven for 10 min at 120 °C with prestirring for 30 s. After the mixture was cooled to room temperature, the supernatant was transferred to an Eppendorf vial, and the solution was concentrated to dryness by an air stream. The residue was redissolved in 100 μL of methanol (HPLC grade). A 1:10 dilution of this solution was used for LC−MS analysis.

Procedure E (Solid-Phase Capping and Delevulination). Solid-phase synthesis was performed either in a Schlenk tube fitted with a cooling jacket or in a normal Schlenk tube under an argon atmosphere. The resin was swollen in dry CH_2Cl_2 (1 mL/100 mg of resin) for 10 min, followed by addition of pyridine (300 μL/100 mg of resin), acetic anhydride (300 μL/100 mg of resin), and a catalytic amount of DMAP. After 5 h at room temperature the resin was washed with CH_2Cl_2 (5 × 3 mL/100 mg of resin), MeOH (5 × 3 mL/100 mg of resin), and dry diethyl ether (2 × 3 mL/100 mg of resin) and dried in high vacuum. The resin was used without further characterization for the delevulination: The resin was swollen in dry CH_2Cl_2 (1 mL/100 mg resin) for 10 min, followed by addition of hydrazine acetate (5 equiv in 200 μL of methanol). After 5 h at room temperature the resin was washed with CH_2Cl_2 (5 × 3 mL/100 mg of resin), methanol (5 × 3 mL/100 mg of resin), and dry diethyl ether (2 × 3 mL/100 mg of resin) and dried in high vacuum. The resin was used without further characterization for the subsequent glycosylation.

Methyl 2-*O*-Benzoyl-3-*O*-benzyl-4-*O*-levulinoyl-α/β-L-idopyranosyluronate Trichloroacetimidate (2). To a solution of thioglycoside **1** (110 mg, 0.18 mmol) in CH_2Cl_2 (1.86 mL) were added NIS (84 mg, 0.37 mmol) and trifluoroacetic acid (28 μL, 0.37 mmol) at 0 °C. After 15 min TLC analysis showed complete consumption of the starting material. The reaction was quenched with saturated $Na_2S_2O_3$ aq solution and was washed with saturated $NaHCO_3$ aq solution. The organic layer was dried over $MgSO_4$ and concentrated in vacuum. The crude was dissolved in dry CH_2Cl_2 (2.4 mL), and trichloroacetonitrile (0.36 mL, 3.6 mmol) and a catalytic amount of DBU (3.6 μL, 0.024 mmol) were added at 0 °C. After being stirred for 1 h at room temperature, the reaction mixture was concentrated. The residue was purified by column chromatography (hexane/ethyl acetate, 7:3, with 1% of Et_3N) to yield **2** as a viscous oil (90 mg, 75%): ^{1}H NMR (500 MHz, $CDCl_3$) δ = 8.74 (s, 0.8 H, N*H*CCl$_3$), 8.69 (s, 0.2H, N*H*CCl$_3$), 8.11−8.08 (m, 2H, aromatic), 7.59−7.53 (m, 1H, aromatic), 7.45−7.26 (m, 7H, aromatic), 6.56 (s, 0.8H, H-1α), 6.34 (s, *J* = 1.8 Hz, H-1β), 5.51 (m, 0.2H, H-2β), 5.37 (m, 0.8H, H-2α), 5.34 (m, 0.8H, H-4α), 5.28 (m, 0.2H, H-4β), 5.12 (d, *J* = 1.9 Hz, 0.8H, H-5α), 4.86−4.75 (m, 2.2H, CH_2Ph, H-5β), 4.14 (t, 0.2H, H-3β), 4.01 (m, 0.8H, H-3α), 3.79 (s, 3H, CH_{3COOMe}), 2.60−2.56 (m, 2H, CH_{2Lev}), 2.45−2.40 (m, 2H, CH_{2Lev}), 2.36−2.31 (m, 2H, CH_{2Lev}), 2.06 and 2.04 (2s, 3H, CH_{3Lev}) ppm; ^{13}C NMR (126 MHz, $CDCl_3$) δ = 205.7, 171.5, 168.0, 167.1, 165.4, 164.9, 160.2, 160.0, 137.1, 136.8, 133.8, 133.5, 129.9, 129.0, 128.6, 128.5, 128.3, 127.9, 127.6, 95.0 (C-1α), 94.5 (C-1β), 73.3 (C-5β), 73.1 (C-3β), 72.6, 71.5 (C-3α), 67.7 (C-5α), 67.4 (C-4α), 67.3 (C-4β), 66.0 (C-2β), 65.2 (C-2α), 52.7 (CH_{3COOMe}), 37.7, 29.5, 27.8 ppm.

Methyl (4-*O*-Acetyl-3-*O*-benzyl-1,2-*O*-[(1-pent-4-enyloxy)-ethylidene]-β-L-idopyranuronate (3). The peracetylated compound **31** (109 mg, 0.257 mmol) was dissolved in dry CH_2Cl_2 (2.6 mL), and 30% HBr in AcOH (0.26 mL) was added at 0 °C and the resulting mixture stirred for 3 h. The reaction mixture was diluted with cold CH_2Cl_2 and washed with ice-cold water and cold saturated $NaHCO_3$ aq solution. The organic layer was dried over $MgSO_4$, filtered, concentrated, and used in the next reaction without further purification. A solution of bromide in dry CH_2Cl_2 (0.5 mL) containing 2,6-lutidine (0.59 mL, 5.1 mmol), and 1-pentenol (0.26 mL, 2.6 mmol) was stirred for 20 h at room temperature under a dry atmosphere of argon. The mixture was diluted with CH_2Cl_2 and washed with saturated $NaHCO_3$ aq solution and water. The organic layer was dried over $MgSO_4$, filtered, and concentrated. The residue was purified by column chromatography (hexane/ethyl acetate, 6:4, containing 1% triethylamine) to obtain the orthoacetate **3** as a viscous oil (71 mg, 0.15 mmol, 60% in two steps): $[\alpha]_D^{20}$ = −19.2 (*c* = 1, $CHCl_3$); ^{1}H NMR (500 MHz, $CDCl_3$) δ = 7.48−7.32 (m, 5H, aromatic), 5.83−5.75 (m, 1H, CH_{pent}), 5.53 (d, *J* = 2.7 Hz, H-1), 5.22−5.19 (m, 1H, H-4), 5.03−4.94 (m, 2H, CH_{2pent}), 4.81 (d, *J* = 11.7 Hz, 1H, CH_2Ph), 4.68 (d, *J* = 11.7 Hz, 1H, CH_2Ph), 4.54 (d, 1H,

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J = 1.3 Hz, H-5), 4.12 (t, J = 2.3 Hz, 1H, H-3), 4.05−4.04 (m, 1H, H-2), 3.78 (s, 3H, CH_{3COOMe}), 3.53−3.41 (m, 2H, CH_{2pent}), 2.12−2.07 (m, 2H, CH_{2pent}), 2.03 (s, 3H, CH_{3Ac}), 1.73 (s, 3H, CH_3), 1.66−1.62 (m, 2H, CH_{2pent}) ppm; ^{13}C NMR (126 MHz, $CDCl_3$) δ = 170.3, 168.3, 138.2 (CH_{pent}), 137.0, 128.7−128.1 ($C_{aromatic}$), 124.1 (Cq, orthoester), 115.0 (CH_{2pent}), 96.7 (C-1), 76.0 (C-2), 73.04 (C_{Bn}), 71.5 (C-3), 69.8 (C-5), 67.0 (C-4), 61.3 (CH_{2pent}), 52.7 (CH_{3COOMe}), 30.3 (CH_{2pent}), 28.7 (CH_{2pent}), 25.3 (CH_3), 20.9 (CH_{3Ac}) ppm; HRMS (ESI) m/z calcd for $C_{23}H_{30}O_9$ $[M + Na]^+$ 473.1782, found 473.1763.

Methyl (3-*O*-Benzyl-4-*O*-levulinoyl-1,2-*O*-[(1-pent-4-enyloxy)levulinylidene]-*β*-L-idopyranuronate (4). The per-levulinated compound **32** (133 mg, 0.22 mmol) was dissolved in dry CH_2Cl_2, and 30% HBr in AcOH (0.76 mL) was added at 0 °C and the resulting mixture stirred for 3 h. The mixture was diluted with cold CH_2Cl_2 and sequentially washed with ice-cold water and cold saturated $NaHCO_3$ aq solution. The organic layer was dried over $MgSO_4$, filtered, concentrated, and used in the next reaction without further purification. A solution of the bromide in dry CH_2Cl_2 (0.5 mL) containing 2,6-lutidine (0.52 mL, 4.47 mmol), and 1-pentenol (0.23 mL, 2.26 mmol) was stirred for 20 h at room temperature under argon. The mixture was diluted with CH_2Cl_2 and washed with saturated $NaHCO_3$ aq solution, and water. The organic layer was dried over $MgSO_4$, filtered, and concentrated. The residue was purified by column chromatography (hexane/ethyl acetate, 6:4, containing 1% triethylamine) to obtain **4** as a viscous oil (91 mg, 73%): $[\alpha]_D^{20}$ = −7.4 (c = 1, $CHCl_3$); ^{1}H NMR (500 MHz, $CDCl_3$) δ = 7.38−7.31 (m, 5H, aromatic), 5.82−5.74 (m, 1H, CH_{pent}), 5.49 (d, J = 2.7 Hz, 1H, H-1), 5.20−5.19 (m, 1H, H-4), 5.03−4.95 (m, 2H, CH_{2pent}), 4.81 (d, J = 11.7 Hz, 1H, CH_2Ph), 4.66 (d, J = 11.7 Hz, 1H, CH_2Ph), 4.51 (d, 1H, J = 1.3 Hz, H-5), 4.08−4.05 (m, 2H, H-3, H-2), 3.79 (s, 3H, CH_{3COOMe}), 3.51−3.41 (m, 2H, CH_{2pent}), 2.81−2.69 (m, 4H, CH_{2Lev}), 2.54−2.51 (m, 2H, CH_{2Lev}), 2.29−2.25 (m, 2H, CH_{2Lev}), 2.18 (s, 3H, CH_{3Lev}), 2.16 (s, 3H, CH_{3Lev}), 2.10−2.06 (m, 2H, CH_{2pent}), 1.65−1.60 (m, 2H, CH_{2pent}) ppm; ^{13}C NMR (126 MHz, $CDCl_3$) δ = 208.4, 206.3, 172.0, 167.9, 138.1 (CH_{pent}), 137.0, 128.8, 128.4, 128.1, 124.4 (Cq, orthoester), 115.1 (CH_{2pent}), 96.5 (C-1), 75.6 (C-2), 73.1 (C_{Bn}), 71.8 (C-3), 69.7 (C-5), 67.0 (C-4), 61.5 (CH_{2pent}), 52.7 (CH_{3COOMe}), 38.7, 37.9 (CH_{2Lev}), 32.0 (CH_{2Lev}), 30.3 (CH_{2pent}), 30.0, 29.9 (CH_{3Lev}), 28.7 (CH_{2pent}), 28.1 (CH_{2Lev}) ppm; HRMS (ESI) m/z calcd for $C_{29}H_{38}O_{11}$ $[M + Na]^+$ 585.2312, found 585.2309.

Methyl (4-*O*-Benzoyl-3-*O*-benzyl-1,2-*O*-[(1-pent-4-enyloxy)-benzylidene]-*β*-L-idopyranuronate (5). The perbenzoylated compound **33** (310 mg, 0.508 mmol) was dissolved in dry CH_2Cl_2 (9.3 mL), 30% HBr in AcOH (1.72 mL) was added at 0 °C, and the solution was stirred for 3 h. The mixture was diluted with cold CH_2Cl_2 and washed with ice-cold water and cold saturated $NaHCO_3$ aq solution. The organic layer was dried over $MgSO_4$, filtered, concentrated, and used in the next reaction without further purification. A solution of bromide in dry CH_2Cl_2 (1 mL) containing 2,6-lutidine (1.18 mL, 10.2 mmol) and 1-pentenol (0.52 mL, 5.1 mmol) was stirred for 20 h at room temperature under a dry atmosphere of argon. The mixture was diluted with CH_2Cl_2 (200 mL) and washed with saturated $NaHCO_3$ solution and water. The organic layer was dried over $MgSO_4$, filtered, and concentrated. The residue was purified by column chromatography (hexane/ethyl acetate, 7:3, containing 1% triethylamine) to obtain the syrupy **5** (214 mg, 73%): $[\alpha]_D^{20}$ = −1.7 (c = 1, $CHCl_3$); ^{1}H NMR (500 MHz, $CDCl_3$) δ = 7.73−7.21 (m, 16H, aromatic), 5.80−5.73 (m, 1H, CH_{pent}), 5.71 (d, J = 2.7 Hz, 1H, H-1), 5.47−5.46 (m, 1H, H-4), 5.01−4.97 (m, 3H, CH_{2pent}, CH_2Ph), 4.78 (d, J = 11.7 Hz, CH_2Ph), 4.68 (d, J = 1.3 Hz, 1H, H-5), 4.38−4.37 (m, 1H, H-2), 4.28 (t, J = 2.17 Hz, 1H, H-3), 3.69 (s, 3H, CH_{3COOMe}), 3.44−3.34 (m, 2H, CH_{2pent}), 2.11−2.05 (m, 2H, CH_{2pent}), 1.68−1.62 (m, 2H, CH_{2pent}) ppm; ^{13}C NMR (126 MHz, $CDCl_3$) δ = 168.1, 165.9, 138.1 (CH_{pent}), 137.0, 136.9, 133.2, 130.0, 129.2, 128.8, 128.4, 128.4, 128.1, 127.1, 122.4 (Cq, orthoester), 115.0 (CH_{pent}), 96.9 (C-1), 75.4 (C-2), 73.2 (C_{Bn}), 72.1 (C-3), 70.2 (C-5), 67.1 (C-4), 63.5 (CH_{2pent}), 52.7 (CH_{3COOMe}), 30.3 (CH_{2pent}), 28.9 (CH_{2pent}) ppm; HRMS (ESI) m/z calcd for $C_{33}H_{34}O_9$ $[M + Na]^+$ 597.2101, found 597.2082.

Methyl (3-*O*-Benzyl-4-*O*-levulinoyl-1,2-*O*-[(1-pent-4-enyloxy)benzylidene)]-*β*-L-idopyranuronate (6). The reaction was carried out according to general procedure A using compound **35** (205 mg, 0.44 mmol), levulinic acid (152 mg, 1.31 mmol), EDC·HCl (250 mg, 1.31 mmol), and a catalytic amount of DMAP in dry CH_2Cl_2 (4 mL). The crude product was purified by flash chromatography (hexane/ethyl acetate, 8:2, with 1% triethylamine) to obtain compound **6** as a viscous oil (225 mg, 90%): $[\alpha]_D^{20}$ = +19.7 (c = 1, $CHCl_3$); ^{1}H NMR (500 MHz, $CDCl_3$) δ = 7.75−7.73 (m, 2H, aromatic), 7.38−7.33 (m, 5H, aromatic), 5.80−5.74 (m, 1H, CH_{pent}), 5.66 (d, J = 2.8 Hz, H-1), 5.17 (m, 1H, H-4), 5.02−4.94 (m, 2H, CH_{2pent}), 4.82 (d, J = 11.8 Hz, 1H, CH_2Ph), 4.70 (d, J = 11.8 Hz, 1H, CH_2Ph), 4.55 (d, J = 1.0 Hz, 1H, H-5), 4.31−4.30 (m, 1H, H-2), 4.14−4.13 (m, 1H, H-3), 3.75 (s, 3H, CH_{3COOMe}), 3.48−3.41 (m, 2H, CH_{2pent}), 2.34−2.18 (m, 2H, CH_{2Lev}), 2.13−2.08 (m, 2H, CH_{2Lev}), 2.00 (s, 3H, CH_{3Lev}), 1.70−1.64. (m, 2H, CH_{2pent}) ppm; ^{13}C NMR (126 MHz, $CDCl_3$) δ = 206.4, 171.7, 167.9, 138.1 (CH_{pent}), 137.4, 137.0, 129.2, 128.8, 128.4, 128.1, 128.0, 127.0, 122.4 (Cq, orthoester), 115.0 (CH_{2pent}), 96.8 (C-1), 75.4 (C-2), 73.1 (C_{Bn}), 71.6 (C-3), 69.7 (C-5), 66.8 (C-4), 63.3 (CH_{2pent}), 52.6 (CH_{3COOMe}), 37.6 (CH_{2Lev}), 30.3 (CH_{2Lev}), 29.7 (CH_{3Lev}), 28.9 (CH_{2Lev}), 28.1 (CH_{2Lev}) ppm; HRMS (ESI) m/z calcd for $C_{31}H_{36}O_{10}$ $[M + Na]^+$ 591.2206, found 591.2197.

Phenyl 2-*O*-Benzoyl-3-*O*-benzyl-6-*O*-(dimethylthexylsilyl)-4-*O*-levulinoyl-1-thio-*α*-L-idopyranoside (8). The reaction was carried out according to general procedure A using compound **20** (1.13 g, 1.86 mmol), levulinic acid (1.30 g, 11.2 mmol), EDC·HCl (2.15 g, 11.2 mmol), and a catalytic amount of DMAP in dry CH_2Cl_2 (20 mL). Compound **8** was obtained as a colorless syrup (860 mg, 65%): R_f = 0.33 (hexane/ethyl acetate, 4:1); $[\alpha]_D^{20}$ = −13.5 (c = 1.0, $CHCl_3$); ^{1}H NMR (500 MHz, $CDCl_3$) δ = 8.10−8.05 (m, 2H, aromatic), 7.59−7.55 (m, 3H, aromatic), 7.47−7.43 (m, 4H, aromatic), 7.39−7.36 (m, 2H, aromatic), 7.33−7.23 (m, 4H, aromatic), 5.64 (s, 1H, H-1), 5.46−5.44 (m, 1H, H-2), 5.10 (s, 1H, H-4), 4.89 (d, J = 11.9 Hz, 1H, CH_2Ph), 4.87−4.83 (td, J = 2.0, 6.5 Hz, 1H, H-5), 4.79 (d, J = 11.9 Hz, 1H, CH_2Ph), 3.99−3.95 (m, 1H, H-3), 3.82−3.77 (m, 2H, H-6ab), 2.67−2.52 (m, 3H, CH_{2Lev}), 2.47−2.38 (m, 1H, CH_{2Lev}), 2.07 (s, 3H, CH_{3Lev}), 1.66−1.58 (m, 1H, CH_{thexyl}), 0.90 (d, J = 6.9 Hz, 6H, $CH_{3thexyl}$), 0.85 (2s, 6H, $CH_{3thexyl}$), 0.13 (s, 3H, $SiCH_3$), 0.11 (s, 3H, $SiCH_3$) ppm; ^{13}C NMR (126 MHz, $CDCl_3$) δ = 205.9, 172.1, 165.2, 137.5, 136.4, 133.6, 131.4, 129.9, 129.6, 129.0, 128.5, 127.9, 127.6, 127.3, 86.1 (C-1), 72.8 (C_{Bn}), 72.3 (C-3), 70.0 (C-2), 67.4 (C-5), 67.2 (C-4), 61.4 (C-6), 37.8 (CH_{2Lev}), 34.2 (CH_{thexyl}), 29.7 (CH_{3Lev}), 28.0 (CH_{2Lev}), 25.2 (Cq_{thexyl}), 20.3, 20.2, 18.6 ($CH_{3thexyl}$), −3.5, −3.7 ($Si(CH_3)_2$) ppm; HRMS (ESI) m/z calcd for $C_{39}H_{50}O_8SSi$ $[M + Na]^+$ 729.2893, found 729.2894.

Phenyl 2-*O*-Benzoyl-3,6-di-*O*-benzyl-4-*O*-levulinoyl-1-thio-*α*-L-idopyranoside (9). The reaction was carried out according to general procedure A using compound **24** (220 mg, 395 μmol), levulinic acid (140 mg, 1.18 mmol), EDC·HCl (225 mg, 1.18 mmol), and a catalytic amount of DMAP in dry CH_2Cl_2 (3 mL). Compound **9** was obtained as a colorless syrup (258 mg, 94%): R_f = 0.45 (hexane/ethyl acetate, 3:1); $[\alpha]_D^{20}$ = −10.7 (c = 1.0, $CHCl_3$); ^{1}H NMR (500 MHz, $CDCl_3$, 25) δ = 8.08−8.06 (m, 2H, aromatic), 7.59−7.54 (m, 3H, aromatic), 7.42−7.19 (m, 15H, aromatic), 5.62 (s, 1H, H-1), 5.45−5.42 (m, 1H, H-2), 5.13−5.09 (m, 1H, H-5), 5.08−5.06 (m, 1H, H-4), 4.90 (d, J = 11.8 Hz, 1H, CH_2Ph), 4.77 (d, J = 11.8 Hz, 1H, CH_2Ph), 4.58 (d, J = 11.4 Hz, 1H, CH_2Ph), 4.53 (d, J = 11.8 Hz, 1H, CH_2Ph), 3.92−3.90 (m, 1H, H-3), 3.76−3.71 (m, 1H, H-6a), 3.71−3.66 (m, 1H, H-6b), 2.65−2.43 (m, 3H, CH_{2Lev}), 2.40−2.31 (m, 1H, CH_{2Lev}), 2.06 (s, 3H, CH_{3Lev}) ppm; ^{13}C NMR (126 MHz, $CDCl_3$) δ = 205.8, 171.9, 165.2, 133.3−125.1 ($C_{aromatic}$), 86.1 (C-1), 72.7 (C_{Bn}), 71.9 (C_{Bn}), 71.5 (C-3), 70.7 (C-2), 68.5 (C-6), 67.2 (C-4), 66.4 (C-5), 37.7 (CH_{2Lev}), 29.6 (CH_{3Lev}), 27.8 (CH_{2Lev}) ppm; HRMS (ESI) m/z calcd for $C_{38}H_{38}O_8S$ $[M + Na]^+$ 677.2180, found 677.2155.

Phenyl 6-*O*-Acetyl-2-*O*-benzoyl-3-*O*-benzyl-4-*O*-levulinoyl-1-thio-*α*-L-idopyranoside (10). To a solution of **7** (400 mg, 0.498 mmol) in THF (2 mL) at 0 °C was added HF−pyridine (1 mL). The reaction mixture was allowed to warm to room temperature and stirred overnight. Next the reaction was quenched by addition of saturated

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$NaHCO_3$ aq solution and solid $NaHCO_3$ and washed with saturated $NaHCO_3$ aq solution and water. The organic layer was dried over $MgSO_4$ and concentrated in vacuo. Flash chromatography (0−20% ethyl acetate/hexane) afforded phenyl 2-*O*-benzoyl-3-*O*-benzyl-4-*O*-levulinoyl-1-thio-α-L-idopyranoside (141 mg, 50%): ^{1}H NMR (500 MHz, $CDCl_3$) δ = 8.16−8.08 (m, 2H, aromatic), 7.64−7.56 (m, 3H, aromatic), 7.54−7.26 (m, 10H, aromatic), 5.64 (s, 1H, H-1), 5.52−5.48 (m, 1H, H-2), 5.14−5.10 (m, 1H, H-5), 4.99−4.91 (m, 1H, H-4), 4.94 (d, J = 11.8 Hz, 1H, CH_2Ph), 4.80 (d, J = 11.8 Hz, 1H, CH_2Ph), 3.96−3.91 (m, 1H, H-3), 3.85 (dd, J = 11.6, 6.9 Hz, 1H, H-6a), 3.76 (dd, J = 11.6, 6.3 Hz, 1H, H-6b), 2.79−2.69 (m, 1H, CH_{2Lev}), 2.69−2.56 (m, 2H, CH_{2Lev}), 2.44−2.34 (m, 1H, CH_{2Lev}), 2.12 (s, 3H, CH_{3Lev}) ppm; ^{13}C NMR (126 MHz, $CDCl_3$) δ 206.4, 172.5, 165.1, 137.1, 135.6, 133.5, 131.8, 129.7, 129.4, 129.0, 128.4, 128.4, 127.8, 127.5, 86.1, 72.5, 72.1, 69.1, 67.2, 66.8, 61.1, 37.8, 29.5, 27.8 ppm; MALDI-TOF m/z calcd for $C_{31}H_{32}O_8S$ $[M + Na]^+$ 587.2, found 587.4. To a solution of phenyl 2-*O*-benzoyl-3-*O*-benzyl-4-*O*-levulinoyl-1-thio-α-L-idopyranoside (0.095 g, 0.168 mmol) in CH_2Cl_2 (1 mL) at 0 °C were added pyridine (0.020 mL, 0.252 mmol) and acetic anhydride (0.021 g, 0.202 mmol). The reaction was allowed to warm to room temperature and stirred until completion. The mixture was diluted with CH_2Cl_2 and washed with saturated $CuSO_4$ aq solution and water. The organic layer was dried over $MgSO_4$, filtered, and concentrated in vacuum. Flash column chromatography (0−30% ethyl acetate/hexane) afforded **10** as a colorless syrup (102 mg, quantitative): ^{1}H NMR (500 MHz, $CDCl_3$) δ = 8.15−8.08 (m, 2H, aromatic), 7.65−7.56 (m, 3H, aromatic), 7.54−7.25 (m, 10H, aromatic), 5.70−5.64 (m, 1H, H-1), 5.50−5.44 (m, 1H, H-2), 5.16−5.09 (m, 1H, H-5), 5.07−5.02 (m, 1H, H-4), 4.94 (d, J = 11.8 Hz, 1H, CH_2Ph), 4.79 (d, J = 11.7 Hz, 1H, CH_2Ph), 4.33 (dd, J = 7.9, 11.5 Hz, 1H, H-6a), 4.28 (dd, J = 5.0, 11.5 Hz, 1H, H-6b), 3.98−3.92 (m, 1H, H-3), 2.72−2.52 (m, 3H, CH_{2Lev}), 2.47−2.37 (m, 1H, CH_{2Lev}), 2.11 (s, 3H, CH_{3Lev}), 2.07 (s, 3H, CH_{3Ac}) ppm; ^{13}C NMR (126 MHz, $CDCl_3$) δ = 205.7, 171.9, 170.5, 165.0, 137.1, 135.7, 133.5, 131.7, 129.8, 129.4, 128.8, 128.4, 128.3, 127.9, 127.6, 127.5, 86.0 (C-1), 72.7 (C_{Bn}), 71.9 (C-3), 68.8 (C-2), 67.0 (C-4), 64.6 (C-5), 62.7 (C-6), 37.7 (CH_{2Lev}), 29.5 (CH_{3Lev}), 27.8 (CH_{2Lev}), 20.7 (CH_{3Ac}) ppm; LRMS (MALDI-TOF) m/z calcd for $C_{33}H_{34}O_9S$ $[M + Na]^+$ 629.2, found 629.7; HRMS (ESI) m/z calcd for $C_{33}H_{34}O_9S$ $[M + Na]^+$ 629.1821, found 629.1844.

Phenyl 2-*O*-Benzoyl-3-*O*-benzyl-4-*O*-levulinoyl-6-*O*-(*p*-methoxyphenyl)-1-thio-α-L-idopyranoside (11). The reaction was carried out according to general procedure A using compound **21** (246 mg, 420 μmol), levulinic acid (146 mg, 1.26 mmol), EDC·HCl (242 mg, 1.26 mmol), and a catalytic amount of DMAP in dry CH_2Cl_2 (3 mL). Compound **11** was obtained as a colorless syrup (259 mg, 90%): R_f = 0.22 (hexane/ethyl acetate, 3:1); $[\alpha]_D^{20}$ = −15.1 (c = 1.0, $CHCl_3$); ^{1}H NMR (500 MHz, $CDCl_3$) δ = 7.89−7.80 (m, 2H, aromatic), 7.59−7.54 (m, 2H, aromatic), 7.52−7.48 (m, 1H, aromatic), 7.42−7.19 (m, 10H, aromatic), 6.88 (d, J = 9.2 Hz, 2H, aromatic$_{PMP}$), 6.83 (d, J = 9.2 Hz, 2H, aromatic$_{PMP}$), 5.59 (s, 1H, H-1), 5.48−5.46 (m, 1H, H-2), 5.28−5.24 (m, 1H, H-5), 5.15 (br s, 1H, H-4), 4.93 (d, J = 11.8 Hz, 1H, CH_2Ph), 4.79 (d, J = 11.7 Hz, 1H, CH_2Ph), 4.18 (dd, J = 9.9, 7.2 Hz, 1H, H-6a), 4.10 (dd, J = 9.9, 5.2 Hz, 1H, H-6b), 3.96−3.94 (m, 1H, H-3), 3.77 (s, 3H, CH_{3PMP}), 2.64−2.48 (m, 3H, CH_{2Lev}), 2.40−2.34 (m, 1H, CH_{2Lev}), 2.06 (s, 3H, CH_{3Lev}) ppm; ^{13}C NMR (126 MHz, $CDCl_3$) δ = 206.1, 172.6, 165.3, 154.2, 152.9, 137.4, 135.9, 133.6−127.6 ($C_{aromatic}$), 115.8, 114.7 ($C_{aromaticPMP}$), 86.3 (C-1), 72.8 (C_{Bn}), 72.2 (C-3), 69.3 (C-2), 67.7 (C-6), 67.5 (C-4), 65.5 (C-5), 55.8 (CH_{3PMP}), 37.8 (CH_{2Lev}), 29.7 (CH_{3Lev}), 28.0 (CH_{2Lev}) ppm; HRMS (ESI) m/z calcd for $C_{38}H_{38}O_9S$ $[M + Na]^+$ 693.2134, found 693.2120.

Phenyl 2-*O*-Benzoyl-3-*O*-benzyl-4-*O*-levulinoyl-6-*O*-(*p*-methoxybenzyl)-1-thio-α-L-idopyranoside (12). The reaction was carried out according to general procedure A using compound **25** (127 mg, 216 μmol), levulinic acid (50 mg, 433 μmol), EDC·HCl (83 mg, 0.433 μmol), and a catalytic amount of DMAP in dry CH_2Cl_2 (2 mL). Compound **12** was obtained as a colorless syrup (120 mg, 81%): R_f = 0.25 (hexane/ethyl acetate, 3:1); $[\alpha]_D^{20}$ = −49.6 (c = 1.0, $CHCl_3$); ^{1}H NMR (500 MHz, $CDCl_3$) δ 8.11−8.05 (m, 2H, aromatic), 7.61−7.54 (m, 3H, aromatic), 7.49−7.40 (m, 4H, aromatic), 7.40−7.36 (m, 2H, aromatic), 7.34−7.29 (m, 1H, aromatic), 7.28−7.21 (m, 5H, aromatic), 6.87 (d, J = 8.6 Hz, 1H, aromatic$_{PMB}$), 5.62 (br s, 1H, H-1), 5.44 (m, 1H, H-2), 5.11−5.03 (m, 2H, H-4, H-5), 4.90 (d, J = 11.8 Hz, 1H, CH_2Ph), 4.77 (d, J = 11.8 Hz, 1H, CH_2Ph), 4.52 (d, J = 11.4 Hz, 1H, CH_{2PMB}), 4.46 (d, J = 11.5 Hz, 1H, CH_{2PMB}), 3.93−3.90 (m, 1H, H-3), 3.80 (s, 3H, CH_{3PMB}), 3.72 (dd, J = 9.9, 6.8 Hz, 1H, H-6a), 3.66 (dd, J = 10.0, 5.4 Hz, 1H, H-6b), 2.66−2.57 (m, 1H, CH_{2Lev}), 2.57−2.44 (m, 2H, CH_{2Lev}), 2.39−2.31 (m, 1H, CH_{2Lev}), 2.07 (s, 3H, CH_{3Lev}) ppm; ^{13}C NMR (126 MHz, $CDCl_3$) δ = 206.0, 172.1, 165.3, 159.3, 137.4, 136.0, 133.6, 132.1, 132.1, 130.3, 130.0, 130.0, 129.7, 129.6, 129.5, 129.1, 129.1, 129.0, 128.6, 128.5, 127.9, 127.7, 127.7, 127.6, 113.8 ($C_{aromaticPMB}$), 86.3 (C-1), 73.1 (CH_{2PMB}), 72.8 (C_{Bn}), 72.3 (C-3), 69.5 (C-2), 68.7 (C-6), 67.6 (C-4), 65.8 (C-5), 55.4 (CH_{3PMB}), 37.9 (CH_{2Lev}), 29.8 (CH_{3Lev}), 27.9 (CH_{2Lev}) ppm; HRMS (ESI) m/z calcd for $C_{39}H_{40}O_9S$ $[M + NH_4]^+$ 702.2731 found 702.2722.

Phenyl 2-*O*-Benzoyl-3-*O*-benzyl-4-*O*-levulinoyl-1-thio-6-*O*-[(triisopropylsiloxy)methyl]-α-L-idopyranoside (13). To a solution of phenyl 2-*O*-benzoyl-3-*O*-benzyl-4-*O*-levulinoyl-1-thio-α-L-idopyranoside (0.260 g, 0.460 mmol) in CH_2Cl_2 (2 mL) at 0 °C were added freshly distilled DIPEA (0.402 mL, 2.302 mmol) and (triisopropylsiloxy)methyl chloride (0.260 mL, 0.921 mmol). The reaction was allowed to warm to room temperature and stirred until completion. The mixture was diluted with CH_2Cl_2, washed with water, dried over $MgSO_4$, and concentrated in vacuum. Flash column chromatography (0−20% ethyl acetate/hexane) afforded **13** as a colorless syrup (220 mg, 64%): ^{1}H NMR (500 MHz, $CDCl_3$) δ = 8.15−7.10 (m, 15H, aromatic), 5.63 (s, 1H, H-1), 5.50−5.44 (m, 1H, H-2), 5.11−5.05 (m, 2H, H-4, H-5), 4.99−4.93 (m, 2H, CH_{2TOM}), 4.92 (d, J = 11.8 Hz, 1H, CH_2Ph), 4.81 (d, J = 11.8 Hz, 1H, CH_2Ph), 3.98−3.93 (m, 1H, H-3), 3.88−3.78 (m, 2H, H-6ab), 2.71−2.52 (m, 3H, CH_{2Lev}), 2.49−2.39 (m, 1H, CH_{2Lev}), 2.10 (s, 3H, CH_{3Lev}), 1.11−1.07 (m, 21H, $6CH_{3TOM}$, $3CH_{TOM}$) ppm; ^{13}C NMR (126 MHz, $CDCl_3$) δ = 205.7, 172.0, 165.2, 137.3, 135.9, 133.4, 131.94, 129.8, 129.5, 128.8, 128.4, 127.8, 127.5, 127.4, 90.1 (CH_{2TOM}), 86.2 (C-1), 72.6 (C_{Bn}), 72.0 (C-3), 69.4 (C-2), 67.4 (C-4), 66.3 (C-6), 65.6 (C-5), 37.8 (CH_{2Lev}), 29.6 (CH_{3Lev}), 27.8 (CH_{2Lev}), 17.8 (CH_{3TOM}), 12.0 (CH_{TOM}) ppm; LRMS (MALDI-TOF) m/z calcd for $C_{41}H_{54}O_9SSi$ $[M + Na]^+$ 774.00, found 773.95; HRMS (ESI) m/z calcd for $C_{41}H_{54}O_9SSi$ $[M + Na]^+$ 773.3156, found 773.3118.

2-*O*-Benzoyl-3-*O*-benzyl-6-*O*-(dimethylthexylsilyl)-4-*O*-levulinoyl-α/β-L-idopyranosyl Trichloroacetimidate (14). The thioglycoside **8** (820 mg, 1.16 mmol) was hydrolyzed using NIS (662 mg, 2.94 mmol) and TfOH (11 μL, 0.12 mmol) in wet THF at room temperature for 6 h. The reaction mixture was quenched with saturated $NaHCO_3$ aq solution and solid $Na_2S_2O_3$. The mixture was filtered and washed with saturated $NaHCO_3$ aq solution, water, and brine. The organic layer was dried over $MgSO_4$, filtered, and concentrated. The reaction crude was purified by column chromatography on silica (hexane/ethyl acetate, 4:1). 2-*O*-Benzoyl-3-*O*-benzyl-6-*O*-(dimethylthexylsilyl)-4-*O*-levulinoyl-α/β-L-idopyranose was obtained as a colorless syrup (534 mg, 75%): R_f = 0.23 (hexane/ethyl acetate, 4:1); MALDI-TOF m/z calcd for $C_{33}H_{46}O_9Si$ $[M + Na]^+$ 637.28, found 637.57. 2-*O*-Benzoyl-3-*O*-benzyl-6-*O*-(dimethylthexylsilyl)-4-*O*-levulinoyl-α/β-L-idopyranose (753 mg, 1.25 mmol) and trichloroacetonitrile (2.51 mL, 25 mmol) were dissolved in anhydrous CH_2Cl_2 (10 mL) with activated molecular sieves. After 30 min of stirring, the solution was cooled to 0 °C and DBU (55 μL, 0.38 mmol) was added. After 2 h, TLC (hexane/ethyl acetate, 4:1) indicated complete conversion of the starting material. The mixture was concentrated under reduced pressure and purified by column chromatography on silica (hexane 100% → hexane/ethyl acetate, 4:1, with 1% triethylamine) to obtain compound **14** as a colorless solid, α/β mixture (ratio 5.8:1) (683 mg, 72%), R_f = 0.23 (hexane/ethyl acetate, 4:1). Data for the α-anomer: ^{1}H NMR (500 MHz, $CDCl_3$) δ = 8.63 (s, 1H, $OCNHCCl_3$), 8.10 (d, J = 7.7 Hz, 2H, aromatic), 7.59 (t, J = 7.4 Hz, 1H, aromatic), 7.49−7.24 (m, 7H, aromatic), 6.41 (s, 1H, H-1), 5.38 (s, 1H, H-2), 5.12 (br s, 1H, H-4), 4.84 (d, J = 11.6 Hz, 1H, CH_2Ph), 4.75 (d, J = 11.6 Hz, 1H, CH_2Ph), 4.55 (t, J = 6.5 Hz, 1H, H-5), 3.99 (s, 1H, H-3), 3.80−3.70 (m, 2H, H-6), 2.64−2.36 (m, 4H, $2CH_{2Lev}$), 2.07 (s, 3H, CH_{3Lev}), 1.28−1.24 (m,

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1H, CH_{thexyl}), 0.85 (d, J = 6.7 Hz, 2 × 3H, $CH_{3thexyl}$), 0.81 (s, 6H, $CH_{3thexyl}$), 0.08 (s, 3H, $SiCH_3$), 0.07 (s, 3H, $SiCH_3$) ppm; ^{13}C NMR (126 MHz, $CDCl_3$) δ = 205.4, 171.9, 165.0, 129.7−127.4 ($C_{aromatic}$), 94.9 (C-1), 72.3 (C_{Bn}), 71.9 (C-3), 68.5 (C-5), 66.5 (C-2), 66.3 (C-4), 61.1 (C-6), 37.7 (CH_{2Lev}), 33.9 (CH_{thexyl}) 29.7 (CH_{3Lev}) 27.9 (CH_{2Lev}), 27.8 (CH_{2Lev}), 20.2 ($CH_{3thexyl}$), 18.5 ($CH_{3thexyl}$), −4.1 ($SiCH_3$) ppm; MALDI-TOF m/z calcd for $C_{35}H_{46}Cl_3NO_9Si$ [M + Na]$^+$ 780.19, found 780.10.

2-*O*-Benzoyl-3-*O*-benzyl-4-*O*-levulinoyl-6-*O*-(*p*-methoxyphenyl)-α/β-L-idopyranosyl Trichloroacetimidate (15). The thioglycoside **11** (2.10 g, 3.13 mmol) was hydrolyzed using NIS (1.76 g, 7.83 mmol) and TfOH (27 μL, 0.31 mmol) in wet THF at room temperature for 6 h. The reaction mixture was quenched with saturated $NaHCO_3$ solution and solid $Na_2S_2O_3$. The mixture was filtered and washed with saturated $NaHCO_3$ solution, water, and brine. The reaction crude was purified by column chromatography on silica (hexane/ethyl acetate, 4:1): R_f = 0.21 (hexane/ethyl acetate, 2:1); MALDI-TOF m/z calcd for $C_{33}H_{46}O_9Si$ [M + Na]$^+$ 637.28, found 637.57. 2-*O*-Benzoyl-3-*O*-benzyl-4-*O*-levulinoyl-6-*O*-(*p*-methoxyphenyl)-α/β-L-idopyranose (3.13 mmol) and trichloroacetonitrile (3.14 mL, 31.3 mmol) were dissolved in anhydrous CH_2Cl_2 (16 mL) with activated molecular sieves. After 30 min of stirring, the solution was cooled to 0 °C and DBU (417 μL, 0.32 mmol) was added. After 2 h, TLC (hexane/ethyl acetate, 3:1) indicated complete conversion of the starting material. The mixture was concentrated under reduced pressure and purified by column chromatography on silica (hexane 100% → hexane/ethyl acetate, 2:1) to obtain compound **15** as a colorless syrup, α/β mixture (ratio 2:1) (1.27 g, 56% over two steps), R_f = 0.40 (hexane/ethyl acetate, 2:1). Data for the α-anomer: ^1H NMR (500 MHz, $CDCl_3$) δ = 8.61 (s, 1H, $OCNHCCl_3$), 8.09−7.93 (m, 2H, aromatic), 7.56−7.45 (m, 1H, aromatic), 7.43−7.20 (m, 7H, aromatic), 6.83−6.65 (m, 4H, $aromatic_{PMP}$), 6.38 (s, 1H, H-1), 5.33 (s, 1H, H-2), 5.13 (s, 1H, H-4), 4.81 (d, J = 11.6 Hz, 1H, CH_2Ph), 4.74 (s, 1H, H-5), 4.69 (d, J = 11.6 Hz, 1H, CH_2Ph), 4.10−4.07 (m, 1H, H-6a), 4.01−3.95 (m, 1H, H-6b), 3.93 (s, 1H, H-3), 3.68 (s, 3H, CH_{3PMP}), 2.55−2.22 (m, 4H, CH_{2Lev}), 1.97 (s, 3H, CH_{3Lev}) ppm; ^{13}C NMR (126 MHz, $CDCl_3$) δ = 205.9, 172.0, 165.5, 165.1, 160.6, 160.3, 154.2, 152.4, 133.6−128.2 ($C_{aromatic}$), 115.9−114.6 ($C_{aromaticPMP}$), 94.8 (C-1), 91.1 (CCl_3) 72.5 (C_{Bn}), 71.9 (C-3), 67.5 (C-2), 67.1 (C-6), 66.5 (C-5), 66.0 (C-4), 55.7 (CH_{3PMP}), 37.7 (CH_{2Lev}), 29.7 (CH_{3Lev}), 27.8 (CH_{2Lev}) ppm; MALDI-TOF m/z calcd for $C_{35}H_{46}Cl_3NO_9Si$ [M + Na]$^+$ 780.19, found 780.10; HRMS (ESI) m/z calcd for $C_{34}H_{34}Cl_3NO_{10}$ [M + Na]$^+$ 744.1146, found 744.1146.

2-Azido-6-*O*-benzoyl-3-*O*-benzyl-2-deoxy-4-O-levulinoyl-α-D-glucopyranosyl Trichloroacetimidate (16). To a cooled (0 °C) solution of compound **29** (2.0 g, 3.26 mmol) in dry THF (16 mL) were added AcOH (0.20 mL) and TBAF (1.38 mL, 3.59 mmol). After 3 h, water was added and the mixture was diluted with ethyl acetate and washed with water. The aqueous layer was extracted with ethyl acetate, and the combined organic layers were dried over $MgSO_4$ and concentrated to dryness. The residue was concentrated and used in the next reaction without further purification. The hemiacetal (1.62 g, 3.27 mmol) and trichloroacetonitrile (4.9 mL, 49 mmol) were dissolved in anhydrous CH_2Cl_2 (32 mL) with activated molecular sieves. After 30 min of stirring, the solution was cooled to 0 °C and DBU (48 μL, 0.33 mmol) was added. After 2 h, TLC (hexane/ethyl acetate, 3:1) indicated complete conversion of the starting material. Then the mixture was concentrated under reduced pressure. The title compound **16** was obtained after column chromatography on silica (hexane 100% → hexane/ethyl acetate, 2:1) as a colorless solid (1.78 g, 85%): $[\alpha]_D^{20}$ = +64.9 (c = 1.0, $CHCl_3$); ^1H NMR (500 MHz, $CDCl_3$) δ = 8.75 (s, 1H, $OCNHCl_3$), 8.01 (m, 2H, aromatic), 7.55 (m, 1H, aromatic), 7.42 (m, 2H, aromatic), 7.33 (m, 2H, aromatic), 6.45 (d, J = 3.5 Hz, 1H, H-1), 5.30 (dd, J = 9.6, 9.3 Hz, 1H, H-4), 4.86 (d, J = 11.0 Hz, 1H, CH_2Ph), 4.77 (d, J = 11.0 Hz, 1H, CH_2Ph), 4.50 (dd, J = 12.3, 2.1 Hz, 1H, H-6a), 4.32 (dd, J = 12.3, 5.1 Hz, 1H, H-6b), 4.26 (ddd, J = 9.3, 5.1, 2.1 Hz, 1H, H-5), 4.08 (dd, J = 10.1, 9.6 Hz, 1H, H-3), 3.78 (dd, J = 10.1, 3.5 Hz, 1H, H-2), 2.77−2.62 (m, 2H, CH_{2Lev}), 2.54−2.50 (m, 1H, CH_{2Lev}), 2.45 (m, 1H, CH_{2Lev}), 2.12 (s, 3H, CH_{3Lev}) ppm; ^{13}C NMR (126 MHz, $CDCl_3$) δ = 206.1 (OCNH), 171.5 (C_q), 166.0 (C_q), 160.4 (C_q), 137.2−128.0 ($C_{aromatic}$), 94.2 (C-1), 77.6 (C-3), 77.2 (CCl_3), 75.1 (C_{Bn}), 70.8 (C-5), 70.0 (C-4), 62.6 (C-2), 62.2 (C-6), 37.7 (CH_{2Lev}), 29.6 (CH_{3Lev}), 27.8 (CH_{2Lev}) ppm; HRMS (ESI) m/z calcd for $C_{27}H_{27}Cl_3N_4O_8$ [M + Na]$^+$ 663.0787, found 663.0784.

2-Azido-6-*O*-benzoyl-3-*O*-benzyl-2-deoxy-4-O-levulinoyl-α/β-D-glucopyranosyl *N*-Phenyltrifluoroacetimidate (17). To a cooled (0 °C) solution of compound **29** (0.773 g, 1.26 mmol) in dry THF (6 mL) were added AcOH (0.079 mL) and TBAF (1.38 mL, 1.26 mmol). After 3 h, water was added and the mixture was diluted with ethyl acetate and washed with water. The aqueous layer was extracted with ethyl acetate, and the combined organic layers were dried over $MgSO_4$ and concentrated to dryness. The residue was concentrated and used in the next reaction without further purification. To a solution of hemiacetal (636 mg, 1.28 mmol) in acetone (10 mL) were added potassium carbonate (350 mg, 2.56 mmol) and *N*-phenyltrifluoroacetimidoyl chloride (600 mg, 2.89 mmol). The reaction was stirred overnight, and the solvent was removed in vacuo. Flash chromatography on silica gel (hexane → hexane/ethyl acetate, 2:1, with 1% triethylamine) afforded a mixture (1:1) of **17α** and **17β** (765 mg, 91%). Data for the α-anomer: ^1H NMR (500 MHz, $CDCl_3$) δ = 8.05−8.03 (m, 2H, aromatic), 7.59−7.56 (m, 1H, aromatic), 7.45−7.42 (m, 2H, aromatic), 7.37−7.31 (m, 5H, aromatic), 7.26−7.22 (m, 2H, aromatic), 7.11−7.08 (m, 1H, aromatic), 6.72 (d, 2H, aromatic), 6.42 (br s, 1H, H-1), 5.27 (t, J = 9.8 Hz, 1H, H-4), 4.88 (d, J = 11.0 Hz, CH_2Ph), 4.77 (d, J = 11.0 Hz, CH_2Ph), 4.51 (dd, J = 12.4 Hz, 2.3 Hz, 1H, H-6a), 4.36 (dd, J = 12.4, 5.4 Hz, 1H, H-6b), 4.19−4.17 (m, 1H, H-5), 4.05 (t, J = 9.7 Hz, 1H, H-3), 3.76−3.74 (m, 1H, H-2), 2.67−2.64 (m, 2H, CH_{2Lev}), 2.6−2.53 (m, 1H, CH_{2Lev}), 2.46−2.40 (m, 1H, CH_{2Lev}), 2.13 (s, 3H, CH_{3Lev}) ppm; ^{13}C NMR (126 MHz, $CDCl_3$) δ = 206.2, 171.7, 166.2, 143.1, 137.4, 133.3, 129.9, 129.0, 128.7, 128.6, 128.2, 124.7, 119.4, 92.7 (C-1), 78.0 (C-3), 75.5 (C_{Bn}), 70.9 (C-5), 70.2 (C-4), 62.7 (C-2), 62.4 (C-6), 37.9 (CH_{2Lev}), 29.8 (CH_{3Lev}), 28.0 (CH_{2Lev}) ppm. Data for the β-anomer: ^1H NMR (500 MHz, $CDCl_3$) δ = 8.02−8.00 (m, 2H, aromatic), 7.56−7.53 (m, 1H, aromatic), 7.39−7.30 (m, 7H, aromatic), 7.25−7.22 (m, 2H, aromatic), 7.12−7.09 (m, 1H, aromatic), 6.75−6.74 (m, 2H, aromatic), 5.60 (br s, 1H, H-1), 5.17 (t, J = 9.7 Hz, 1H, H-4), 4.85 (d, J = 11.3 Hz, 1H, CH_2Ph), 4.74 (d, J = 11.3 Hz, 1H, CH_2Ph), 4.49 (dd, J = 12.4, 2.2 Hz, 1H, H-6a), 4.32 (dd, J = 12.3, 6.2 Hz, 1H, H-6b), 3.79−3.75 (m, 2H, H-2, H-5), 3.60−3.56 (m, 1H, H-3), 2.74−2.62 (m, 2H, CH_{2Lev}), 2.54−2.48 (m, 1H, CH_{2Lev}), 2.44−2.38 (m, 1H, CH_{2Lev}), 2.12 (s, 3H, CH_{3Lev}) ppm; ^{13}C NMR (126 MHz, $CDCl_3$) δ = 206.2, 171.7, 166.2, 143.1, 137.5, 133.2, 129.9, 129.8, 128.9, 128.8, 128.6, 128.5, 128.26, 128.2, 124.6, 119.3, 95.5 (C-1), 80.3 (C-3), 75.4 (C_{Bn}), 73.3 (CF_3), 70.0 (C-4), 65.1 (C-5, C-2), 62.7 (C-6), 37.9 (CH_{2Lev}), 29.8 (CH_{3Lev}), 28.0 (CH_{2Lev}) ppm.

Phenyl 2-*O*-Benzoyl-3-*O*-benzyl-1-thio-α-L-idopyranoside (19). To a solution of 1,6-anhydro compound **18** (328 mg, 0.920 mmol) in dry CH_2Cl_2 (3.5 mL) were added trimethyl(phenylthio)-silane (0.57 mL, 3.0 mmol) and ZnI_2 (0.65 g, 1.8 mmol, protected from light and dried under high vacuum). The mixture was stirred at room temperature overnight and filtered through a pad of Celite. The filtrate was diluted with CH_2Cl_2, after which a solution of HCl in dioxane and water were added. The mixture was stirred at room temperature for 15 min, and the organic layer was washed with aq 1 M HCl solution, saturated $NaHCO_3$ aq solution, and water, filtered, and concentrated. The crude product was purified by flash chromatography (hexane/ethyl acetate, 4:1 to 1:1) to obtain compound **19** as a white solid (0.252 g, 77%): ^1H NMR (500 MHz, $CDCl_3$) δ = 8.03−8.02 (m, 2H, aromatic), 7.58−7.24 (m, 15H, aromatic), 5.64 (s, 1H, H-1), 5.54 (s, 1H, H-2), 4.93−4.90 (d, J = 11.8 Hz, 1H, CH_2Ph), 4.78 (m, 1H, H-5), 4.67 (d, J = 11.8 Hz, 1H, CH_2Ph), 3.97 (dd, J = 11.8, 6.3 Hz, 1H, H-6a), 3.93−3.82 (m, 3H, H-6b, H-3, H-4), 3.10−2.51 (br s, 1H, OH), 2.04−1.65 (br s, 1H, OH) ppm; ^{13}C NMR (126 MHz, $CDCl_3$) δ = 165.0, 137.2, 135.6, 133.7, 132.0, 129.7, 129.1, 128.7, 128.5, 128.0, 127.8, 127.7, 127.5, 86.7 (C-1), 74.0 (C-3), 72.3 (C_{Bn}), 69.9 (C-2), 68.4 (C-4), 68.2 (C-5), 63.3 (C-6) ppm; HRMS (ESI) m/z calcd for $C_{26}H_{26}O_6S$ [M + Na]$^+$ 489.1348, found 489.1320.

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Phenyl 2-*O*-Benzoyl-3-*O*-benzyl-6-*O*-(dimethylthexylsilyl)-1-thio-α-L-idopyranoside (20). To a solution of thiophenyl glycoside **19** (1.02 g, 2.19 mmol) in dry pyridine (9 mL) was added a catalytic amount of DMAP, followed by addition of (TDS)Cl (2.63 mmol). The reaction mixture was stirred overnight at room temperature. The TLC control (hexane/ethyl acetate, 2:1) indicated full conversion of the starting material. The mixture was diluted with CH_2Cl_2 (∼100 mL) and washed with saturated $CuSO_4$ aq solution (3 × ∼100 mL), water (∼100 mL), and brine (∼100 mL). The organic layer was dried over $MgSO_4$, filtered, and concentrated. The crude product was purified by column chromatography on silica using a hexane/ethyl acetate gradient (100% → 50% hexane). The title compound was obtained as a colorless oil (1.13 g, 85%): R_f = 0.56 (hexane/ethyl acetate, 4:1); ^{1}H NMR (126 MHz, $CDCl_3$) δ = 8.04−7.98 (m, 2H, aromatic), 7.60−7.53 (m, 3H, aromatic), 7.46−7.22 (m, 10H, aromatic), 5.61 (br s, 1H, H-1), 5.50−5.48 (m, 1H, H-2), 4.91 (d, J = 12.0 Hz, 1H, CH_2Ph), 4.83 (td, J = 5.3, 1.5 Hz, 1H, H-5), 4.78 (d, J = 11.9 Hz, 1H, CH_2Ph), 3.94−3.85 (m, 4H, H-3, H-6ab, H-4), 3.01 (br s, OH), 1.68−1.60 (m, 1H, CH_{thexyl}), 0.89 (d, J = 6.9 Hz, 6H, $CH_{3thexyl}$), 0.87 (s, 6H, $CH_{3thexyl}$), 0.11 (s, 6H, $SiCH_3$) ppm; ^{13}C NMR (126 MHz, $CDCl_3$) δ = 167.1, 129.8, 129.7, 133.4, 131.6, 128.8, 128.2, 127.5, 127.1, 85.9, 77.0, 72.7, 72.1, 69.8, 67.0, 67.2, 61.2, 37.7, 29.7, 27.8, 27.7, 27.6, 20.1, 18.6, −3.4, −3.7 ppm; MALDI-TOF m/z calcd for $C_{34}H_{44}O_6SSi$ 631.25 $[M + Na]^+$, found 631.33 $[M + Na]^+$; HRMS (ESI) m/z calcd for $C_{34}H_{44}O_6SSi$ $[M + Na]^+$ 631.2526, found 631.2534.

Phenyl 2-*O*-Benzoyl-3-*O*-benzyl-6-*O*-(*p*-methoxyphenyl)-1-thio-α-L-idopyranoside (21). A solution of compound **19** (2.20 g, 1.85 mmol) and *p*-methoxyphenol (2.92 g, 23.5 mmol) in dry THF (6 mL) was added to a solution of DIAD (1.85 mL, 9.40 mmol) and triphenylphosphine (2.47 g, 9.40 mmol) in dry THF (5 mL). After being stirred overnight at room temperature, the mixture was diluted with ethyl acetate and washed with 1 M NaOH aq, water, and brine. After being dried over $MgSO_4$ and concentrated under reduced pressure, the crude material was purified by column chromatography on silica using hexane/ethyl acetate (gradient 3:1 → 1:1). The title compound was obtained as a colorless syrup (1.75 g, 70%): R_f = 0.38 (hexane/ethyl acetate, 3:1); $[\alpha]_D^{20}$ = +8.8 (c = 1.0, $CHCl_3$); ^{1}H NMR (500 MHz, $CDCl_3$) δ = 8.01−7.99 (m, 2H, aromatic), 7.66−7.65 (m, 2H, aromatic), 7.61−7.57 (m, 1H, aromatic), 7.49−7.29 (m, 10H, aromatic), 6.90 (d, J = 9.2 Hz, 2H, $aromatic_{PMP}$), 6.84 (d, J = 9.2 Hz, 2H, $aromatic_{PMP}$), 5.61 (s, 1H, H-1), 5.56−5.54 (m, 1H, H-2), 5.21−5.17 (m, 1H, H-5), 4.95 (d, J = 11.8 Hz, 1H, CH_2Ph), 4.71 (d, J = 11.8 Hz, 2H, CH_2Ph), 4.25 (d, J = 5.9 Hz, 2H, H-6ab), 3.95−3.88 (m, 2H, H-3, H-4), 3.78 (s, 3H, CH_{3PMP}) ppm; ^{13}C NMR (126 MHz, $CDCl_3$) δ = 164.9, 154.1, 153.0, 137.3, 135.8, 133.7−127.8 ($C_{aromatic}$), 115.6−114.7 ($C_{aromaticPMP}$), 86.8 (C-1), 74.0 (C-3), 72.4 (C_{Bn}), 70.1 (C-2), 68.3 (C-6), 67.6 (C-4), 67.2 (C-5), 55.7 (CH_{3PMP}) ppm; MALDI-TOF m/z calcd for $C_{33}H_{32}O_7S$ 595.18 $[M + Na]^+$, found 595.44; HRMS (ESI) m/z calcd for $C_{33}H_{32}O_7S$ $[M + Na]^+$ 595.1766, found 595.1754.

Phenyl 2-*O*-Benzoyl-3-*O*-benzyl-4,6-*O*-benzylidene-1-thio-α-L-idopyranoside (22). To a solution of diol **19** (500 mg, 1.07 mmol) and benzyladehyde dimethyl acetal (10.7 mmol, 1.1 mL) in DMF (5 mL) was added a catalytic amount of CSA, and the mixture was heated to 60 °C under reduced pressure for 5 h. After being cooled to room temperature, the mixture was diluted with CH_2Cl_2 (100 mL), and the organic layer was washed with saturated NH_4Cl aq solution (3 × 100 mL), water (100 mL), and brine (100 mL). After being dried over $MgSO_4$ and concentrated under reduced pressure, the crude material was purified by column chromatography on silica using hexane/ethyl acetate (gradient 4:1 → 2:1). The title compound was obtained as a colorless syrup (468 mg, 79%): R_f = 0.56 (hexane/ethyl acetate, 3:1); $[\alpha]_D^{20}$ = +42.5 (c = 1.0, $CHCl_3$); ^{1}H NMR (500 MHz, $CDCl_3$) δ = 7.88 (d, J = 8.3, 2H, aromatic), 7.51−7.07 (m, 18H, aromatic), 5.75 (br s, 1H, H-1), 5.52 (s, 1H, H_{acetal}), 5.48−5.43 (br s, 1H, H-2), 4.91 (d, J = 11.8 Hz, 1H, CH_{2Ph}), 4.64 (d, J = 11.8 Hz, 1H, CH_2Ph), 4.45 (br s, 1H, H-5), 4.32 (d, J = 12.6 Hz, 1H, H-6a), 4.13 (d, J = 12.6 Hz, 1H, H-6b), 4.05 (br s, 1H, H-4), 3.85 (br s, 1H, H-3) ppm; ^{13}C NMR (126 MHz, $CDCl_3$) δ = 165.7 (Cq), 137.8−126.3 ($C_{aromatic}$), 101.0 (C_{acetal}), 85.9 (C-1), 73.2 (C-4), 73.1 (C-3), 72.4 (C_{Bn}), 69.9 (C-6), 67.8 (C-2), 60.6 (C-5) ppm; MALDI-TOF m/z calcd for $C_{33}H_{30}O_6S$ 577.17 $[M + Na]^+$, found 577.36; HRMS (ESI) m/z calcd for $C_{33}H_{30}O_6S$ $[M + Na]^+$ 577.1661, found 577.1683.

Phenyl 2-*O*-Benzoyl-3-*O*-benzyl-4,6-*O*-(*p*-methoxybenzylidene)-1-thio-α-L-idopyranoside (23). To a solution of diol **19** (250 mg, 536 μmol) and *p*-anisaldehyde (650 μL, 5.36 mmol) in toluene (5 mL) was added a catalytic amount of CSA, and the mixture was heated under reflux (Dean−Stark) for 2 h. After being cooled to room temperature, the mixture was neutralized with triethylamine, and the crude product was concentrated under reduced pressure. The crude material was purified by column chromatography on silica using hexane/ethyl acetate (gradient 4:1 → 2:1). The title compound was obtained as a colorless syrup (263 mg, 84%): R_f = 0.65 (hexane/ethyl acetate, 3:1); $[\alpha]_D^{20}$ = −77.3 (c = 1.0, $CHCl_3$); ^{1}H NMR (500 MHz, $CDCl_3$) δ = 8.01−7.97 (m, 2H, aromatic), 7.60−7.20 (m, 15H, aromatic), 6.79 (m, 2H, $aromatic_{PMP}$), 5.83 (br s, 1H, H-1), 5.57−5.51 (m, 2H, H-2, H_{acetal}), 4.99 (d, J = 11.8 Hz, 1H, CH_2Ph), 4.72 (d, J = 11.8 Hz, 1H, CH_2Ph), 4.52 (br s, 1H, H-5), 4.38 (dd, J = 12.7, 1.7 Hz, 1H, H-6a), 4.19 (dd, J = 12.8, 2.0 Hz, 1H, H-6b), 4.11 (br s, 1H, H-4), 3.92 (br s, 1H, H-3), 3.80 (s, 3H, CH_{3PMP}) ppm; ^{13}C NMR (126 MHz, $CDCl_3$) δ = 165.8, 160.3, 137.4, 136.7, 133.2, 130.6, 130.6, 130.2, 129.7, 129.1, 128.7, 128.3, 128.2, 128.0, 127.8, 127.1, 113.5 ($C_{aromaticPMP}$), 101.2 (C_{acetal}), 86.1 (C-1), 73.3 (C-3), 73.3 (C-4), 72.6 (C_{Bn}), 70.1 (C-6), 68.1 (C-2), 60.7 (C-5), 55.4 (CH_{3PMP}) ppm; MALDI-TOF m/z calcd for $C_{34}H_{32}O_7S$ 607.18 $[M + Na]^+$, found 607.9; HRMS (ESI) m/z calcd for $C_{34}H_{32}O_7S$ $[M + Na]^+$ 607.1766, found 607.1776.

Phenyl 2-*O*-Benzoyl-3,6-di-*O*-benzyl-1-thio-α-L-idopyranoside (24). Under an argon atmosphere, trifluoroacetic acid (172 μL, 2.25 mmol) was added slowly to a solution of the acetal **22** (250 mg, 451 μmol) and triethylsilane (360 μL, 2.25 mmol) in dry THF (2 mL) at 0 °C and the resulting mixture stirred for 2 h. The mixture was diluted with CH_2Cl_2 (25 mL) and washed with saturated $NaHCO_3$ aq solution. After being dried over $MgSO_4$ and concentrated under reduced pressure, the crude material was purified by column chromatography on silica using hexane/ethyl acetate (gradient 3:1 → 1:1). The title compound was obtained as a colorless syrup (175 mg, 70%): R_f = 0.40 (hexane/ethyl acetate, 3:1); $[\alpha]_D^{20}$ = +25.9 (c = 1.0, $CHCl_3$); ^{1}H NMR (500 MHz, $CDCl_3$) δ = 8.03−7.99 (m, 2H, aromatic), 7.62−7.56 (m, 3H, aromatic), 7.48−7.42 (m, 4H, aromatic), 7.40−7.28 (m, 8H, aromatic), 7.26−7.20 (m, 3H, aromatic), 5.62 (s, 1H, H-1), 5.54−5.51 (m, 1H, H-2), 5.03−4.99 (m, 1H, H-5), 4.93 (d, J = 11.8 Hz, 1H, CH_2Ph), 4.68 (d, J = 11.8 Hz, 1H, CH_2Ph), 4.64 (d, J = 11.8 Hz, 1H, CH_2Ph), 4.59 (d, J = 11.8 Hz, 1H, CH_2Ph), 3.92−3.81 (m, 1H, H-3, H-4, H-6ab), 2.72 (br s, 1H, OH) ppm; ^{13}C NMR (126 MHz, $CDCl_3$) δ = 165.2, 138.1, 137.5, 136.0, 133.7−127.7 ($C_{aromatic}$), 86.9 (C-1), 74.3 (C-3), 73.6 (C_{Bn}), 72.5 (C_{Bn}), 70.5 (C-6), 70.1 (C-2), 68.1 (C-4), 67.4 (C-5) ppm; MALDI-TOF m/z calcd $C_{33}H_{32}O_6S$ $[M + Na]^+$ 579.18, found 579.25; HRMS (ESI) m/z calcd for $C_{33}H_{32}O_6S$ $[M + Na]^+$ 579.1817, found 579.1809.

Phenyl 2-*O*-Benzoyl-3-*O*-benzyl-6-*O*-(*p*-methoxybenzyl)-1-thio-α-L-idopyranoside (25). Under an argon atmosphere, I_2 (416 mg, 1.64 mmol) was added portionwise in 5 min to a solution of the acetal **23** (240 mg, 410 μmol) and sodium cyanoborohydride (258 mg, 4.10 mmol) in dry CH_2Cl_2 (2 mL) at −20 °C and the resulting mixutre stirred for 15 min. The mixture was diluted with CH_2Cl_2 (25 mL) and washed with saturated $NaHCO_3$ aq solution. After being dried over $MgSO_4$ and concentrated under reduced pressure, the crude material was purified by column chromatography on silica using hexane/ethyl acetate (gradient 3:1 → 1:1). The title compound was obtained as a colorless syrup (146 mg, 61%): R_f = 0.34 (hexane/ethyl acetate, 3:1); $[\alpha]_D^{20}$ = −97.7 (c = 1.0, $CHCl_3$); ^{1}H NMR (500 MHz, $CDCl_3$) δ = 8.02−7.97 (m, 2H, aromatic), 7.61−7.55 (m, 3H, aromatic), 7.48−7.40 (m, 4H, aromatic), 7.40−7.35 (m, 2H, aromatic), 7.34−7.21 (m, 6H, aromatic), 6.90−6.85 (m, 2H, $aromatic_{PMB}$), 5.61 (br s, 1H, H-1), 5.52−5.49 (m, 1H, H-2), 4.99−4.95 (m, 1H, H-5), 4.91 (d, J = 11.8 Hz, 1H, CH_2Ph), 4.67 (d, J = 11.8 Hz, 1H, CH_2Ph), 4.57 (d, J = 11.5 Hz, 1H, CH_{2PMB}), 4.51 (d, J = 11.4 Hz, 1H, CH_{2PMB}), 3.88 (td, J = 2.9, 1.4 Hz, 1H, H-3), 3.86−3.76 (m,

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6H, H-4, H-6, CH_{3PMB}), 2.87 (br s, 1H, OH) ppm; ^{13}C NMR (126 MHz, $CDCl_3$) δ = 165.2, 159.4, 137.5, 136.0, 133.7, 132.2, 130.2, 129.9, 129.5, 129.5, 129.4, 129.0, 128.8, 128.7, 128.6, 128.1, 128.0, 127.9, 127.7, 113.9 ($C_{aromaticPMB}$), 86.9 (C-1), 74.3 (C-3), 73.3 (C_{Bn}), 72.5 (C_{Bn}), 70.2 (C-6), 70.0 (C-2), 68.2 (C-4), 67.4 (C-5), 55.4 (CH_{3PMB}) ppm; MALDI-TOF m/z calcd for $C_{34}H_{34}O_7S$ $[M + Na]^+$ 609.19, found 608.96; HRMS (ESI) m/z calcd for $C_{34}H_{34}O_7S$ $[2M + NH_4]^+$ 1190.4389, found 1190.4389.

2-Azido-3-*O*-benzyl-1-*O*-(*tert*-butyldimethylsilyl)-2-deoxy-β-D-glucopyranose (27). EtSH (8 mL, 103.52 mmol) and catalytic pTsOH were added to a solution of 2-azido-3-*O*-benzyl-4,6-*O*-benzylidene-1-*O*-(*tert*-butyldimethylsilyl)-2-deoxy-β-D-glucopyranose (**26**) (10.3 g, 20.70 mmol) in dry CH_2Cl_2. After being stirred for 3 h under argon, the mixture was neutralized with solid $NaHCO_3$, diluted with CH_2Cl_2, and washed with H_2O. The organic layer was dried over $MgSO_4$ and concentrated. The purification of the residue was carried out by column chromatography (hexane/ethyl acetate, 7:3) to yield **27** (7.25 g, 89%): ^1H NMR (500 MHz, $CDCl_3$) δ = 7.38−7.29 (m, 5H, aromatic), 4.95 (d, J = 11.5 Hz, 1H, CH_2Ph), 4.71 (d, J = 11.4 Hz, 1H, CH_2Ph), 4.57 (d, J = 7.6 Hz, 1H, H-1), 3.83 (dd, J = 11.8, 3.7 Hz, 1H, H-6a), 3.74 (dd, J = 11.8, 5.0 Hz, 1H, H-6b), 3.58 (dd, J = 9.7, 8.7 Hz, 1H, H-4), 3.32−3.27 (m, 2H, H-2, H-5), 3.21 (dd, J = 9.9, 8.7 Hz, 1H, H-3), 0.95 (s, 9H, TBS), 0.17 and 0.16 (2s, 6H, TBS) ppm; ^{13}C NMR (126 MHz, $CDCl_3$) δ = 138.2, 128.8, 128.3, 128.2, 97.4 (C-1), 82.5 (C-3), 75.3 (C-5), 75.1 (C_{Bn}), 70.6 (C-4), 68.4 (C-2), 62.7 (C-6), 25.7 (CH_{3TBS}), 18.1 (Cq_{TBS}), −4.2 (CH_{3TBS}), −5.0 (CH_{3TBS}) ppm; HRMS (ESI) m/z calcd for $C_{19}H_{31}N_3O_5Si$ $[M + Na]^+$ 432.1931, found 432.1913.

2-Azido-6-*O*-benzoyl-3-*O*-benzyl-1-*O*-(*tert*-butyldimethylsilyl)-2-deoxy-β-D-glucopyranose (28). BzCN (2.1 mL of a 0.9 M solution in dry CH_3CN) and catalytic Et_3N (3.5 mL) were added to a cooled (−40 °C) solution of **27** (7.25 g, 17.70 mmol) in dry CH_3CN (35 mL). After 4 h, additional BzCN was added (0.5 mL) until the starting material had disappeared. After 7 h, MeOH was added and the mixture was allowed to reach room temperature. The solvent was evaporated, and the residue was dissolved in MeOH and concentrated to dryness. Purification was carried out by column chromatography (hexane/ethyl acetate, 4:1) to afford the product **28** (8.18 g, 90%): ^1H NMR (500 MHz, $CDCl_3$) δ = 8.06−8.04 (m, 2H, aromatic), 7.59−7.56 (m, 1H, aromatic), 7.45−7.32 (m, 7H, aromatic), 5.96 (d, J = 11.4 Hz, 1H, CH_2Ph), 4.76 (d, J = 11.4 Hz, 1H, CH_2Ph), 4.61−4.58 (m, 2H, H-6a, H-1), 4.55 (dd, J = 12.0 Hz, 5.1 Hz, 1H, H-6b), 3.58−3.51 (m, 2H, H-4, H-5), 3.35 (dd, J = 7.6 Hz, 9.9 Hz, 1H, H-2), 3.25 (dd, J = 9.9, 8.0 Hz, 1H, H-3), 2.74 (br s, 1H, OH), 0.93 (s, 9H, CH_{3TBS}), 0.16 and 0.15 (2s, 6H, CH_{3TBS}) ppm; ^{13}C NMR (126 MHz, $CDCl_3$) δ = 166.9, 138.1, 133.3, 130.0, 129.9, 129.9, 129.8, 128.8, 128.8, 128.5, 128.5, 128.4, 128.3, 128.2, 97.5 (C-1), 82.2 (C-3), 75.3 (CH_2Ph), 74.0 (C-5), 70.4 (C-4), 68.3 (C-2), 64.0 (C-6), 25.7 (CH_{3TBS}), 18.1 (Cq_{TBS}), −4.2 (CH_{3TBS}), −5.1 (CH_{3TBS}) ppm; HRMS (ESI) m/z calcd for $C_{26}H_{35}N_3O_6Si$ $[M + Na]^+$ 536.2187, found 536.2214.

2-Azido-6-*O*-benzoyl-3-*O*-benzyl-1-*O*-(*tert*-butyldimethylsilyl)-2-deoxy-4-*O*-levulinoyl-β-D-glucopyranose (29). The reaction was carried out according to general procedure A using compound **28** (9.81 g, 19.09 mmol), levulinic acid (3.32 g, 28.6 mmol), EDC·HCl (5.5 g, 28.6 mmol), and a catalytic amount of DMAP (50 mg, 0.44 mmol) in dry CH_2Cl_2 (5 mL). The residue was purified by column chromatography (hexane/ethyl acetate, 9:1) to obtain compound **29** (9.96 g, 91%): ^1H NMR (500 MHz, $CDCl_3$) δ = 8.06−8.02 (m, 2H, aromatic), 7.58−7.53 (m, 1H, aromatic), 7.46−7.40 (m, 2H, aromatic), 7.38−7.26 (m, 5H, aromatic), 5.09−5.02 (m, 1H, H-4), 4.82 (d, J = 11.4 Hz, 1H, CH_2Ph), 4.67 (d, J = 11.4 Hz, 1H, CH_2Ph), 4.57 (m, 1H, H-1), 4.49 (dd, J = 12.1, 2.4 Hz, 1H, H-6), 4.28 (dd, J = 12.1, 6.8 Hz, 1H, H-6), 3.73−3.68 (m, 1H, H-5), 3.44−3.40 (m, 2H, H-2, H-3), 2.77−2.58 (m, 2H, CH_{2Lev}), 2.54−2.46 (m, 1H, CH_{2Lev}), 2.42−2.34 (m, 1H, CH_{2Lev}), 2.12 (s, 3H, CH_{3Lev}), 0.89 (s, 9H, TBS), 0.11 (s, 6H, TBS) ppm; ^{13}C NMR (126 MHz, $CDCl_3$) δ = 206.28, 171.80, 166.22, 137.96, 133.22, 129.94, 129.89, 128.56, 128.44, 128.12, 127.99, 97.34 (C-1), 80.01 (C-3), 75.01 (C_{Bn}), 72.43 (C-5), 70.72 (C-4), 68.46 (C-2), 63.36 (C-6), 37.95 (CH_{2Lev}), 29.83 (CH_{3Lev}), 27.99 (CH_{2Lev}), 25.66 (CH_{3TBS}), 18.06 (Cq_{TBS}), −4.21 (CH_{3TBS}), −5.14 (CH_{3TBS}) ppm; HRMS (ESI) m/z calcd for $C_{31}H_{41}N_3O_8Si$ $[M + Na]^+$ 634.2561, found 634.2565.

Methyl 1,2,4-tri-*O*-levulinoyl-3-*O*-benzyl-β-L-idopyranurate (32). Compound **30** (1.0 g, 3.35 mmol) was dissolved in dry CH_2Cl_2 at −25 °C, and EDC·HCl (3.2 g, 16.75 mmol), DMAP (1.64 g, 13.4 mmol), and levulinic acid (1.7 mL, 16.75 mmol) were added. The mixture was stirred overnight at −25 °C, warmed to room temperature, and stirred for 3 h. The reaction was diluted with CH_2Cl_2 and washed with 1 M HCl, water, saturated $NaHCO_3$ aq solution, and brine. The organic layer was dried over $MgSO_4$, filtered, and concentrated. The crude product was purified by column chromatography (hexane/ethyl acetate, 7:3), and syrupy compound **32** was obtained (1.58 g, 80%): $[\alpha]_D^{20}$ = +2.2 (c = 1, $CHCl_3$); ^1H NMR (500 MHz, $CDCl_3$) δ = 7.38−7.29 (m, 5H, aromatic), 6.05 (d, J = 1.7 Hz, H-1), 5.19−5.17 (m, 1H, H-4), 5.06−5.04 (m, 1H, H-2), 4.76 (d, J = 2.2 Hz, 1H, H-5), 4.72 (m, 2H, CH_2Ph), 3.94 (t, J = 3.0 Hz, 1H, H-3), 3.78 (s, 3H, CH_3), 2.86−2.49 (m, 12H, CH_{2Lev}), 2.17 (s, 6H, CH_{3Lev}), 2.16 (s, 3H, CH_{3Lev}) ppm; ^{13}C NMR (126 MHz, $CDCl_3$) δ = 206.38 (C═O, Lev), 206.28 (2 × C═O, Lev), 172.13, 171.91, 170.70, 167.34, 136.86, 128.65, 128.29, 127.90, 90.36 (C-1), 73.44 (C-3), 73.38 (C-5), 73.23 (C_{Bn}), 67.18 (C-4), 66.27 (C-2), 52.71 (CH_{3COOMe}), 37.83 (CH_{2Lev}), 37.77 (CH_{2Lev}), 37.69 (CH_{2Lev}), 29.93 (CH_{3Lev}), 29.88 (CH_{3Lev}), 29.84 (CH_{3Lev}), 27.97 (CH_{2Lev}), 27.93 (CH_{2Lev}), 27.89 (CH_{2Lev}) ppm; HRMS (ESI) m/z calcd for $C_{29}H_{36}O_{13}$ $[M + Na]^+$ 615.2054, found 615.2031.

Methyl 1,2,4-Tri-*O*-benzoyl-3-*O*-benzyl-β-L-idopyranurate (33). The triol **30** (2.08g, 6.97 mmol) was dissolved in dry CH_2Cl_2 at −40 °C, benzoyl chloride (6.1 mL, 53 mmol), pyridine (5.6 mL, 69.7 mmol), and DMAP (0.1 equiv) were added, and the reaction was stirred overnight. The residue was dissolved in CH_2Cl_2, and water was carefully added with cooling and vigorous stirring to decompose the excess benzoyl chloride. The product was extracted with CH_2Cl_2, 1 M aq HCl, a saturated aqueous solution of $NaHCO_3$, water, and brine, dried, and evaporated. The crude product was purified by column chromatography (hexane/ethyl acetate, 8:2) to obtain the perbenzoylated compound **33** (3.86g, 91%): $[\alpha]_D^{20}$ = −18.3 (c = 1, $CHCl_3$); ^1H NMR (500 MHz, $CDCl_3$) δ = 8.05−7.13 (m, 20H, aromatic), 6.49 (d, J = 1.3 Hz, H-1), 5.50−5.49 (m, 2H, H-2, H-4), 5.08 (d, J = 1.9 Hz, 1H, H-5), 4.93 (d, J = 11.6 Hz, 1H, CH_2Ph), 4.90 (d, J = 11.6 Hz, 1H, CH_2Ph), 4.37 (t, J = 3.0 Hz, 1H, H-3), 3.73 (s, 3H, CH_3) ppm; ^{13}C NMR (126 MHz, $CDCl_3$) δ = 167.70, 165.74, 165.66, 164.45, 136.89, 133.73, 133.63, 133.38, 130.34, 130.12, 129.22, 128.99, 128.82, 128.58, 128.48, 128.29, 128.10, 91.01 (C-1), 73.83, 73.79 (C-5, C-3), 73.50 (C_{Bn}), 68.09, 66.97 (C-2, C-4), 52.79 (CH_{3COOMe}) ppm; HRMS (ESI) m/z calcd for $C_{35}H_{30}O_{10}$ $[M + Na]^+$ 633.1736, found 633.1757.

Methyl (3-*O*-Benzyl-1,2-*O*-[(1-pent-4-enyloxy)benzylidene]-β-L-*threo*-hex-4-enopyranuronate (34). Compound **5** (0.020 g, 0.035 mmol) was dissolved in MeOH (0.5 mL) and treated with a catalytic amount of sodium methoxide (0.5 equiv) overnight. The crude reaction mixture was quenched with Amberlite IR120 (H^+), filtered, and concentrated to obtained compound **34** (14 mg, 90%): ^1H NMR (500 MHz, $CDCl_3$) δ = 7.54−7.31 (m, 10H, aromatic), 6.22 (dd, J = 1.1 Hz, 5.2 Hz, H-4), 5.96 (d, J = 4.0 Hz, H-1), 5.83−5.74 (m, 1H, CH_{pent}), 5.03−4.95 (m, 2H, CH_{2pent}), 4.80−4.76 (m, 1H, H-2), 4.67 (d, J = 11.7 Hz, 1H, CH_2Ph), 4.60 (d, J = 11.7 Hz, 1H, CH_2Ph), 4.27−4.25 (dd, J = 2.1, 5.2 Hz, 1H, H-3), 3.73 (s, 3H, CH_3), 3.52−3.43 (m, 2H, CH_{2pent}), 2.14−2.10 (m, 2H, CH_{2pent}), 1.71−1.66 (m, 2H, CH_{2pent}) ppm; ^{13}C NMR (126 MHz, $CDCl_3$) δ = 162.1, 143.6, 138.1 (CH_{pent}), 137.4, 137.1, 129.3, 128.7, 128.5, 128.3, 128.2, 128.1, 126.4, 122.3, 115.1 (CH_{2pent}), 108.1 (C-4), 96.8 (C-1), 71.2 (C_{Bn}), 67.1 (C-3), 63.2 (CH_{2pent}), 52.6 (CH_{3COOMe}), 30.3 (CH_{2pent}), 28.8 (CH_{2pent}) ppm.

Methyl 3-*O*-Benzyl-1,2-*O*-[(1-pent-4-enyloxy)benzylidene]-β-L-idopyranuronate (35). To a solution of compound **5** (105 mg, 0.182 mmol) in dry toluene (0.4 mL) was added trimethyltin hydroxide (18 mg, 0.201 mmol). The reaction mixture was stirred in the microwave at 100 °C until TLC indicated the disappearance of the starting material (1 h). The mixture was concentrated and dried under high vacuum. The residue was dissolved in dry MeOH, and a solution of 1 M NaOMe (0.27 mL) was added. The mixture was placed in the

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microwave at 60 °C and after 1 h 30 min was quenched with Amberlite IR-120 (H^+) until pH 7. The reaction crude was dissolved in dry CH_2Cl_2 (0.4 mL), and MeOH (1.1 mL), EDC·HCl (286 mg, 1.5 mmol), and DMAP (86 mg, 0.71 mmol) were added. After being stirred overnight, the reaction mixture was concentrated and purified by flash chromatography (hexane/ethyl acetate, 6:4, with 1% triethylamine) to obtain compound **35** (52 mg, 60%): ^{1}H NMR (500 MHz, MeOD) δ = 7.72−7.32 (m, 10H, aromatic), 5.80 (m, 1H, CH_{pent}), 5.63 (d, J = 2.8 Hz, 1H, H-1), 5.05−4.92 (m, 2H, CH_{2pent}), 4.74 (m, 2H, CH_2Ph), 4.50 (d, J = 1.7 Hz, 1H, H-5), 4.36−4.32 (m, 1H, H-2), 4.07−4.02 (m, 2H, H-3, H-4), 3.73 (s, 3H, CH_3), 3.44 (m, 2H, CH_{2pent}), 2.11 (m, 2H, CH_{2pent}), 1.70−1.59 (m, 2H, CH_{2pent}) ppm; ^{13}C NMR (126 MHz, MeOD) δ = 170.8, 139.2, 139.0, 138.8, 130.2, 129.6, 129.2, 129.1, 129.0, 127.8, 123.5, 115.4, 98.6 (C-1), 77.4 (C-2), 76.0 (C-3), 73.8 (C_{Bn}), 73.0 (C-5), 68.0 (C-4), 64.1 (CH_{2pent}), 52.6 (CH_{3COOMe}), 31.3 (CH_{2pent}), 29.9 (CH_{2pent}) ppm; HRMS (ESI) m/z calcd for $C_{26}H_{30}O_8$ $[M + Na]^+$ 493.1838, found 493.1832.

4-[(Phenylcarboxy)methyl]benzyl *N*-Benzyl-*N*-[5-((2-*O*-benzoyl-3-*O*-benzyl-6-*O*-(dimethylthexylsilyl)-4-*O*-levulinoyl-α-L-idopyranosyl)oxy)pentyl]carbamate (38). The reaction was carried out according to general procedure B using linker acceptor **36** (100 mg, 0.217 mmol), thiophenyl donor **8** (230 mg, 0.326 mmol), and (TMS)OTf (0.25 equiv, 2.83 μL, 0.03 mmol). The product was obtained as a colorless syrup (183 mg, 80%): ^{1}H NMR (500 MHz, $CDCl_3$) δ = 8.10−8.04 (m, 4H, aromatic), 7.59−7.52 (m, 2H, aromatic), 7.46−7.09 (m, 18H, aromatic), 5.35 (s, 2H, CH_2Ph_{Bz}), 5.20−5.13 (m, 3H, H-2, CH_2Ph_{Carba}), 5.04−5.00 (m, 1H, H-4), 4.95 (br s, 1H, H-1), 4.81−4.75 (m, 1H, CH_2Ph), 4.70 (d, J = 11.8 Hz, 1H, CH_2Ph), 4.47 (d, J = 14.1 Hz, 2H, CH_2PhN), 4.36−4.29 (m, 1H, H-5), 3.89−3.86 (m, 1H, H-3), 3.80−3.67 (m, 3H, H-6, $OCH_{2Linker}$), 3.46−3.34 (m, 1H, $OCH_{2Linker}$), 3.25−3.11 (m, 2H, $NCH_{2Linker}$), 2.68−2.53 (m, 3H, CH_{2Lev}), 2.50−2.42 (m, 1H, CH_{2Lev}), 2.08 (s, 3H, CH_{3Lev}), 1.66−1.46 (m, 5H, $CH_{2Linker}$, CH_{thexyl}), 1.37−1.25 (m, 2H, $CH_{2Linker}$), 0.86 (d, J = 7.0 Hz, 6H, $CH_{3thexyl}$), 0.83 (s, 6H, $CH_{3thexyl}$), 0.11 (s, 3H, CH_3Si), 0.09 (s, 3H, CH_3Si) ppm; ^{13}C NMR (126 MHz, $CDCl_3$) δ = 206.0, 172.2, 166.5, 165.4, 156.2, 138.1, 137.1, 135.9, 135.8, 133.5, 133.2, 130.2, 129.9, 129.8, 128.7, 128.55, 128.5, 128.4, 128.3, 128.2, 127.9, 127.7, 127.6, 127.2, 98.1 (C-1), 73.5 (C-3), 72.3 (C_{Bn}), 68.5 (C-2), 67.9, 67.8 (C-4, $OCH_{2Linker}$), 66.9 (CH_2Ph_{Carba}), 66.6 (C-5), 66.5 (CH_2Ph_{Bz}), 61.8 (CH_{thexyl}), 50.4 (CH_2PhN), 46.4 ($NCH_{2Linker}$), 37.9 (CH_{2Lev}), 34.2 (CH_{thexyl}), 29.8 (CH_{3Lev}), 29.3 ($CH_{2Linker}$), 28.0 (CH_{2Lev}), 25.2 (Cq_{thexyl}), 23.6 ($CH_{2Linker}$), 20.4, 20.3, 18.7, 18.6 ($CH_{3thexyl}$), −3.4, −3.5 (CH_3Si) ppm; HRMS (ESI) m/z calcd for $C_{61}H_{75}NO_{13}Si$ $[M + Na]^+$ 1080.4900, found: 1080.4887.

4-[(Phenylcarboxy)methyl]benzyl *N*-Benzyl-*N*-[5-((2-*O*-benzoyl-3-*O*-benzyl-4-*O*-levulinoyl-6-*O*-(*p*-methoxyphenyl)-α-L-idopyranosyl)oxy)pentyl)carbamate (39). The reaction was carried out according to general procedure B using linker acceptor **36** (100 mg, 0.217 mmol), thiophenyl donor **11** (218 mg, 0.326 mmol), and (TMS)OTf (0.25 equiv, 2.83 μL, 0.03 mmol). The product was obtained as a colorless syrup (175 mg, 79%): ^{1}H NMR (500 MHz, $CDCl_3$) δ = 8.12−8.00 (m, 4H, aromatic), 7.60−7.52 (m, 2H, aromatic), 7.48−7.33 (m, 9H, aromatic), 7.30−7.10 (m, 9H, aromatic), 6.85−6.76 (m, 4H, $aromatic_{PMP}$), 5.34 (s, 2H, CH_2Ph_{Bz}), 5.21−5.12 (m, 3H, H-2, CH_2Ph_{Carba}), 5.09 (s, 1H, H-4), 4.98 (d, J = 9.1 Hz, 1H, H-1), 4.85−4.79 (m, 1H, CH_2Ph), 4.72−4.62 (m, 2H, H-5, CH_2Ph), 4.46 (d, J = 16.2 Hz, 2H, CH_2PhN), 4.11 (dd, J = 11.9, 4.7 Hz, 1H, H-6a), 4.02 (d, J = 4.0 Hz, 1H, H-6b), 3.87 (s, 1H, H-3), 3.80−3.74 (m, 4H, CH_{3PMP}, $OCH_{2Linker}$), 3.49−3.36 (m, 1H, $OCH_{2Linker}$), 3.21−3.15 (m, 2H, $NCH_{2Linker}$), 2.63−2.49 (m, 3H, CH_{2Lev}), 2.43−2.39 (m, 1H, CH_{2Lev}), 2.07 (s, 3H, CH_{3Lev}), 1.72−1.52 (m, 4H, $CH_{2Linker}$), 1.38−1.27 (m, 2H, $CH_{2Linker}$) ppm; ^{13}C NMR (126 MHz, $CDCl_3$) δ = 205.9, 172.1, 166.5, 165.1, 156.1, 154.1, 152.7, 133.2−127.1 ($C_{aromatic}$), 116.6−114.5 ($C_{aromaticPMP}$), 98.1 (C-1), 73.0 (C-3), 72.1 (C_{Bn}), 68.7 (C-4), 67.9 ($OCH_{2Linker}$), 67.7 (C-6), 67.5 (C-2), 66.7 (CH_2Ph_{Carba}), 66.4 (CH_2Ph_{Bz}), 64.5 (C-5), 54.7 (CH_{3PMP}), 50.4 (CH_2PhN), 46.2 ($NCH_{2Linker}$), 37.8 (CH_{2Lev}), 29.8 (CH_{3Lev}), 29.1−23.5 (CH_{2Lev}, $CH_{2Linker}$) ppm; HRMS (ESI) m/z calcd for $C_{60}H_{63}NO_{14}$ $[M + Na]^+$ 1044.4141, found 1044.4147.

4-[(Phenylcarboxy)methyl]benzyl *N*-Benzyl-*N*-[5-((2-*O*-benzoyl-3,6-di-*O*-benzyl-4-*O*-levulinoyl-α-L-idopyranosyl)oxy)-pentyl]carbamate (40). The reaction was carried out according to general procedure B using linker acceptor **36** (100 mg, 0.217 mmol) and thiophenyl donor **9** (213 mg, 0.326 mmol). NIS (1.5 equiv, 73 mg, 0.33 mmol) and (TMS)OTf (0.25 equiv, 9.8 μL, 0.054 mmol) were added at −20 °C. The product was obtained as a colorless syrup (179 mg, 82%): ^{1}H NMR (500 MHz, $CDCl_3$) δ = 8.09−8.05 (m, 4H, aromatic), 7.59−7.52 (m, 2H, aromatic), 7.49−7.11 (m, 23H, aromatic), 5.35 (s, 2H, CH_2Ph_{Bz}), 5.20−5.14 (m, 3H, H-2, CH_2Ph_{carba}), 5.04−5.01 (m, 1H, H-4), 4.98−4.93 (m, 1H, H-1), 4.83−4.76 (m, 1H, CH_2Ph), 4.68 (d, J = 11.8 Hz, 1H, CH_2Ph), 4.58 (d, J = 11.9 Hz, 1H, CH_2Ph), 4.54−4.49 (m, 2H, H-5, CH_2Ph), 4.46 (d, J = 15.0 Hz, 2H, CH_2PhN), 3.85−3.82 (m, 1H, H-3), 3.80−3.70 (m, 1H, $OCH_{2Linker}$), 3.65 (dd, J = 10.0, 6.7 Hz, 1H, H-6a), 3.60 (dd, J = 10.0, 5.6 Hz, H-6b), 3.47−3.36 (m, 1H, $OCH_{2Linker}$), 3.21−3.10 (m, 2H, $NCH_{2Linker}$), 2.63−2.49 (m, 3H, CH_{2Lev}), 2.43−2.39 (m, 1H, CH_{2Lev}), 2.07 (s, 3H, CH_{3Lev}), 1.67−1.42 (m, 4H, $CH_{2Linker}$), 1.36−1.28 (m, 2H, $CH_{2Linker}$) ppm; ^{13}C NMR (126 MHz, $CDCl_3$) δ = 206.1, 172.1, 166.5, 165.4, 156.8, 156.2, 138.2, 138.0, 137.2, 135.8, 133.5, 133.2, 130.2, 130.0, 129.9, 129.8, 129.8, 128.7, 128.6, 128.5, 128.5, 128.4, 128.4, 128.3, 128.2, 127.9, 127.9, 127.8, 127.7, 127.6, 127.4, 127.2, 98.2 (C-1), 73.5 (C_{Bn}), 73.3 (C-3), 72.2 (C_{Bn}), 69.2 (C-6), 68.0 ($OCH_{2Linker}$), 67.9 (C-2, C-4), 66.9 (CH_2Ph_{Carba}), 66.5 (CH_2Ph_{Bz}), 65.0 (C-5), 50.6, 50.3 (CH_2PhN), 47.4, 46.3 ($NCH_{2Linker}$), 37.9 (CH_{2Lev}), 29.8 (CH_{3Lev}), 29.3 ($CH_{2Linker}$), 28.0 (CH_{2Lev}), 27.6, 23.6 ($CH_{2Linker}$) ppm; MALDI-TOF: m/z calcd for $C_{60}H_{63}NO_{13}$ $[M + Na]^+$ 1028.42, found 1028.39; HRMS (ESI) m/z calcd for $C_{60}H_{63}NO_{13}$ $[M + Na]^+$ 1028.4192, found 1028.4195.

4-[(Phenylcarboxy)methyl]benzyl *N*-Benzyl-*N*-[5-((2-*O*-benzoyl-3-*O*-benzyl-4-*O*-levulinoyl-6-*O*-(*p*-methoxybenzyl)-α-L-idopyranosyl)oxy)pentyl]carbamate (41). The reaction was carried out according to general procedure B using linker acceptor **36** (100 mg, 0.217 mmol) and thiophenyl donor **12** (222 mg, 0.326 mmol). NIS (1.5 equiv, 73 mg, 0.33 mmol) and (TMS)OTf (0.25 equiv, 2.83 μL, 0.03 mmol) were added at −20 °C. The product was obtained as a colorless syrup (157 mg, 70%): ^{1}H NMR (500 MHz, $CDCl_3$) δ = 8.11−8.03 (m, 4H, aromatic), 7.58−7.53 (m, 2H, aromatic), 7.46−7.21 (m, 20H, aromatic), 6.85 (d, J = 8.1 Hz, 2H, $aromatic_{PMB}$), 5.35 (s, 2H, CH_2Ph_{Bz}), 5.22−5.11 (m, 3H, H-2, CH_2Ph_{Carba}), 5.03−5.00 (m, 1H, H-4), 4.94 (d, J = 6.2 Hz, 1H, H-1), 4.79 (d, J = 11.6 Hz, 1H, CH_2Ph), 4.67 (d, J = 11.8 Hz, 1H, CH_2Ph), 4.53−4.39 (m, 5H,CH_{2PMB}, CH_2PhN, H-5), 3.82 (td, J = 2.8, 1.3 Hz, 1H, H-3), 3.77 (s, 3H, CH_{3PMB}), 3.76−3.69 (m, 1H, $OCH_{2Linker}$), 3.64−3.54 (m, 2H, H-6), 3.47−3.35 (m, 1H, $OCH_{2Linker}$), 3.24−3.08 (m, 2H, $NCH_{2Linker}$), 2.66−2.43 (m, 3H, CH_{2Lev}), 2.42−2.32 (m, 1H, CH_{2Lev}), 2.08 (s, 3H, CH_{3Lev}), 1.58−1.45 (m, 4H, $CH_{2Linker}$), 1.36−1.25 (m, 2H, $CH_{2Linker}$) ppm; ^{13}C NMR (126 MHz, $CDCl_3$) δ = 206.1, 172.1, 166.5, 165.4, 159.3, 156.8, 156.2, 138.0, 137.1, 135.9, 133.5, 133.2, 130.3, 130.2, 130.0, 129.9, 129.8, 129.5, 128.8, 128.7, 128.6, 128.5, 128.4, 128.4, 128.2, 128.2, 127.9, 127.7, 127.6, 127.4, 127.2, 113.8 ($C_{aromaticPMB}$), 98.2 (C-1), 73.2, 72.1, 68.7, 68.0, 67.9, 66.9, 66.5, 64.9, 55.4 (CH_{3PMB}), 50.7, 50.3 (CH_2PhN), 47.4, 46.4 ($NCH_{2Linker}$), 37.9 (CH_{2Lev}), 29.8 (CH_{3Lev}), 29.3 ($CH_{2Linker}$), 28.0 (CH_{2Lev}), 27.6 ($CH_{2Linker}$), 23.6 ($CH_{2Linker}$) ppm; HRMS (ESI) m/z calcd for $C_{61}H_{65}NO_{14}$ $[M + NH_4]^+$ 1053.4743 found 1053.4774.

4-[(Phenylcarboxy)methyl]benzyl *N*-Benzyl-*N*-[5-((2-*O*-benzoyl-3-*O*-benzyl-4-*O*-levulinoyl-6-*O*-[(triisopropylsiloxy)-methyl]-α-L-idopyranosyl)oxy)pentyl]carbamate (42). The reaction was carried out according to general procedure B using linker acceptor **36** (75 mg, 0.16 mmol) and thiophenyl donor **13** (100 mg, 0.133 mmol). NIS (45 mg, 0.20 mmol) and TfOH (1.1 μL, 0.013 mmol) were added at −20 °C. The residue was purified by preparative TLC (30% ethyl acetate/hexane) to afford **42** (131 mg, 91%): ^{1}H NMR (500 MHz, $CDCl_3$) δ = 8.12−8.02 (m, 4H, aromatic), 7.61−7.10 (m, 20H, aromatic), 5.39−5.32 (s, 2H, CH_2Ph_{Bz}), 5.23−5.12 (m, 3H, H-2, CH_2Ph_{Carba}), 5.02−4.97 (m, 1H, H-4), 4.96−4.88 (m, 3H, H-1, CH_{2TOM}), 4.83−4.74 (m, 1H, CH_2Ph), 4.68 (d, J = 11.8 Hz, 1H, CH_2Ph), 4.53−4.40 (m, 3H, H-5, CH_2PhN), 3.87−3.80 (m, 1H, H-3), 3.80−3.68 (m, 3H, H-6, $OCH_{2Linker}$), 3.46−3.33 (m, 1H, $OCH_{2Linker}$),

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3.28−3.10 (m, 2H, $NCH_{2Linker}$), 2.69−2.52 (m, 3H, CH_{2Lev}), 2.51−2.40 (m, 1H, CH_{2Lev}), 2.08 (s, 3H, CH_{3Lev}), 1.70−1.40 (m, 4H, $CH_{2Linker}$), 1.40−1.20 (m, 2H, $CH_{2Linker}$), 1.15−1.00 (m, 21H, $6CH_{3TOM}$, $3CH_{TOM}$) ppm; ^{13}C NMR (126 MHz, $CDCl_3$) δ = 205.8, 172.0, 166.4, 165.3, 156.6, 137.9, 137.8, 137.0, 136.9, 135.7, 133.4, 133.0, 130.1, 129.8, 129.7, 128.5, 128.4, 128.4, 128.3, 128.2, 128.0, 127.7, 127.6, 127.5, 127.4, 127.3, 127.2, 127.1, 97.9 (C-1), 90.1 (CH_{2TOM}), 73.0 (C-3), 71.9 (C_{Bn}), 67.8 (C-4, $CH_{2Linker}$), 67.7 (C-2), 66.7 (CH_2Ph_{Carba}), 66.6 (C-6), 66.3 (CH_2Ph_{Bz}), 64.8 (C-5), 50.5, 50.2 (CH_2PhN), 47.2, 46.2 ($NCH_{2Linker}$), 37.8 (CH_{2Lev}), 29.6 (CH_{3Lev}), 29.3, 29.1 ($CH_{2Linker}$), 27.9 (CH_{2Lev}), 27.5 ($CH_{2Linker}$), 23.4 ($CH_{2Linker}$), 17.8 (CH_{3TOM}), 11.9 (CH_{TOM}) ppm; LRMS (MALDI-TOF) m/z calcd for $C_{63}H_{79}NO_{14}Si$ $[M + Na]^+$ 1125.37, found 1125.00; HRMS (ESI) m/z calcd for $C_{63}H_{79}NO_{14}Si$ $[M + Na]^+$ 1124.5167, found 1124.5140.

4-[(Phenylcarboxy)methyl]benzyl *N*-Benzyl-*N*-[5-((6-*O*-acetyl-2-*O*-benzoyl-3-*O*-benzyl-4-*O*-levulinoyl-α-L-idopyranosyl)oxy)pentyl]carbamate (43). The reaction was carried out according to general procedure B using linker acceptor **36** (20 mg, 0.041 mmol) and thiophenyl donor **10** (30 mg, 0.050 mmol). NIS (17 mg, 0.075 mmol) and TfOH (41 μL of a 0.1 M solution in CH_2Cl_2) were added at −20 °C. The residue was purified by preparative TLC (40% ethyl acetate/hexane) to afford **43** (21 mg, 52%): ^{1}H NMR (500 MHz, $CDCl_3$) δ = 8.14−8.02 (m, 4H, aromatic), 7.62−7.08 (m, 20H, aromatic), 5.35 (s, 2H, CH_2Ph_{Bz}), 5.24−5.08 (m, 3H, H-2, CH_2Ph_{Carba}), 4.99−4.90 (m, 2H, H-1, H-4), 4.87−4.74 (m, 1H, CH_2Ph), 4.67 (d, J = 11.6 Hz, 1H, CH_2Ph), 4.56−4.40 (m, 3H, H-5, CH_2PhN), 4.30−4.08 (m, 2H, H-6), 3.86−3.80 (m, 1H, H-3), 3.79−3.64 (m, 1H, $OCH_{2Linker}$), 3.50−3.34 (m, 1H, $OCH_{2Linker}$), 3.30−3.10 (m, 2H, $NCH_{2Linker}$), 2.70−2.51 (m, 3H, CH_{2Lev}), 2.50−2.39 (m, 1H, CH_{2Lev}), 2.09 (s, 3H, CH_{3Lev}), 2.07−1.99 (m, 3H, CH_{3Ac}), 1.70−1.45 (m, 4H, $CH_{2Linker}$), 1.40−1.20 (m, 2H, $CH_{2Linker}$) ppm; ^{13}C NMR (126 MHz, $CDCl_3$) δ = 205.8, 172.0, 170.5, 166.4, 165.2, 156.6, 137.9, 137.7, 137.0, 136.9, 135.7, 133.5, 133.0, 130.1, 129.8, 129.7, 129.5, 128.5, 128.4, 128.2, 128.0, 127.7, 127.5, 127.3, 127.2, 127.1, 97.9 (C-1), 72.8 (C-3), 72.1 (C_{Bn}), 67.9 ($CH_{2Linker}$), 67.4 (C-4), 67.2 (C-2), 66.7 (CH_2Ph_{carba}), 66.3 (CH_2Ph_{Bz}), 63.7 (C-5), 62.8 (C-6), 50.5, 50.2 (CH_2PhN), 47.2, 46.2 ($NCH_{2Linker}$), 37.8 (CH_{2Lev}), 29.6 (CH_{3Lev}), 29.1 ($CH_{2Linker}$), 27.9 (CH_{2Lev}), 27.5 ($CH_{2Linker}$), 23.5 ($CH_{2Linker}$), 20.7 (CH_{3Ac}) ppm; LRMS (MALDI-TOF) m/z calcd for $C_{55}H_{59}NO_{14}$ $[M + Na]^+$ 981.04, found 980.85. HRMS (ESI) m/z calcd for $C_{55}H_{59}NO_{14}$ $[M + Na]^+$ 980.3828, found 980.3755.

4-[(Phenylcarboxy)methyl]benzyl *N*-Benzyl-*N*-[5-(methyl ((2-*O*-benzoyl-3-*O*-benzyl-4-*O*-levulinoyl-α-L-idopyranosyl)oxy)-uronate)pentyl]carbamate (44). The glycosylation was carried out according to general procedure B using the following conditions:

(1) Linker acceptor **36** (35 mg, 0.076 mmol) and thiophenyl donor **1** (55 mg, 0.093 mmol). NIS (21 mg, 0.093 mmol) and (TMS)OTf (1.6 μL, 0.008 mmol) were added at 0 °C. The crude product was purified by column chromatography using hexane/ethyl acetate (7:3) to obtain compound **44** as a white solid (0.040 g, 55%).

(2) Linker acceptor **36** (30 mg, 0.051 mmol) and thiophenyl donor **1** (19 mg, 0.042 mmol). NIS (28 mg, 0.123 mmol) and (TMS)OTf (1.5 μL, 0.008 mmol) were added at room temperature. The crude product was purified by column chromatography using hexane/ethyl acetate (7:3) to obtain compound **44** (0.026 g, 66%).

(3) Linker acceptor **36** (35 mg, 0.073 mmol) and *n*-pentenyl donor **6** (50 mg, 0.088 mmol). NIS (49 mg, 0.219 mmol) and (TMS)OTf (2.3 μL, 0.015 mmol) were added at 0 °C. The crude product was purified by column chromatography using hexane: ethyl acetate (7:3) to obtain compound **44** (0.047 g, 69%).

Data for **44**: ^{1}H NMR (500 MHz, $CDCl_3$) δ = 8.07−7.19 (m, 24H, aromatic), 5.35 (s, 2H, CH_2Ph_{Bz}), 5.26 (m, 1H, H-4), 5.19−5.15 (m, 3H, H-2, CH_2Ph_{Carba}), 5.12 (br s, 1H, H-1), 4.93 (br s, 1H, H-5), 4.82 (d, J =11.8 Hz, 1H, CH_2Ph), 4.72 (d, J = 11.8 Hz, 1H, CH_2Ph), 4.47 (d, J = 12.4 Hz, 2H, CH_2PhN), 3.89 (m, 1H, H-3), 3.79 (s, 3H, CH_3), 3.79−3.73 (m, 1H, $OCH_{2Linker}$), 3.50−3.40 (m, 1H, $OCH_{2Linker}$), 3.25−3.12 (m, 2H, $NCH_{2Linker}$), 2.63−2.61 (m, 2H, CH_{2Lev}), 2.50−2.37 (m, 2H, CH_{2Lev}), 2.08 (s, 3H, CH_{3Lev}), 1.60−1.51 (m, 4H, $CH_{2Linker}$), 1.30−1.26 (m, 2H, $CH_{2Linker}$) ppm; ^{13}C NMR (126 MHz, $CDCl_3$) δ = 205.9, 171.6, 169.1, 166.5, 165.3, 156.7, 156.2, 138.0, 137.6, 137.1, 137.0, 135.9, 133.6, 133.1, 130.2, 129.9, 129.8, 129.6, 128.6, 128.5, 128.4, 128.1, 127.8, 127.6, 127.3, 127.2, 98.5 (C-1), 72.5 (C-3), 72.2 (CH_2Ph), 68.7 ($OCH_{2Linker}$), 68.2 (C-4), 67.0 (C-2), 66.9 (CH_2Ph_{Carba}), 66.5 (CH_2Ph_{Bz}), 66.0 (C-5), 52.6 (CH_{3COOMe}), 50.6, 50.3 (CH_2PhN), 47.3, 46.3 ($NCH_{2Linker}$), 37.8 (CH_{2Lev}), 29.7 (CH_{3Lev}), 29.2 ($CH_{2Linker}$), 28.0 (CH_{2Lev}), 27.62 ($CH_{2Linker}$), 23.4 ($CH_{2Linker}$) ppm; HRMS (ESI) m/z calcd for $C_{54}H_{57}NO_{14}$ $[M + Na]^+$ 966.3677, found 966.3693.

4-[(Phenylcarboxy)methyl]benzyl *N*-Benzyl-*N*-[5-((4-*O*-(2-azido-3-*O*-benzyl-6-*O*-benzoyl-2-deoxy-4-*O*-levulinoyl-α-D-glucopyranosyl)-3-*O*-benzyl-2-*O*-benzoyl-6-*O*-(*tert*-butyldiphenylsilyl)-α-L-idopyranosyl)oxy)pentyl]carbamate (45). Compound **39** (125 mg, 108 mmol) was delevulinated with hydrazine acetate (19 mg, 216 μmol) in CH_2Cl_2/MeOH (2.7 mL/0.27 mL). When TLC (hexane/ethyl acetate, 2:1) showed complete conversion, the reaction mixture was diluted with dichloromethane (50 mL) and washed twice with 1 M HCl (100 mL), saturated $NaHCO_3$ aq solution (100 mL), and brine (100 mL). The organic phase was dried over $MgSO_4$ and concentrated under reduced pressure. The crude product was purified by column chromatography (hexane/ethyl acetate, 8:2) to obtain 4-[(phenylcarboxy)methyl]benzyl *N*-benzyl-*N*-[5-((4-*O*-(2-azido-3-*O*-benzyl-6-*O*-benzoyl-2-deoxy-α-D-glucopyranosyl)-3-*O*-benzyl-2-*O*-benzoyl-6-*O*-(*tert*-butyldiphenylsilyl)-α-L-idopyranosyl)oxy)-pentyl]carbamate (97 mg, 85%): ^{1}H NMR (500 MHz, $CDCl_3$) δ = 8.13−7.20 (m, 34H, aromatic), 5.40 (s, 2H, CH_2Ph_{Bz}), 5.31−5.22 (m, 3H, H-2, CH_2Ph_{Carba}), 5.02 (s, 1H, H-1), 4.89 (d, J = 11.8 Hz, 1H, CH_2Ph), 4.69 (d, J = 11.8 Hz, 1H, CH_2Ph), 4.54−4.51 (m, 2H, CH_2PhN), 4.39 (m, 1H, H-5), 3.99−3.98 (m, 2H, H-6), 3.90−3.83 (m, 3H, H-3, H-4, $OCH_{2Linker}$), 3.46−3.44 (m, 1H, $OCH_{2Linker}$), 3.28−3.21 (m, 2H, $NCH_{2Linker}$), 2.79 (br s, 1H, OH), 1.68−1.56 (m, 4H, $CH_{2Linker}$), 1.37−1.29 (m, 2H, $CH_{2Linker}$), 1.13 (9H, s, $(CH_3)_3C$) ppm. The glycosylation reaction was carried out according to general procedure C using idose acceptor (20 mg, 0.019 mmol), azidoglucose donor **16** (17 mg, 0.026 mmol), and (TMS)OTf (0.25 equiv, 47 μL of a 0.1 M solution). The reaction mixture was purified by column chromatography using hexane/ethyl acetate (8:2) to obtain compound **45** (12 mg, 42%): ^{1}H NMR (500 MHz, $CDCl_3$) δ = 8.14−8.06 (m, 5H, aromatic), 7.97−7.94 (m, 2H, aromatic), 7.75−7.68 (m, 4H, aromatic), 7.51−7.13 (m, 34H, aromatic), 5.35 (s, 2H, CH_2Ph_{Bz}), 5.20−5.12 (m, 3H, H-2, CH_2Ph_{Carba}), 5.09−5.03 (m, 2H, H-1, H-4′), 4.87 (d, J = 11.5 Hz, 1H, CH_2Ph), 4.81 (d, J = 3.7 Hz, 1H, H-1′), 4.74 (d, J = 11.5 Hz, CH_2Ph), 4.48−4.42 (m, 2H, CH_2PhN), 4.35−4.28 (m, 3H, H-5, CH_2Ph), 4.18−4.14 (m, 1H, H-3), 4.07 (d, J = 3.0 Hz, 2H, H-6′), 3.96−3.87 (m, 3H, H-6, H-5′), 3.84−3.80 (m, 1H, H-4), 3.75−3.69 (m, 1H, $OCH_{2Linker}$), 3.66 (t, J = 9.7 Hz, 1H, H-3′), 3.35 (dd, J = 10.0, 3.8 Hz, 2H, H-2′, $OCH_{2Linker}$), 3.21−3.10 (m, 2H, $NCH_{2Linker}$), 2.64−2.60 (m, 2H, CH_{2Lev}), 2.47−2.40 (m, 1H, CH_{2Lev}), 2.36−2.30 (m, 1H, CH_{2Lev}), 2.09 (s, 3H, CH_{3Lev}), 1.59−1.46 (m, 4H, $CH_{2Linker}$), 1.30−1.19 (m, 2H, $CH_{2Linker}$), 1.06 (s, 9H, $(CH_3)_3C$) ppm. ^{13}C NMR (126 MHz, $CDCl_3$) δ = 206.0, 171.4, 166.5, 166.1, 165.8, 156.7, 156.2, 138.0, 137.5, 135.9, 135.8, 135.7, 133.3, 133.2, 133.1, 133.0, 130.2, 130.1, 130.0, 130.0, 129.9, 129.8, 128.7, 128.6, 128.5, 128.4, 128.4, 128.3, 128.1, 128.0, 127.9, 127.8, 127.2, 98.5 (C-1), 97.6 (C-1′), 78.6 (C-3′), 75.1 (C_{Bn}), 74.3 (C-4), 73.5 (C-3), 72.6 (C_{Bn}), 70.4 (C-4′), 69.9 (C-2), 68.9 (C-5′), 68.5 (C-5), 67.9 ($OCH_{2Linker}$), 66.9 (CH_2Ph_{Carba}), 66.5 (CH_2Ph_{Bz}), 63.7 (C-6), 63.6 (C-2′), 62.3 (C-6′), 50.6, 50.3 (CH_2PhN), 47.4, 46.4 ($NCH_{2Linker}$), 37.9 (CH_{2Lev}), 37.8 (CH_{2Lev}), 29.8 (CH_{3Lev}), 29.5 ($CH_{2Linker}$), 29.2 ($CH_{2Linker}$), 28.2, 28.1, 27.9 (CH_{2Lev}), 27.7 ($CH_{2Linker}$), 27.0, 26.9 (CH_{3Lev}), 23.6, 23.5 ($CH_{2Linker}$), 19.3, 19.2 $(CH_3)_3$) ppm; HRMS (ESI) m/z calcd for $C_{89}H_{94}N_4O_{18}Si$ $[M + Na]^+$ 1558.6261, found 1558.6282.

4-[(Phenylcarboxy)methyl]benzyl *N*-Benzyl-*N*-[5-((4-*O*-(2-azido-3-*O*-benzyl-6-*O*-benzoyl-2-deoxy-4-*O*-levulinoyl-α-D-glucopyranosyl)-3-*O*-benzyl-2-*O*-benzoyl-6-*O*-(dimethylthexylsilyl)-α-L-idopyranosyl)oxy)pentyl]carbamate (46). Compound **38** (150 mg, 142 μmol) was delevulinated with hydrazine acetate (20

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mg, 212 μmol) in CH_2Cl_2/methanol (4:1, 2.5 mL). When TLC (hexane/ethyl acetate, 2:1) showed complete conversion, the mixture was concentrated, and the residue was purified by column chromatography (0−30% ethyl acetate/hexane) to afford the glycosyl acceptor (125 mg, 91%): ^{1}H NMR (500 MHz, $CDCl_3$) δ = 8.11−7.98 (m, 4H, aromatic), 7.61−7.52 (m, 2H, aromatic), 7.48−7.11 (m, 18H, aromatic), 5.36 (s, 2H, CH_2Ph_{Bz}), 5.25−5.12 (m, 3H, H-2, CH_2Ph_{Carba}), 4.95−4.90 (br s, 1H, H-1), 4.82 (d, *J* = 11.7 Hz, 1H, CH_2Ph), 4.63 (d, *J* = 11.7 Hz, 1H, CH_2Ph), 4.48 (d, *J* = 11.3 Hz, 2H, CH_2PhN), 4.28−4.20 (m, 1H, H-5), 3.88−3.80 (m, 4H, H-6, H-3, H-4), 3.80−3.72 (m, 1H, $OCH_{2Linker}$), 3.48−3.35 (m, 1H, $OCH_{2Linker}$), 3.28−3.13 (m, 2H, $NCH_{2Linker}$), 2.86 (br s, 1H, OH), 1.68−1.47 (m, 5H, CH_{thexyl}, $CH_{2Linker}$), 1.42−1.24 (m, 2H, $CH_{2Linker}$), 0.89 (d, *J* = 7.0 Hz, 6H, $CH_{3thexyl}$), 0.87 (s, 6H, $CH_{3thexyl}$), 0.14, 0.13 (2s, CH_3Si) ppm; ^{13}C (126 MHz, $CDCl_3$) δ = 166.5, 165.3, 156.7, 156.2, 138.1, 137.0, 135.8, 133.5, 133.2, 130.2, 129.9, 129.8, 129.6, 128.6, 128.5, 128.5, 128.4, 128.4, 128.1, 128.1, 127.9, 127.8, 127.7, 127.4, 127.2, 98.5, 75.6, 71.9, 68.5, 67.9, 67.6, 66.9, 66.5, 63.2, 50.7, 50.4, 47.4, 46.3, 34.2, 29.3, 28.1, 27.7, 25.2, 23.6, 20.4, 18.7, 18.6 ppm; HRMS (ESI) *m*/*z* calcd for $C_{56}H_{73}N_2O_{11}Si$ $[M + NH_4]^+$ 977.4978, found 977.5001. The glycosylation reaction was carried out according to general procedure C using idose acceptor (46 mg, 48 μmol), azidoglucose donor **16** (43 mg, 67 μmol), and (TMS)OTf (0.25 equiv, 2.16 μL, 12 μmol). The product **46** was obtained as a colorless syrup (35 mg, 51%): ^{1}H NMR (500 MHz, $CDCl_3$) δ = 8.17−7.97 (m, 6H, aromatic), 7.62−7.05 (m, 28H, aromatic), 5.35 (s, 2H, CH_2Ph_{Bz}), 5.25−5.10 (m, 4H, H-2, H-4′, CH_2Ph_{Carba}), 5.04 (br s, 1H, H-1), 4.89 (d, *J* = 3.7 Hz, 1H, H-1′), 4.85−4.79 (m, 1H, CH_2Ph), 4.72 (d, *J* = 11.6 Hz, 1H, CH_2Ph), 4.51−4.34 (m, 5H, CH_2PhN, CH_2Ph, H-6a′), 4.30 (dd, *J* = 12.3, 4.6 Hz, 1H, H-6b′), 4.25−4.10 (m, 3H, H-3, H-5, H-5′), 3.94−3.84 (m, 3H, H-6, H-4), 3.83−3.70 (m, H-3′, $OCH_{2Linker}$), 3.47−3.33 (m, 2H, H-2′, $OCH_{2Linker}$), 3.26−3.06 (m, 2H, OCH_2−Linker), 2.77−2.58 (m, 2H, CH_{2Lev}), 2.57−2.46 (m, 1H, CH_{2Lev}), 2.43−2.31 (m, 1H, CH_{2Lev}), 2.11 (s, 3H, CH_{3Lev}), 1.68−1.46 (m, 5H, CH_{thexyl}, $CH_{2Linker}$), 1.34−1.23 (m, 2H, $CH_{2Linker}$), 0.97−0.81 (m, 12H, $CH_{3thexyl}$), 0.16 (s, 3H, CH_3−Si), 0.14 (s, 3H, CH_3−Si) ppm; ^{13}C NMR (126 MHz, $CDCl_3$) δ = 207.1, 206.1, 171.6, 166.5, 166.2, 165.7, 156.8, 156.2, 138.0, 137.5, 137.1, 135.9, 133.3, 133.3, 133.2, 130.2, 130.1, 129.9, 129.8, 128.7, 128.5, 128.4, 128.4, 128.1, 128.0, 127.9, 127.8, 127.4, 127.2, 98.5 (C-1), 97.5 (C-1′), 78.3 (C-3′), 75.1 (C_{Bn}), 73.7 (C-4), 73.6 (C-3), 72.7 (C_{Bn}), 70.7, 70.3 (C-2, C-4′), 69.0, 68.9 (C-5, C-5′), 68.1 ($OCH_{2Linker}$), 66.9 (CH_2Ph_{Bz}), 66.5 (CH_2Ph_{Bz}), 63.6 (C-2′), 62.7 (C-6′), 62.5 (C-6), 50.7, 50.4 (CH_2PhN), 47.4, 46.4 ($NCH_{2Linker}$), 37.9 (CH_{2Lev}), 34.2 (CH_{thexyl}), 29.8 (CH_{3Lev}), 29.3, 28.2 ($CH_{2Linker}$), 28.0, 27.7 (CH_{2Lev}, $CH_{2Linker}$), 25.3 (Cq_{thexyl}), 23.6 ($CH_{2Linker}$), 20.5, 20.5, 18.7 ($CH_{3thexyl}$), −3.1, −3.3 (CH_3−Si) ppm; HRMS (ESI) *m*/*z* calcd for $C_{81}H_{94}N_4O_{18}Si$ $[M + Na]^+$ 1461.6225, found 1461.6293.

4-[(Phenylcarboxy)methyl]benzyl *N*-Benzyl-*N*-[5-((4-*O*-(2-azido-3-*O*-benzyl-6-*O*-benzoyl-2-deoxy-4-*O*-levulinoyl-α-D-glucopyranosyl)-3-*O*-benzyl-2-*O*-benzoyl-6-*O*-(*p*-methoxyphenyl)-α-L-idopyranosyl)oxy)pentyl]carbamate (47). Compound **39** (110 mg, 107 μmol) was delevulinated with hydrazine acetate (20 mg, 212 μmol) in CH_2Cl_2/methanol (4:1, 2.5 mL). When TLC (hexane/ethyl acetate, 2:1) showed complete conversion, the reaction mixture was diluted with dichloromethane (50 mL) and washed twice with 1 M HCl (100 mL), saturated $NaHCO_3$ solution (100 mL), and brine (100 mL). The organic phase was dried over $MgSO_4$, concentrated under reduced pressure, and purified by column chromatography (0−30% ethyl acetate/hexane) to afford the glycosyl acceptor (88 mg, 90%): ^{1}H NMR (500 MHz, $CDCl_3$) δ = 8.20−7.97 (m, 4H, aromatic), 7.70−7.52 (m, 2H, aromatic), 7.49−7.11 (m, 18H, aromatic), 6.91−6.76 (m, 4H, $aromatic_{PMP}$), 5.34 (s, 2H, CH_2Ph_{Bz}), 5.25 (s, 1H, H-2), 5.16 (d, *J* = 18.7 Hz, 2H, CH_2Ph_{Carba}), 4.96 (d, *J* = 7.6 Hz, 1H, H-1), 4.84 (dd, *J* = 11.3, 2.4 Hz, 1H, CH_2Ph), 4.62 (d, *J* = 13.2 Hz, 2H, CH_2Ph, H-5), 4.47 (d, *J* = 12.8 Hz, 2H, CH_2PhN), 4.16 (s, 2H, H-6), 3.92−3.76 (m, 3H, H-4, H-3, $OCH_{2Linker}$), 3.75 (s, 3H, CH_{3PMP}), 3.55−3.36 (m, 1H, $OCH_{2Linker}$), 3.30−3.11 (m, 2H, $NCH_{2Linker}$), 2.61 (br s, 1H, OH), 1.59 (s, 4H, $CH_{2Linker}$), 1.33 (s, 2H $CH_{2Linker}$) ppm; ^{13}C NMR (126 MHz, $CDCl_3$) δ = 166.6, 165.2, 154.2, 153.0, 138.1, 138.1, 138.0, 137.2, 137.1, 135.9, 133.8, 133.2, 130.2, 129.9, 129.5, 129.4, 128.8, 128.7, 128.6, 128.5, 128.5, 128.4, 128.2, 127.9, 127.8, 127.4, 127.4, 127.2, 115.7, 114.8, 98.5, 75.1, 71.9, 68.6, 68.1, 68.0, 67.6, 66.9, 66.5, 66.0, 55.8, 50.3, 47.3, 46.3, 29.3, 23.6 ppm; HRMS (ESI) *m*/*z* calcd for $C_{55}H_{57}NO_{12}$ $[M + NH_4]^+$ 941.4219, found 941.4220. The glycosylation reaction was carried out according to general procedure C using idose acceptor (60 mg, 65 μmol), azidoglucose donor **16** (58 mg, 91 μmol), and (TMS)OTf (0.25 equiv, 2.89 μL, 16 μmol). The product **47** was obtained as a colorless syrup (60 mg, 65%): ^{1}H NMR (500 MHz, $CDCl_3$) δ = 8.23−8.16 (m, 2H, aromatic), 8.08−8.05 (m, 2H, aromatic), 8.03−7.97 (m, 2H, aromatic), 7.63−7.10 (m, 28H, aromatic), 6.92−6.75 (m, 4H, $aromatic_{PMP}$), 5.35 (s, 2H, CH_2Ph_{Bz}), 5.25−5.11 (m, 3H, CH_2Ph_{Carba}, H-2), 5.05−4.99 (m, 2H, H-1, H-4′), 4.88 (d, *J* = 11.8 Hz, CH_2Ph), 4.82 (d, *J* = 3.2 Hz, 1H, H-1′), 4.69 (d, *J* = 12.6 Hz, CH_2Ph), 4.65−4.58 (m, 1H, H-5), 4.47 (d, *J* = 12.2 Hz, 2H, CH_2PhN), 4.35−4.23 (m, 4H, H-6a′, H-6a, CH_2Ph), 4.19−4.04 (m, 3H, H-6b′, H-6b, H-3), 4.08−4.03 (m, 1H, H-5′), 3.97−3.93 (m, 1H, H-4), 3.81−3.68 (m, 5H, H-3′, $OCH_{2Linker}$, CH_{3PMP}), 3.47−3.38 (m, 1H, $OCH_{2Linker}$), 3.34 (dd, *J* = 10.1, 3.5 Hz, 1H, H-2′), 3.25−3.11 (m, 2H, $NCH_{2Linker}$), 2.67−2.53 (m, 2H, CH_{2Lev}), 2.40−2.23 (m, 2H, CH_{2Lev}), 2.09 (s, 3H, CH_{3Lev}), 1.59−1.46 (m, 4H, $CH_{2Linker}$), 1.37−1.24 (m, 2H, $CH_{2Linker}$) ppm; ^{13}C NMR (126 MHz, $CDCl_3$) δ = 206.1, 171.6, 166.5, 166.2, 165.9, 154.3, 152.4, 137.8, 137.5, 135.9, 133.5, 133.2, 133.2, 130.2, 130.0, 129.9, 129.9, 129.8, 128.7, 128.5, 128.4, 128.2, 128.1, 128.0, 127.9, 127.2, 115.4, 114.9 ($C_{aromaticPMP}$), 98.6 (C-1), 96.7 (C-1′), 78.3 (C-3′), 75.1 (C_{Bn}), 72.2 (C_{Bn}), 72.1 (C-4), 71.8 (C-3), 70.6 (C-4′), 69.0 (C-2, C-5′), 68.1 ($OCH_{2Linker}$), 66.9 (CH_2Ph_{Carba}), 66.7 (CH_2Ph_{Bz}), 66.5 (C-6), 65.4 (C-5), 63.5 (C-2′), 62.6 (C-6′), 55.8 (CH_{3PMP}), 50.7, 50.4 (CH_2PhN), 47.4, 46.4 ($NCH_{2Linker}$), 37.9 (CH_{2Lev}), 29.8 (CH_{3Lev}), 28.1, 27.9 ($CH_{2Linker}$), 27.7 (CH_{2Lev}), 23.6 ($CH_{2Linker}$) ppm; HRMS (ESI) *m*/*z* calcd for $C_{80}H_{82}N_4O_{19}$ $[M + NH_4]^+$ 1420.5912, found 1420.5927.

4-[(Phenylcarboxy)methyl]benzyl *N*-Benzyl-*N*-[5-((4-*O*-(2-azido-3-*O*-benzyl-6-*O*-benzoyl-2-deoxy-4-*O*-levulinoyl-α-D-glucopyranosyl)-2-*O*-benzoyl-3,6-di-*O*-benzyl-α-L-idopyranosyl)oxy)pentyl]carbamate (48). Compound **40** (145 mg, 0.144 mmol) was delevulinated with hydrazine acetate (20 mg, 212 μmol) in CH_2Cl_2/MeOH (4:1, 2.5 mL). When TLC (hexane/ethyl acetate, 2:1) showed complete conversion, the mixture was concentrated, and the residue was purified by column chromatography (0−30% ethyl acetate/hexane) to afford the glycosyl acceptor (119 mg, 91%): ^{1}H NMR (500 MHz, $CDCl_3$) δ = 8.09−8.05 (m, 2H, aromatic), 8.04−7.98 (m, 2H, aromatic), 7.61−7.52 (m, 2H, aromatic), 7.48−7.11 (m, 23H, aromatic), 5.35 (s, 2H, CH_2Ph_{Bz}), 5.22 (br s, 1H, H-2), 5.20−5.13 (d, *J* = 16.2 Hz, 2H, CH_2Ph_{Carba}), 4.95 (d, *J* = 6.7 Hz, 1H, H-1), 4.86−4.78 (m, 1H, CH_2Ph), 4.61 (m, 3H, CH_2Ph), 4.51−4.35 (m, 3H, CH_2PhN, H-5), 3.85−3.70 (m, 4H, H-3, H-4, H-6), 3.46−3.36 (m, 1H, $OCH_{2Linker}$), 3.27−3.09 (m, 2H, $NCH_{2Linker}$), 2.77 (br s, 1H, OH), 1.67−1.47 (m, 4H, $CH_{2Linker}$), 1.38−1.28 (m, 2H, $CH_{2Linker}$) ppm; ^{13}C NMR (126 MHz, $CDCl_3$) δ = 166.5, 165.3, 138.2, 138.0, 135.9, 133.6, 133.2, 130.2, 129.9, 129.8, 129.6, 128.7, 128.7, 128.6, 128.5, 128.4, 128.2, 127.9, 127.8, 127.8, 127.8, 127.7, 127.4, 127.2, 98.6, 75.3, 73.7, 71.9, 70.5, 68.2, 68.1, 66.9, 66.5, 66.3, 53.6, 50.7, 50.3, 47.4, 46.4, 29.3, 28.1, 27.6, 23.6 ppm; HRMS (ESI) *m*/*z* calcd for $C_{55}H_{57}NO_{11}$ $[M + NH_4]^+$ 925.4270, found 925.4261. The glycosylation reaction was carried out according to general procedure C using idose acceptor (57 mg, 63 μmol), azidoglucose donor **16** (58 mg, 88 μmol), and (TMS)OTf (0.25 equiv, 2.84 μL, 16 μmol). The product was obtained as a colorless syrup (45 mg, 51%): ^{1}H NMR (500 MHz, $CDCl_3$) δ = 8.17−8.13 (m, 2H, aromatic), 8.09−8.05 (m, 2H, aromatic), 8.02−7.98 (m, 2H, aromatic), 7.59−7.09 (m, 33H, aromatic), 5.35 (s, 2H, CH_2Ph_{Bz}), 5.23−5.12 (m, 3H, CH_2Ph_{Carba}, H-2), 5.08 (t, *J* = 9.7 Hz, 1H, H-4′), 5.00 (br s, 1H, H-1), 4.85 (d, *J* = 11.7 Hz, 1H, CH_2Ph), 4.81 (d, *J* = 3.6 Hz, 1H, H-1′), 4.69 (d, *J* = 11.7 Hz, 1H, CH_2Ph), 4.52 (s, 2H, CH_2Ph), 4.49−4.39 (m, 3H, CH_2PhN, H-5), 4.34 (dd, *J* = 12.2, 2.4 Hz, 1H, H-6a′), 4.31 (d, *J* = 11.0 Hz, 1H, CH_2Ph), 4.27 (d, *J* = 10.9 Hz, 1H, CH_2Ph), 4.21 (dd, *J* = 12.3, 5.0 Hz, 1H, H-6b′), 4.17−4.08 (m, 2H, H-5, H-3), 3.82−3.79 (m, 1H, H-4), 3.79−3.70 (m, 4H, H-6ab, H-3′, $OCH_{2Linker}$), 3.46−3.38 (m, 1H, $OCH_{2Linker}$), 3.36 (dd, *J* =

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10.1, 3.5 Hz, 1H, H-2′), 3.25−3.10 (m, 2H, $NCH_{2Linker}$), 2.74−2.57 (m, 2H, CH_{2Lev}), 2.53−2.45 (m, 1H, CH_{2Lev}), 2.41−2.32 (m, 1H, CH_{2Lev}), 2.12 (s, 3H, CH_{3Lev}), 1.58−1.43 (m, 4H, $CH_{2Linker}$), 1.35−1.24 (m, 2H, $CH_{2Linker}$) ppm; ^{13}C NMR (126 MHz, $CDCl_3$) δ = 206.1, 171.6, 166.5, 166.2, 165.8, 156.8, 156.2, 138.1, 138.0, 137.9, 137.5, 137.0, 135.9, 133.4, 133.2, 130.2, 130.1, 130.0, 129.9, 129.8, 128.7, 128.5, 128.4, 128.4, 128.2, 128.0, 128.0, 128.0, 127.8, 127.8, 127.6, 127.4, 127.2, 98.5 (C-1), 97.7 (C-1′), 78.4 (C-3′), 75.0 (C_{Bn}), 74.1 (C-4), 73.4 (C_{Bn}), 72.8 (C-3), 72.4 (C_{Bn}), 70.7 (C-4′), 69.4 (C-6), 69.3 (C-2), 69.1 (C-5), 68.1 ($OCH_{2Linker}$), 66.9 (CH_2Ph_{Carba}), 66.5 (CH_2Ph_{Bz}), 66.3 (C-5), 63.6 (C-2′), 62.7 (C-6′), 50.7, 50.4 (CH_2PhN), 47.4, 46.3 ($NCH_{2Linker}$), 37.9 (CH_{2Lev}), 29.8 (CH_{3Lev}), 29.3 ($CH_{2Linker}$), 28.0 (CH_{2Lev}), 27.7, 23.6 ($CH_{2Linker}$) ppm; HRMS (ESI) m/z calcd for $C_{80}H_{82}N_4O_{18}$ $[M + Na]^+$ 1409.5516, found 1409.5499.

4-[(Phenylcarboxy)methyl]benzyl *N*-Benzyl-*N*-[5-((4-*O*-(2-azido-3-*O*-benzyl-6-*O*-benzoyl-2-deoxy-4-*O*-levulinoyl-α-D-glucopyranosyl)-3-*O*-benzyl-2-*O*-benzoyl-6-*O*-(*p*-methoxybenzyl)-α-L-idopyranosyl)oxy)pentyl]carbamate (49). Compound **41** (110 mg, 106 μmol) was delevulinated with hydrazine acetate (20 mg, 212 μmol) in CH_2Cl_2/methanol (4:1, 2.5 mL). When TLC (hexane/ethyl acetate, 2:1) showed complete conversion, the reaction mixture was diluted with dichloromethane (50 mL) and washed twice with 1 M HCl (100 mL), saturated $NaHCO_3$ solution (100 mL), and brine (100 mL). The organic phase was dried over $MgSO_4$, concentrated under reduced pressure, and purified by column chromatography (0−30% ethyl acetate/hexane) to afford the glycosyl acceptor (85 mg, 86%): ^1H NMR (500 MHz, $CDCl_3$) δ = 8.10−8.04 (m, 2H, aromatic), 8.03−7.99 (m, 2H, aromatic), 7.65−7.50 (m, 2H, aromatic), 7.49−7.36 (m, 7H, aromatic), 7.36−7.19 (m, 12H, aromatic), 7.14 (d, J = 7.1 Hz, 1H, aromatic), 6.86 (d, J = 8.0 Hz, 2H, $aromatic_{PMB}$), 5.34 (s, 2H, CH_2Ph_{Bz}), 5.21 (s, 1H, H-2), 5.17 (d, J = 17.2 Hz, 2H, CH_2Ph_{Carba}), 4.94 (d, J = 6.3 Hz, 1H, H-1), 4.81 (d, J = 11.0 Hz, 1H, CH_2Ph), 4.60 (d, J = 11.7 Hz, 1H, CH_2Ph), 4.52 (s, 2H, CH_{2PMB}), 4.50−4.43 (m, 2H, CH_2PhN), 4.39 (br s, 1H, H-5), 3.82−3.75 (m, 5H, H-3, H-4, CH_{3PMB}), 3.71 (d, J = 5.4 Hz, 2H, H-6ab), 3.41 (d, J = 19.8 Hz, 1H, $OCH_{2Linker}$), 3.28−3.10 (m, 2H, $NCH_{2Linker}$), 2.80 (br s, 1H, OH), 1.54 (m, 4H, $CH_{2Linker}$), 1.32 (m, 2H, $CH_{2Linker}$) ppm; ^{13}C NMR (126 MHz, $CDCl_3$) δ = 166.6, 165.3, 159.4, 138.1, 133.6, 133.2, 130.2, 130.2, 129.9, 129.8, 129.4, 128.7, 128.5, 128.4, 128.2, 127.9, 127.8, 127.8, 127.5, 127.3, 113.9, 98.6, 75.4, 73.4, 71.9, 70.2, 68.2, 68.0, 66.9, 66.5, 66.3, 55.4, 50.7, 50.4, 47.4, 46.3, 29.3, 23.6 ppm; HRMS (ESI) m/z calcd for $C_{56}H_{59}NO_{12}$ $[M + NH_4]^+$ 960.3929, found 960.3662. The glycosylation reaction was carried out according to general procedure C using idose acceptor (62 mg, 66 μmol), azidoglucose donor **16** (59 mg, 92 μmol), and (TMS)OTf (0.25 equiv, 3.0 μL, 16.5 μmol). The product was obtained as a colorless syrup (57 mg, 61%): ^1H NMR (500 MHz, $CDCl_3$) δ = 8.21−8.13 (m, 2H, aromatic), 8.09−8.05 (m, 2H, aromatic), 8.03−7.99 (m, 2H, aromatic), 6.84 (d, J = 8.3 Hz, 1H, $aromatic_{PMB}$), 5.35 (s, 2H, CH_2Ph_{Bz}), 5.22−5.13 (m, 3H, H-2, CH_2Ph_{Carba}), 5.09 (t, J = 9.7 Hz, 1H, H-4′), 4.99 (br s, 1H, H-1), 4.85 (d, J = 12.0 Hz, 1H, CH_2Ph), 4.82 (d, J = 3.6 Hz, 1H, H-1′), 4.69 (d, J = 11.7 Hz, 1H, CH_2Ph), 4.50−4.38 (m, 5H, CH_2PhN, H-5, CH_{2PMB}), 4.38−4.21 (m, 4H, H-6ab′, CH_2Ph), 4.17−4.13 (m, 1H, H-5′), 4.11 (t, J = 3.3 Hz, 1H, H-3), 3.82−3.79 (m, 1H, H-4), 3.78−3.68 (m, 7H, H-6ab, H-3′, CH_{3PMB}, $OCH_{2Linker}$), 3.47−3.38 (m, 1H, $OCH_{2Linker}$), 3.36 (dd, J = 10.1, 3.6 Hz, 1H, H-2′), 3.26−3.10 (m, 2H, $NCH_{2Linker}$), 2.75−2.59 (m, 2H, CH_{2Lev}), 2.56−2.47 (m, 1H, CH_{2Lev}), 2.42−2.33 (m, 1H, CH_{2Lev}), 2.12 (s, 3H, CH_{3Lev}), 1.60−1.45 (m, 4H, $CH_{2Linker}$), 1.37−1.28 (m, 2H, $CH_{2Linker}$) ppm; ^{13}C NMR (126 MHz, $CDCl_3$) δ = 206.2, 171.6, 166.5, 166.2, 165.8, 159.3, 156.7, 156.2, 137.9, 137.5, 135.9, 133.4, 133.2, 130.2, 130.0, 130.0, 129.9, 129.8, 129.8, 129.3, 128.7, 128.6, 128.6, 128.5, 128.4, 128.4, 128.2, 128.0, 128.0, 127.8, 127.4, 127.2, 113.9 ($C_{aromaticPMB}$), 98.5 (C-1), 97.6 (C-1′), 78.4 (C-3′), 75.0 (C_{Bn}), 74.0 (C-4), 73.1 (CH_{2PMB}), 72.8 (C-3), 72.3 (C_{Bn}), 70.7 (C-4′), 69.3 (C-6, C-2), 69.1 (C-5′), 68.0 ($OCH_{2Linker}$), 66.9 (CH_2Ph_{Carba}), 66.5 (CH_2Ph_{Bz}), 66.3 (C-5), 63.6 (C-2′), 62.7 (C-6′), 55.3 (CH_{3PMB}), 50.6, 50.4 (CH_2PhN), 47.4, 46.3 ($NCH_{2Linker}$), 37.9 (CH_{2Lev}), 29.8 (CH_{3Lev}), 29.2 ($CH_{2Linker}$), 28.0 (CH_{2Lev}), 27.6, 23.5 ($CH_{2Linker}$) ppm; HRMS (ESI) m/z calcd for $C_{81}H_{84}N_4O_{19}$ $[M + NH_4]^+$ 1439.5622, found 1439.5650.

4-[(Phenylcarboxy)methyl]benzyl *N*-Benzyl-*N*-[5-((4-*O*-(2-azido-3-*O*-benzyl-6-*O*-benzoyl-2-deoxy-4-*O*-levulinoyl-α-D-glucopyranosyl)-2-*O*-benzoyl-3-*O*-benzyl-6-*O*-[(triisopropylsiloxy)methyl]-α-L-idopyranosyl)oxy)pentyl]carbamate (50). Compound **42** (31 mg, 0.028 mmol) was delevulinated with hydrazine acetate (5 mg, 57 μmol) in CH_2Cl_2/MeOH (9:1, 1 mL). When TLC (hexane/ethyl acetate, 2:1) showed complete conversion (2 h), the mixture was concentrated, and the residue was purified by column chromatography (0−30% ethyl acetate/hexane) to afford the idose acceptor (20 mg, 71%): ^1H NMR (500 MHz, $CDCl_3$) δ = 8.12−7.98 (m, 4H), 7.64−7.10 (m, 20H), 5.35 (s, 2H), 5.24−5.12 (m, 3H), 4.99−4.88 (m, 3H), 4.85−4.77 (m, 1H), 4.62 (d, J = 11.8 Hz, 1H), 4.53−4.43 (m, 2H), 4.43−4.36 (m, 1H), 3.91−3.68 (m, 5H), 3.47−3.32 (m, 1H), 3.28−3.10 (m, 2H), 2.75 (d, J = 8.6 Hz, 1H), 1.72−1.44 (m, 4H), 1.40−1.20 (m, 2H), 1.17−0.99 (m, 21H) ppm; ^{13}C NMR (126 MHz, $CDCl_3$) δ = 166.4, 165.2, 156.1, 137.9, 137.1, 136.9, 135.7, 133.4, 133.0, 130.1, 129.8, 129.7, 129.4, 128.5, 128.4, 128.3, 128.2, 128.0, 127.8, 127.6, 127.5, 127.3, 127.2, 127.1, 98.5, 90.1, 75.2, 71.7, 68.1, 67.8, 67.6, 66.7, 66.4, 66.1, 50.5, 50.2, 47.2, 46.2, 29.7, 29.1, 28.0, 27.5, 23.4, 17.8, 12.0 ppm; HRMS (ESI) m/z calcd for $C_{58}H_{73}NO_{12}Si$ $[M + Na]^+$ 1026.4800, found 1026.4738. The glycosylation reaction was carried out according to general procedure C using idose acceptor (20 mg, 20 μmol), azidoglucose donor **16** (16 mg, 24 μmol), and (TMS)OTf (0.10 equiv, 20 μL of a 0.1 M solution). The residue was purified by preparative TLC (40% ethyl acetate/hexane) to afford **50** (15 mg, 50%): ^1H NMR (500 MHz, $CDCl_3$) δ = 8.20−7.96 (m, 6H, aromatic), 7.64−7.06 (m, 28H, aromatic), 5.35 (s, 2H, CH_2Ph_{Bz}), 5.24−5.08 (m, 4H, CH_2Ph_{Carba}, H-2, H-4′), 5.00−4.89 (m, 3H, CH_{2TOM}, H-1), 4.85−4.80 (m, 2H, H-1′, CH_2Ph), 4.69 (d, J = 11.6 Hz, 1H, CH_2Ph), 4.52−4.43 (m, 2H, CH_2PhN), 4.42−4.21 (m, 2H, H-6′, H-5, CH_2Ph), 4.19−4.13 (m, 1H, H-5′), 4.11−4.06 (m, 1H, H-3), 3.94−3.80 (m, 3H, H-6, H-4), 3.80−3.68 (m, 2H, H-3′, $OCH_{2Linker}$), 3.45−3.32 (m, 2H, H-2′, $OCH_{2Linker}$), 3.28−3.06 (m, 2H, $NCH_{2Linker}$), 2.73−2.57 (m, 2H, CH_{2Lev}), 2.55−2.43 (m, 1H, CH_{2Lev}), 2.42−2.28 (m, 1H, CH_{2Lev}), 2.10 (s, 3H, CH_{3Lev}), 1.75−1.40 (m, 4H, $CH_{2Linker}$), 1.40−1.20 (m, 2H, $CH_{2Linker}$), 1.15−0.95 (m, 21H, $6CH_{3TOM}$, $3CH_{TOM}$) ppm; ^{13}C NMR (126 MHz, $CDCl_3$) δ = 205.9, 171.4, 166.4, 166.1, 165.7, 156.6, 156.1, 137.8, 137.4, 136.9, 135.7, 133.2, 133.0, 130.1, 129.8, 129.8, 129.7, 128.5, 128.4, 128.3, 128.2, 128.0, 127.9, 127.8, 127.7, 127.2, 127.1, 98.3 (C-1), 97.3 (C-1′), 89.9 (CH_{2TOM}), 78.3 (C-3′), 74.9 (C_{Bn}), 73.5 (C-4), 72.8 (C-3), 72.2 (C_{Bn}), 70.5, 69.4 (C-2, C-4′), 68.9 (C-5′), 67.9 ($OCH_{2Linker}$), 66.7 (CH_2Ph_{Carba}), 66.4 (C-5, CH_2Ph_{Bz}), 66.3 (C-6), 63.4 (C-2′), 62.5 (C-6′), 50.5, 50.2 (CH_2PhN), 47.2, 46.2 ($NCH_{2Linker}$), 37.8 (CH_{2Lev}), 29.7 (CH_{3Lev}), 29.1−27.5 (CH_{2Lev}, $CH_{2Linker}$), 23.4 ($CH_{2Linker}$), 18.0, 17.8 (CH_{3TOM}), 11.9 (CH_{TOM}) ppm; LRMS (MALDI-TOF) m/z calcd for $C_{83}H_{98}N_4O_{19}Si$ $[M + Na]^+$ 1506.65, found 1505.33; HRMS (ESI) m/z calcd for $C_{83}H_{98}N_4O_{19}Si$ $[M + Na]^+$ 1506.6487, found 1506.6523.

4-[(Phenylcarboxy)methyl]benzyl *N*-Benzyl-*N*-[5-((4-*O*-(2-azido-3-*O*-benzyl-6-*O*-benzoyl-2-deoxy-4-*O*-levulinoyl-α-D-glucopyranosyl)-6-*O*-acetyl-2-*O*-benzoyl-3-*O*-benzyl-α-L-idopyranosyl)oxy)pentyl]carbamate (51). Compound **43** (31 mg, 0.028 mmol) was delevulinated with hydrazine acetate (5 mg, 57 μmol) in CH_2Cl_2/MeOH (9:1, 1 mL). When TLC (hexane/ethyl acetate, 2:1) showed complete conversion (2 h), the mixture was concentrated, and the residue was purified by column chromatography (0−40% EtOAc/hexanes) to afford the idose acceptor (20 mg, 91%): ^1H NMR (500 MHz, $CDCl_3$) δ = 8.12−7.94 (m, 4H, aromatic), 7.66−7.06 (m, 20H, aromatic), 5.35 (s, 2H, CH_2Ph_{Bz}), 5.26−5.10 (m, 3H, H-2, CH_2Ph_{Carba}), 4.96−4.88 (d, J = 7.2 Hz, 1H, H-1), 4.87−4.78 (m, 1H, CH_2Ph), 4.62 (d, J = 11.8 Hz, 1H, CH_2Ph), 4.54−4.39 (m, 3H, H-5, CH_2PhN), 4.35 (dd, J = 11.6, 7.5 Hz, 1H, H-6a), 4.27 (dd, J = 11.3, 4.5 Hz, 1H, H-6b), 3.85−3.79 (br s, 1H, H-3), 3.79−3.65 (m, 2H, H-4, $OCH_{2Linker}$), 3.51−3.34 (m, 1H, $OCH_{2Linker}$), 3.31−3.10 (m, 2H, $NCH_{2Linker}$), 2.08−2.00 (m, 3H, CH_{3Ac}), 1.72−1.44 (m, 4H, $CH_{2Linker}$), 1.44−1.16 (m, 2H, $CH_{2Linker}$) ppm; ^{13}C NMR (125 MHz, $CDCl_3$) δ = 170.7, 166.4, 165.0, 156.1, 137.9, 137.7, 137.0,

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136.9, 135.8, 133.6, 133.0, 130.1, 129.7, 129.1, 128.6, 128.5, 128.4, 128.3, 128.3, 128.0, 127.8, 127.6, 127.3, 127.3, 127.1, 98.2 (C-1), 74.8 (C-3), 71.8 (C_{Bn}), 67.9 ($OCH_{2Linker}$), 67.7 (C-2), 67.1 (C-4), 66.8 (CH_2Ph_{Carba}), 66.3 (CH_2Ph_{Bz}), 65.4 (C-5), 63.7 (C-6), 50.5, 50.2 (CH_2PhN), 47.2, 46.2 ($NCH_{2Linker}$), 29.1, 28.0, 27.5, 23.5 ($CH_{2Linker}$), 20.8 (CH_{3Ac}) ppm. The glycosylation reaction was carried out according to general procedure C using idose acceptor (123 mg, 128 μmol), azidoglucose donor **16** (115 mg, 179 μmol), and (TMS)OTf (7 μL, 32 μmol). The product **51** was obtained as an unseparable α/β mixture (25 mg, 15%). Selected characteristic NMR signals: ^{1}H NMR (500 MHz, $CDCl_3$) δ = 5.29−5.25 (m, 3H, H-1′α, CH_2Ph_{Carba}), 4.98 (d, J = 3.5 Hz, 1H, H-1β), 4.91−4.83 (m, 2H, H-1α), 4.67−4.57 (m, 3 H, H-1′β, CH_2−Bn) ppm; ^{13}C NMR (126 MHz, $CDCl_3$) δ = 97.9 (C-1α, $J_{C,H}$ = 171 Hz), 97.8 (C-1α, $J_{C,H}$ = 172 Hz), 96.3 (C-1′β, $J_{C,H}$ = 162 Hz), 91.9 (C-1′α, $J_{C,H}$ = 171 Hz) ppm; HRMS (ESI) *m*/*z* calcd for $C_{75}H_{78}N_4O_{19}$ [M + Na]$^+$ 1361.5152, found 1361.5129.

4-[(Phenylcarboxy)methyl]benzyl *N*-Benzyl-*N*-[5-(methyl ((4-*O*-(2-azido-3-*O*-benzyl-6-*O*-benzoyl-2-deoxy-4-*O*-levulinoyl-α-D-glucopyranosyl)-2-*O*-benzoyl-3-*O*-benzyl-α-L-idopyranosyl)-oxy)uronate)pentyl]carbamate (52). To a solution of **44** (169 mg, 0.179 mmol) in dry CH_2Cl_2/MeOH (4.5 mL/0.45 mL) was added hydrazine acetate (24 mg, 0.27 mmol). The reaction was stirred for 3 h at room temperature. The crude product was purified by column chromatography (hexane/ethyl acetate, 6:4) to afford the idose acceptor (0.128 g, 85%): ^{1}H NMR (500 MHz, $CDCl_3$) δ = 8.12−7.95 (m, 4H, aromatic), 7.64−7.10 (m, 20H, aromatic), 5.35 (s, 2H, CH_2Ph_{Bz}), 5.24−5.16 (m, 3H, H-2, CH_2Ph_{Carba}), 5.12 (br s, 1H, H-1), 4.90 (m, 1H, H-5), 4.82 (m, 1H, CH_2Ph), 4.64 (d, 1H, J = 11.6 Hz, CH_2Ph), 4.47 (d, J = 11.4 Hz, 2H, CH_2PhN), 4.11 (br s, 1H, H-4), 3.87 (m, 1H, H-3), 3.82 (s, 3H, CH_{3COOMe}), 3.78−3.73 (m, 1H, $CH_{2Linker}$), 3.51−3.45 (m, 1H, $CH_{2Linker}$), 3.24−3.14 (m, 2H, $CH_{2Linker}$), 2.80 (br s, 1H, OH), 1.64−1.43 (m, 4H, $CH_{2Linker}$), 1.40−1.24 (m, 2H, $CH_{2Linker}$) ppm; ^{13}C NMR (125 MHz, $CDCl_3$) δ = 170.0, 166.3, 165.0, 156.0, 137.8, 137.5, 137.0, 135.7, 133.7, 133.0, 130.0, 129.7, 129.7, 129.0, 128.6, 128.5, 128.4, 128.3, 128.0, 127.8, 127.7, 127.6, 127.3, 127.2, 127.1, 98.7, 74.3, 71.8, 68.7, 68.2, 67.6, 67.3, 66.8, 66.3, 52.4, 50.5, 50.2, 47.2, 46.1, 29.7, 29.1, 27.9, 27.5, 23.3 ppm. The glycosylation reaction was carried out according to general procedure C using the following conditions:

(1) Idose acceptor (56 mg, 0.066 mmol) and azidoglucose donor **17** (62 mg, 0.093 mmol). (TMS)OTf (0.6 μL, 0.003 mmol) was added at 0 °C. The reaction mixture was purified by flash column chromatography using hexane/ethyl acetate (8:2) to obtain compound **52** (26 mg, 32%).

(2) Acceptor (40 mg, 0.047 mmol) and azidoglucose donor **16** (42 mg, 0.065 mmol). (TMS)OTf (0.6 μL, 0.003 mmol) was added at 0 °C. The reaction mixture was purified by flash column chromatography using toluene/ethyl acetate (6:4) followed by preparative TLC eluting with hexane/ethyl acetate (6:4) to obtain compound **52** (30 mg, 48%).

Data for **52**: ^{1}H NMR (500 MHz, $CDCl_3$) δ = 8.22−8.17 (m, 2H, aromatic), 8.10−8.02 (m, 4H, aromatic), 7.11 (m, 28H, aromatic), 5.36 (s, 2H, CH_2Ph_{Bz}), 5.21−5.13 (m, 5H, H-1, H-2, H-4′, CH_2Ph_{Carba}), 4.92 (d, J = 11.5 Hz, CH_2Ph), 4.87 (s, 1H, H-5), 4.77 (d, J = 3.10 Hz, H-1′), 4.74 (d, J = 11.5 Hz, CH_2Ph), 4.61 (dd, J = 1.8, 12.4 Hz, 1H, H-6′a), 4.48 (d, J = 10.8 Hz, 2H, CH_2PhN), 4.28 (dd, J = 1.8, 12.4 Hz, 1H, H-6′b), 4.20−4.17 (m, 1H, H-4), 4.16−4.11 (m, 1H, H-5′), 4.09−4.06 (m, 2H, H-3, CH_2Ph), 4.02 (d, J = 10.8 Hz, 1H, CH_2Ph), 3.82 (s, 3H, CH_{3COOMe}), 3.77−3.74 (m, 1H, $OCH_{2Linker}$), 3.62 (t, J = 9.4 Hz, H-3′), 3.55−3.42 (m, 1H, $OCH_{2Linker}$), 3.30 (dd, J = 3.1, 9.9 Hz, H-2′), 3.24−3.17 (m, 2H, $NCH_{2Linker}$), 2.69−2.66 (m, 2H, CH_{2Lev}), 2.57−2.42 (m, 2H, CH_{2Lev}), 2.11 (s, 3H, CH_{3Lev}), 1.63−1.51 (m, 4H, $CH_{2Linker}$), 1.31−1.27 (m, 2H, $CH_{2Linker}$) ppm; ^{13}C NMR (126 MHz, $CDCl_3$) δ = 205.9, 171.1, 169.6, 166.3, 166.0, 165.4, 156.5, 156.0, 137.8, 137.7, 137.4, 137.2, 136.9, 136.9, 136.8, 136.8, 135.6, 133.3, 132.9, 132.9, 130.0, 129.8, 129.6, 129.6, 128.5, 128.4, 128.3, 128.2, 127.9, 127.8, 127.7, 127.6, 127.2, 127.2, 127.0, 99.1 (C-1), 99.0 (C-1), 77.9 (C-3′), 76.0 (C-4), 74.5 (CH_2Ph), 72.6 (C-3), 72.2 (CH_2Ph), 70.1 (C-4′), 68.9 (C-5′), 68.5 ($CH_{2Linker}$), 68.0 (C-2), 67.2 (C-5), 66.7 (CH_2Ph_{Carba}), 66.3 (CH_2Ph_{Bz}), 63.2 (C-2′), 61.8 (C-6), 52.3 (CH_{3COOMe}), 50.4, 50.1 (CH_2PhN), 47.1, 46.0 ($NCH_{2Linker}$), 37.7 ($CH_{2Linker}$), 29.6 (CH_{3Lev}), 29.0 ($CH_{2Linker}$), 27.8 (CH_{2Lev}, $CH_{2Linker}$), 27.4 ($CH_{2Linker}$), 23.3 ($CH_{2Linker}$) ppm; LRMS (MALDI-TOF) *m*/*z* calcd for $C_{74}H_{76}N_4O_{19}$ [M + Na]$^+$ 1348.40, found 1347.78; HRMS (ESI) *m*/*z* calcd for $C_{74}H_{76}N_4O_{19}$ [M + Na]$^+$ 1347.5001, found 1347.4924.

***tert*-Butyldimethylsilyl 2-Azido-3,6-di-*O*-benzyl-2-deoxy-D-glucopyranose (53).** To a solution of *tert*-butyldimethylsilyl 2-azido-3-*O*-benzyl-4,6-*O*-benzylidene-2-deoxy-β-D-glucopyranoside (**26**) (180 mg, 0.36 mmol) in dry CH_2Cl_2 were added triethylsilane (0.34 mL, 2.17 mmol) and trifluoroacetic acid (0.17 mL, 2.17 mmol) at 0 °C. After 2 h, the reaction was quenched with triethylamine and concentrated. The crude product was purified by column chromatography (hexane/ethyl acetate, 9:1 to 7:3) to obtain **53** (140 mg, 78%): ^{1}H NMR (500 MHz, $CDCl_3$) δ = 7.44−7.28 (m, 10H, aromatic), 4.93 (d, J = 11.4 Hz, 1H, CH_2Ph), 4.78 (d, J = 11.4 Hz, 1H, CH_2Ph), 4.64−4.52 (m, 3H, CH_2Ph, H-1), 3.73 (d, J = 4.7 Hz, 2H, H-6), 3.65 (dd, J = 8.8, 9.5 Hz, 1H, H-4), 3.46−3.39 (m, 1H, H-5), 3.33 (dd, J = 7.6, 10.0 Hz, 1H, H-2), 3.23 (dd, J = 8.7, 9.9 Hz, 1H, H-3), 2.90−2.50 (br s, 1H, OH), 0.96 (s, 9H, CH_{3TBS}), 0.19 (s, 6H, CH_{3TBS}) ppm; ^{13}C NMR (125 MHz, $CDCl_3$) δ = 138.2, 137.8, 128.6, 128.4, 128.0, 127.9, 127.7, 127.6, 97.2 (C-1), 82.3 (C-3), 74.9 (C_{Bn}), 74.0 (C-5), 73.7 (C_{Bn}), 71.9 (C-4), 70.3 (C-6), 68.1 (C-2), 25.6 (CH_{3TBS}), −4.3 ($SiCH_3$), −5.3 ($SiCH_3$) ppm; HRMS (ESI) *m*/*z* calcd for $C_{26}H_{37}N_3O_5Si$ [M + Na]$^+$ 522.2400, found 522.2388.

Dimethylthexylsilyl 2-Azido-6-*O*-benzoyl-3-*O*-benzyl-2-deoxy-D-glucopyranose (54). EtSH (0.25 mL, 3.3 mmol) and catalytic *p*TsOH (35 mg) were added to a solution of dimethylthexylsilyl 2-azido-3-*O*-benzyl-4,6-*O*-benzylidene-2-deoxy-α,β-D-glucopyranose (350 mg, 0.66 mmol) in dry CH_2Cl_2 (8 mL). After being stirred for 3 h under argon, the mixture was neutralized with solid $NaHCO_3$, diluted with CH_2Cl_2, washed with water, dried over $MgSO_4$, and concentrated. The purification of the residue was carried out by column chromatography (hexane/ethyl acetate, 8:2) to yield dimethylthexylsilyl 2-azido-3-*O*-benzyl-2-deoxy-α,β-D-glucopyranose (271 mg, 94%): ^{1}H NMR (500 MHz, $CDCl_3$) δ = 7.41−7.28 (m, 5H, aromatic), 4.95 (d, J = 11.4 Hz, 1H, CH_2Ph), 4.72 (d, J = 11.4 Hz, 1H, CH_2Ph), 4.55 (d, J = 7.5 Hz, 1H, H-1), 3.81 (dd, J = 11.8, 3.6 Hz, 1H, H-6a), 3.73 (dd, J = 11.8, 4.8 Hz, 1H, H-6b), 3.56 (dd, J = 9.7, 8.7 Hz, 1H, H-4), 3.27 (m, 2H, H-2, H-5), 3.21 (m, 1H, H-3), 1.68 (m, 1H, CH_{thexyl}), 0.92−0.90 (2s, 12H, $CH_{3thexyl}$), 0.21 and 0.20 (2s, 6H, $Si(CH_3)_2$) ppm; ^{13}C NMR (126 MHz, $CDCl_3$) δ = 138.2, 128.8, 128.2, 128.1, 97.2, 82.6, 75.2, 75.1, 70.6 68.6, 62.6, 34.0, 24.9, 20.1, 20.0, 18.60, 18.5, −1.9, −3.1. BzCN (76 mg, 0.58 mmol) and a catalytic amount of Et_3N were added to a cooled (−40 °C) solution of dimethylthexylsilyl 2-azido-3-*O*-benzyl-2-deoxy-α,β-D-glucopyranose (250 mg, 0.57 mmol) in dry CH_3CN (11 mL). After 4 h, MeOH was added and the mixture was allowed to reach room temperature. The solvent was evaporated, and the residue was dissolved in MeOH and concentrated to dryness. The purification was carried out by flash column chromatography (hexane/ethyl acetate, 9:1) to afford **54** (250 mg, 80%): ^{1}H NMR (500 MHz, $CDCl_3$) δ = 8.05−8.03 (m, 2H, aromatic), 7.59−7.55 (m, 1H, aromatic), 7.47−7.42 (m, 2H, aromatic), 7.40−7.30 (m, 5H, aromatic), 4.97 (d, J = 11.4 Hz, 1H, CH_2Ph), 4.74 (d, J = 11.4 Hz, 1H, CH_2Ph), 4.57−4.56 (m, 3H, H-6ab, H-1), 3.56−3.50 (m, 2H, H-4, H-5), 3.32 (dd, J = 9.9, 7.6 Hz, 1H, H-2), 3.26−3.22 (m, 1H, H-3), 2.52 (br s, OH), 1.67−1.61 (m, 1H, CH_{thexyl}), 0.88−0.86 (3s, 12H, $CH_{3thexyl}$), 0.18−0.16 (2s, 6H, $Si(CH_3)_2$) ppm; ^{13}C NMR (126 MHz, $CDCl_3$) δ = 207.2, 166.9, 133.4, 129.9, 128.9, 128.5, 128.3, 97.3 (C-1), 82.3 (C-3), 75.3 (C_{Bn}), 74.0, 70.4 (C-4, C-5), 68.5 (C-2), 63.9 (C-6), 34.0 (CH_{thexyl}), 20.1, 20.0, 18.6, 18.5 ($CH_{3thexyl}$), −2.0, −3.1 ($Si(CH_3)_2$) ppm; HRMS (ESI) *m*/*z* calcd for $C_{28}H_{39}N_3O_6Si$ [M + Na]$^+$ 564.2506, found 564.2471.

4-[(Phenylcarboxy)methyl]benzyl *N*-Benzyl-*N*-[5-(methyl ((4-*O*-(2-azido-6-*O*-benzoyl-3-*O*-benzyl-2-deoxy-α-D-glucopyranosyl)-2-*O*-benzoyl-3-*O*-benzyl-α-L-idopyranosyl)oxy)uronate)-pentyl]carbamate (55). To a solution of **52** (94 mg, 0.071 mmol) in dry CH_2Cl_2/MeOH (25 mL/2.5 mL) was added hydrazine acetate (9 mg, 0.106 mmol). The reaction was stirred for 3 h, and the crude

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product was concentrated and purified using hexane/ethyl acetate (6:4) to obtain **55** as a white solid (70 mg, 80%): ^{1}H NMR (500 MHz, $CDCl_3$) δ = 8.20−8.15 (m, 2H, aromatic), 8.10−8.00 (m, 4H, aromatic), 7.58−7.15 (m, 28H, aromatic), 5.36 (s, 2H, CH_2Ph_{Bz}), 5.19−5.16 (m, 4H, H-1, H-2, CH_2Ph_{Carba}), 4.88−4.82 (m, 4H, H-5, H-1′, H-6a, CH_2Ph), 4.74 (d, 1H, CH_2Ph), 4.47−4.45 (m, 3H, CH_2Ph, H-6b), 4.36 (d, 1H, CH_2Ph), 4.16−4.13 (m, 3H, CH_2Ph, H-3, H-4), 4.04−4.02 (m, 1H, H-5′), 3.83 (s, 3H, CH_{3COOMe}), 3.78−3.75 (m, 1H, $OCH_{2Linker}$), 3.54−3.46 (m, 3H, H-3′, H-4′, $OCH_{2Linker}$), 3.23−3.13 (m, 3H, H-2′, $NCH_{2Linker}$), 3.04 (br s, 1H, OH), 1.63−1.50 (m, 4H, $CH_{2Linker}$), 1.31−1.25 (m, 2H, $CH_{2Linker}$) ppm; ^{13}C NMR (126 MHz, $CDCl_3$) δ = 169.9, 167.5, 166.5, 165.6, 156.7, 156.2, 137.9, 137.7, 133.5, 133.1, 130.1, 129.9, 129.8, 129.5, 128.8, 128.6, 128.5, 128.4, 128.1, 128.0, 127.9, 127.4, 127.2, 99.4 (C-1′), 99.2 (C-1), 79.3 (C-3′), 75.7 (C-4), 75.0 (CH_2Ph), 73.2 (C-3), 72.4 (CH_2Ph), 71.4 (C-4′), 70.5 (C-5′), 68.7 ($CH_{2Linker}$), 68.0 (C-2), 67.5 (C-5), 66.9 (CH_2Ph_{Carba}), 66.5 (CH_2Ph_{Bz}), 63.2 (C-2′), 63.1 (C-6′), 52.4 (CH_{3COOMe}), 50.6, 50.3 (CH_2PhN), 47.3 ($NCH_{2Linker}$), 46.3 ($CH_{2Linker}$), 29.2 ($CH_{2Linker}$), 27.63 ($CH_{2Linker}$), 23.5 ($CH_{2Linker}$) ppm; HRMS (ESI) m/z calcd for $C_{69}H_{70}N_4O_{17}$ $[M + Na]^+$ 1249.4634, found 1249.4623.

***tert*-Butyldimethylsilyl 2-Azido-3,6-di-*O*-benzyl-2-deoxy-4-*O*-(methyl (2,4-di-*O*-acetyl-3-*O*-benzyl-α-L-idopyranosyl)-uronate)-D-glucopyranose (56).** The reaction was carried out according to general procedure B using acceptor **53** (32 mg, 0.064 mmol) and *n*-pentenyl donor **3** (222 mg, 0.326 mmol). NIS (22 mg, 0.097 mmol) and (TMS)OTf (2.3 μL, 0.013 mmol) were added at 0 °C, and the mixture was stirred for 2 h. The crude product was concentrated, and analysis by LC−MS showed 40% formation of the desired disaccharide (calcd for $C_{44}H_{57}N_3O_{13}SiNa$ 886.37 g/mol, found 886.29 g/mol) and 20% of a disaccharide lacking one acetyl group (calcd for $C_{42}H_{55}N_3O_{12}SiNa$ 844.36 g/mol, found 844.28 g/mol). The crude product was dissolved in dry pyridine (1 mL), acetic anhydride (0.5 mL) was added at 0 °C, and the reaction was stirred overnight. EtOH was added, and the reaction crude was concentrated. The crude product was purified by column chromatography (hexane/ethyl acetate, 8:2) to obtain **56** (27 mg): ^{1}H NMR (500 MHz, $CDCl_3$) δ = 7.40−7.19 (m, 15H, aromatic), 5.21 (br s, 1H, H-1′), 5.08−5.04 (m, 1H), 5.02 (d, J = 2.3 Hz, 1H), 4.87−4.83 (m, 1H), 4.72−4.68 (m, 3H, CH_2Ph), 4.60 (d, J = 12.3 Hz, 1H, CH_2Ph), 4.53−4.47 (m, 3H, CH_2Ph, H-1), 4.00 (t, J = 9.5 Hz, 1H), 3.82−3.79 (m, 1H), 3.72 (dd, J = 11.2, 3.8 Hz, 1H, H-6a), 3.67 (dd, J = 11.4, 2.3 Hz, 1H, H-6b), 3.38 (m, 5H, CH_{3COOMe}), 3.21 (t, J = 9.6 Hz, 1H), 2.01 and 2.00 (2s, 6H, CH_{3Ac}), 0.93 (s, 9H, CH_{3TBS}), 0.15 (s, 3H, $SiCH_3$), 0.14 (s, 3H, $SiCH_3$) ppm; ^{13}C NMR (126 MHz, $CDCl_3$) δ = 170.2, 169.9, 168.7, 138.3, 138.2, 137.5, 128.6, 128.4, 128.3, 128.2, 128.1, 127.6, 127.6, 127.4, 97.5 (C-1), 97.4 (C-1′), 81.0, 75.4, 74.5 (C_{Bn}), 74.1, 73.3 (C_{Bn}), 72.6 (C_{Bn}), 72.5, 68.9, 68.2 (C-6), 68.0, 67.2, 66.4, 52.2 (CH_{3COOMe}), 25.7 (CH_{3TBS}), 21.1, 20.9 (CH_{3Ac}), 18.1 (Cq_{TBS}), −4.1, −5.1 ($Si(CH_3)_2$) ppm; HRMS (ESI) m/z calcd for $C_{44}H_{57}N_3NaO_{13}Si$ $[M + Na]^+$ 886.3553, found 886.3527.

Dimethylthexylsilyl 2-Azido-6-*O*-benzoyl-3-*O*-benzyl-2-deoxy-4-*O*-(methyl (3-*O*-benzyl-2,4-di-*O*-levulinoyl-α-L-idopyranosyl)uronate)-D-glucopyranose (57). The reaction was carried out according to general procedure B using acceptor **54** (32 mg, 0.064 mmol) and *n*-pentenyl donor **4** (29 mg, 0.051 mmol). NIS (12 mg, 0.055 mmol) and (TMS)OTf (1.33 μL, 0.010 mmol) were added at 0 °C, and the mixture was stirred for 2 h. The crude product was concentrated, and the conversion to disaccharide **57** was determinated by LC−MS to be 30% (calcd for $C_{52}H_{67}N_3O_{16}SiNH_4^+$ 1040.43 g/mol, found 1040.42 g/mol).

Dimethylthexylsilyl 2-Azido-6-*O*-benzoyl-3-*O*-benzyl-2-deoxy-4-*O*-(methyl (2,4-di-*O*-benzoyl-3-*O*-benzyl-α-L-idopyranosyl)uronate)-D-glucopyranose (58). The reaction was carried out according to general procedure B using acceptor **53** (45 mg, 0.083 mmol) and *n*-pentenyl donor **5** (76 mg, 0.083 mmol). NIS (56 mg, 0.249 mmol) and (TMS)OTf (3 μL, 0.016 mmol) were added at 0 °C, and the mixture was stirred for 2 h. The crude product was concentrated and purified by column chromatography (hexane/ethyl acetate, 7:3) to obtain **58** (73 mg, 85%): $[\alpha]_D^{20}$ = −33.6 (c = 1, $CHCl_3$); ^{1}H NMR (500 MHz, $CDCl_3$) δ = 8.06−7.95 (m, 4H, aromatic), 7.67−7.62 (m, 2H, aromatic), 7.57−7.48 (m, 2H, aromatic), 7.44−7.17 (m, 15H, aromatic), 7.01−7.95 (m, 2H, aromatic), 5.41−5.37 (m, 2H, H-1′, H-4′), 5.22−5.15 (m, 2H, H-5′, H-2′), 4.89−4.82 (m, 3H, CH_2Ph, H-6), 4.74 (d, J = 10.9 Hz, CH_2Ph), 4.70 (d, J = 10.9 Hz, CH_2Ph), 4.54 (d, J = 7.2 Hz, 1H, H-1), 4.42 (dd, J = 11.9, 6.1 Hz, 1H, H-6), 4.14−4.11 (m, 1H, H-3′), 3.98 (dd, J = 9.8, 8.6 Hz, 1H, H-4), 3.69−3.63 (m, 1H, H-5), 3.40−3.30 (m, 5H, CH_{3COOMe}, H-2, H-3), 1.64−1.58 (m, 1H, CH_{thexyl}), 0.85−0.83 (12H, $CH_{3thexyl}$), 0.14−0.11 (6H, $Si(CH_3)_2$) ppm; ^{13}C NMR (126 MHz, $CDCl_3$) δ = 168.8, 166.1, 165.6, 165.4, 138.1, 137.4, 133.6, 133.3, 133.1, 130.1, 130.0, 129.9, 129.4, 128.9, 128.6, 128.4, 128.4, 128.3, 128.2, 127.7, 127.5, 97.8 ($J_{C1',H1'}$ = 171 Hz, C-1′), 97.2 ($J_{C1,H1}$ = 160 Hz, C-1), 81.1 (C-3), 75.2 (C-4), 74.8 (C_{Bn}), 73.8 (C-5), 73.0 (C_{Bn}), 72.9 (C-3′), 69.1 (C-2), 68.5 (C-4′), 67.7 (C-2′), 67.1 (C-5′), 63.2 (C-6), 52.3 (CH_{3COOMe}), 34.0 (CH_{thexyl}), 20.1, 20.0, 18.6, 18.5 ($CH_{3thexyl}$), −2.0, −3.2 ($Si(CH_3)_2$) ppm; HRMS (ESI) m/z calcd for $C_{56}H_{63}N_3O_{14}Si$ $[M + Na]^+$ 1052.3977, found 1052.3912.

4-[(Phenylcarboxy)methyl]benzyl *N*-Benzyl-*N*-[5-(methyl ((4-*O*-(2-azido-6-*O*-benzoyl-3-*O*-benzyl-2-deoxy-4-*O*-(methyl (2-*O*-benzoyl-3-*O*-benzyl-4-*O*-levulinoyl -L-idopyranosyl)-uronate)-α-D-glucopyranosyl)-2-*O*-benzoyl-3-*O*-benzyl-α-L-idopyranosyl)oxy)uronate)pentyl]carbamate (59). The glycosylation was carried out according to general procedure B using the following conditions:

(1) Acceptor **55** (35 mg, 0.028 mmol) and thiophenyl donor **1** (21 mg, 0.034 mmol) (55 mg, 0.093 mmol). NIS (19 mg, 0.084 mmol) and (TMS)OTf (1.5 μL, 0.006 mmol) were added at room temperature. The crude was product was purified by column chromatography using hexane/ethyl acetate (7:3) to obtain compound **59** (16 mg, 34%).

(2) Acceptor **55** (64 mg, 0.052 mmol) and donor **6** (36 mg, 0.062 mmol). NIS (35 mg, 0.156 mmol) and (TMS)OTf (1.8 μL, 0.01 mmol) were added at 0 °C. The crude product was purified by column chromatography using hexane/ethyl acetate (7:3) to obtain compound **59** (40 mg, 45%).

Data for **59**: ^{1}H NMR (500 MHz, $CDCl_3$) δ = 8.12−8.00 (m, 8H, aromatic), 7.57−7.13 (m, 36H, aromatic), 5.44 (d, J = 3.6 Hz, 1H, H-1″), 5.35 (s, 2H, CH_2Ph_{Bz}), 5.20−5.16 (m, 5H, H-1, H-2″, H-4″, CH_2Ph_{Carba}), 5.09 (s, 1H, H-2), 4.88 (d, J = 11.4 Hz, 1H, CH_2Ph), 4.83−4.70 (m, 7H, $H\text{-}6_a$, H-5″, H-1′, H-5, CH_2Ph), 4.48−4.45 (m, 3H, $H\text{-}6_b$, CH_2PhN), 4.41 (d, J = 10.4 Hz, 4H, CH_2Ph), 4.13−4.09 (m, 1H, H-3), 4.03−3.89 (m, 5H, H-4′, H-5′, H-3″, H-4, CH_2Ph), 3.78−3.70 (m, 1H, $OCH_{2Linker}$), 3.68 (s, 3H, CH_{3COOMe}), 3.55−3.46 (m, 2H, H-3′, $OCH_{2Linker}$), 3.42 (s, 3H, CH_{3COOMe}), 3.27 (dd, J = 10.3, 3.4 Hz, 1H, H-2′), 3.24−3.11 (m, 2H, $NCH_{2Linker}$), 2.59 (t, J = 6.6 Hz, 2H, CH_{2Lev}), 2.38 (t, J = 6.6 Hz, 2H, CH_{2Lev}), 2.09 (s, 3H, CH_{3Lev}), 1.58−1.43 (m, 4H, $CH_{2Linker}$), 1.35−1.24 (m, 2H, $CH_{2Linker}$) ppm; ^{13}C NMR (126 MHz, $CDCl_3$) δ = 205.8, 171.6, 169.8, 168.7, 166.5, 166.1, 165.7, 165.1, 156.7, 156.2, 138.0, 137.7, 137.3, 137.0, 135.8, 133.6, 133.5, 133.1, 133.0, 130.2, 130.0, 129.8, 129.3, 128.7, 128.6, 128.5, 128.4, 128.2, 128.1, 128.0, 127.9, 127.5, 127.3, 127.2, 99.1 (C-1, $J_{C1,H1}$ = 171 Hz), 98.9 (C-1′, $J_{C1',H1'}$ = 169 Hz), 98.1 (C-1″, $J_{C1'',H1''}$ = 171 Hz), 78.6 (H-3′), 75.7, 75.6 (C-4, C-4′), 74.6 (CH_2Ph), 74.3 (C-3), 73.4 (CH_2Ph), 72.8 (C-3″), 72.4, 70.2 (C-5′), 69.8 (C-2″), 68.6 ($CH_{2Linker}$), 68.3 (C-2, C-4″), 67.6 (C-5), 66.9 (CH_2Ph_{carba}), 66.5 (CH_2Ph_{Bz}), 63.8 (C-2′), 62.2 (C-6), 52.4 (CH_{3COOMe}), 52.0 (CH_{3COOMe}), 50.6, 50.3 (CH_2PhN), 47.3, 46.3 ($NCH_{2Linker}$), 37.7 (CH_{2Lev}), 29.7 (CH_{3Lev}), 29.2 ($CH_{2Linker}$), 28.1 ($CH_{2Linker}$), 27.8 ($CH_{2Linker}$, CH_{3Lev}), 27.6 ($CH_{2Linker}$), 23.5 ($CH_{2Linker}$) ppm; HRMS (ESI) m/z calcd for $C_{95}H_{96}N_4O_{26}$ $[M + Na]^+$ 1731.6205, found 1731.6274.

Resin-Bound DOXyl *N*-Benzyl-*N*-[5-(methyl ((2-*O*-benzoyl-3-*O*-benzyl-4-*O*-levulinoyl-α-L-idopyranosyl)oxy)uronate)-pentyl]carbamate (SP-63). The reaction was performed according to general procedure D employing the following conditions:

(1) Resin **SP-62** (200 mg, 0.22 mmol/g), donor **1** (120 mg, 0.20 mmol), NIS (58 mg, 0.26 mmol), and (TMS)OTf (1.4 μL, 0.008 mmol) in dry CH_2Cl_2 (2 mL) at room temperature.

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(2) Resin **SP-62** (250 mg, 0.2 mmol/g), donor **2** (200 mg, 0.15 mmol), and (TMS)OTf (1.1 μL, 0.006 mmol) in dry CH_2Cl_2 (2 mL) at −40 °C.
(3) Resin **SP-62** (160 mg, 0.2 mmol/g), donor **6** (94 mg, 0.16 mmol), and (TMS)OTf (1.2 μL, 0.007 mmol) in dry CH_2Cl_2 (2 mL) at 0 °C.

The conversion of every glycosylation reaction was determined after analytical NaOMe cleavage: 4-(hydroxymethyl)benzyl *N*-benzyl-*N*-[5-(methyl ((2-*O*-benzoyl-3-*O*-benzyl-4-*O*-levulinoyl-α-L-idopyranosyl)-oxy)uronate)pentyl]carbamate (**64**). Conversions: (1) 84%, (2) 87%, (3) 85%. LC−MS (ESI) (*m*/*z*): retention time (t_R) at 5.10 min (**64**), calcd for $C_{34}H_{41}NO_{10}$ $[Na]^+$ 646.3, found 646.2; t_R at 5.79 min (**64** + Me), calcd for $C_{35}H_{43}NO_{10}$ $[Na]^+$ 660.3, found 660.2. The resin **SP-63** (94 mg, 0.22 mmol/g) was transformed to resin-bound 4-(hydroxymethyl)benzyl *N*-benzyl-*N*-[5-(methyl ((2-*O*-benzoyl-3-*O*-benzyl-α-L-idopyranosyl)oxy)uronate)pentyl]carbamate (**SP-65**) using general procedure E.

Resin-Bound DOXyl *N*-Benzyl-*N*-[5-(methyl ((4-*O*-(2-azido-3-*O*-benzyl-6-*O*-benzoyl-2-deoxy-4-*O*-levulinoyl-α-D-glucopyranosyl)-2-*O*-benzoyl-3-*O*-benzyl-α-L-idopyranosyl)oxy)-uronate)pentyl]carbamate (SP-66). The reaction was performed according to general procedure D using the following conditions:

(1) One cycle on resin **SP-65** (250 mg, 0.44 mmol/g) with trichloroacetimidate **16** (1 × 3 equiv, 192 mg) and (TMS)OTf (1.8 μL, 0.01 mmol) in dry CH_2Cl_2 (1.4 mL) at −40 °C. Conversion was determined after analytical sodium methoxide cleavage: 4-(hydroxymethyl)benzyl *N*-benzyl-*N*-[5-(methyl ((4-*O*-(2-azido-3-*O*-benzyl-6-*O*-benzoyl-2-deoxy-α-D-glucopyranosyl)-2-*O*-benzoyl-3-*O*-benzyl-α-idopyranosyl)oxy)uronate)-pentyl]carbamate (**67**). Conversion: 21%. LC−MS (ESI) (*m*/*z*) t_R at 5.86 min, calcd for $C_{47}H_{56}N_4O_{14}$ $[NH_4]^+$ 918.38, found 918.36.
(2) Four cycles on resin **SP-65** (155 mg, 0.22 mmol/g) with trichloroacetimidate **16** (3 × 5 equiv, 65 mg, 0.16 mmol) and (TMS)OTf (68 μL of a 0.1 M solution of (TMS)OTf) in dry CH_2Cl_2 (1.2 mL) at −20 °C. Conversion was determined after analytical dibutyltin oxide cleavage as 4-(hydroxymethyl)benzyl *N*-benzyl-*N*-[5-(methyl ((4-*O*-(2-azido-3-*O*-benzyl-6-*O*-benzoyl-2-deoxy-α-D-glucopyranosyl)-2-*O*-benzoyl-3-*O*-benzyl-α-idopyranosyl)oxy)uronate)pentyl]carbamate (**68**). Conversion: 84%. LC−MS (ESI) (*m*/*z*): t_R at 11.96 min, calcd for $C_{67}H_{72}N_4O_{18}$ $[NH_4]^+$ 1238.4, found 1238.3. The resin **SP-66** (135 mg, 0.22 mmol/g) was transformed to resin-bound 4-(hydroxymethyl)benzyl *N*-benzyl-*N*-[5-(methyl ((4-*O*-(2-azido-3-*O*-benzyl-6-*O*-benzoyl-2-deoxy-α-D-glucopyranosyl)-2-*O*-benzoyl-3-*O*-benzyl-α-idopyranosyl)oxy)uronate)pentyl]-carbamate (**SP-69**) using general procedure E.

Resin-Bound DOXyl *N*-Benzyl-*N*-[5-(methyl ((4-*O*-(2-azido-3-*O*-benzyl-6-*O*-benzoyl-2-deoxy-4-*O*-(methyl (2-*O*-benzoyl-3-*O*-benzyl-4-*O*-levulinoyl-α-L-idopyranosyl)uronate)-α-D-glucopyranosyl)-2-*O*-benzoyl-3-*O*-benzyl-α-L-idopyranosyl)oxy)-uronate)pentyl]carbamate (SP-70). The reaction was performed according to general procedure D using three cycles on resin **SP-69** (127 mg, 0.22 mmol/g) with donor **6** (79 mg, 0.14 mmol) and (TMS)OTf (56 μL of a 0.1 M solution of (TMS)OTf) in dry CH_2Cl_2 (0.96 mL) at −20 °C. Conversion was determined after analytical dibutyltin oxide-mediated cleavage: 4-(hydroxymethyl)benzyl *N*-benzyl-*N*-[5-(methyl ((4-*O*-(2-azido-3-*O*-benzyl-6-*O*-benzoyl-2-deoxy-4-*O*-(methyl (2-*O*-benzoyl-3-*O*-benzyl-4-*O*-levulinoyl-α-L-idopyranosyl)uronate)-α-D-glucopyranosyl)-2-*O*-benzoyl-3-*O*-benzyl-α-L-idopyranosyl)oxy)uronate)pentyl]carbamate (**71**). Conversion: 76%. LC−MS (ESI) (*m*/*z*): t_R at 13.35 min, calcd for $C_{88}H_{92}N_4O_{25}$ $[NH_4]^+$ 1622.6, found 1622.4. The resin **SP-70** (125 mg, 0.2 mmol/g) was swollen in dry CH_2Cl_2 (2 mL), dry MeOH (1 mL) and dibutyltin oxide (123 mg) were added, and the reaction was treated in the microwave for 10 min at 120 °C. The resin was washed three times with a solution of CH_2Cl_2/MeOH (1:1) and three times with MeOH. This cleavage was repeated until no further release of compound from the resin was observed and employing a large excess of dibutyltin oxide (820 mg) in the last cleavage cycle. The crude was dissolved in MeOH, filtered, taken up in CH_2Cl_2 (0.2 mL), and treated with pyridine (0.9 mL, 0.52 mmol), benzoyl chloride (1.2 mL, 0.26 mmol), and a catalytic amount of DMAP. After 12 h, the reaction mixture was diluted with CH_2Cl_2 and successively washed with a saturated aq solution of $CuSO_4$ and H_2O. The organic phase was then dried over anhydrous $MgSO_4$, filtered, and concentrated. Column chromatography and preparative TLC (30% EtOAc/hexane) afforded compound **59** as a white solid (3.7 mg, 8% overall yield).

Resin-Bound DOXyl *N*-Benzyl-*N*-[5-((6-*O*-acetyl-2-*O*-benzoyl-3-*O*-benzyl-4-*O*-levulinoyl-α-L-idopyranosyl)oxy)pentyl]-carbamate (SP-72). The reaction was performed according to general procedure D using resin **SP-62** (100 mg, 0.44 mmol/g) and thioglycoside **10** (3 equiv, 73 mg, 0.12 mmol). NIS (36 mg, 0.16 mmol) and TfOH (44 μL of a 0.1 M solution in CH_2Cl_2) were added at −20 °C. Conversion was determined after analytical NaOMe cleavage: 4-(hydroxymethyl)benzyl *N*-benzyl-*N*-[5-((3-*O*-benzyl-α-L-idopyranosyl)oxy)pentyl]carbamate (**73**). Conversion: 96%. LC−MS (ESI) (*m*/*z*): calcd $C_{34}H_{43}N_{43}O_9$ $[NH_4]^+$ 627.29, found 627.30. The resin **SP-72** (100 mg, 0.44 mmol/g) was transformed to resin-bound 4-(hydroxymethyl)benzyl *N*-benzyl-*N*-[5-((6-*O*-acetyl-2-*O*-benzoyl-3-*O*-benzyl-α-L-idopyranosyl)oxy)pentyl]carbamate (**SP-74**) using general procedure E.

Resin-Bound DOXyl *N*-Benzyl-*N*-[5-((6-*O*-acetyl-4-*O*-(2-azido-6-*O*-benzoyl-3-*O*-benzyl-2-deoxy-4-*O*-levulinoyl-α-D-glucopyranosyl)-2-*O*-benzoyl-3-*O*-benzyl-α-L-idopyranosyl)-oxy)pentyl]carbamate (SP-75). The reaction was performed according to general procedure D using one cycle on resin **SP-74** (100 mg, 0.44 mmol/g) with trichloroacetimidate **16** (1 × 3 equiv, 80 mg) and (TMS)OTf (1.8 μL, 0.01 mmol) at −40 °C. Conversion was determined after analytical sodium methoxide cleavage: 4-(hydroxymethyl)benzyl *N*-benzyl-*N*-[5-((4-*O*-(2-azido-3-*O*-benzyl-2-deoxy-α-D-glucopyranosyl)-3-*O*-benzyl-α-L-idopyranosyl)oxy)pentyl]-carbamate (**76**). Conversion: 22%. LC−MS (ESI) (*m*/*z*): calcd for $C_{47}H_{58}N_4O_{13}$ $[NH_4]^+$ 904.40, found 904.37.

Resin-Bound DOXyl *N*-Benzyl-*N*-[5-((2-*O*-benzoyl-3-*O*-benzyl-6-*O*-(dimethylthexylsilyl)-4-*O*-levulinoyl-α-L-idopyranosyl)-oxy)pentyl]carbamate (SP-77). The reaction was performed according to general procedure D using resin **SP-62** (150 mg, 0.44 mmol/g, 66 μmol), thioglycoside **8** (5 equiv, 116 mg, 0.165 mmol), NIS (6.5 equiv, 48 mg, 0.215 mmol), and (TMS)OTf (33 μL, 0.1 M solution in CH_2Cl_2). Conversion was determined after analytical NaOMe cleavage as 4-(hydroxymethyl)benzyl *N*-benzyl-*N*-[5-((3-*O*-benzyl-6-*O*-(dimethylthexylsilyl)-α-L-idopyranosyl)oxy)pentyl]-carbamate (**78**). Conversion: >95%. LC−MS (ESI) (*m*/*z*): calcd for $C_{42}H_{61}N_1O_9Si$ $[NH_4]^+$ 769.44, found 769.25. The resin **SP-77** (150 mg, 0.44 mmol/g, 66 μmol) was transformed to resin-bound 4-(hydroxymethyl)benzyl *N*-benzyl-*N*-[5-((2-*O*-benzoyl-3-*O*-benzyl-6-*O*-(dimethylthexylsilyl)-α-L-idopyranosyl)oxy)pentyl]carbamate (**SP-79**) using general procedure E.

Resin-Bound DOXyl *N*-Benzyl-*N*-[5-((4-*O*-(2-azido-6-*O*-benzoyl-3-*O*-benzyl-2-deoxy-4-*O*-levulinoyl-α-D-glucopyranosyl)-2-*O*-benzoyl-3-*O*-benzyl-6-*O*-(dimethylthexylsilyl)-α-L-idopyranosyl)oxy)pentyl]carbamate (SP-80). The reaction was performed according to general procedure D using three cycles on resin **SP-79** (150 mg, 0.44 mmol/g, 66 μmol) and trichloroacetimidate **16** (3 × 3 equiv, 64 mg, 0.198 mmol). (TMS)OTf (33 μL, 0.1 M solution in CH_2Cl_2) was added at −20 °C. Conversion was determined after analytical NaOMe cleavage: 4-(hydroxymethyl)-benzyl *N*-benzyl-*N*-[5-((4-*O*-(2-azido-3-*O*-benzyl-2-deoxy-α-D-glucopyranosyl)-3-*O*-benzyl-6-*O*-(dimethylthexylsilyl)-α-L-idopyranosyl)-oxy)pentyl]carbamate (**81**). Conversion: 77%. LC−MS (ESI) (*m*/*z*): calcd for $C_{55}H_{76}N_4O_{13}Si$ $[NH_4]^+$ 1046.55, found 1046.69. The resin **SP-80** (150 mg, 0.44 mmol/g, 66 μmol) was transformed to resin-bound 4-(hydroxymethyl)benzyl *N*-benzyl-*N*-[5-((4-*O*-(2-azido-6-*O*-benzoyl-3-*O*-benzyl-2-deoxy-α-D-glucopyranosyl)-2-*O*-benzoyl-3-*O*-benzyl-6-*O*-(dimethylthexylsilyl)-α-L-idopyranosyl)oxy)pentyl]-carbamate (**SP-82**) using general procedure E.

Resin-Bound DOXyl *N*-Benzyl-*N*-[5-((4-*O*-(2-azido-6-*O*-benzoyl-4-*O*-(2-*O*-benzoyl-3-*O*-benzyl-6-*O*-(dimethylthexylsilyl)-α-L-idopyranosyl)-3-*O*-benzyl-2-deoxy-α-D-glucopyranosyl)-2-*O*-benzoyl-3-*O*-benzyl-6-*O*-(dimethylthexylsilyl)-α-L-

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idopyranosyl)oxy)pentyl]carbamate (SP-83). The reaction was performed according to general procedure D using three cycles on resin **SP-82** (70 mg, 0.44 mmol/g, 31 μmol), trichloroacetimidate **14** (4 × 3 equiv, 70 mg, 92 μmol), and (TMS)OTf (31 μL, 0.1 M solution in CH_2Cl_2). Conversion was determined after analytical NaOMe cleavage: 4-(hydroxymethyl)benzyl *N*-benzyl-*N*-[5-((4-*O*-(2-azido-4-*O*-(3-*O*-benzyl-6-*O*-(dimethylthexylsilyl)-α-L-idopyranosyl)-3-*O*-benzyl-2-deoxy-α-D-glucopyranosyl)-3-*O*-benzyl-6-*O*-(dimethylthexylsilyl)-α-L-idopyranosyl)oxy)pentyl]carbamate (**84**). Conversion: 77%. LC−MS (ESI) (*m*/*z*): calcd for $C_{55}H_{76}N_4O_{13}Si$ $[NH_4]^+$ 1046.55, found 1046.69.

Resin-Bound DOXyl *N*-Benzyl-*N*-[5-((2-*O*-benzoyl-3-*O*-benzyl-4-*O*-levulinoyl-6-*O*-(*p*-methoxyphenyl)-α-L-idopyranosyl)-oxy)pentyl]carbamate (SP-85). The reaction was performed according to general procedure D using resin **SP-62** (200 mg, 0.44 mmol/g, 88 μmol), thioglycoside **11** (5 equiv, 295 mg, 0.44 mmol), NIS (6.5 equiv, 128 mg, 0.572 mmol), and (TMS)OTf (88 μL, 0.1 M solution in CH_2Cl_2). Conversion was determined after analytical NaOMe cleavage as 4-(hydroxymethyl)benzyl *N*-benzyl-*N*-[5-((3-*O*-benzyl-6-*O*-(*p*-methoxyphenyl)-α-L-idopyranosyl)oxy)pentyl]-carbamate (**86**). Conversion: >95%. LC−MS (ESI) (*m*/*z*): calcd for $C_{41}H_{49}NO_{10}$ $[NH_4]^+$ 733.37, found 733.26. The resin **SP-85** (200 mg, 0.44 mmol/g, 88 μmol) was transformed to resin-bound 4-(hydroxymethyl)benzyl *N*-benzyl-*N*-[5-((2-*O*-benzoyl-3-*O*-benzyl-6-*O*-(*p*-methoxyphenyl)-α-L-idopyranosyl)oxy)pentyl]carbamate (**SP-87**) using general procedure E.

Resin-Bound 4-(Hydroxymethyl)benzyl *N*-Benzyl-*N*-[5-((4-*O*-(2-azido-6-*O*-benzoyl-3-*O*-benzyl-2-deoxy-4-*O*-levulinoyl-α-D-glucopyranosyl)-2-*O*-benzoyl-3-*O*-benzyl-6-*O*-(*p*-methoxyphenyl)-α-L-idopyranosyl)oxy)pentyl]carbamate (SP-88). The reactions were performed according to general procedure D using the following conditions:

(1) Four cycles on resin **SP-87** (200 mg, 0.44 mmol/g, 88 μmol) with trichloroacetimidate **16** (3 equiv, 169 mg, 0.264 mmol)) and (TMS)OTf (44 μL, 0.1 M solution in CH_2Cl_2).
(2) Two cycles on resin **SP-87** (120 mg, 0.44 mmol/g, 52.8 μmol) with trichloroacetimidate **16** (6 equiv, 203 mg, 0.157 mmol)) and (TMS)OTf (44 μL, 0.1 M solution in CH_2Cl_2).
(3) One cycle on resin **SP-87** (120 mg, 0.44 mmol/g, 52.8 μmol) with trichloroacetimidate **16** (12 equiv, 406 mg, 0.364 mmol) and (TMS)OTf (52 μL, 0.1 M solution in CH_2Cl_2).
(4) Two cycles on resin **SP-87** (200 mg, 0.44 mmol/g, 88 μmol) with trifluoroacetimidate **17** (6 equiv, 353 mg, 0.528 mmol) and (TMS)OTf (88 μL, 0.1 M solution in CH_2Cl_2).
(5) Two cycles on resin **SP-87** (120 mg, 0.44 mmol/g, 52.8 μmol) with trichloroacetimidate **16** (cycle 1, 12 equiv, 406 mg, 0.364 mmol; cycle 2, 6 equiv, 203 mg, 0.157 mmol) and (TMS)OTf (44 μL, 0.1 M solution in CH_2Cl_2).
(6) One cycle on resin **SP-87** (200 mg, 0.22 mmol/g, 44 μmol) with trichloroacetimidate **16** (1 × 6 equiv, 203 mg, 0.157 mmol) and (TMS)OTf (44 μL, 0.1 M solution in CH_2Cl_2).

The conversions were determined after analytical NaOMe cleavage: DOXyl *N*-benzyl-*N*-[5-((4-*O*-(2-azido-3-*O*-benzyl-2-deoxy-α-D-glucopyranosyl)-3-*O*-benzyl-6-*O*-(*p*-methoxyphenyl)-α-L-idopyranosyl)-oxy)pentyl]carbamate (**89**). Conversions: (1) 80%, (2) 85%, (3) 68%, (4) 70%, (5) 85%, (6) 90%. LC−MS (ESI) (*m*/*z*): calcd for $C_{54}H_{64}N_4O_{14}$ $[Na]^+$ 1015.43, found 1015.29. The resin **SP-88** (340 mg, 0.22 mmol/g, 74.8 μmol) was transformed to resin-bound 4-(hydroxymethyl)benzyl *N*-benzyl-*N*-[5-((4-*O*-(2-azido-6-*O*-benzoyl-3-*O*-benzyl-2-deoxy-α-D-glucopyranosyl)-2-*O*-benzoyl-3-*O*-benzyl-6-*O*-(*p*-methoxyphenyl)-α-L-idopyranosyl)oxy)pentyl]carbamate (**SP-90**) using general procedure E.

Resin-Bound DOXyl *N*-Benzyl-*N*-[5-((4-*O*-(2-azido-4-*O*-(2-*O*-benzoyl-3-*O*-benzyl-4-*O*-levulinoyl-6-*O*-(*p*-methoxyphenyl)-α-L-idopyranosyl)-6-*O*-benzoyl-3-*O*-benzyl-2-deoxy-α-D-glucopyranosyl)-2-*O*-benzoyl-3-*O*-benzyl-6-*O*-(*p*-methoxyphenyl)-α-L-idopyranosyl)oxy)pentyl]carbamate (SP-91). The reaction was performed according to general procedure D using two cycles on resin **SP-90** (200 mg, 0.44 mmol/g, 88 μmol) with trichloroacetimidate **15** (2 × 6 equiv, 388 mg, 528 μmol) and (TMS)OTf (88 μL, 0.1 M solution in CH_2Cl_2). Conversion was determined after analytical NaOMe cleavage: DOXyl *N*-benzyl-*N*-[5-((4-*O*-(2-azido-4-*O*-(3-*O*-benzyl-6-*O*-(*p*-methoxyphenyl)-α-L-idopyranosyl)-3-*O*-benzyl-2-deoxy-α-D-glucopyranosyl)-3-*O*-benzyl-6-*O*-(*p*-methoxyphenyl)-α-L-idopyranosyl)oxy)pentyl]carbamate (**92**). Conversion: 94%. LC−MS (ESI) (*m*/*z*): calcd for $C_{74}H_{86}N_4O_{20}$ $[NH_4]^+$ 1368.62, found 1368.20.

4-(Acetoxymethyl)benzyl *N*-Benzyl-*N*-[5-((2-*O*-acetyl-4-*O*-(6-*O*-acetyl-2-azido-4-*O*-(2,4-di-*O*-acetyl-3-*O*-benzyl-6-*O*-(*p*-methoxyphenyl)-α-L-idopyranosyl)-3-*O*-benzyl-2-deoxy-α-D-glucopyranosyl)-3-*O*-benzyl-6-*O*-(*p*-methoxyphenyl)-α-L-idopyranosyloxy)pentyl]carbamate (93). Monosaccharide formation was performed according to general procedure D using resin **SP-62** (1.18 g, 0.22 mmol/g, 260 μmol), thioglycoside **11** (5 equiv, 870 mg, 1.29 mmol), NIS (6 equiv, 350 mg, 1.56 mmol), and (TMS)OTf (5 μL, 30 μmol). After capping and delevulination, disacccharide formation was performed according to general procedure D using three cycles on resin **SP-87** (180 mg (198 mg), 0.44 mmol/g, 40 μmol) with trichloroacetimidate **16** (3 × 6 equiv, 152 mg, 238 μmol) and (TMS)OTf (79 μL, 0.1 M solution in CH_2Cl_2). After capping and delevulination, disacccharide formation was performed according to general procedure D using two cycles on resin **SP-91** (180 mg (198 mg), 0.44 mmol/g, 40 μmol) with trichloroacetimidate **15** (2 × 6 equiv, 171 mg, 237 μmol) and (TMS)OTf (79 μL, 0.1 M solution in CH_2Cl_2). The resin **SP-91** (175 mg, resin after cleavage 136 mg, 299 μmmol) was swollen in 4 mL of dry CH_2Cl_2 and then treated with 0.25 M NaOMe solution (1 mL) for 5 min at 55 °C under microwave irradiation. Then the resin was washed with 2 × 5 mL of CH_2Cl_2/MeOH (1:1) and 2 × 5 mL of MeOH. This procedure was repeated until the TLC control (CH_2Cl_2/MeOH, 98:2) showed no further compound cleavage (eight cycles). The washing solutions were pooled and neutralized with Amberlite IR-120 (H^+). After concentration, crude **92** (39 mg) was acetylated overnight at room temperature with Ac_2O and a catalytic amount of DMAP in pyridine. The reaction mixture was diluted with CH_2Cl_2 (50 mL), and the organic layer was washed with 2 × 1 M HCl (50 mL), saturated $CuSO_4$ (50 mL), water, and brine. After concentration the crude product was purified by column chromatography on silica gel using a hexane/acetone gradient. The product was obtained as a colorless syrup (34 mg, 72%): ^{1}H NMR (500 MHz, $CDCl_3$) δ = 7.37−7.28 (m, 14H, aromatic), 7.26−7.20 (m, 10H, aromatic), 7.14−6.95 (m, 6H, aromatic$_{PMP}$), 6.85−6.73 (m, 2H, aromatic$_{-PMP}$), 5.19−5.09 (m, 2H, CH_2Ph_{Carba}), 5.08 (s, 2H, CH_2Ph_{Ac}), 4.99−4.96 (m, 1H, H-2), 4.98−4.90 (m, 3H, H-4″, H-1′, H-1″), 4.86−4.78 (m, 4H, H-2″, H-1, CH_2Ph), 4.74−4.58 (m, 4H, CH_2Ph), 4.57−4.51 (m, 2H, H-5, H-5″), 4.50−4.43 (m, 2H, CH_2PhN), 4.31 (dd, *J* = 12.3, 2.1 Hz, 1H, H-6′), 4.20−4.15 (m, 1H, H-6″), 4.11−4.04 (m, 2H, H-6″, H-6′), 3.96−3.85 (m, 3H, H-3, H-4, H-5′), 3.85−3.77 (m, 2H, H-3′, H-4′), 3.76−3.65 (m, 10H, H-3″, H-6, $OCH_{2Linker}$, 2 × CH_{3PMP}), 3.45−3.34 (m, 1H, $OCH_{2Linker}$), 3.32 (dd, *J* = 9.6, 3.6 Hz, 1H, H-2′), 3.25−3.13 (m, 2H, CH_2N_{Linker}), 2.11 (s, 3H, CH_{3Ac}), 2.09 (s, 3H, CH_{3Ac}), 2.01 (s, 3H, CH_{3Ac}), 1.99 (s, 3H, CH_{3Ac}), 1.97 (s, 3H, CH_{3Ac}), 1.67−1.47 (m, 4H, $CH_{2Linker}$), 1.38−1.24 (m, 2H, $CH_{2Linker}$) ppm; ^{13}C NMR (126 MHz, $CDCl_3$) δ = 171.0, 170.6, 170.3, 170.3, 169.6, 154.2, 154.1, 152.6, 152.3, 138.0, 137.8, 137.8, 137.5, 128.7, 128.6, 128.5, 128.5, 128.4, 128.3, 128.2, 128.2, 128.1, 127.9, 127.8, 127.8, 127.7, 127.4, 127.2, 115.4, 115.4, 115.0, 114.6 ($C_{aromaticPMP}$), 98.2 ($J_{C,H}$ = 170 Hz, C-1), 98.0 ($J_{C,H}$ = 169 Hz, C-1″), 95.9 ($J_{C,H}$ = 171 Hz, C-1′), 78.9 (C-3′), 75.2 (C_{Bn}), 74.7 (C-4′), 73.1 (C-3″), 72.6 (C_{Bn}), 72.2 (C_{Bn}), 71.5 (C-3), 70.4 (C-4), 69.9 (C-5′), 68.2 (C-2), 68.1 (C-2″, $OCH_{2Linker}$), 67.6 (C-4″), 66.9 (CH_2Ph_{carba}), 66.7 (C-6, C-6″), 66.1 (CH_2Ph_{Ac}), 65.4, 65.3 (C-5, C-5″), 64.0 (C-2′), 62.3 (C-6′), 55.8 (CH_{3PMP}), 55.7 (CH_{3PMP}), 50.6, 50.3 (CH_2PhN), 47.4, 46.3 ($NCH_{2Linker}$), 29.3, 28.1, 27.6, 23.5 ($CH_{2Linker}$), 21.1, 21.0, 21.0, 20.9 (CH_{3Ac}) ppm; HRMS (ESI) *m*/*z* calcd for $C_{84}H_{96}N_4O_{25}$ $[M + Na]^+$ 1583.6256, found 1583.6265.

■ ASSOCIATED CONTENT

Supporting Information

Annotated HPLC traces of solid-phase reactions after cleavage of a resin aliquot and ^{1}H and ^{13}C NMR and HSQC (only for

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final compound **93**) spectra for all new compounds. This material is available free of charge via Internet at http://pubs.acs.org.

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Notes

The authors declare no competing financial interest.

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