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Glycal Glycosylation and 2-Nitroglycal Concatenation, a Powerful Combination for Mucin Core Structure Synthesis

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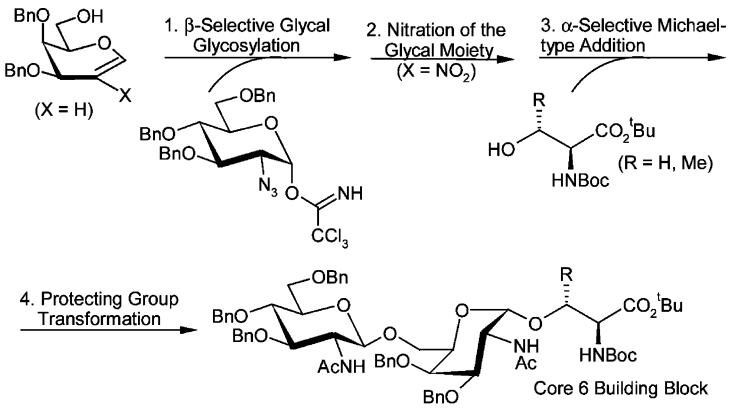

A 3,4-*O*-unprotected galactal derivative having bulky 6-*O*-TIPS protection (compound **2**) could be regioselectively 3-*O*-glycosylated with *O*-(galactopyranosyl) trichloroacetimidates; depending on the protecting group pattern stereoselectively α- and *β*-linked disaccharides were obtained. With *O*-(2-azido-2-deoxyglucopyransyl) trichloroacetimidate as donor (compound **10A**), glycosylation of **2** and of a 6-*O*-unprotected galactal derivative led in acetonitrile as solvent exclusively to a *β*(1−3)- and a *β*(1−6)-linked disaccharide, respectively. Nitration of the galactal moieties of the saccharides followed by Michael-type addition of serine and threonine derivatives (**7a**,**b**) installed the α-*galacto*-configuration, thus readily furnishing *O*-glycosyl amino acid building blocks for the incorporation of core 1, core 2, core 3, core 6, and core 8 structures into glycopeptides. 2-Nitrogalactal and 2-nitroglucal derivatives could be also successfully employed in glycoside bond formation via Michael-type addition in a reiterative manner, affording the corresponding core 5, core 7, and core 6 building blocks. In this approach, highly stereoselective glycoside bond formations were based exclusively on Michael-type addition to the nitro-enol ether moiety of the 2-nitroglycals. Hence, 2-nitroglycals are versatile intermediates for base-catalyzed glycoside bond formation.

Introduction

The mucin glycoproteins have attracted much attention because of their fundamental importance in biological processes.[1] The core structures bear at the reducing end an *N*-acetyl galactosamine residue α-glycosidically linked to L-serine or L-threonine (the T_N-antigen).[1,2] Eight core structures of mucin-type glycopeptides and the ST_N-antigen have been identified to date which contain additional glycosyl residues at position 3 and/or position 6 to form complex *O*-glycans (Figure 1). These basic structures are constituents of various glycoproteins, as for instance of the antifreeze glycoproteins which are essential for the survival of fish living under water freezing temperature conditions.[3,4]

(1) (a) Varki, A. *Glycobiology* **1993**, *3*, 97−130. (b) Brockhausen, I. *Biochem. Biophys. Acta* **1999**, *1473*, 67−95. (c) Brocke, C.; Kunz, H. *Bioorg. Med. Chem.* **2002**, *10*, 3085−3112. (d) Devine, P. L.; McKenzie, I. F. C. *BioEssays* **1992**, *14*, 619−625. (e) Gum, J. R., Jr. *Biochem. Soc. Trans.* **1995**, *23*, 795−799.(f) Tsuboi, S.; Fukuda, M. *BioEssays* **2001**, *23*, 46−53. (g) Danishefsky, S. J.; Allen, J. R. *Angew. Chem.* **2000**, *112*, 882−911; *Angew. Chem., Int. Ed.* **2000**, *39*, 836−863.

(2) Grogan, M. J.; Pratt, M. R.; Marcaurelle, L. A.; Bertozzi, C. R. *Annu. Rev. Biochem.* **2002**, *71*, 593−634.

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Core 1: Galβ(1-3)-GalNAcα(1-O)Ser/Thr
Core 8: Galα(1-3)-GalNAcα(1-O)Ser/Thr

Core 3: GlcNAcβ(1-3)-GalNAcα(1-O)Ser/Thr
Core 6: GlcNAcβ(1-6)-GalNAcα(1-O)Ser/Thr

Core 5: GalNAcα(1-3)-GalNAcα(1-O)Ser/Thr
Core 7: GalNAcα(1-6)-GalNAcα(1-O)Ser/Thr

Core 2: GlcNAcβ(1-6), Galβ(1-3) >GalNAcα(1-O)Ser/Thr
Core 4: GlcNAcβ(1-6), GlcNAcβ(1-3) >GalNAcα(1-O)Ser/Thr
ST_N-Antigen: Neu5Acα(2-6)GalNAcα(1-O)Ser/Thr

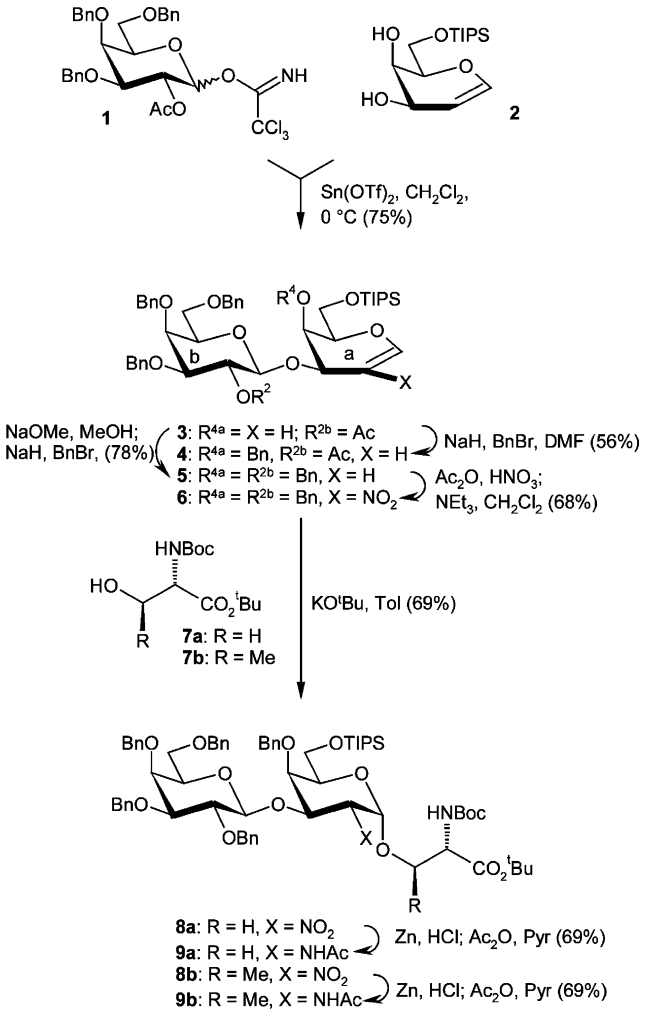
T_N-Antigen

FIGURE 1. T_N- and ST_N-antigens and the mucin core structures.

Previous approaches toward the construction of the characteristic α-glycosidic linkage between 2-acetamido-2-deoxy-D-galactopyranose and the side-chain hydroxy groups of L-serine or L-threonine rely in most cases on the methodology introduced by Paulsen in 1978[5] in which the nonparticipating azido group is selected as latent amino function at position 2. This way α-selective glycosylations with various donors and serine or threonine acceptors could be successfully performed by various groups.[6] Also versatile 2-azido-2-deoxygalactose-based acceptors could be generated and employed for chain extension.[6,7]

Expanding the range of the previously reported efficient direct glycosylation of particularly acid-sensitive galactal derivatives with *O*-glycosyl trichloroacetimidates as glycosyl donors in the presence of $Sn(OTf)_2$ as mild catalyst[8,9] and widening the scope of the 2-nitro-glycal concatenation methodoloy[10] should permit highly versatile approaches toward the synthesis of all mucin core structures and derivatives thereof. The synthetic strategies and the results are discussed in this paper.

SCHEME 1. Synthesis of Core 1 Building Blocks 9a,b



Results and Discussion

Galactal Glycosylation followed by 2-Nitrogalactal Concatenation. The mucin core structure synthesis requires α- and β(1−3)-glycosidic linkages of galactose (Gal) to *N*-acetylgalactosamine (GalNAc) (core 1 and 8), β(1−3)-and β(1−6)-linkages of *N*-acetyl glucosamine (GlcNAc) to GalNAc (core 3 and 6), α(1−3)- and α(1−6)-linkages of GalNAc to GalNAc (core 5 and 7), and formation of branched trisaccharides having β(1−3)-linkage of Gal or GlcNAc and β(1−6)-linkages of GlcNAc to GalNAc (core 2 and 4) (Scheme 1). Hence, for the galactal glycosylation−nitrogalactal concatenation strategy generating two glycosidic linkages, as shown in Figure 2, first α- and β-selective glycosylation of galactal at 3-*O* and/or 6-*O* under mild conditions is required (step 1). As reported,[8] this demand is already fulfilled for the 3-*O*-galactosylation of galactal with the help of a standard glycosyl donor (step 1a). However, for

(3) (a) Harding, M. M.; Anderberg, P. I.; Haymet, A. D. J. *Eur. J. Biochem.* **2003**, *270*, 1381−1392. (b) Yeh, Y.; Feeney, R. F. *Chem. Rev.* **1996**, *96*, 601−617. (c) Ben, R. N. *ChemBioChem* **2001**, *2*, 161−166.

(4) Tachibana, Y.; Fletcher, G. L.; Fujitani, N.; Monde, K.; Nishimura, S.-I. *Angew. Chem.* **2004**, *116*, 874−880; *Angew. Chem., Int. Ed.* **2004**, *43*, 856−862.

(5) Paulsen, H.; Stenzel, W. *Chem. Ber.* **1978**, *111*, 2334−2347; Paulsen, H.; Stenzel, W. *Chem. Ber.* **1978**, *111*, 2348−2357; Paulsen, H.; Kolar, C.; Stenzel, W. *Chem. Ber.* **1978**, *111*, 2358−2369; Paulsen, H.; Kolar, C. *Chem. Ber.* **1979**, *112*, 3190−3202.

(6) (a) Ferrari, B.; Pavia, A. A. *Carbohydr. Res.* **1980**, *79*, C1−C7. (b) Paulsen, H.; Hölck, J.-P. *Carbohydr. Res.* **1982**, *109*, 89−107.(c) Grundler, G.; Schmidt, R. R. *Liebigs Ann.* **1984**, 1826−1847. (d) Kinzy, W.; Schmidt, R. R. *Carbohydr. Res.* **1987**, *164*, 265−276. (e) Paulsen, H.; Rauwald, W.; Weichert, U. *Liebigs Ann.* **1988**, 75−86. (f) Kinzy, W.; Schmidt, R. R. *Carbohydr. Res.* **1989**, *193*, 33−47. (g) Nakahara, Y.; Iijima, H.; Sibayama, S.; Ogawa, T. *Tetrahedron Lett.* **1990**, *31*, 6897−6900. (h) Rademann, J.; Schmidt, R. R. *Carbohydr. Res.* **1995**, *269*, 217−225. (i) Chen, ×.-T.; Sames, D.; Danishefsky, S. J. *J. Am. Chem. Soc.* **1998**, *120*, 7760−7769. (j) Tsudu, T.; Nishimura, S. I. *Chem. Commun.* **1996**, 2779−2780. (k) Schwarz, J. K.; Kuduk, S. D.; Chen, ×.-T.; Sames, D.; Glunz, P. W.; Danishefsky, S. J. *J. Am. Chem. Soc.* **1999**, *121*, 2662−2673. (l) Marcurelle, L. T.; Bertozzi, C. R. *J. Am. Chem. Soc.* **2001**, *123*, 1487−1505. (m) Tseng, P. H.; Jiang, W. T.; Chang, M. Y.; Chen, S. T. *Chem. Eur. J.* **2001**, *7*, 498−510.

(7) Herzner, H.; Reipen, T.; Schulz, M.; Kunz, H. *Chem. Rev.* **2000**, *100*, 4495−4538.

(8) Geiger, J.; Barroca, N.; Schmidt, R. R. *Synlett* **2004**, 836−840.

(9) Glycosylation methods using glycals as acceptors and as donors employing 3,3-dimethyldioxirane for the activation of the double bond has been developed. See for example: Halcomb, R. L.; Danishefsky, S. J. *J. Am. Chem. Soc.* **1989**, *111*, 6661−6666; Liu, K. K.-C.; Danishefsky, S. J. *J. Org. Chem.* **1994**, *59*, 1892−1894; Zheng, C.; Seeberger, P. H.; Danishefsky, S. J. *J. Org. Chem.* **1998**, *63*, 1126−1130; Danishefsky, S. J.; Bilodeau, M. T. *Angew. Chem.* **1996**, *108*, 1482−1522; *Angew. Chem., Int. Ed.* **1996**, *35*, 1380−1419.

(10) (a) Winterfeld, G. A.; Schmidt, R. R. *Angew. Chem.* **2001**, *113*, 2718−2721; *Angew. Chem. Int. Ed. Engl.* **2001**, *40*, 2654−2657. (b) Winterfeld, G. A.; Khodair, A. I.; Schmidt, R. R. *Eur. J. Org. Chem.* **2003**, 1009−1021.

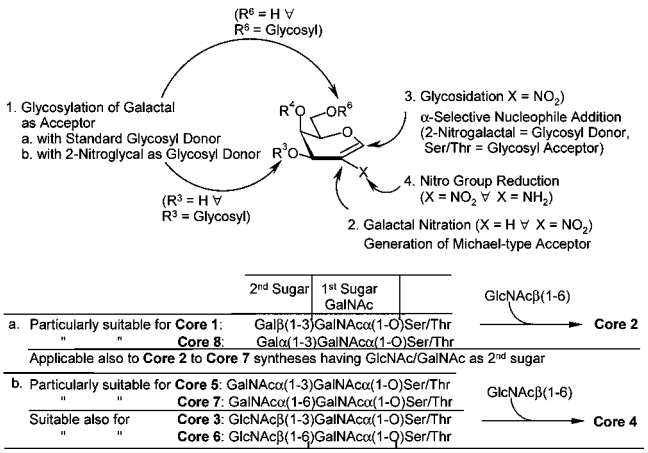
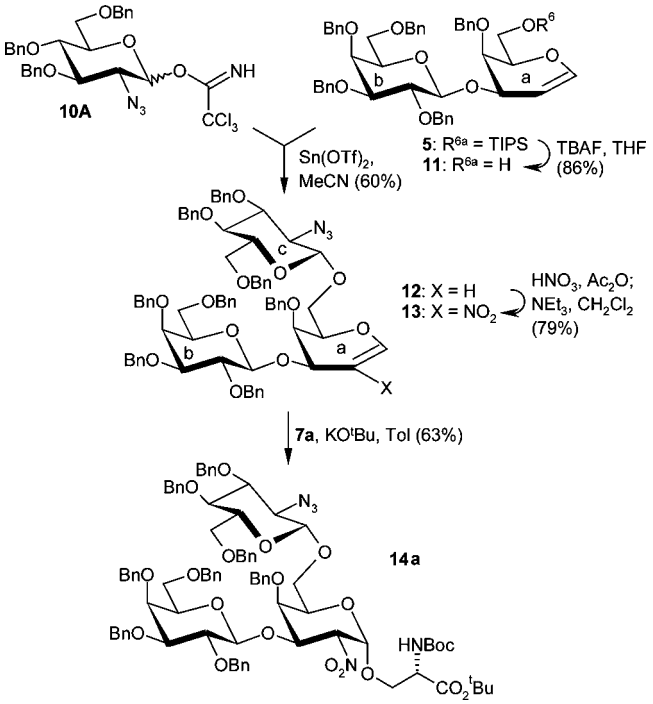


FIGURE 2. Generation of two glycosidic linkages via galactal glycosylation followed by 2-nitrogalactal concatenation.

the introduction of the GalNAc residue (core 5 and 7) and particularly for the introduction of the less reactive GlcNAc residue (leading to core structures 2, 3, 4, and 6), suitable glycosyl donors and reaction conditions have to be developed. The regioselectivity of 3-*O* and/or 6-*O*-glycosylation of galactal can be controlled with minimal protecting group manipulations because these two hydroxy groups can be readily differentiated in this acceptor.[11] Second, nitro group introduction at *C*-2 of the galactal moiety has to be performed via a highly selective electrophilic substitution reaction (step 2). Third, Michael-type addition of alcohols and particularly of serine (Ser) and threonine (Thr) derivatives as nucleophiles at the anomeric carbon of the nitrogalactal moiety should be α-selective with the nitro group at *C*-2 adopting after protonation the equatorial position. Thus, it was perceived that via substrate stereocontrol two stereogenic centers will be generated, hopefully leading directly to the desired α-*galacto*-configured compounds (step 3). Fourth, transformation of the nitro group into an amino group will provide the target compounds (step 4). The application of this synthesis strategy (via steps 1a, 2, 3, and 4 in this part) is demonstrated in successful synthesis of core 1 and core 8 mucin structures where it is particularly suitable. However, core 2, core 3, and core 6 building blocks could also be efficiently obtained using this strategy.

As designed, glycosylation of 3,4-*O*-unprotected galactal **2**[12] with galactosyl donor **1**[13] in the presence of $Sn(OTf)_2$ as catalyst in CH_2Cl_2 at 0 °C afforded the *β*-linked disaccharide **3** in 75% yield (^{1}H NMR: $J_{1b,2b}$ = 8.3 Hz). Direct *O*-benzylation of **3** led to 4-*O*-benzyl derivative **4**. However, nitration of this compound having a 2b-*O*-acetyl group was met with difficulties (Scheme 1). Removal of the 2b-*O*-acetyl group from **3** followed by *O*-benzylation furnished **5** which on nitration via addition−elimination at the enol ether moiety led cleanly to **6** having the nitrogalactal moiety for Michael-type addition of commercially available serine and threonine derivatives **7a**,**b**. Treatment of **6** with **7a** or **7b** in the presence of potassium *tert*-butoxide in toluene proved to be most efficient in shifting the Michael addition−elimination equilibrium to the product side. Thus, the α-*galacto*-configuration was exclusively installed, affording the

SCHEME 2. Synthesis of Core 2 Building Block 14



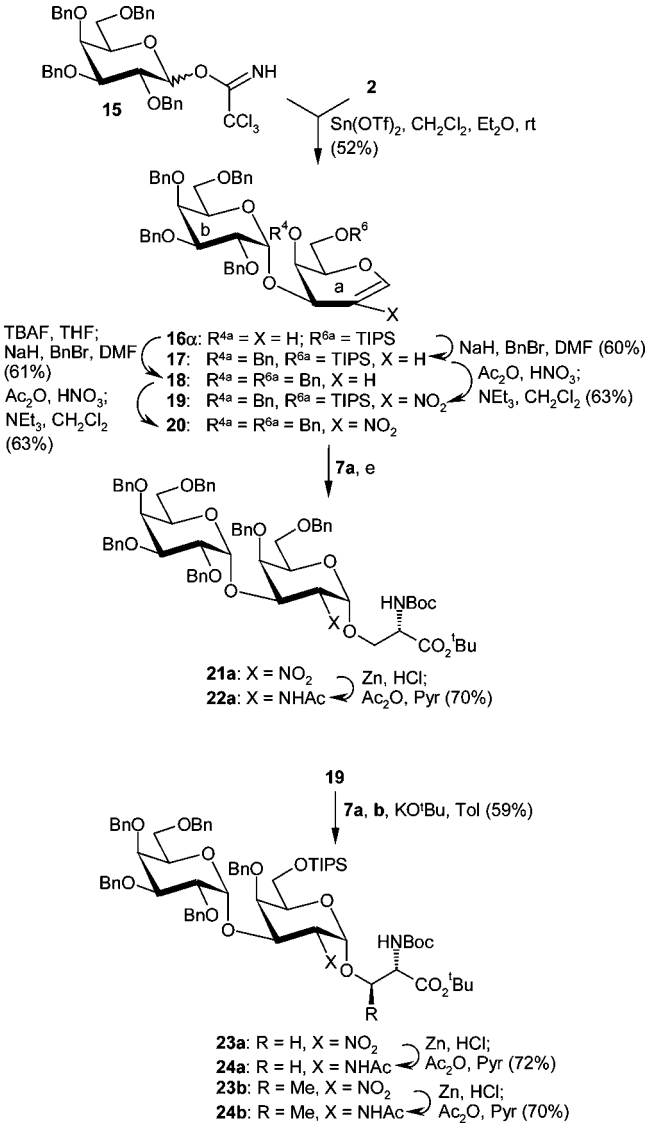
desired adducts **8a**,**b** in 65% yield each (^{1}H NMR: $J_{1a,2a}$ = 3.6 Hz). Reduction of the nitro group with zinc/HCl[8,14] in a water−acetic acid−THF mixture at 0 °C and then N-acetylation with acetic anhydride in pyridine furnished target molecules **9a**,**b** in only five steps.

Disaccharide **5**, after 6a-*O*-desilylation with tetrabutylammonium fluoride (TBAF) in THF, furnished **11**, which is obviously also an ideal precursor for the synthesis of core 2 building blocks, if 6a-*O*-glycosylation of the galactal moiety of **11** with a glucosamine precursor can be performed. To this end, known *O*-(2-azido-2-deoxy-glucopyranosyl) trichloroacetimidate **10A**[15] was selected as reactive glycosyl donor which in acetonitrile at low temperature was expected to lead to *β*-linkage due to the nitrile effect (Scheme 2).[16] As expected, under these conditions activation of **10A** with tin(II) triflate was still possible, and this way the desired *β*-linked trisaccharide **12** was obtained exclusively in good yield (^{1}H NMR: $J_{1c,2c}$ = br s). Nitration of **12** (to form **13**) and serine **7a** addition under standard conditions afforded target molecule **14a** with α-linked serine as the only product (^{1}H NMR: $J_{1a,2a}$ = 4.6 Hz). The ease of azido and nitro group transformation into *N*-acetylamino groups will be demonstrated for another example (see below).

An efficient method for the α-selective 3-*O*-galactosylation of 6-*O*-triisopropylsilyl (TIPS)-protected galactal **2** as acceptor with *O*-benzyl-protected galactosyl donor **15**[17] is not yet available.[8] However, variations of solvent and temperature conditions exhibited that the α/*β*-ratio can be greatly improved by performing the reaction in a dichloromethane/ether mixture[18] with tin(II) triflate as catalyst at room temperature leading to a

(11) Kinzy, W.; Schmidt, R. R. *Tetrahedron Lett.* **1987**, *28*, 1981−1984.
(12) Gervay, J.; Peterson, J. M.; Oriyama, T.; Danishefsky, S. J. *J. Org. Chem.* **1993**, *58*, 5465−5468.
(13) Sakai, K.; Nakahara, Y.; Ogawa, T. *Tetrahedron Lett.* **1990**, *31*, 3035−3038.
(14) (a) Brown, H. C.; Brown, C. A. *J. Am. Chem. Soc.* **1963**, *85*, 1005−1006. (b) Geiger, J. Dissertation, Universität Konstanz, 2005.
(15) Kinzy, W.; Schmidt, R. R. *Liebigs Ann. Chem.* **1985**, 1537−1545.
(16) Schmidt, R. R.; Behrendt, M.; Toepfer, A. *Synlett* **1990**, 694−697.
(17) Wegmann, B.; Schmidt, R. R. *J. Carbohydr. Chem.* **1987**, 357−375.
(18) Schmidt, R. R. *Angew. Chem., Int. Ed.* **1998**, *25*, 212−235; and references therein.

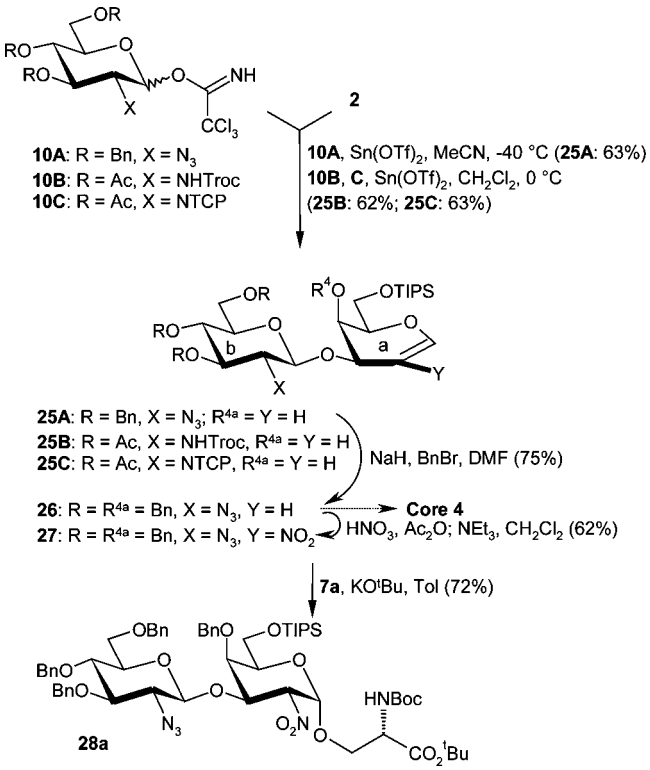
SCHEME 3. Synthesis of Core 8 Building Blocks 22 and 24a,b



10:1 **16**α/**16**β ratio in 52% yield (^{1}H NMR, **16**α: $J_{1b,2b}$ = 3.8 Hz; **16**β: ^{1}H NMR: $J_{1b,2b}$ = 7.8 Hz) (Scheme 3). 4a-*O*-Benzylation of **16**α under standard conditions to form **17** followed by nitration led to the disaccharide **19**, which contains the 2-nitrogalactal moiety. 6a-*O*-Desilylation of **16**α and then 4a,6a-*O*-dibenzylation afforded per-*O*-benzylated disaccharide **18**, which on nitration provided the desired *C*-2a-nitro derivative **20**. Both compounds, **19** and **20**, were subjected to base-catalyzed addition of serine and threonine derivatives **7a**,**b**. Thus, **20** was readily reacted with **7a** to give the desired α-*galacto*-configured addition product **21a** (^{1}H NMR: $J_{1a,2a}$ = 3.8 Hz) indicating that the high stereocontrol is not only supported by sterically demanding 6a-*O*-groups but also by corresponding 3a-*O*-groups. Similarly, from **19** and **7a**,**b** α-galacto-configured products **23a**,**b** were obtained (^{1}H NMR: $J_{1a,2a}$ = 4.2 Hz). Nitro group reduction of **21a** and **23a**,**b** with Zn/HCl in a water/acetic acid/THF mixture afforded the core 8 building blocks **22a** and **24a**,**b**, respectively.

Further extension of this method to β-selective attachment of glucosamine donor **10A** to 6-*O*-protected galactal **2** as acceptor would permit the synthesis of core 3 building blocks (Scheme 4). Indeed, with acetonitrile as solvent and tin(II)

SCHEME 4. Synthesis of Core 3 Building Block 28a

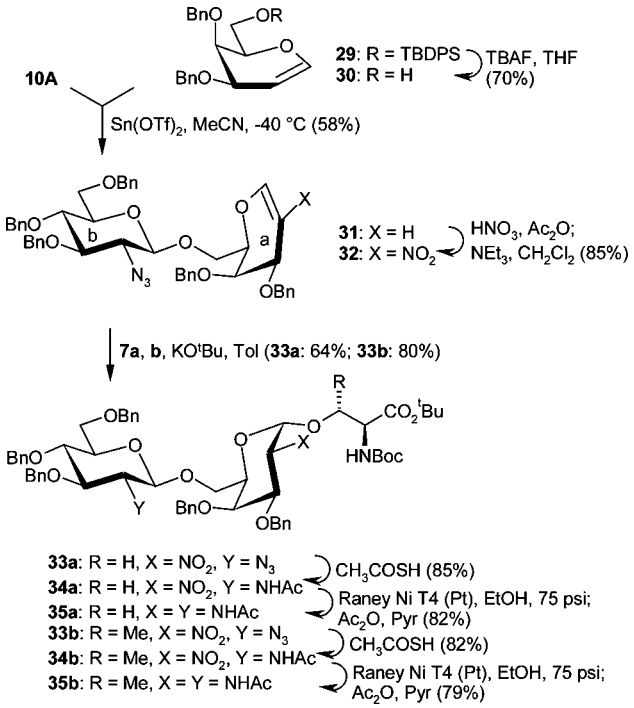


triflate as catalyst at −40 °C exclusively the desired β-linked disaccharide **25A** could be obtained in good yield (^{1}H NMR: $J_{1b,2b}$ = 8.6 Hz). Even glucosamine donors **10B**,[19] **10C**,[20] requiring generally stronger activation conditions than **10A**, reacted smoothly with acceptor **2** in dichloromethane as solvent at 0 °C to afford disaccharides **25B**,**C**, respectively, in similar yield as **25A**. 4a-*O*-Benzylation of **25A** (→ **26**) and then nitration led to *C*-2a-nitro derivative **27**. Addition of serine derivative **7a** in the presence of potassium *tert*-butoxide in toluene gave exclusively α-*galacto*-configured core 3 building block **28a** (^{1}H NMR: $J_{1a,2a}$ = 3.8 Hz). Similar to the core 2 building block synthesis (Scheme 2) galactal containing disaccharide **26** is also an ideal precursor for core 4 building block synthesis.

With these results in hand, it was perceived that the synthesis of core 6 building blocks should be also readily achievable. To this end, known galactal derivative **29**[21] was 6-*O*-desilylated with TBAF in THF furnishing the required 6-*O*-unprotected acceptor **30** (Scheme 5) which on reaction with donor **10A** in acetonitrile at −40 °C under tin(II) triflate catalysis led only to β-linked disaccharide **31** in good yield (^{1}H NMR: $J_{1b,2b}$ = 7.2 Hz). Nitration of **31** to **32** and then base-catalyzed addition of **7a**,**b** afforded exclusively the desired α-linked disaccharides **33a**,**b** in 64% yield each. For these examples, also azido and nitro group reduction was investigated. Treatment of **33a**,**b** with thioacetic acid led cleanly to azide transformation into acetylamino groups furnishing compounds **34a**,**b**. Nitro group reduction in **34a**,**b** could be performed by treatment with platinized Raney-Ni T4[22] under hydrogen pressure followed by treatment

(19) Dullenkopf, W.; Castro-Palomino, J. C.; Manzoni, L.; Schmidt, R. R. *Carbohydr. Res.* **1996**, *296*, 135−147.
(20) Castro-Palomino, J. C.; Schmidt, R. R. *Tetrahedron Lett.* **1995**, *36*, 5343−5346.
(21) Timmers, C. M.; Wigchert, S. C. M.; Leeuwenburgh, M. A.; Marel, G. A. v. d.; van Boom, J. H. *Eur. J. Org. Chem.* **1998**, 91−92.

SCHEME 5. Synthesis of Core 6 Building Blocks 35a,b



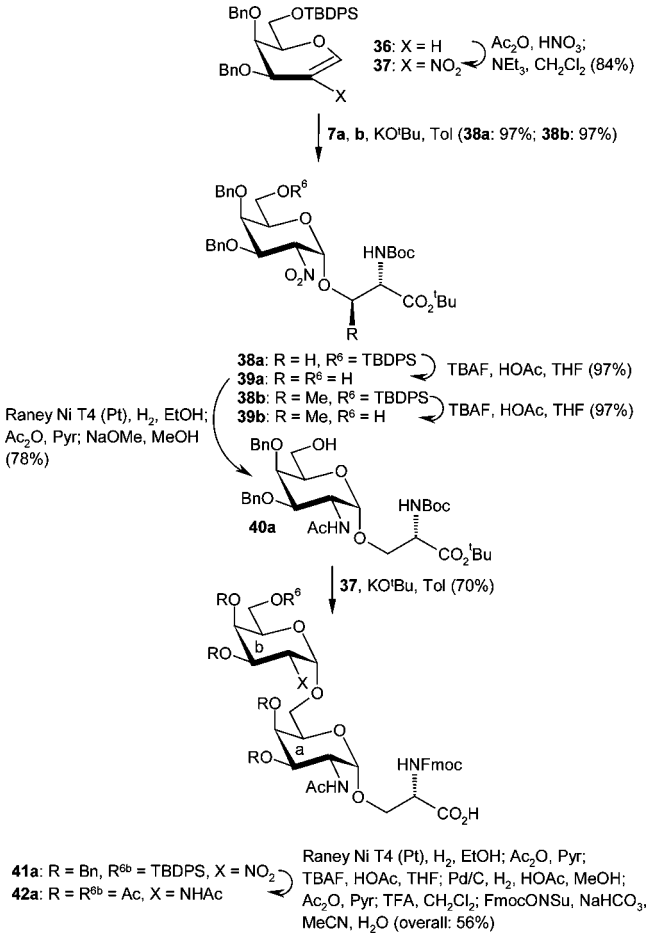
of the intermediates with acetic anhydride pyridine afforded the target compounds **35a**,**b** in very good yields.

Reiterative 2-Nitroglycal Concatenation. The presence of GalNAcα(1−3)- and GalNAcα(1−6)GalNAc linkages in mucin core 5 and core 7, respectively, provides an interesting alternative to the above-reported glycoside bond formation methodology: glycosidations can be exclusively based on base-catalyzed 2-nitroglycal concatenation (Figure 2, step 1b). This strategy (via steps 1b, 2, 3, and 4 in this part) should be particularly suitable for core 5 and core 7 syntheses if not only primary sugar hydroxy groups (as required for core 7) but also secondary sugar hydroxy groups (as in core 5) can be added to the 2-nitroglycal moiety. This way, synthesis strategies starting both from the reducing end or from the nonreducing end can be undertaken. This synthetic design should also be useful, for instance, in core 3 and core 6 syntheses if 2-nitroglucal can be successfully integrated in this 2-nitroglycal concatenation scheme.

The synthesis of a core 7 building block (see Scheme 6) starts from the reducing end. Known galactal derivative **36**[21] was transformed under standard conditions into *C*-2-nitro derivative **37**. Addition of serine and threonine derivatives **7a**,**b** in the presence of potassium *tert*-butoxide as base in toluene afforded exclusively the desired 2-nitro-2-deoxy-α-d-galactopyranosides **38a**,**b** (^{1}H NMR: $J_{1,2}$ = 4.2 Hz). Cleavage of the 6-*O*-*tert*-butyl-diphenylsilyl (TBDPS) group with TBAF in the presence of acetic acid in THF furnished 6-*O*-unprotected derivatives **39a**,**b**. However, investigations toward addition of **39a** to **37** in the presence of potassium *tert*-butoxide in toluene led to *β*-elimination of **7a** and its readdition to **37** furnishing **38a**; practically no disaccharide was obtained. In order to avoid this reaction, the nitro group in **39a** was transformed into an *N*-acetylamino group as described above, affording the T_N-antigen building block **40a**. Investigation of Michael-type

(22) Nishimura, S. *Bull. Chem. Soc. Jpn.* **1959**, *32*, 61−64.

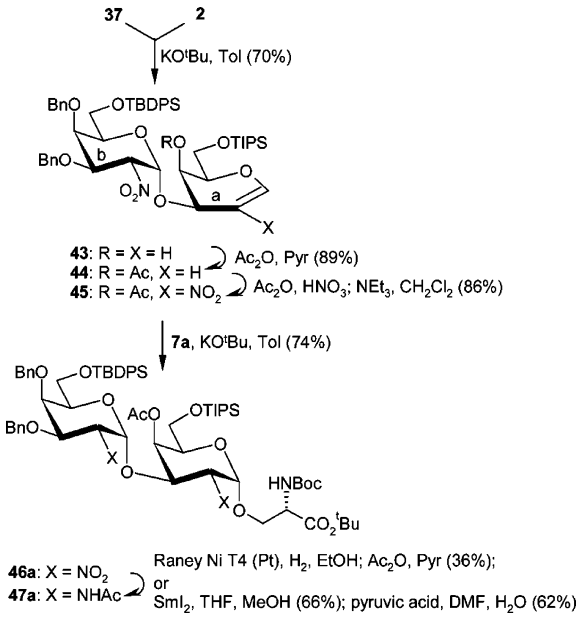
SCHEME 6. Synthesis of Core 7 Building Blocks 41a and 42a



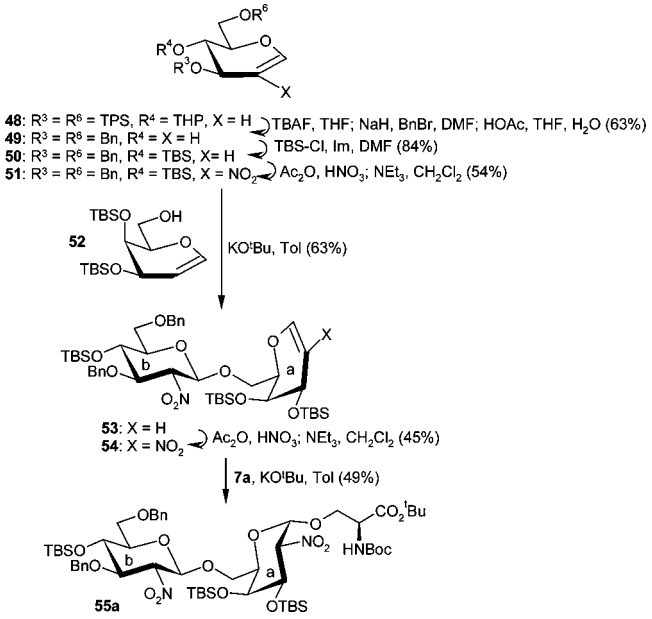
addition of this compound to **37** led cleanly to the desired disaccharide **41a** having the required α-*galacto* configuration (^{1}H NMR: $J_{1b,2b}$ = 4.3 Hz). Hydrogenation of the nitro group with platinized Raney-Ni T4 in ethanol, then *N*-acetylation, hydrogenolytic cleavage of the *O*-benzyl groups and per-*O*-acetylation afforded after four steps the core 7 building block **42a** in 56% yield.

The decisive step in core 5 building block synthesis, based on reiterative nitrogalactal concatenation starting from the nonreducing end, is successful Michael-type addition of secondary sugar hydroxy groups to 2-nitrogalactal derivatives. To this end, base-catalyzed reaction of **37** with 3,4-*O*-unprotected galactal **2** was investigated. To our delight, the desired α(1−3)-linked disaccharide **43** was cleanly obtained under standard conditions (^{1}H NMR: $J_{1b,2b}$ = 4.2 Hz) (Scheme 7). However, 3,4,6-tri-*O*-benzyl-2-nitrogalactal afforded with **2** a 3:1-mixture of the α/*β*-anomers.[14b] Thus, it appears that the bulky 6-*O*-TBDPS group in **37** supported α-addition which is also favored for stereoelectronic reasons. The 4a-hydroxy group in **43** was acetylated to obtain **44** whose nitration proceeded well in the presence of the axial acetoxy group affording 2-nitro derivative **45** in 86% yield. Also Michael-type addition of **7a** could be carried out under standard conditions in the presence of the 4a-*O*-acetyl group furnishing the desired α-anomer **46a** (^{1}H NMR: $J_{1a,2a}$ = 4.2 Hz) in 74% yield. One-pot transformation of the two nitro groups into *N*-acetylamino groups could be carried out on hydrogenation with platinized Raney-Ni T4 as catalyst and then *N*-acetylation with acetic anhydride in pyridine

SCHEME 7. Synthesis of Core 5 Building Block 47a



SCHEME 8. Synthesis of Core 6 Building Block 55a



affording core 5 building block **47a**. Reduction of **46a** with SmI_2 in a mixture of methanol−THF[23] afforded the 2a,2b-dihydroxyamino derivative which on treatment with pyruvic acid in aqueous DMF[24] furnished also **47a** in better yield.

So far, the 2-nitroglycal concatenation was essentially based on 2-nitrogalactal derivatives, which, in the presence of a suitable protecting group pattern, led with alcohols as nucleophiles cleanly to α-*galacto*-configured adducts. However, under variation of the base and/or the nucleophile also *β-galacto*-configured adducts could be obtained preferentially or even exclusively.[25] Extension of the reiterative nitroglycal concatenation to other mucin core structures would require *β*-selective

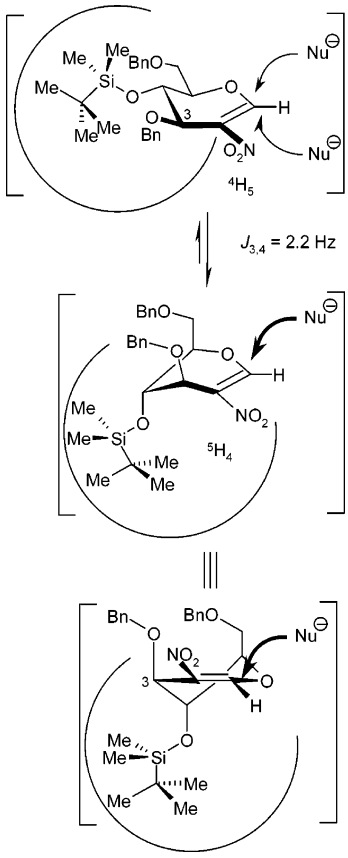


FIGURE 3. Conformation of **51**.

addition to 2-nitroglucal derivatives as well, for which in earlier studies even with simple alcohols as nucleophiles mainly modest results were obtained.[26] To this end, a 2-nitroglucal derivative **51** was designed having 3,6-di-*O*-benzyl and sterically demanding 4-*O*-*tert*-butyldimethylsilyl (TBS) protection on the α-face (Scheme 8). For the synthesis of compound **51**, glucal **48**[11] was converted to **49**[27] via *O*-desilylation, *O*-benzylation, and acid-catalyzed tetrahydropyranyl (THP) cleavage. Introduction of the 4-*O*-TBS group to get **50** followed by nitration furnished **51**. It was expected that the bulky TBS group together with the allylic effect would favor transition of the $^4H_5$ conformer of **51** into the $^5H_4$ conformer with essentially axial substituents at *C*-3, *C*-4, and *C*-5. This way, as shown in Figure 3 for steric and stereoelectronic reasons nucleophilic attack at *C*-1 should preferably take place from the *β*-side. This assumption was supported by the ^{1}H NMR data of **51** ($J_{3,4}$ = 2.2 Hz) and by the following reaction: Base-catalyzed addition of 6a-*O*-unprotected galactal **52**, having also bulky 3-*O*-and 4-*O*-silyl protecting groups, led exclusively to *β-gluco*-configured product **53** in which the b-ring adopted the $^4C_1$ conformation (^{1}H NMR: $J_{1b,2b}$ = 8.1, $J_{3,4}$ = 8.9, $J_{4,5}$ = 8.9 Hz). Nitration of **53** under standard conditions forming **54** and then Michael-type addition of **7a** afforded the desired core 6 building block **55a** in good yield (^{1}H NMR: $J_{1a,2a}$ = 4.1 Hz). Hence, extension of

(23) Kende, A. S.; Mendoza, J. S. *Tetrahedron Lett.* **1991**, *32*, 1699−1702.

(24) (a) Chow, K. Y.-S.; Bode, J. W. *J. Am. Chem. Soc.* **2004**, *126*, 8126−8127. (b) Sohn, S. S.; Bode, J. W. *Org. Lett.* **2005**, *7*, 3873−3876.

(25) Das, J.; Schmidt, R. R. *Eur. J. Org. Chem.* **1998**, 1609−1613. (b) Winterfeld, G. A.; Das, J.; Schmidt, R. R. *Eur. J. Org. Chem.* **2000**, 3047−3050. (c) Barroca, N.; Schmidt, R. R. *Org. Lett.* **2004**, *6*, 1551−1554.

(26) (a) Lemieux, R. U.; Nagabushan, T. L.; O'Neill, I. K. *Can. J. Chem.* **1968**, *46*, 413−418. (b) Takamoto, T.; Sudoh, R.; Nakagawa, T. *Carbohydr. Res.* **1973**, *27*, 135−140.

(27) Danishefsky, S. J.; Behar, V.; Randolph, J. T.; Lloyd, K. O. *J. Am. Chem. Soc.* **1995**, *117*, 5701−5711.

this methodology to 2-nitroglucals could be successfully demonstrated.

Conclusion

The 2-nitroglycal concatenation concept for glycoside bond formation consisting of mild acid-catalyzed *O*-glycosylation of glycals, nitration of the enol ether moiety to generate Michael-type acceptors, highly stereoselective addition of nucleophiles, particularly of low reactive alcohols, and then nitro group reduction to the amino group could be successfully applied to the synthesis of practically all mucin core structures. This way, α- and *β*-selective glycosylation of galactals with galactopyranosyl and 2-amino-2-deoxy-glucopyranosyl donors could be obtained. The concept is also accessible to reiteration, thus permitting the linkage of GlcNAc and GalNAc residues in various combinations. The high stereocontrol in the Michael-type addition is based on stereoelectronic and/or steric effects. Hence, the selection of the protecting group pattern plays an important role.

Glycosidically linked galactose, glucose, and 2-amino-2-deoxy-galactose and -glucose residues are basic constituents of practically all mammalian oligosaccharides and not only of the mucin core structures. Hence, the base-catalyzed nitroglycal concatenation concept has a very wide scope, and it is a valuable addition to the many acid-promoted methodologies developed for glycoside bond formation.[18,28]

Experimental Section

General Procedure for the Nitration of Glycals (A). Concentrated nitric acid (5 mL, 79 mmol) was added dropwise to acetic anhydride (50 mL) at 10 °C (temperature of the solution) under constant stirring. Once the addition was complete, the solution was cooled to −30 °C. Then a solution of the glycal (20.7 mmol) in acetic anhydride (10 mL) was added over a period of 10−15 min, and the mixture was stirred at this temperature for 1 h. The reaction mixture was poured onto ice−water (150 mL). Brine (100 mL) was added, and the aqueous layer was extracted with diethyl ether (3 × 150 mL). The combined organic extracts were dried over sodium sulfate and the solvents removed by coevaporation with toluene. The crude 2-nitro sugar intermediate was dissolved in dichloromethane (10 mL) and slowly added to an ice-cold, stirred solution of triethylamine (3.5 mL, 25 mmol) in dichloromethane (10 mL). After complete addition, the cooling bath was removed and stirring continued for 25 min. The organic phase was washed with 1 n HCl solution and dried over sodium sulfate. Removal of the solvent in vacuo and then silica gel chromatography of the crude furnished 2-nitroglycals.

General Procedure for the Transformation of the Nitro Group to the Acetamido Group (B). The nitro compound (1.0 mmol) was dissolved in a mixture of THF (75 mL), concd HCl (3 mL), HOAc (18 mL), and H_2O (30 mL) and cooled to 0 °C. Zinc dust (24 mmol) was added. After stirring for 2 h at 0 °C, excess zinc(II) dust was removed by filtration; the reaction mixture was diluted with CH_2Cl_2, washed with H_2O, sat. aq $NaHCO_3$, and H_2O, and dried over anhyd $MgSO_4$. Evaporation of the solvents and acetylation of the residue with acetic anhydride/pyridine (2:1) followed by concentration of the mixture and purification by silica gel chromatography afforded the *N*-acetamido glycoside.

***O*-(2-*O*-Acetyl-3,4,6-tri-*O*-benzyl-*β*-D-galyctopyranosyl)-(1→3)-6-*O*-(triisopropylsilyl)-D-galactal (3).** Imidate **1**[13] (9.0 g, 0.014 mol) and selectively protected galactal **2**[12] (3.37 g, 0.012 mol) were dissolved in CH_2Cl_2 (60 mL) and cooled to 0 °C. Then a mixture of tin(II) triflate (140 mg, 0.36 mmol) and MeCN (3 mL) was added dropwise within 15 min. After 30 to 60 min (TLC-monitoring), the reaction was stopped by adding triethylamine. The organic phase was removed under reduced pressure. Purification of the residue by flash chromatography (petroleum ether/ethyl acetate = 6:1) afforded disaccharide **3** (8.2 g, 0.011 mol, 75%) as a slightly yellow oil. $R_f = 0.44$ (petroleum ether/ethyl acetate = 3:1); $[\alpha]_D = -5.1$ ($c = 1$, $CHCl_3$). ^{1}H NMR (600 MHz, $CDCl_3$): $\delta = 7.37-7./$(m, 15 H, arom. H), 6,37 (d, $J_{1,2} = 6.2$ Hz, 1 H, 1a-H), 5.39 (dd, $J_{2,1} = 8.3$ Hz, $J_{2,3} = 10.1$ Hz, 1 H, 2b-H), 4.95.(d, $J = 11.6$., 1 H, benzyl H), 4,69 (d, $J = 12.2$ Hz, 1 H, benzyl H), 4.62−4.58 (m, 2 H, 2a-H, benzyl H), 4.54−4.51 (m, 2 H, 1b-H, benzyl H), 4.46−4.44 (m, 2 H, benzyl H), 4.38 (s, 1 H, 3a-H), 4.14 (s, 1 H, 4a-H), 4.03−3.99 (m, 2 H, 6a-H, 4b-H), 3.90−3.87 (m, 2 H, 5a-H, 6a′-H), 3.64−3.55 (m, 4 H, 3b-H, 5b-H, 6b-H, 6b′-H), 2.76 (s, 1 H, OH), 2.04 (s, 3 H, OAc), 1.13−1.03 (m, 21 H, TIPS). ^{13}C NMR (151 MHz, $CDCl_3$): $\delta = 169.4$ (C-Ac), 145.0 (C-1a), 138.2−127.2 (18 C, arom. C), 100.5 (C-1b), 98.7 (C-2a), 80.5, 80.0 (C-3b), 76.9 (C-5a), 75.0, 74.5, 73.7 (C-5b), 73.0, 72.7 (C-3a), 72.4 (C-4b), 71.3 (C-2b), 68.2 (C-6b), 63.3 (C-4a), 61.6 (C-6a), 20.9−11.8 (9 C). MALDI-MS (positive mode, DHB): $[M + Na]^+$: *m*/*z* calcd.: 800.0, found: 800.0. $C_{44}H_{60}SiO_{10}$ (776.98) calcd.: C: 68.02, H: 7.72, found: C: 67.67, H: 7.86.

***O*-(2-*O*-Acetyl-3,4,6-tri-*O*-benzyl-*β*-D-galactopyranosyl)-(1→3)-3-*O*-benzyl-6-*O*-(triisopropylsilyl)-D-galactal (4).** To a solution of **3** (1.0 g, 1.29 mmol) in DMF (5 mL) was added NaH (53 mg, 2.21 mmol). After 15 min of stirring, BnBr (0.17 mL, 1.42 mmol) was added dropwise. After termination of the reaction, ethyl acetate was added (10 mL) and the organic phase washed (3 × 5 mL H_2O), dried with $MgSO_4$, and concentrated under reduced pressure. Purification by flash chromatography (petroleum ether/ethyl acetate = 7.5:1) afforded entirely protected disaccharide **4** (624 mg, 0.72 mmol, 56%) as a slightly yellow oil. $R_f = 0.80$ (petroleum ether/ethyl acetate = 2:1); $[\alpha]_D = -29.7$ ($c = 1$, $CHCl_3$). ^{1}H NMR (250 MHz, $CDCl_3$): $\delta = 7.40-7.22$ (m, 20 H, arom. H), 6.33 (d, $J_{1,2} = 6.4$ Hz, 1 H, 1a-H), 5.48 (dd, $J_{2,1} = J_{2,3} = 8.0$ Hz, 1 H, 2b-H), 4.98 (d, $J = 11.0$ Hz, 1 H, benzyl H), 4.97 (d, $J = 11.0$ Hz, 1 H, benzyl H), 4.72−4.51 (m, 7 H, 1b-H, 2a-H, 3a-H, benzyl H), 4.45 (s, 2 H, benzyl H), 4.01 (br s, 2 H, 4a-H, 5a-H), 3.92−3.92 (m, 1 H, 4b-H), 3.68 (d, 2 H, 6a-H, 6a′-H), 3.63−3.54 (m, 4 H, 3b-H, 5b-H, 6b-H, 6b′-H), 1.99 (s, 3 H, OAc), 1.05 (m, 21 H, TIPS). MALDI-MS (positive mode, DHB): $[M + Na]^+$: *m*/*z* calcd.: 890.1, found: 890.4. $C_{51}H_{66}O_{10}Si$ (867.11) calcd.: C: 70.64, H: 7.67, found: C: 70.64, H: 7.57.

***O*-(2,3,4,6-Tetra-*O*-benzyl-*β*-D-galactopyranosyl)-(1→3)-3-*O*-benzyl-6-*O*-(triisopropylsilyl)-D-galactal (5). 3** (1.6 g, 2.06 mmol) was dissolved in 30 mL methanol and added a spatula sodium methanolate. After termination of the reaction, the solvent was evaporated in vacuo. The residue was then dissolved in DMF, and NaH (236 mg, 10.0 mmol) and BnBr (0.6 mL, 4.53 mmol) were added. The reaction was terminated after 16 h by adding ethyl acetate. The organic phase was washed with water, then dried with $MgSO_4$, and finally the solvents removed under reduced pressure. Purification by flash chromatography (toluene/ethyl acetate = 10:1) furnished compound **5** (1.4 g, 1.60 mmol, 78%) as slightly yellow oil. $R_f = 0.79$ (petroleum ether/ethyl acetate = 4:1); $[\alpha]_D = +28.0$ ($c = 1$, $CHCl_3$). ^{1}H NMR (250 MHz, $CDCl_3$): $\delta = 7.30-7.22$ (m, 25 H, arom. H), 6.23 (dd, $J_{1,2} = 6.2$ Hz, $J_{1,3} < 1.0$ Hz, 1 H, 1a-H), 5.13 (d, $J = 11.8$ Hz, 1 H, benzyl H), 5.01 (d, $J = 11.2$ Hz, 1 H, benzyl H), 4.97 (d, $J = 11.2$ Hz, 1 H, benzyl H), 4.82−4.62 (m, 7 H, 2a-H, 3a-H, benzyl H), 4.59 (d, $J_{1,2} = 7.6$ Hz, 1 H, 1b-H), 4.44 (s, 2 H, benzyl H), 4.13 (br s, 1 H, 5a-H), 3.97−3.83 (m, 4 H, 4a-H, 4b-H, 2b-H, 6-H), 3.68−3.55 (m, 5 H, 3 × 6-H, 5b-H, 3b-H), 1.05−1.02 (m, 21 H, TIPS). MALDI-MS (positive mode, DHB): $[M + Na]^+$: *m*/*z* calcd.: 938.3, found: 939.4. $C_{56}H_{70}O_9Si$ (915.27 × H_2O) calcd.: C: 72.07, H: 7.78, found: C: 72.00, H: 7.83.

(28) (a) Schmidt, R. R.; Kinzy, W. *Adv. Carbohydr. Chem. Biochem.* **1994**, *50*, 21−123. (b) Toshima, K.; Tatsuta, K. *Chem. Rev.* **1993**, *93*, 1503−1531. (c) Davis, B. G. *J. Chem. Soc., Perkin Trans. 1* **2000**, 2137−2160. (d) Seeberger, P. H.; Hase, W. *Chem. Rev.* **2000**, *100*, 4349−4394.

***O*-(2,3,4,6-Tetra-*O*-benzyl-*β*-D-galactopyranosyl)-(1→3)-3-*O*-benzyl-2-nitro-6-*O*-(triisopropylsilyl)-D-galactal (6).** Following general procedure A from **5** (320 mg, 0.35 mmol), after flash chromatography with toluene/ethyl acetate (40:1) compound **6** (228 mg, 0.24 mmol, 68%) was obtained as a slightly yellow oil. R_f = 0.50 (toluene/ethyl acetate = 5:1); $[\alpha]_D = +3.5$ ($c = 0.25$, $CHCl_3$). ^{1}H NMR (250 MHz, $CDCl_3$): $\delta = 8.08$ (s, 1 H, 1a-H), 7.29−7.21 (m, 25 H, arom. H), 5.09 (d, $J_{3,4} = 4.6$ Hz, 1 H, 3a-H), 5.05−5.00 (m, 2 H, benzyl H), 4.95 (d, $J_{1,2} = 7.7$ Hz, 1 H, 1b-H), 4.74−4.52 (m, 6 H, benzyl H), 4.34 (s, 2 H, benzyl H), 4.15−4.08 (m, 1 H, 5a-H), 3.99 (dd, $J_{4,3} = 4.6$ Hz, $J_{4,5} = 2.7$ Hz, 1 H, 4a-H), 3.89 (d, $J = 2.6$ Hz, 1 H, 4b-H), 3.77 (dd, $J_{2,1} = 7.7$, $J_{2,3} = 10.4$ Hz,1 H, 2b-H), 3−67-3.50 (m, 6 H, 3b-H, 5b-H, 6a-H, 6a′-H, 6b-H, 6b′-H), 0.98−0.97 (m, 21 H, TIPS). MALDI-MS (positive mode, DHB): $[M + Na]^+$: *m*/*z* calcd.: 982.1, found: 982.4. $C_{56}H_{69}NO_{11}Si$ (960.23) calcd.: C: 70.05, H: 7.24, N: 1.46, found: C: 70.44, H: 7.17, N: 1.53.

***O*-(2,3,4,6-Tetra-*O*-benzyl-*β*-D-galactopyranosyl)-(1→3)-(4-*O*-benzyl-2-deoxy-2-nitro-6-(triisopropylsilyl)-α-D-galactopyranosyl)-*N*-(*tert*-butyloxycarbonyl)-L-serine *tert*-Butyl Ester (8a). 6** (111 mg, 0.12 mmol) and **7a** (70 mg, 0.25 mmol) were dissolved in 5 mL of dry toluene. Then potassium *tert*-butoxide (3 mg, 0.026 mmol) was added under stirring. After 2 h the reaction was neutralized with acetic acid and the solvent removed in vacuo. Purification by flash chromatography with toluene/ethyl acetate (40:1) furnished compound **8a** (95 mg, 0.08 mmol, 65%) as a colorless oil. $R_f = 0.53$ (petroleum ether/ethyl acetate = 5:1); $[\alpha]_D = +17.9$ ($c = 1$, $CHCl_3$) = +17.9. ^{1}H NMR (600 MHz, $CDCl_3$): $\delta = 7.32-7.16$ (m, 25 H, arom. H), 5.27 (d, $J_{1,2} = 3.6$ Hz, 1 H, 1a-H), 5.18 (d, $J = 8.4$ Hz, 1 H, Ser-NH), 5.00 (d, $J = 12.0$ Hz, 1 H, benzyl H), 4.93 (dd, $J_{2,1} = 3.6$, $J_{2,3} = 10.8$, 1 H, 2a-H), 4.90 (d, $J = 12.6$ Hz, 1 H, benzyl H), 4.82 (d, $J_{1,2} = 7.2$ Hz, 1 H, 1b-H),4.75−4.70 (m, 3 H, benzyl H), 4.65−4.56 (m, 4 H, 3a-H, benzyl H), 4.54−4.41 (m, 2 H, benzyl H), 4.30−4.29 (m, 1 H, α-Ser-H), 4.11 (s, 1 H, 4a-H), 3.98 (s, 1 H, 4b-H), 3.83 (s, 2 H, *β*-Ser-H, *β*′-Ser-H), 3.77−3.75 (m, 2 H, 2b-H, 5a-H), 3.73 (dd, $J_{6,5} = J_{6,6'} = 9.0$, 1 H, 6b-H), 3.68 (s, 2 H, 5b-H, 6a-H), 3.60−3.56 (m, 3 H, 3b-H, 6b′-H,. 6a′-H), 1.44 (2 × s, 18 H, Boc, t-Bu), 1.04−1.00 (m, 21 H, TIPS). ^{13}C NMR (151 MHz, $CDCl_3$): $\delta = 168.8$, 155.6, 139.1−127.2 (30 C, arom. C), 105.1 (C-1b), 96.7 (C-1a), 84.0 (C-2a), 83.8, 82.0 (C-3b), 80.0, 79.6 (C-2b), 77.3, 75.5 (C-4a), 74.7 (C-3a), 74.7, 74.6, 73.7 (C-4b), 73.6, 73.1, 72.8 (C-5b), 71.8 (C-5a), 69.1 (C-*β*), 68.2 (C-6a), 68.0, 62.1 (C-6b), 54.1 (C-α), 28.4, 27.9 (2 C), 18.0 (2 C), 11.8 (10 C). MALDI-MS (positive mode, DHB): $[M + Na]^+$: *m*/*z* calcd.: 1243.6, found: 1242.1. $C_{68}H_{92}N_2SiO_{16}$ (1221.55) calcd.: C: 66.84, H: 7.59, N: 2.29, found: C: 66.04, H: 6.70, N: 2.56.

***O*-(−2,3,4,6-Tetra-*O*-benzyl-*β*-D-galactopyranosyl)-(1→3)-(2-acetamido-4-*O*-benzyl-2-deoxy-6-(triisopropylsilyl)-α-D-galactopyranosyl)-*N*-(*tert*-butyloxycarbonyl)-L-serine *tert*-Butyl Ester (9a).** Following general procedure B from **8a** (70 mg, 0.06 mmol) after flash chromatography with petroleum ether/ethyl acetate (2:1) compound **9a** (51 mg, 0.041 mmol, 69%) was obtained as a colorless oil. $R_f = 0.25$ (petroleum ether/ethyl acetate = 2:1); $[\alpha]_D = +1.4$ ($c = 0.1$, $CHCl_3$). ^{1}H NMR (600 MHz, $CDCl_3$): $\delta = 7.33-7.18$ (m, 25 H, arom. H), 5.51 (d, $J = 8.5$ Hz, 1 H, GalNAc-NH), 5.23 (d, $J = 8.4$ Hz, 1 H, Ser-NH), 4.97 (d, $J = 11.4$ Hz, 2 H, benzyl H), 4.87 (d, $J = 11.4$ Hz, 1 H, benzyl H), 4.86 (br s, 1 H, 1a-H), 4.74 (s, 2 H, 2a-H, benzyl H), 4.69 (d, $J = 12.0$ Hz, 1 H, benzyl H), 4.68 (d, $J = 12.0$ Hz, 1 H, benzyl H), 4.54−4.43 (m, 2 H, benzyl H, 1b-H), 4.43−4.40 (m, 3 H, benzyl H), 4.30 (br s, 1 H, α-Ser-H), 4.06 (s, 1 H, 4a-H), 3.94 (s, 1 H, 4b-H), 3.84−3.78 (m, 3 H, 2b-H, 3a-H, *β*-Ser-H), 3.74−3.69 (m, 4 H, 6a-H, 5a-H, *β*′-Ser-H, 6b-H), 3.65−3.53 (m, 4 H, 5b-H, 3b-H, 6b′-H, 6a′-H), 2.04 (s, 3 H, OAc), 1.45, 1.44 (2 × s, 18 H, Boc, t-Bu), 1.04−1.00 (m, 21 H, TIPS). ^{13}C NMR (151 MHz, $CDCl_3$): $\delta = 105.8$ (C-1b), 99.0 (C-1a), 82.1 (C-3b), 79.4 (C-2b), 78.5 (C-3a), 75.8 (C-4a), 73.5 (C-4b), 73.1 (C-5b), 72.0 (C-5a), 68.6 (C-*β*), 68.3 (C-6a), 62.9 (C-6b), 54.4 (C-α), 49.1 (C-2a), 29.7−11.8 (14 C). MALDI-MS (positive mode, DHB): $[M + Na]^+$: *m*/*z* calcd.: 1255.6, found: 1256.8. $C_{70}H_{96}N_2O_{15}Si$ (1233.60) calcd.: C: 68.16, H: 7.84, N: 2.27, found: C: 68.16, H: 7.87, N: 2.16.

***O*-(−2,3,4,6-Tetra-*O*-benzyl-*β*-D-galactopyranosyl)-(1→3)-(2-acetamido-4-*O*-benzyl-2-deoxy-6-(triisopropylsilyl)-α-D-galactopyranosyl)-*N*-(*tert*-butyloxycarbonyl)-L-threonine *tert*-Butyl Ester (9b).** Following the procedure for the synthesis of **8a** from **6** (100 mg, 0.11 mmol), **7b** (72 mg, 0.25 mmol), and potassium *tert*-butoxide in dry toluene after flash chromatography with petroleum ether/ethyl acetate (2:1) **8b** was obtained. From this product following general procedure B compound **9b** (57 mg, 0.046 mmol, 42%) was obtained as a colorless oil. $R_f = 0.23$ (petroleum ether/ethyl acetate = 2:1); $[\alpha]_D = +5.5$ ($c = 0.45$, $CHCl_3$). ^{1}H NMR (600 MHz, $CDCl_3$): $\delta = 7.39-7.16$ (m, 25 H, arom. H), 5.63 (d, $J = 9.0$ Hz, 1 H, GalNAc-NH), 5.07 (d, $J = 9.5$ Hz, 1 H, Thr-NH), 4.92 (d, $J = 11.4$ Hz, 2 H, benzyl H), 4.78−4.79(m, 2 H, 1a-H, 2a-H), 4.74−4.66 (m, 3 H, benzyl H), 4.51 (d, $J_{1,2} = 7.8$ Hz, 1 H, 1b-H), 4.52 (d, $J = 10.8$ Hz, 2 H, benzyl H), 4.42−4.37 (m, 3 H, benzyl H), 4.10−4.09 (m, 2 H, α-Thr-H, *β*-Thr-H), 4.04 (s, 1 H, 4a-H), 3.95 (s, 1 H, 4b-H), 3.82−3.70 (m, 4 H, 2b-H, 3a-H, 5a-H, 6a-H), 3.69−3.64 (m, 1 H, 6b-H), 3.55 (d, $J = 9.0$ Hz, 3 H, 3b-H, 6b′-H, 6a′-H), 1.72 (s, 3 H, NAc) 1.46, 1.44 (2 × s, 18 H, Boc, *t*-Bu), 1.28 (d, $J = 6.0$ Hz, 3 H, Me), 1.02−0.98 (m, 21 H, TIPS). ^{13}C NMR (151 MHz, $CDCl_3$): $\delta = 139.1-127.1$ (30 C, arom. C), 105.8 (C-1b), 100.4 (C-1a), 82.2 (C-3b), 79.6 (C-2b), 78.6 (C-3a), 76.1 (C-*β*), 76.0 (C-4a), 74.8, 74.5, 74.1, 73.6 (C-4b), 73.1 (C-5b), 72.3 (C-5a), 71.1, 68.6 (C-6a), 63.2 (C-6b), 58.8 (C-α), 48.6 (C-2a), 29.7 (3 C), 28.4 (3 C), 28.1 (3 C), 23.4 (2 C), 18.0 (2 C), 11.8 (10 C). MALDI-MS (positive mode, DHB): $[M + Na]^+$: *m*/*z* calcd.: 1269.7, found: 1269.0. $C_{71}H_{98}N_2O_{15}Si$ (1247.63) calcd.: C: 68.35, H: 7.92, N: 2.25, found: C: 68.08, H: 8.00, N: 2.12.

***O*-(2,3,4,6-Tetra-*O*-benzyl-*β*-D-galactopyranosyl)-(1→3)-4-*O*-benzyl-D-galactal (11).** To a mixture of TIPS-protected saccharide **5** (320 mg, 0.35 mmol) and THF (20 mL) was added TBAF in THF (0.4 mL, 1 m solution). After 6 h the solvent was removed. Purification by flash chromatography (toluene/ethyl acetate = 5:1) afforded after lyophilization **11** (225 mg, 0.30 mmol, 86%) as a colorless powder; mp 43 °C. $R_f = 0.20$ (toluene/ethyl acetate = 5:1); $[\alpha]_D = -36.8$ ($c = 1$, $CHCl_3$). ^{1}H NMR (250 MHz, $CDCl_3$): $\delta = 7.38-7.42$ (m, 25 H, arom. H), 6.40 (dd, $J_{1,2} = 6.2$ Hz, $J_{1,3} = 1.6$ Hz, 1 H, 1a-H), 5.10 (t, $J = 11.8$ Hz, $J = 10.7$ Hz, 3 H, benzyl H), 4.84−4.70 (m, 5 H, 2a-H, benzyl H), 4.62−4.51 (m, 3 H, 3a-H, benzyl H), 4.42 (s, 2 H, 1b-H, benzyl H), 3.96−3.75 (m, 5 H, 4a-H, 5a-H, 4b-H, 2b-H, 6-H), 3.60−3.54 (m, 5 H, 3 × 6-H, 5b-H, 3b-H), 2.51 (s, 1 H, OH). ^{13}C NMR (63 MHz, $CDCl_3$): $\delta = 144.5$ (C-1a), 138.2−127.7 (30 C, arom. C), 103.1 (C-1b), 100.1 (C-2a), 96.1, 82.1 (C-3b), 79.7 (C-2b), 75.3 (C-5a), 74.6, 73.9 (C-4b), 73.6, 73.5, 73.2, (C-5b), 72.3 (C-5a), 71.8 (C-3b), 71.2 (C-4a), 69.0 (C-6a), 62.0 (C-6b). MALDI-MS (positive mode, DHB): $[M + Na]^+$: *m*/*z* calcd.: 781.3, found: 780.9. $C_{47}H_{50}O_9$ (758.89), calcd.: C: 74.38, H: 6.64, found: C: 74.57, H: 6.73.

***O*-(2-*O*-Azido-3,4,6-tri-*O*-benzyl-2-deoxy-*β*-D-glucopyranosyl)-(1→6)-[(*O*-(2,3,4,6-tetra-*O*-benzyl-*β*-D-galactopyranosyl)-(1×a83)]-4-*O*-benzyl-D-galactal (12).** A mixture of **11** (189 mg, 0.25 mmol) and **10A**[12] (160 mg, 0.27 mmol) was dissolved in MeCN and cooled to −40 °C, and tin(II) triflate (4 mg, 0.01 eq) in MeCN (1 mL) was added dropwise. After 30 min $NaHCO_3$ and CH_2Cl_2 were added and the suspension was washed with water. The solution was dried with $MgSO_4$ and the solvent removed under reduced pressure. Purification by flash chromatography (toluene/ethyl acetate 20:1) afforded **12** (182 mg, 0.15 mmol, 60%) as a slightly yellow oil. $R_f = 0.51$ (toluene/ethyl acetate = 20:1); $[\alpha]_D = -10.5$ ($c = 0.5$, $CHCl_3$). ^{1}H NMR (600 MHz, $CDCl_3$): $\delta = 7.34-7.14$ (m, 40 H, arom. H), 6.40 (d, $J_{1,2} = 5.6$ Hz, 1 H, 1a-H), 5.05 (d, $J = 12.0$ Hz, 2 H, benzyl H), 4.98 (d, $J = 10.8$ Hz, 1 H, benzyl H), 4.92 (d, $J = 10.$ Hz, 1 H, benzyl H), 4.85 (d, $J = 10.7$ Hz, 1 H, benzyl H), 4.83 (d, $J = 5.7$ Hz, 1 H, 2a-H), 4.78−4.68 (m, 7 H, benzyl H), 4.56 (d, $J = 4.2$ Hz, 1 H, 3a-H), 4.53−4.51 (m, 2 H, 1b-H, benzyl

H), 4.45−4.40 (m, 3 H, benzyl H), 4.23 (br s, 1 H, 1c-H), 4.19 (s, 1 H, 5a-H), 3.84 (dd, $J_{2,1} = J_{2,3} = 8.7$ Hz, 1 H, 2b-H), 3.91−3.90 (m, 3 H, 4b-H, 6a-H, 6a′-H), 3.66−3.53 (m, 7 H, 3b-H, 4b-H, 4c-H, 6b-H, 6b-′H, 6c-H, 6c′-H), 3.54 (d, $J = 5.8$ Hz, 2 H, 2c-H, 3c-H), 3.27 (d, $J = 8.4$ Hz, 1 H, 5c-H). ^{13}C NMR (151 MHz, $CDCl_3$): $\delta = 144.2$ (C-1a), 138.8−127.5 (48 C, arom. C), 102.8 (C-1b), 102.4 (C-1c), 100.1 (C-2a), 83.0 (C-3b), 82.1 (C-3b), 79.6 (C-2b), 77.6 (C-4c), 76.0 (C-5a), 75.4, 75.2, 74.9, 74.9 (C-5c), 74.8, 74.5, 73.8 (C-4b), 73.8, 73.5, 73.4 (C-5b), 73.1, 71.4, (C-3a), 71.4 (C-4a), 69.0 (C-6a), 68.7 (C-6b), 68.4 (C-6c), 66.2 (C-2a). MALDI-MS (positive mode, DHB): $[M + Na]^+$: *m*/*z* calcd.: 1238.5, found: 1237.5. HRMS (ESI) *m*/*z* calcd for $[C_{74}H_{77}N_3O_{13} + Na]^+$ 1238.5348, found 1238.5325.

***O*-(2-*O*-Azido-3,4,6-tri-*O*-benzyl-2-deoxy-*β*-D-glucopyranosyl)-(1→6)-[(*O*-(2,3,4,6-tetra-*O*-benzyl-*β*-D-galactopyranosyl)-(1×a83)]-4-*O*-benzyl-2-nitro-D-galactal (13).** Following general procedure A from **12** (320 mg, 0.35 mmol), after flash chromatography with toluene/ethyl acetate (10:1) compound **13** (228 mg, 0.24 mmol, 68%) was obtained as a slightly yellow oil. $R_f = 0.38$ (toluene/ethyl acetate = 20:1); $[\alpha]_D = +2.5$ ($c = 0.25$, $CHCl_3$). ^{1}H NMR (600 MHz, $CDCl_3$): $\delta = 8.13$ (s, 1 H, 1a-H), 7.33−7.15 (m, 40 H, arom. H), 5.24 (br s, 1 H, 3a-H), 4.97 (d, $J = 11.5$ Hz, 2 H, benzyl H), 4.93 (d, $J_{1,2} = 7.6$ Hz, 1 H, 1b-H), 4.83 (d, $J = 10.8$ Hz, 1 H, benzyl H), 4.73−4.70 (m, 3 H, benzyl H), 4.69−4.67 (m, 1 H, 4a-H), 4.62 (d, $J = 9.1$ Hz, 1 H, benzyl H), 4.58−4.40 (m, 9 H, benzyl H), 4.11 (d, $J = 8.3$ Hz, 1 H, 6a-H), 4.06 (d, $J_{1,2} = 6.9$ Hz, 1 H, 1c-H), 3.90−3.88 (m, 3 H, 4b-H, 5a-H, 6a′-H), 3.78 (dd, $J_{1,2} = J_{2,3} = 10.2$ Hz, 1 H, 2b-H), 3.67−3.69 (m, 1 H, 5b-H), 3.29−3.56 (m, 5 H, 3b-H, 4c-H, 6b-H, 6c-H, 6c′-H), 3.52 (d, $J = 9.7$ Hz, 1 H, 6b′-H), 3.39 (dd, $J_{2,1} = J_{2,3} = 6.9$ Hz, 1 H, 2c-H), 3.26 (dd, $J_{3,4} = J_{3,2} = 6.9$ Hz, 1 H, 3c-H) 3.13 (d, $J = 7.8$ Hz, 1 H, 5c-H). ^{13}C NMR (151 MHz, $CDCl_3$): $\delta = 155.1$ (C-1a), 138.8−127.5 (48 C, arom. C), 103.5 (C-1b), 102.6 (C-1c), 82.8 (C-3c), 82.2 (C-3b), 79.8 (C-2b), 78.7 (C-4a), 77.3 (C-4c), 75.4, 75.2, 75.1, 74.9 (C-5c), 74.8, 74.7, 74.2 (C-4b), 73.4, 73.3 (C-5b), 72.8, 72.5, 72.1, 70.7 (C-5a), 68.8 (C-6c), 68.3 (C-6a), 68.0 (C-6b), 66.1 (C-2a). MALDI-MS (positive mode, DHB): $[M + Na]^+$: *m*/*z* calcd.: 1283.5, found: 1282.5. HRMS (ESI) *m*/*z* calcd for $[C_{74}H_{76}N_4O_{15} + Na]^+$ 1283.5199, found 1283.5178.

***O*-(2-*O*-Azido-3,4,6-tri-*O*-benzyl-2-deoxy-*β*-D-glucopyranosyl)-(1→6)-[(*O*-(2,3,4,6-tetra-*O*-benzyl-*β*-D-galactopyranosyl)-(1→3)]-4-*O*-benzyl-2-deoxy-2-nitro-α-D-galactopyranosyl)-*N*-(*tert*-butyloxycarbonyl)-L-serine *tert*-Butyl Ester (14a).** To a mixture of **13** (40 mg, 0.032 mmol), **7a** (12 mg, 0.048 mmol), and dry toluene (1 mL) was added potassium *tert*-butoxide (0.4 mg, 0.003 mmol) under stirring. After 2 h the reaction mixture was neutralized with acetic acid and the solvent concentrated under reduced pressure. Purification by flash chromatography (toluene/ethyl acetate = 10:1) afforded **14** (31 mg, 0.0020 mmol, 63%) as a colorless oil. $R_f = 0.55$ (toluene/ethyl acetate = 20:1); $[\alpha]_D = +0.6$ ($c = 0.08$, $CHCl_3$). ^{1}H NMR (600 MHz, $CDCl_3$): $\delta = 7.34-7.14$ (m, 40 H, arom. H), 6.40 (d, $J_{1,2} = 4.6$ Hz, 1 H, 1a-H), 5.23 (d, $J = 8.8$ Hz, 1 H, Ser-NH), 5.00 (d, $J = 11.4$ Hz, 1 H, benzyl H), 4.91 (dd, $J_{2,1} = 4.6$ Hz, $J_{2,3} = 9.6$ Hz, 1 H, 2a-H), 4.87−4.85 (m, 2 H, benzyl H), 4.78 (m, 3 H, 1b-H, benzyl H), 4.72 (d, $J = 13.4$ Hz, 1 H, benzyl H), 4.64−4.53 (m, 8 H, 3a-H, benzyl H), 4.46−4.44 (m, 3 H, benzyl H), 4.29−4.26 (m, 2 H, 1c −H, α-Ser-H), 4.00 (br s, 1 H, 4a-H), 3.96 (br s, 2 H, 4b-H, 5a-H), 3.90 (br s, 1 H, *β*-Ser-H), 3.83 (d, $J = 9.1$ Hz, 1 H, *β*-H), 3.78−3.77 (m, 1 H; 2b-H), 3.74−3.55 (m, 9 H, 3b-H, 4c-H, 5c-H, 6b-H, 6b′-H, 6c-H, 6c′-H, 6a-H, 6a′-H), 3.38−3.35 (m, 2 H, 5b-H, 3c-H), 3.31 (dd, $J_{2,1} = J_{2,3} = 8.2$ Hz, 1 H, 2c-H), 1.47, 1.44 (2′ s, 18 H, Boc, t-Bu). ^{13}C NMR (151 MHz, $CDCl_3$ (selected data)): $\delta = 105.0$ (C-1b), 102.2 (C-1c), 96.5 (C-1a), 83.8 (C-2a), 83.0 (C-3c), 82.1 (C-3b), 79.5 (C-2b), 77.6 (C-4c), 75.6 (C-4a), 74.9 (C-5b), 73.8 (C-4b), 72.9 (C-5c), 70.1 (C-5a), 69.1 (C-*β*), 68.5 (C-6b), 68.2 (C-6c), 66.5 (C-2c), 54.3 (C-α). MALDI-MS (positive mode, DHB): $[M + Na]^+$: *m*/*z* calcd.: 1544.7, found: 1544.2. HRMS (ESI) *m*/*z* calcd for $[C_{86}H_{99}N_5O_{20} + Na]^+$ 1544.6775, found 1544.6765.

***O*-(2,3,4,6-Tetra-*O*-benzyl-α-D-galactopyranosyl)-(1→3)-(2-acetamido-di-4,6-*O*-benzyl-2-deoxy-α-D-galactopyranosyl)-*N*-(*tert*-butyloxycarbonyl)-L-serine *tert*-Butyl Ester (22a).** Following general procedure B from **21a** (140 mg, 0.12 mmol) after flash chromatography with petroleum ether/ethyl acetate (5:1), compound **22a** (97 mg, 0.083 mmol, 69%) was obtained as a colorless oil. $R_f = 0.22$ (toluene/ethyl acetate = 5:1). $[\alpha]_D = +5.1$ ($c = 0.3$, $CHCl_3$). ^{1}H NMR (600 MHz, $CDCl_3$): $\delta = 7.34-7.11$ (m, 30 H, arom. H), 5.98 (d, $J = 8.9$ Hz, 1 H, GalNAc-NH), 5.47 (d, $J = 8.4$ Hz, 1 H, Ser-NH), 5.05 (d, $J = 11.5$ Hz, 1 H, benzyl H), 4.94 (d, $J_{1,2} = 3.2$ Hz, 1 H, 1b-H), 4.85 (d, $J = 11.6$ Hz, 2 H, benzyl H), 4.83 (d, $J = 11.8$ Hz, 1 H, benzyl H), 4.81 (d, $J_{1,2} = 4.1$ Hz, 1 H, 1a-H), 4.70−4.60 (m, 4 H, 2a-H, benzyl H), 4.53−4.37 (m, 4 H, benzyl H), 4.29−4.22 (m, 2 H, α-Ser-H, benzyl H), 4.12−4.07 (m, 2 H, 2b-H, 5a-H), 3.95−3.93 (m, 1 H, 3b-H), 3.85−3.77 (m, 6 H, 3a-H, 4a-H, 4b-H, 5b.H, *β*-Ser-H, *β*′-Ser-H), 3.53−3.47 (m, 3 H, 6a-H, 6b-H, 6b′-H), 3.42−3.40 (m, 1 H, 6a′-H), 1.86 (s, 3 H, Ac), 1.42, 1.40 (2 × s, 18 H, t-Bu, Boc). ^{13}C NMR (63 MHz, $CDCl_3$): $\delta = 170.3$, 169.6, 139.2−127.0 (36 C, arom. C), 99.2 (C-1b), 98.9 (C-1a), 82.1, 79.1 (C-3b), 77.6 (C-3a), 76.3 (C-2b), 75.1 (C-4b), 74.8, 74.6, 74.4, 73.8, 73.0, 70.1 (C-5a), 70.0 (C-5b), 69.6 (C-*β*), 69.5 (C-6a), 68.6 (C-6b), 67.1, 54.5 (C-α), 48.9 (C-2a), 28.3 (4 C), 28.0 (4 C), 23.1 (2 C). MALDI-MS (positive mode, DHB): $[M + Na]^+$: *m*/*z* calcd.: 1189.6, found: 1188.8. $C_{68}H_{82}N_2O_{15}$ (1167.38) calcd.: C: 69.96, H: 7.08, N: 2.40, found: C: 68.94, H: 7.04, N: 2.27.

***O*-(2,3,4,6-Tetra-*O*-benzyl-α-D-galactopyranosyl)-(1→3)-(2-acetamido-4-*O*-benzyl-2-deoxy-6-*O*-(triisopropylsilyl)-<bold>α-D-galactopyranosyl)-*N*-(*tert*-butyloxycarbonyl)-L-serine *tert*-Butyl Ester (24a)**. Following general procedure B from **23a** (50 mg, 0.043 mmol) after flash chromatography with toluene/ethyl acetate (5:1), compound **24a** (36 mg, 0.031 mmol, 72%) was obtained as a colorless oil. $R_f = 0.65$ (toluene/ethyl acetate = 5:1); $[\alpha]_D = +11.6$ ($c = 1$, $CHCl_3$). ^{1}H NMR (250 MHz, $CDCl_3$): $\delta = 7.21-7.00$ (m, 25 H, arom. H), 5.83 (d, $J = 8.8$ Hz, 1 H, GalNAc-NH), 5.20 (d, $J = 8.6$ Hz, 1 H, Ser-NH), 4.98 (d, $J = 11.4$ Hz, 1 H, benzyl H), 4.81 (d, $J_{1,2} = 3.6$ Hz, 1 H, 1b-H), 4.77−4.68 (m, 2 H, benzyl H), 4.64 (d, $J_{1,2} = 2.0$ Hz, 1 H, 1a-H), 4.52−4.49 (m, 3 H, 2a-H, benzyl H), 4.45−4.22 (m, 5 H, benzyl H), 4.20−4.05 (m, 1 H, α-H), 3.96−3.89 (m, 2 H, 2b-H, 5b-H), 3.83−3.75 (m, 2 H, 3b-H, 4a-H), 3.66−3.51 (m, 7 H, 3a-H, 4b-H, 5a-H, 6a-H, 6a′-H, *β*-Ser-H, *β*′-Ser-H), 3.32−3.24 (m, 2 H, 6b-H, 6b′-H), 1.72 (s, 3 H, Ac), 1.43, 1.40 (2 × s, 18 H, t-Bu, Boc), 1.03−0.90 (m, 21 H, TIPS). ^{13}C NMR (63 MHz, $CDCl_3$): $\delta = 168.6$, 163.0, 137.0−125.3 (30 C, arom. C), 97.6 (C-1b), 97.5 (C-1a), 94.5, 80.1 (C-3b), 77.8 (C-3a), 76.3 (*β*-C), 74.5 (C-4a), 73.8 (4b-H), 73.3, 73.0 (C-5a), 72.7, 72.3, 71.5, 70.7 (C-5b), 68.6, 67.8, 67.3, 62.7, 60.5, 53.1, 53.0 (C-α), 47.5 (C-2a), 26.7, 10.3 (16 C). MALDI-MS (positive mode, DHB): $[M + Na]^+$: *m*/*z* calcd.: 1256.6, found: 1257.5. $C_{70}H_{96}N_2O_{15}Si$ (1233.60) calcd.: C: 68.15, H: 7.84, N: 2.27, found: C: 67.77, H: 8.35, N: 2.38.

***O*-(2,3,4,6-Tetra-*O*-benzyl-α-D-galactopyranosyl)-(1→3)-(2-acetamido-4-*O*-benzyl-2-deoxy-6-*O*-(triisopropylsilyl)-<bold>α-D-galactopyranosyl)-*N*-(*tert*-butyloxycarbonyl)-L-threonine *tert*-Butyl Ester (24b).** Following general procedure B from **23b** (50 mg, 0.04 mmol) after flash chromatography with toluene/ethyl acetate (5:1), compound **24b** (35 mg, 0.03 mmol, 70%) was obtained as a colorless oil. $R_f = 0.69$ (toluene/ethyl acetate = 5:1); $[\alpha]_D = +2.9$ ($c = 0.19$, $CHCl_3$). ^{1}H NMR (600 MHz, $CDCl_3$): $\delta = 7.3-7.19$ (m, 25 H, arom. H), 6.00 (d, $J = 8.9$ Hz, 1 H, GalNAc-NH), 5.24 (d, $J = 8.2$ Hz, 1 H, Thr-NH), 5.10 (d, $J = 12.0$ Hz, 1 H, benzyl H), 4.97 (d, $J_{1,2} = 3.6$ Hz, 1 H, 1b-H), 4.88 (d, $J = 12.0$ Hz, 1 H, benzyl H), 4.80 (d, $J = 11.0$ Hz, 1 H, benzyl H), 4.76 (s, 2 H, 1a-H, 2a-H), 4.69−4.62 (m, 2 H, benzyl H), 4.50 (d, $J = 12.0$ Hz, 1 H, benzyl H), 4.40 (t, $J = 11.4$ Hz, 1 H, benzyl H), 4.38−4.23 (m, 3 H, benzyl H), 4.13−4.10 (m, 3 H, 3b-H, α-Thr-H, *β*-Thr-H), 4.06 (dd, $J_{2,1} = 3.6$ Hz, $J_{2,3} = 9.6$ Hz, 1-H, 2b-H), 3.98 (s, 1 H, 3b-H), 3.96 (s, 1 H, 4a-H,), 3.81−3.77 (m, 3 H, 3a-H, 4b-H, 5a-H), 3.72−3.69 (m, 2 H, 6a-H, 6a′-H), 3.48−3.47 (m,

1 H, 6b-H), 3.43−3.40 (m, 1 H, 6b′-H), 1.93 (s, 3 H, Ac), 1.42, 1.38 (2 × s, 18 H, t-Bu, Boc), 1.26 (d, J = 8.4 Hz, 3 H, Me), 1.03−1.00 (m, 21 H, TIPS). ^{13}C NMR (151 MHz, $CDCl_3$, selected data): δ = 100.3 (C-1a), 98.6 (C-1b), 79.4 (C-3b), 77.3 (C-3a), 76.1 (C-β), 76.3 (2b-H), 75.5 (4b-H), 74.3 (C-4a), 72.4 (C-5a),-70.1 (C-5b), 69.3 (C-6b), 62.3 (C-6a), 58.6 (C-α), 48.7 (C-2a). MALDI-MS (positive mode, DHB): $[M + Na]^+$: *m/z* calcd.: 1269.6, found: 1268.5. HRMS (ESI) *m/z* calcd for $[C_{71}H_{98}N_2O_{15}Si + Na]^+$ 1269.6629, found 1269.6593.

***O*-(2-Azido-2-deoxy-3,4,6-tri-*O*-benzyl-*β*-D-glucopyranosyl)-(1→3)-(4-*O*-benzyl-2-deoxy-2-nitro-6-*O*-(triisopropylsilyl)-α-D-galactopyranosyl)-*N*-(*tert*-butyloxycarbonyl)-L-serine *tert*-Butyl Ester (28a).** To a solution of **27** (150 mg, 0.17 mmol) and **7a** (66 mg, 0.25 mmol) in dry toluene (5 mL) was added potassium *tert*-butoxide (2 mg, 0.018 mmol) under stirring; after 2 h the mixture was neutralized with acetic acid and the solvent removed in vacuo. Purification by flash chromatography (petroleum ether/ethyl acetate = 10:1) furnished **28a** (141 mg, 0.12 mmol, 72%) as a colorless oil. R_f = 0.65 (petroleum ether/ethyl acetate = 3:1); $[\alpha]_D$ (c = 0.2, $CHCl_3$) = +3.1. ^{1}H NMR (600 MHz, $CDCl_3$): δ = 7.33−7.17 (m, 20 H, arom. H), 5.30 (d, $J_{1,2}$ = 3.8 Hz, 1 H, 1a-H), 5.19 (d, J = 8.6, 1 H, NH), 4.99 (dd, $J_{2,1}$ = 3.8 Hz, $J_{2,3}$ = 10.5 Hz, 1 H, 2a-H), 4.95 (d, J = 11.3 Hz, 1 H, benzyl H), 4.88 (d, J = 11.0 Hz, 1 H, benzyl H), 4.87 (d, J = 10.7 Hz, 1 H, benzyl H), 4.80−4.77 (m, 3 H, 1b-H, benzyl H), 4.63−4.59 (m, 3 H, 3a-H, benzyl H), 4.55 (d, J = 13.9 Hz, 1 H, benzyl H), 4.31 (br s, 1 H, α-Ser-H), 4.21 (s, 1 H, 4a-H), 3.84 (d, J = 6.8 Hz, 4 H, 5a-H, 6b-H, β-Ser-H, β'-Ser-H), 3.76−3.67 (m, 4 H, 4b-H, 6a-H, 6a′-H, 6b′-H), 3.56−3.55 (m, 1 H, 5b-H), 3.45 (dd, $J_{3,2}$ = $J_{3,4}$ = 9.3 Hz, 1 H, 3b-H), 3.32 (dd, $J_{2,1}$ = $J_{2,3}$ = 9.3 Hz, 1 H, 2b-H), 1.45 (2 × s, 18 H, Boc, t-Bu), 1.03−1.00 (m, 21 H, TIPS). ^{13}C NMR (151 MHz, $CDCl_3$): δ = 137.9−127.3 (24 C, arom. C), 10.7 (C-1b), 99.6 (C-1b), 88.5, 83.6 (C-2a), 82.6 (C-3b), 77.3 (C-4b), 76.0 (C-4a), 75.6 (C-3a), 75.3, 74.8 (C-5b), 73.5, 71.6 (C-5a), 69.0 (C-β), 68.9 (C-6b), 66.4 (C-2b), 61.9 (C-6a), 54.1 (C-α), 28.3, 27.8, 18.0, 11.8 (17 C). MALDI-MS (positive mode, DHB): $[M + Na]^+$: *m/z* calcd.: 1178.6, found: 1179.7. $C_{61}H_{85}N_5O_{15}Si$ (1156.44). The mass peak could not be obtained by ESI HRMS.

***O*-(2-Actamido-2-deoxy-3,4,6-tri-*O*-benzyl-*β*-D-glucopyranosyl)-(1→6)-(3,4-di-*O*-benzyl-2-acetamido-2-deoxy-D-galactopyranosyl)-*N*-(*tert*-butyloxycarbonyl)-L-serine *tert*-Butyl Ester (35a).** Following general procedure B from **34a** (150 mg, 0.116 mmol) after flash chromatography with petroleum ether/ethyl acetate (5:1), compound **35a** (160 mg, 82%) was obtained as a colorless solid. **34a** (150 mg, 0.116 mmol) was dissolved in ethanol (6 mL) and transferred to a hydrogen vessel. Platinized Raney nickel T_4 catalyst (freshly prepared, and the material obtained from 2 g of Raney nickel/aluminum alloy was suspended in ethanol, 10 mL) was added to the reaction vessel and the mixture shaken in a Parr apparatus at a hydrogen pressure of 75 psi for 24 h. The catalyst was carefully filtered off and the solvent evaporated. The residue was dissolved in pyridine/acetic anhydride (2:1, 4 mL) and stirred overnight and concentrated, and the crude product was purified by flash chromatography (chloroform/methanol 20:1) to give compound **6** as a colorless solid (160 mg, 82%), mp. 204 °C. R_f 0.56 (toluene/acetone 15:1). $[\alpha]_D$ = +24.5 (c = 0.5, $CHCl_3$). ^{1}H NMR (600 MHz, $CDCl_3$): δ = 7.37−7.18 (m, 25 H, aromatic), 5.84 (d, J = 7.2 Hz, 1 H, -NHAc), 5.47 (d, J = 7.2 Hz, 1 H, NHBoc), 5.36 (d, J = 7.8 Hz, 1 H, -NHAc), 4.90 (d, J = 11.4 Hz, 1 H, -OCH_2Ph), 4.81−4.76 (m, 4 H, 1a-H, -OCH_2Ph), 4.74 (d, J = 7.2 Hz, 1 H, 1b-H), 4.68−4.60 (m, 4 H, 2b-H, -OCH_2Ph), 4.57−4.42 (m, 3 H, -OCH_2-Ph), 4.24 (br s, 1 H, α-Ser-H); 4.06 (br s, 1 H, 3a-H), 3.90 (br s, 1 H, 5a-H), 3.89−3.78 (m, 4 H, 6b-H, 6b′-H, 5b-H, β-Ser-H), 3.73−3.64 (m, 4 H, 6a-H, 6a′-H, β'-Ser-H, 4b-H), 3.57−3.53 (m, 2 H, 3b-H, 4a-H), 3.42 (br t, J = 9.0 Hz, 1 H, 2a-H), 1.88 (s, 3 H, -NHAc), 1.84 (s, 3 H, -NHAc), 1.45, 1.42 (2 s, 18 H, *tert*-butyl). ^{13}C NMR (151 MHz, $CDCl_3$): δ = 170.3, 169.8, 155.3, 138.5−127.5 (m, 30C, aromatic), 100.1 (C-1b), 98.8 (C-1a), 82.4, 80.4 (C-3a), 80.1, 78.5 (C-4b), 77.1 (C-3b), 75.0, 74.6 (C-4a), 74.5, 74.2, 73.4, 72.6 (C-5a), 71.4, 70.6 (C-5b), 68.8 (C-6b), 68.6 (C-6a), 68.5 (β-C), 56.9 (C-2a), 54.4 (α-C), 48.7 (C-2b). MALDI-MS (positive mode, DHB): 1141.1 $[M + Na]^+$. Anal. Calcd for $C_{63}H_{79}N_3O_{15}$ (1117.55): C, 67.66; H, 7.12; N, 3.76, found: C, 67.72; H, 7.17; N, 3.81.

***O*-(2-Actamido-2-deoxy-3,4,6-tri-*O*-benzyl-*β*-D-glucopyranosyl)-(1→6)-(3,4-di-*O*-benzyl-2-acetamido-2-deoxy-D-galactopyranosyl)-*N*-(*tert*-butyloxycarbonyl)-L-threonine *tert*-Butyl Ester (35b).** **35b** was prepared in 79% yield from **34b** following the same procedure as for the preparation of **35a**. $[\alpha]_D$ = +10.5 (c = 0.25, $CHCl_3$). ^{1}H NMR (600 MHz, $CDCl_3$): δ = 7.37−7.18 (m, 25 H, aromatic), 5.65 (d, J = 9.9 Hz, 1 H, -NHAc), 5.46 (d, J = 8.0 Hz, 1 H, -NHAc), 5.05 (d, J = 9.0 Hz, 1 H, -NHBoc), 4.93 (d, J = 11.4 Hz, 1 H, -OCH_2Ph), 4.81−4.75 (m, 3 H, 1a-H, -OCH_2Ph), 4.72 (dd, J = 10.2, 3.6 Hz, 1 H, 2a-H), 4.69−4.63 (m, 3 H, 1b-H, -OCH_2Ph), 4.60−4.54 (m, 3 H, -OCH_2Ph), 4.47−4.45 (m, 2 H, -OCH_2Ph), 4.15 (d, J = 9.0 Hz, 1 H, α-Thre-H), 4.05 (br d, J = 5.4 Hz, 1 H, β-Thre-H), 3.92−3.84 (m, 4 H, 4a-H, 6a-H, 3b-H, 5b-H), 3.74−3.67 (m, 3 H, 6b-H, 6b′-H, 4b-H), 3.65−3.62 (m, 1 H, 6a′-H), 3.56−3.51 (m, 3 H, 2b-H, 3a-H, 5a-H), 1.85 (s, 3 H, -NHAc), 1.79 (s, 3 H, -NHAc), 1.47, 1.41 (s, 18 H, *tert*-butyl), 1.22 (d, J = 5.4 Hz, 3 H, γ-Thre-H). ^{13}C NMR (151 MHz, $CDCl_3$): δ = 170.5, 170.0, 155.7, 138.5−127.5 (m, 30 C, aromatic), 100.4 (C-1b), 99.9 (C-1a), 82.7, 80.9 (C-4a), 80.1, 78.2 (C-4b), 77.5 (C-3a), 76.1, 75.9 (β-C), 74.7 (C-5a), 74.5, 74.2, 73.4, 72.8 (C-3b), 71.6, 70.3 (C-5b), 68.7 (C-6b), 68.4 (C-6a), 58.5 (α-C), 56.2 (C-2b), 48.8 (C-2a), 29.7, 28.3, 28.1, 23.5, 18.6. MALDI-MS (positive mode, DHB): 1155.5 $[M + Na]^+$. Anal. Calcd for $C_{64}H_{81}N_3O_{15}$ (1131.57): C, 67.88; H, 7.21; N, 3.71, found: C, 68.01, H, 7.28; N, 3.82.

***O*-(2-Acetamido-3,4,6-tri-*O*-acetyl-2-deoxy-α-D-galactopyranosyl)-(1→6)-(2-acetamido-3,4-di-*O*-acetyl-2-deoxy-α-D-galactopyranosyl)-*N*-(fluorenylmethyloxycarbonyl)-L-serine *tert*-Butyl Ester (42a).** **41a** (0.15 g, 0.122 mmol) was dissolved in ethanol (5 mL) and transferred to a hydrogenation vessel. Platinized Raney nickel T4 catalyst was freshly prepared and the material obtained from 2 g of Raney nickel/aluminum alloy was suspended in ethanol (15 mL). From a homogeneous suspension of this catalyst 8 mL were added to the reaction vessel and the mixture shaken in a Parr apparatus at a hydrogen pressure of 75 psi for 12 h. The catalyst was filtered off and the solvent evaporated. The residue was dissolved in pyridine/acetic anhydride (2:1, 6 mL) and stirred for 12 h. All volatiles were removed and the crude product purified by flash chromatography (toluene/acetone 2:1) to give the intermediate bis-acetamido product (0.108 g, 70%). This material was dissolved in THF (2 mL) and treated with tetrabutylammonium fluoride solution (0.1 mL of a 1 M solution in THF) and stirred at rt for 4 h. The solution was acidified by addition of acetic acid and concentrated. The crude material was purified by flash chromatography (toluene/acetone 3:2) to give the 6-*O*-unprotected product, which was directly used for subsequent debenzylation. The material was dissolved in methanol/acetic acid (2.5 mL, 4:1) and stirred over Pd/C (0.02 g, 10% palladium) under hydrogen atmosphere for 14 h. The catalyst was filtered off, and all volatiles were removed. The residue was treated with pyridine/acetic anhydride (2 mL, 2:1) for 12 h. Removal of all volatiles and column chromatographic purification of the residue (chloroform/methanol 22:1) gave the Boc-protected *tert*-butyl ester of the target molecule as a colorless foam (0.0602 g, 56% over five steps). R_f = 0.54 (chloroform/methanol 13:1); $[\alpha]_D^{25}$ = +101.3 (c = 1, $CHCl_3$). ^{1}H NMR (600 MHz, $CDCl_3$): δ = 6.34 (d, $^3J_{NH,2}$ = 9.3 Hz, 1 H, GalNHAcb-NH), 5.79 (d, $^3J_{NH,\alpha}$ = 6.3 Hz, 1 H, Ser-NH), 5.66 (d, $^3J_{NH,2}$ = 9.6 Hz, 1 H, GalNHAca-NH), 5.40 (d, $^3J_{4,3}$ = 3.3 Hz, 1 H, 4b-H), 5.37 (d, $^3J_{4,3}$ = 3.3 Hz, 1 H, 4a-H), 5.21 (dd, $^3J_{3,2}$ = 11.3, $^3J_{3,4}$ = 2.3 Hz, 1 H, 3b-H), 5.13 (dd, $^3J_{3,2}$ = 11.3, $^3J_{3,4}$ = 3.2 Hz, 1 H, 3a-H), 4.86 (d, $^3J_{1,2}$ = 3.6 Hz, 1 H, 1a-H), 4.81 (d, $^3J_{1,2}$ = 3.4 Hz, 1 H, 1b-H), 4.66 (ddd, $^3J_{2,NH}$ = 10.5, $^3J_{2,1}$ = 3.4, $^3J_{2,3}$ = 10.5 Hz, 1 H, 2b-H), 4.62 (ddd, $^3J_{2,NH}$ = 9.9, $^3J_{2,1}$ = 3.3, $^3J_{2,3}$ = 9.9 Hz, 1 H, 2a-H), 4.42 (br s, 1 H, α-H), 4.23−4.18 (m, 2 H,

5b-H, 6b-H), 4.08−3.97 (m, 3 H, 5a-H, 6b′-H, β-H), 3.78−3.74 (m, 2 H, 6a-H, β′-H), 3.31 (br s, 1 H, 6a′-H), 2.16−1.98 (7 s, 21 H, 5 OAc, 2 NHAc), 1.15, 1.46 (2 s, 18 H, 2 C_4H_9). ^{13}C NMR (150.8 MHz, $CDCl_3$): δ = 170.9−170.0 (9 C), 155.2, 97.8 (1a-C), 97.4 (1b-C), 82.8, 80.1, 68.4 (3b-C), 68.3 (3a-C), 68.0 (β-C), 67.7 (4a-C), 67.6 (4b-C), 67.1 (5b-C), 65.3 (6a-C), 62.1 (6b-C), 54.0 (α-C), 47.8 (2a-C), 47.3 (2b-C), 28.3 (3 C), 28.0 (3 C), 23.3 (2 C), 23.0, 20.7 (4 C). MS (FAB): calcd.: 877 + 1 (H) = 878, 877 + 23 (Na) = 900, 877 + 173 (Na, NaI) = 1050; found 878 $[M + H]^+$, 900 $[M + Na]^+$, 1050 $[M + NaI + Na]^+$. This intermediate was immediately transformed into the target molecule **42a**:

The intermediate (0.0120 g, 0.0139 mmol) was dissolved in a mixture of trifluoroacetic acid and dichloromethane (2 mL, 1:1) and the solution stirred at rt for 12 h. Then all solvents were evaporated. The residue was redissolved together with Fmoc-ONSu (0.0094 g, 0.0278 mmol) and sodium bicarbonate (0.0233 g, 0.2780 mmol) in acetonitrile/water (3 mL, 1:1) and the mixture stirred for 12 h. The solution was diluted with dichloromethane and acidified with 2 N HCl solution (25 mL) and the aqueous layer extracted with dichloromethane (3 × 25 mL). The combined organic extracts were dried over sodium sulfate and the volatiles evaporated. Column chromatographic purification (10 g silica gel, chloroform/methanol/acetic acid 8:2:1) of the residue afforded **42a** as a colorless foam. (0.0131 g, quantitative). R_f = 0.23 (chloroform/methanol 4:1);); $[\alpha]_D$ = +88.8 (*c* = 1, $CHCl_3$). ^{1}H NMR (600 MHz, $CDCl_3$): δ = 7.89 (d, *J* = 7.5 Hz, 2 H, arom. H), 7.71 (t, *J* = 7.7 Hz, 2 H, arom. H), 7.40−7.30 (m, 4 H, arom. H), 5.45 (d, $^3J_{4,3}$ = 3.2 Hz, 1 H, 4a-H), 5.33 (d, $^3J_{4,3}$ = 2.6 Hz, 1 H, 4b-H), 5.21−5.17 (m, 2 H, 3a-H, 3b-H), 4.88 (d, $^3J_{1,2}$ = 3.3 Hz, 1 H, 1a-H), 4.77 (d, $^3J_{1,2}$ = 3.5 Hz, 1 H, 1b-H); 4.55−4.42 (m, 4 H, β-H, β′-H, 2a-H, 2b-H), 4.35 (t, $^3J_{5,6}$ = 6.6 Hz, $^3J_{5,6'}$ = 5.6 Hz, 1 H, 5a-H), 4.28−4.23 (m, 3 H, 5b-H, α-H, Fmoc-CH), 4.02 (dd, $^3J_{6,5}$ = 6.0, $^2J_{6,6'}$ = 11.2 Hz, 1 H, 6b-H), 3.95 (s, 2 H, Fmoc-CH_2), 3.83 (dd, $^3J_{6',5}$ = 7.0, $^2J_{6,6'}$ = 11.1 Hz, 1 H, 6b′-H), 3.77 (t, $^3J_{6,5}$ = 9.6, $^2J_{6,6'}$ = 9.6 Hz, 1 H, 6a-H), 3.34 (dd, $^3J_{6',5}$ = 5.0, $^2J_{6',6}$ = 9.9 Hz, 1 H, 6a′-H), 2.14−1.86 (7 s, 21 H, 5 OAc, 2 NHAc). ^{13}C NMR (150.8 MHz, $CDCl_3$): δ = 174.0−172.0 (8 C), 145.3−121-0 (12 C), 100.0 (1a-C), 99.1 (1b-C), 71.5 (Fmoc-CH_2),70.1 (3a-C), 69.8 (3b-C), 69.3 (4a-C), 68.8 (2 C, 5a-C, 4b-C), 68.2 (β-C), 68.0 (5b-C), 67.4 (6a-C), 63.0 (6b-C), 57.7 (Fmoc-CH), 49.0 (2a-C), 48.7 (2b-C), 48.4 (α-C), 22.8, 22.7, 20.7 (2 C), 20.6 (2 C), 20.5. MS (FAB): calcd. 943 + 23 (Na) = 966, 943 + 46 (2 Na)- 1 (H) = 988; found 966 $(M + Na)^+$, 988 $(M + 2\ Na - H)^+$. HRMS (ESI) *m/z* calcd for $[C_{44}H_{53}N_3O_{20} + Na]^+$ 966.3114, found 966.3116.

***O*-(2-Acetamido-3,4-di-*O*-benzyl-2-deoxy-6-*O*-(*tert*-butyldiphenylsilyl)- α-D-galactopyranosyl)-(1→3)-(4-*O*-acetyl-2-acetamido-2-deoxy-6-*O*-(triisopropylsilyl)-α-D-galactopyranosyl)-*N*-(*tert*-butyloxycarbonyl)-L-serine *tert*-Butyl Ester (47a)**. To a solution of **46a** (40 mg, 0.03 mmol) in ethanol (5 mL) was added freshly prepared platinized Raney Nickel T4 catalyst, then stirred and left to react for 12 h under hydrogen atmosphere at 50 bar. The catalyst was filtered off and purification by flash chromatography (toluene/ethyl acetate = 2:1) furnished **47a** (17 mg, 0.008 mmol, 26%) and as a second product 6-*O*-TBDPS-protected **40a** (9 mg, 0.01 mmol, 33%) as a colorless lyophilisate. **47a**: R_f = 0.35 (toluene/ethyl acetate 2:1); $[\alpha]_D$ (*c* = 0.12, $CHCl_3$) = +11.8. ^{1}H NMR (600 MHz, $CDCl_3$): δ = 7.63 (d, *J* = 6.7 Hz, 2 H, arom. H) 7.62 (d, *J* = 6.7 Hz, 2 H, arom. H), 7.41−7.24 (m, 16 H, arom. H), 6.83 (d, *J* = 8.6 Hz, 1 H, b-GalNAc-NH), 5.77 (s, 1 H, a-GalNAc-NH), 5.42 (s, 1 H, 4a-H), 5.27 (d, *J* = 8.6 Hz, 1 H, Ser-NH), 5.07 (d, *J* = 10.8 Hz, 1 H, benzyl H), 4.95 (d, $J_{1,2}$ = 2.2 Hz, 1 H, 1a-H), 4.85−4.83 (m, 1 H, 2b-H), 4.80 (s, 1 H, 1b-H), 4.70−4.65 (m, 2 H, benzyl H), 4.48 (d, *J* = 10.9 Hz, 1 H, benzyl H), 4.25 (br s, 2 H, 2a-H, α-Ser-H), 4.03 (s, 2 H, 5a-H, 6b′-H), 3.89−3.85 (m,2 H, 5a-H, 6b′-H), 3.76−3.70 (m, 4 H, 3a-H, 5b-H, 6b′-H, β-Ser-H, β′-Ser-H), 3.65−3.60 (m, 2 H, 6a″-H, 6b″-H), 3.45 (d, *J* = 10.3 Hz, 1 H, 3b-H), 2.14, 2.06 (3 × s, 9 H, OAc), 1.47, 1.40 (2 × s, 18 H, t-Bu, Boc), 1.03−0.95 (m, 30 H, TIPS, t-Bu). ^{13}C NMR (151 MHz, $CDCl_3$) δ = 171.2, 170.6 (C-Ac), 138.8−127.2 (24 C, arom. C), 102.4 (C-1b), 98.5 (C-1a), 82.5, 78.2 (C-3b), 77.1 (C-3b), 73.1 (C-4b), 72.2 (C-5b), 69.9 (C-5a), 69.6 (C-β), 61.4 (C-6b), 61.0 (C-6a), 54.4 (C-α), 49.6 (C-2a), 49.2 (C-2b), 29.7, 28.3, 28.0, 27.0, 23.1, 23.1, 21.2, 19.1, 17.9, 11.8 (20 C). MALDI-MS (positive mode, DHB): $[M + Na]^+$: *m/z* calcd.: 1308.5, found: 1306.9. $C_{69}H_{101}N_3O_{16}Si_2$ (1284.72), calcd.: C: 64.51, H: 7.92, N: 3.27, found: C: 64.17, H: 8.08, N: 3.02.

***O*-(3,6-Di-*O*-benzyl-4-*O*-*tert*-butyldimethylsilyl-2-deoxy-2-nitro-β-D-glucopyranosyl)-(1→6)-(3,4-di-*O*-*tert*-butyldimethylsilyl-2-deoxy-2-nitro-α-D-galactopyranosyl)-*N*-(*tert*-butyloxycarbonyl)-l-serine *tert*-Butyl Ester (55a)**. **54** (0.044 g, 0.049 mmol) and **7a** (0.026 g, 0.098 mmol) were carefully dried under high vacuum and dissolved in dry toluene. The reaction was activated by addition of potassium *tert*-butoxide solution (49 μL of a 1 m solution in THF) at rt under constant stirring. After 45 min the reaction was quenched with acetic acid and concentrated. Flash chromatography of this material (toluene/ethyl acetate 20:1) furnished **55a** as a colorless oil (0.028 g, 49%). R_f = 045 (toluene/ethyl acetate 10:1); $[\alpha]_D^{25}$ = +50.9 (*c* = 2, $CHCl_3$). ^{1}H NMR (600 MHz, $CDCl_3$): δ = 7.33−7.22 (m, 10 H, arom. H), 5.39 (d, $^3J_{NH,\alpha}$ = 8.8 Hz, 1 H, NH), 5.18 (d, $^3J_{1,2}$ = 4.1 Hz, 1 H, 1a-H), 5.03 (d, $^3J_{1,2}$ = 8.2 Hz, 1 H, 1b-H), 4.84 (dd, $^3J_{2,1}$ = 4.1, $^3J_{2,3}$ = 10.3 Hz, 1 H, 2a-H), 4.67 (d, ^2J = 10.7 Hz, 1 H, benzyl H), 4.60 (d, ^2J = 12.2 Hz, 1 H, benzyl H), 4.52 (dd, $^3J_{2,1}$ = 8.2, $^3J_{2,3}$ = 10.0 Hz, 1 H, 2b-H), 4.50 (d, ^2J = 12.2 Hz, 1 H, benzyl H), 4.45 (d, *J* = 10.7 Hz, 1 H, benzyl H), 4.39 (dd, $^3J_{3,2}$ = 10.3, $^3J_{3,4}$ = 2.4 Hz, 1 H, 3a-H), 4.24 (m, 1 H, α-H), 4.10 (t, $^3J_{3,2}$ = 9.1, $^3J_{3,4}$ = 9.1 Hz, 1 H, 3b-H), 3.97 (dd, $^3J_{\alpha,\beta}$ = 2.9, $^3J_{\beta,\beta}$ = 11.2 Hz, 1 H, β-H), 3.85−3.40 (m, 2 H, 5a-H, 6a-H), 3.81 (s, 1 H, 4a-H), 3.78−3.75 (m, 2 H, 4b-H, β-CH), 3.70−3.69 (m, 2 H, 6a′-H, 6b-H), 3.64 (dd, $^3J_{6,5}$ = 4.7, $^2J_{6,6'}$ = 10.9 Hz, 1 H, 6b′-H), 3.60−3.59 (m, 1 H, 5b-H), 1.49, 1.45 (2 s, 18 H, 2 C_4H_9), 0.89−0.83 (3 s, 27 H, 3 C_4H_9), 0.25−0.00 (6 s, 18 H, 6 $SiCH_3$). ^{13}C NMR (151 MHz, $CDCl_3$): δ = 169.2, 155.4, 137.9, 136.9, 128.3−127.5 (10 C), 99.3 (1b-C), 97.5 (1a-C), 89.9 (2b-C), 85.6 (2a-C), 82.6 (3b-C), 82.3 (2-C), 79.8 (2-C), 76.6 (5b-C), 74.9, 73.3, 70.7 (4a-C), 70.3 (β-C), 69.9 (5a-C), 68.9 (3a-C), 68.1 (6b-C), 66.0 (6a-C), 54.4 (α-C), 28.4, 27.9, 26.1, 25.8, 18.5, 18.1, 17.9, −2.2, −3.5, −4.9, −5.6 (2 C). MS (FAB): calcd.: 1165 + 23 (Na) = 1188; found 1188 $[M + Na]^+$. HRMS (ESI) *m/z* calcd for $[C_{56}H_{95}N_3O_{17}Si + Na]^+$ 1188.5861, found 1188.5870.

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Supporting Information Available: NMR spectra, experimental procedures, and physical data. This material is available free of charge via the Internet at http://pubs.acs.org.

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