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Graphical Abstract

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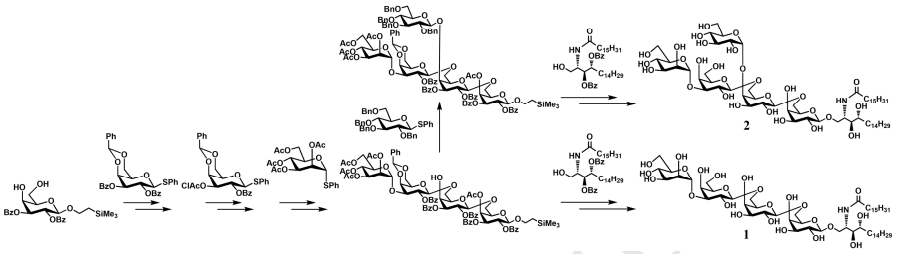

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Synthesis of glycosphingolipids from the fungus *Hirsutella rhossiliensis*

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ABSTRACT

The total synthesis of two neutral glycosphingolipids (GSLs) from the fungus *Hirsutella rhossiliensis* has been achieved. The GSLs possess a common neogala-core (Galβ1-6Gal) and have the following sequence: α-D-Man*p*(1→3)-β-D-Gal*p*(1→6)-β-D-Gal*p*(1→6)-β-D-Gal*p*(1↔1)Cer (**1**) and α-D-Man*p*(1→3)-β-D-Gal*p*(1→6)[α-D-Glc*p*(1→4)]-β-D-Gal*p*(1→6)-β-D-Gal*p*(1↔1)Cer (**2**). Our efficient synthetic strategy uses the different reactivity of the hydroxyl groups of galactose and the α-orienting solvent effect of dioxane-toluene to generate GSLs (**1**) and (**2**).

1. Introduction

Many glycosphingolipids (GSLs) sequences isolated from vertebrates terminate in sialic acid residues. In recent years, the synthesis of these GSLs and the understanding of the biological functions has attracted a lot of attention by various research groups[1]. In contrast, research on GSLs isolated from invertebrates has been neglected. There are only limited reports which describe naturally occurring sequences of GSLs in invertebrates[2-21]. These structures are significantly different from GSLs isolated from vertebrates. Moreover, the biological function of GSLs in invertebrates and fungi are unknown. For this reason we have been interested in the synthesis of glycolipids derived from various invertebrate sources in order to clarify their biological functions[22-37].

Isolation and purification of glycolipids from invertebrate species are very difficult and the amount available is extremely small. As a result, controlled regio- and stereoselective synthetic approaches are required to produce sufficient amounts of homogenous material to explore biological structure/function relationships. Once the synthetic methodology has been developed this approach can also be applied to produce non-natural glycolipid analogs to exploit or manipulate their biological functions.

Tani et al. isolated and characterized three kinds of new GSLs, α-D-Man*p*(1→3)-β-D-Gal*p*(1→6)-β-D-Gal*p*(1→6)-β-D-Gal*p*(1↔1)Cer (**1**), α-D-Man*p*(1→3)-β-D-Gal*p*(1→6)[α-D-Glc*p*(1→4)]-β-D-Gal*p*(1→6)-β-D-Gal*p*(1↔1)Cer (**2**), and α-D-Glc*p*(1→2)-β-D-Gal*p*(1→6)-β-D-Gal*p*(1→6)-β-D-Gal*p*(1↔1)Cer (**3**), which have neogala-series, β-D-Gal*p*(1-6)-β-D-Gal*p*(1-6)-β-D-Gal*p*, as core structure from the nematophagous fungus *Hirsutella rhossiliensis*[38]. Compound **3** was also isolated from mold, *Neurospora crassa* and the synthesis of compound **3** has been

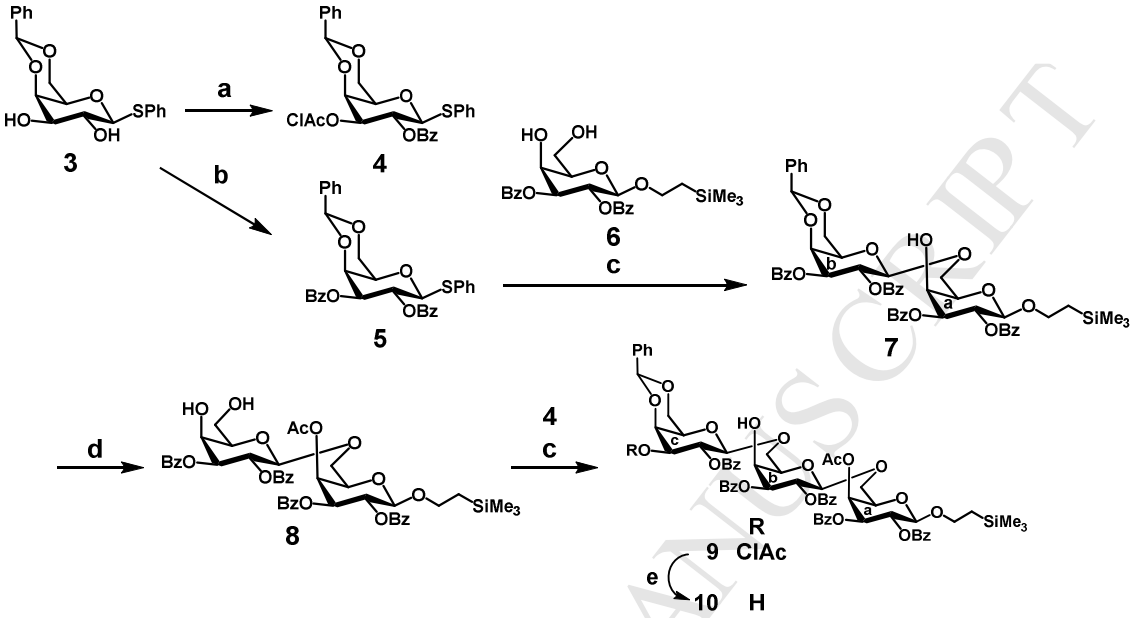
completed by Otsuka et al[22]. In this paper we describe our efforts to prepare GSLs (**1**) and (**2**). We were particularly interested to develop a synthetic scheme which minimizes the number of protection and deprotection steps by exploiting the different reactivities of hydroxyl groups in galactose. This approach is expected to reduce the number of synthetic steps while at the same time improving the overall yield of the desired products.

2. Result and discussion

2.1 Total synthesis of glycosphingolipid 1

The tetrasaccharide glycosphingolipid **1** contains the neogala-core sequence [β-D-Gal*p*(1→6)-β-D-Gal*p*(1→6)-β-D-Gal*p*] was prepared by stepwise synthesis of galactosyl donors and acceptors (Scheme 1). Galactopyranosyl donor **4** and **5** were obtained from phenyl 4,6-*O*-benzylidene-1-thio-β-D-galactopyranoside (**3**)[39]. Regioselective chloroacetylation and subsequently benzoylation of **3** provided donor **4**[40]. Benzoylation of the two free hydroxyl groups of **3** using standard condition provided **5**[41]. We envisaged to achieve regioselective 6-*O*-glycosylation of galactoside acceptor **6** unprotected at both C-4 and C-6 by taking advantage of the greater steric hindrance between primary and secondary (axia) hydroxyl groups as well as using deactivating 2,3-*O*-benzoyl protecting groups. Disaccharide **7** was synthesized by selective glycosylation of diol-based glycosyl acceptor **6**[42] with thiogalactosyl donor **5** using *N*-iodosuccinimde (NIS)/ trifluoromethanesulfonic acid (TfOH) as promoter[43,44]. The β-linkage in **7** was confirmed by ^{1}H-NMR spectroscopy. The nature of the new glycosidic linkage was determined by coupling constant of anomeric proton (H-1', δ = 4.94, J = 8.1 Hz). This reaction was achieved by using small amount of donor **5** (1.1 equv.) which reacted regioselectively with the 6-OH of acceptor **6**. In addition, the glycosylation with the 6-OH was evidenced by HMBC correlation between the signal of C-6 at δ = 66.9 and H-1' at δ = 4.94. The 4-OH group in **7** was acetylated and the benzylidene was cleaved by treatment with 80% AcOH to produce diol **8** in 72% yield. Comparing the ^{1}H-NMR data of **7** with those of **8** showed that H-4 signal of Gal a residue was shifted downfield by 1.49 ppm. This also indicates that the Gal b was bound at the 6-position of Gal a. The same previously described regioselective glycosylation strategy was used to generate trisaccharide **9** from diol **8**. NIS/TfOH promoted glycosylation of thiogalactoside donor **4** with acceptor **8** provided trisaccharide **9** in 78% yield as the only product. The anomeric proton of newly established anomeric

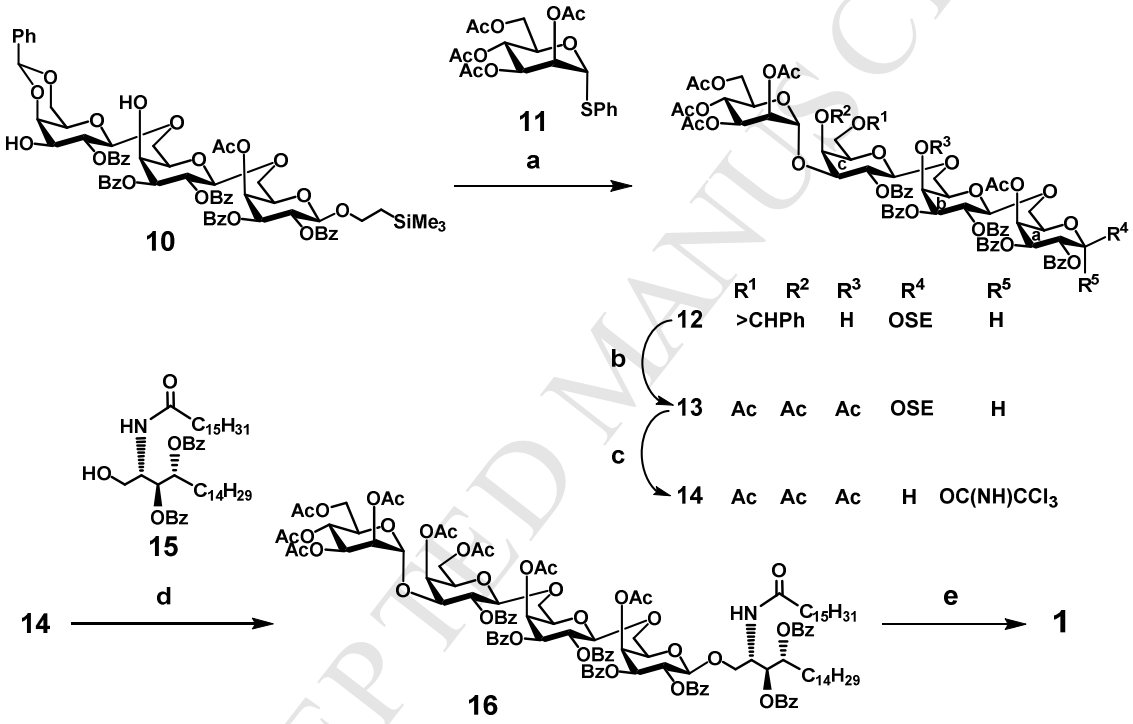
center appeared as a doublet at δ = 7.83 (*J* = 8.2 Hz) consistent with the expected β-linkage. Trisaccharide acceptor **10** was synthesized by hydrolysis of the chloroacetyl group in **9** with aqueous pyridine in 92% yield.



Scheme 1. Reagents and conditions: (a) see ref. 40; (b) benzoyl chloride, pyridine, 87%; (c) NIS, TfOH, 4Å MS, CH_2Cl_2, **7** 86%, **9** 78%; (d) 1) Ac_2O, pyridine, 2) 80% AcOH, 72% (two steps); (e) pyridine, H_2O, 92%.

Regioselective glycosylation of thiomannosyl donor **11**[45] with the trisaccharide diol-acceptor **10** in the presence of NIS and TfOH gave desired disaccharide **12**. As expected, the more reactive equatorial hydroxyl group at 3-position of acceptor **10** was successfully glycosylated. However, we were unable to isolate any other glycosylation product derived from glycosylation of the axial hydroxyl group indicating the highly regioselective nature of this glycosylation. The α-configuration of the new glycosidic linkage in **12** was indicated by the $J_{C\text{-}1',H\text{-}1'}$ value of 170 Hz. Furthermore, the binding to the 3-position was indicated by HMBC between the signal of C-3 of Gal c at δ = 74.8 and H-1 of Man at δ = 5.10. The successful selective introduction of mannose residue to reactive 3-OH makes this strategy very attractive and avoids time-consuming protection and deprotection steps. Removal of the benzylidene of **12** with 80% AcOH and acetylation gave protected tetrasaccharide **13** in 92% yield over two steps. Comparing the ^{1}H-NMR data of **12** with those of **13** showed that H-4 signal of Gal b residue was shifted downfield by 1.30 ppm, so it was confirmed that the mannose was bound to 3-position of the Gal c. Selective removal of 2-(trimethylsilyl)ethyl (TMS-ethyl) group in **13** with trifluoroacetic acid (TFA) in CH_2Cl_2, followed by treatment with CCl_3CN in

the presence of 1,8-diazabicyclo[5,4,0]-undeca-7-ene (DBU)[46] afforded corresponding α-trichloroacetimidate **14** in 90% yield over two steps. Glycosylation of phytoceramide acceptor (2*S*,3*R*,4*R*)-3,4-di-*O*-benzoyl-2-hexadecanamido-octadecane-1,3,4-triol **15**[47] with glycosyl donor **14** in the presence of trimethylsilyl trifluoromethanesulfonate (TMSOTf)[48] afford desired protected glycosphingolipid **16** in 56% yield. Finally, Zemplén-based deacylation of **16** and purification by column chromatography on Sephadex LH-20 produced glycosphingolipid **1** (Scheme 2) in 84% yield. The structure and purity of **1** were demonstrated by its ^{1}H NMR and HR-FABMS data.

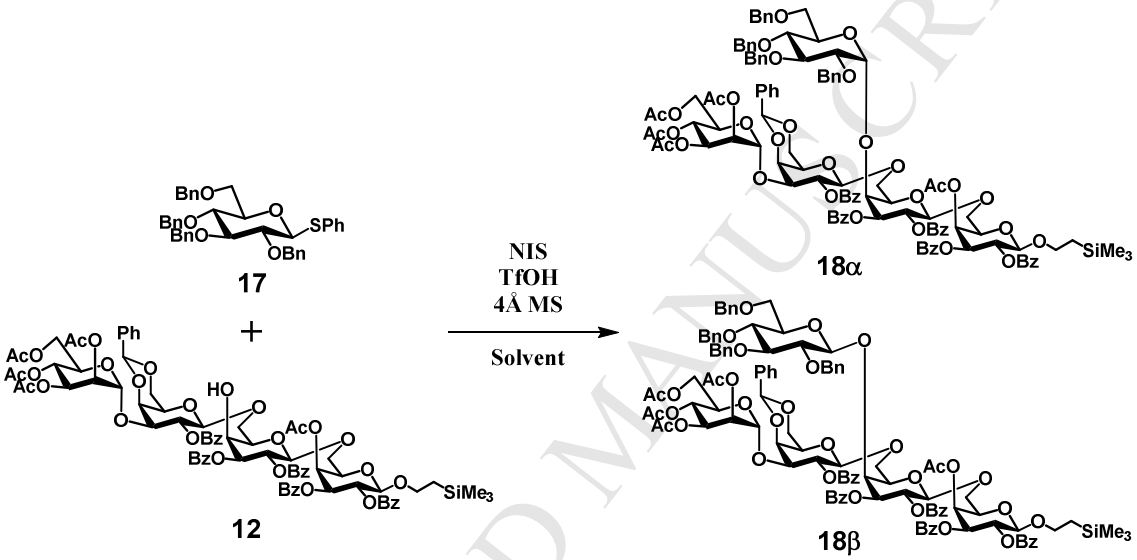


Scheme 2. Reagents and Conditions: a) NIS, TfOH, 4Å MS, CH_2Cl_2, 75%; b) 1) 80%AcOH, 2) Ac_2O, pyridine, 92% (two steps); c) 1) TFA, CH_2Cl_2, 2) CCl_3CN, DBU, CH_2Cl_2, 90% (two steps); d) TMSOTf, 4Å MS, CH_2Cl_2, 56%; e) NaOMe, 1,4-dioxane/MeOH, 84%.

2.2 Total synthesis of glycosphingolipid 2

The pentasaccharide glycosphingolipid **2** contains differs from **1** by addition of a glucose residue to the unreactive axial hydroxyl group in tetrasaccharide **12**. The pentasaccharide portion of glycolipid **2** was synthesized by glycosylation of reactive perbenzylated thioglucoside donor **17**[49] with tetrasaccharide acceptor **12**. We studied

various reaction conditions varying solvent and temperature to optimize the desired α-selectivity in this reaction. Using a toluene/1,4-dioxane mixture[50] as solvent at −20°C resulted in complete α-selectivity in this reaction to produce **18α** in 77% yield. (Scheme 3. Table). The α-linkage was assigned on the homonuclear coupling constant (br. d) of newly anomeric proton signal at δ = 5.10 and carbon signal at δ = 99.4. The β-linkage in **18β** was assigned on proton signal δ = 4.36 (d, *J* = 7.6 Hz) and carbon signal at δ = 103.8.



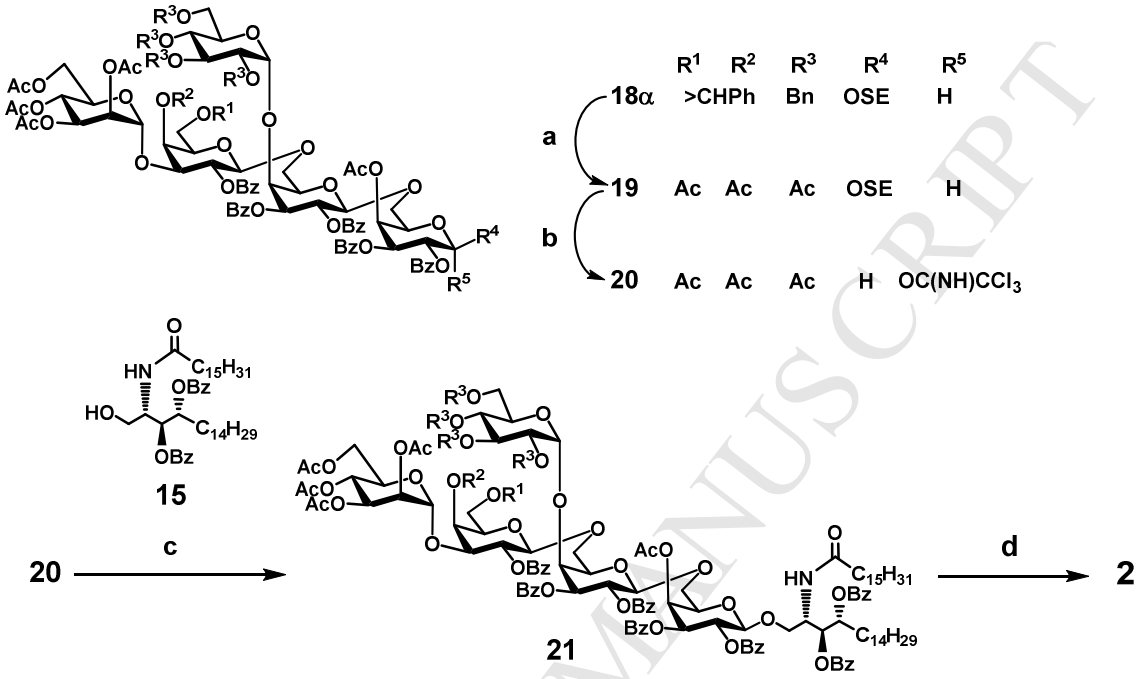
Scheme 3.

Table α-glycosylation under various conditions

Ent.	Solvent	Temp.	Yield	α:β
1	CH_2Cl_2	–40°C	83%	1.2:1
2	CH_2Cl_2/ether = 5/1	–20°C	79%	5:1
3	toluene/1,4-dioxane = 3/1	–20°C	77%	Only α

Removal of benzylidene and benzyl groups in **18α** using catalytic hydrogenolysis over 10%$Pd(OH)_2$/C in THF/MeOH/AcOH followed by acetylation provided *O*-acetylated intermediate **19**. Compound **19** was exposed to TFA to produce the hemiacetal which was converted into α-trichloroacetimidate **20** in quantitative yield. TMSOTf-promoted glycosylation of phytoceramide acceptor **15** with glycosyl imidate donor **20** produced desired β-glycoside **21** in 42% yield. Finally standard deacylation of **21** and purification by column chromatography on Sephadex LH-20 afforded

glycosphingolipid **2** (Scheme 4). The structure and purity of **2** were demonstrated by its ^{1}H NMR, ^{13}C NMR and HR-FABMS data.



Scheme 4. Reagents and Conditions: a) 1) $Pd(OH)_2$-C/H_2, THF/MeOH/AcOH, 2) Ac_2O, Pyr, 86% (two steps); b) 1) TFA, CH_2Cl_2, 2) CCl_3CN, DBU, CH_2Cl_2, quant. (two steps); c) TMSOTf, 4Å MS, CH_2Cl_2, 42%; d) NaOMe, 1,4-dioxane/MeOH, 88%.

3. Conclusion

In summary, a systematic and integrated approach for the synthesis of two naturally occurring glycosphingolipids **1** and **2** from the fungus *Hirsutella rhossiliensis* has been accomplished. The synthetic strategy described may also be useful for the synthesis of related GSLs from other species. Biological activities of glycosphingolipids **1** and **2** is currently in progress, and the results will be reported in detail elsewhere.

4. Experimental

4.1 General

Optical rotations were measured with a Jasco P-1020 digital polarimeter. ^{1}H and ^{13}C

NMR spectra were recorded with a JEOL 400 FT NMR spectrometer. Me_4Si or acetone were used as internal standards for $CDCl_3$, CD_3OD and D_2O. MALDI-TOFMS was recorded on an SHIMADZU AXIMA-CFR Plus mass spectrometer. High-resolution mass spectra were recorded on a JEOL T100LP under ESI conditions. TLC was performed on Silica Gel 60 F254 (E. Merck) with detection by quenching of UV fluorescence and by charring with 10% H_2SO_4 in EtOH. Column chromatography was carried out on Silica Gel 60N 100–210 μm (KANTO KAGAKU). Ultra Pack A (ϕ11 x 300, Silica gel 40 μm, YAMAZEN), Ultra Pack B (ϕ26 x 300, Silica gel 40 μm, YAMAZEN), and Hi-flash column L (ϕ26 x 100, Silica gel 40 μm, YAMAZEN) were used for flash column chromatography.

Phenyl 4,6-*O*-benzylidene-1-thio-β-D-galactopyranoside (**3**)[39], 2-(trimethylsilyl)ethyl 2,3-di-*O*-benzoyl-β-D-galactopyranoside (**6**)[42], phenyl 2,3,4,6-tetra-*O*-acetyl-1-thio-α-D-mannopyranoside (**11**)[45], phenyl 2,3,4,6-tetra-*O*-benzyl-1-thio-β-D-glucopyranoside (**17**)[49] were prepared as reported. Benzoylceramide **15** was prepared from phytosphingosine, which was purchased from Degussa (The Netherlands) by the conventional four-step procedure.[47]

4.2. Phenyl 2,3-di-*O*-benzoyl-4,6-*O*-benzylidene-β-D-galactopyranoside (5)

To a solution of **3** (600 mg, 1.67 mmol) in pyridine (10.0 mL) was added BzCl (0.58 mL, 5.00 mmol), and the mixture was stirred for 1.5 h at 0°C. The mixture diluted with $CHCl_3$, washed with 10% aq. HCl, sat. aq. $NaHCO_3$, and brine, dried ($MgSO_4$) and concentrated. The residue was purified by silica gel column chromatography (ϕ50 x 130 mm) using 4:1 hexane-AcOEt to give **5** (824 mg, 87%) as a white solid.
$[\alpha]_D^{25}$ −20.1 (*c* = 1.0, $CHCl_3$). ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.99–7.23 (m, 20H, 4 x Ph), 5.81 (t, 1H, $J_{1,2} = J_{2,3}$ = 9.9 Hz, H-2), 5.51 (s, 1H, C*H*Ph), 5.36 (dd, $J_{3,4}$ = 3.2 Hz, 1H, H-3), 4.96 (d, 1H, $J_{1,2}$ = 9.8 Hz, H-1), 4.59 (d, 1H, $J_{3,4}$ = 3.2 Hz, H-4), 4.54 (dd, $J_{5,6a}$ = 1.6 Hz, $J_{6a,6b}$ = 12.4 Hz, 1H, H-6a), 4.09 (dd, 1H, $J_{5,6b}$ = 1.5 Hz, $J_{6a,6b}$ = 12.5 Hz, H-6b), 3.75 (br. d, 1H, *J* = 0.9 Hz, H-5); ^{13}C NMR (100 MHz, $CDCl_3$): δ 166.1, 164.9, 137.5, 133.8, 133.3, 133.1, 131.0, 130.1, 129.9, 129.7, 129.6, 129.0, 128.7, 128.4, 128.3, 128.2, 128.1, 126.4, 100.9, 85.2 (C-1), 74.0, 73.6, 69.8, 69.1, 67.0.
HR-FABMS: calcd for $C_{33}H_{28}O_7SNa$: *m/z* 591.1453; found: *m/z* 591.1478 $[M+Na]^+$.

4.3. 2-(Trimethylsilyl)ethyl 2,3-di-*O*-benzoyl-4,6-*O*-benzylidene-β-D-galactopyranosyl-(1→6)-2,3-di-*O*-benzoyl-β-D-galactopyranoside (7)

A mixture of acceptor 2-(trimethylsilyl)ethyl 2,3-di-*O*-benzoyl-β-D-galactopyranoside (**6**) (2.30 g, 4.71 mmol), **5** (2.94 g, 5.18 mmol) and 4Å MS (4.50 g) in dry CH_2Cl_2 (25.0 mL) was stirred for 3 h at room temperature, then cooled to −60°C. NIS (1.75 g, 7.75 mmol) and TfOH (69.6 μL, 0.78 mmol) was added, and the mixture was stirred for 1 h at −60°C, then neutralized with Et_3N. The precipitates were filtrated off and washed with $CHCl_3$. The combined filtrate and washings were successively washed with sat. aq. $Na_2S_2O_3$, sat. aq. $NaHCO_3$, brine, dried ($MgSO_4$), and concentrated. The product was purified by silica gel column chromatography (ϕ40 x 170 mm) using 3:1 hexane-AcOEt to give **7** (3.83 g, 86%) as an amorphous powder.

$[\alpha]_D^{25}$ +103.9 (*c* = 1.0, $CHCl_3$). ^{1}H NMR (400 MHz, $CDCl_3$): δ 8.01–7.27 (m, 25H, 5 x Ph), 5.92 (dd, 1H, $J_{1,2}$ = 8.1 Hz, $J_{2,3}$ = 10.3 Hz, H-2 of Gal b), 5.71 (dd, 1H, $J_{1,2}$ = 8.0 Hz, $J_{2,3}$ = 10.3 Hz, H-2 of Gal a), 5.56 (s, 1H, >C*H*–Ph), 5.42 (dd, 1H, $J_{2,3}$ = 10.2 Hz, $J_{3,4}$ = 3.5 Hz, H-3 of Gal b), 5.25 (dd, 1H, $J_{2,3}$ = 10.2 Hz, $J_{3,4}$ = 3.2 Hz, 1H, H-3of Gal a), 4.94 (d, 1H, $J_{1,2}$ = 8.1 Hz, H-1 of Gal b), 4.62 (d, 1H, $J_{3,4}$ = 3.5 Hz, H-4 of Gal b), 4.58 (d, 1H, $J_{1,2}$ = 8.0 Hz, H-1 of Gal a), 4.42 (dd, 1H, $J_{5,6a}$ = 1.1 Hz, $J_{6a,6b}$ = 12.6 Hz, H-6a of Gal b), 4.29 (br. t, 1H, *J* = 3.4 Hz, H-4 of Gal a), 4.21 (dd, 1H, $J_{5,6a}$ = 6.5 Hz, $J_{6a,6b}$ = 10.6 Hz, H-6a of Gal a), 4.15 (dd, 1H, $J_{5,6b}$ = 1.6 Hz, $J_{6a,6b}$ = 12.4 Hz, H-6b of Gal b), 4.03 (dd, 1H, $J_{5,6b}$ = 6.4 Hz, $J_{6a,6b}$ = 10.7 Hz, H-6b of Gal a), 3.92–3.86 (m, 2H, H-5 of Gal a, C*H*$_2$CH$_2$SiMe$_3$), 3.74 (s, 1H, H-5 of Gal b), 3.45–3.38 (m, 1H, C*H*$_2$CH$_2$SiMe$_3$), 2.78 (d, 1H, $J_{OH,4}$ = 5.3 Hz, 4-OH of Gal a), 0.85–0.62 (m, 2H, CH$_2$C*H*$_2$SiMe$_3$), –0.12 (s, 9H, CH$_2$CH$_2$Si*Me*$_3$); ^{13}C NMR (100 MHz, $CDCl_3$): δ 166.1, 165.6, 165.4, 165.2, 137.4, 133.3, 133.2, 133.1, 132.9, 129.9, 129.8, 129.7, 129.6, 129.4, 129.4, 128.99, 128.96, 128.9, 128.33, 128.32, 128.27, 128.13, 128.08, 126.2, 100.8 (C-1 of Gal b), 100.73, 100.65 (C-1 of Gal a), 74.1, 73.5, 73.4, 72.6, 69.8, 68.84, 68.81, 67.3, 67.0, 66.9, 66.5, 17.6, −1.50.

HR-FABMS: calcd for $C_{52}H_{54}O_{15}SiNa$: *m/z* 969.3130; found: *m/z* 969.3060 $[M+Na]^+$.

4.4. 2-(Trimethylsilyl)ethyl 2,3-di-*O*-benzoyl-β-D-galactopyranosyl-(1→6)-4-*O*-acetyl-2,3-di-*O*-benzoyl-β-D-galactopyranoside (8)

To a solution of **7** (3.83 g, 4.04 mmol) in pyridine (15.0 mL) was added Ac_2O (10 mL) at 0°C, and the mixture was stirred for 18 h at room temperature. The mixture diluted with $CHCl_3$, washed with 10% aq. HCl, sat. aq. $NaHCO_3$, and brine, dried

($MgSO_4$) and concentrated. To a solution of the residue in AcOH (24 mL) was added H_2O (6.0 mL), and the mixture was stirred for 6 h at 70°C. The residue was purified by flash column chromatography (Hi-flash column L) using 1:1 hexane-AcOEt to give **8** (2.60 g, 72%) as an amorphous powder.

$[\alpha]_D^{25}$ +74.3 (*c* = 1.0, $CHCl_3$). ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.97–7.29 (m, 20H, 4 x Ph), 5.82 (dd, 1H, $J_{1,2}$ = 7.8 Hz, $J_{2,3}$ = 10.3 Hz, H-2 of Gal b), 5.78 (d, 1H, $J_{3,4}$ = 3.4 Hz, H-4 of Gal a), 5.63 (dd, 1H, $J_{1,2}$ = 8.0 Hz, $J_{2,3}$ = 10.3 Hz, H-2 of Gal a), 5.40 (dd, 1H, $J_{2,3}$ = 10.3 Hz, $J_{3,4}$ = 3.4 Hz, H-3 of Gal a), 5.30 (dd, 1H, $J_{3,4}$ = 3.2 Hz, $J_{2,3}$ = 10.3 Hz, H-3 of Gal b), 4.78 (d, 1H, $J_{1,2}$ = 7.8 Hz, H-1 of Gal b), 4.68 (d, 1H, $J_{1,2}$ = 8.0 Hz, H-1 of Gal a), 4.45 (br. s, 1H, H-4 of Gal b), 4.07 (t, 1H, $J_{5,6a}$ = $J_{5,6b}$ = 5.9 Hz, H-5 of Gal b), 3.97–3.85 (m, 6H, H-6 of Gal a, H-6 of Gal b, C*H*$_2$CH$_2$SiMe$_3$, 4-O*H* of Gal b), 3.74 (t, $J_{5,6a}$ = $J_{5,6b}$ = 5.9 Hz, 1H, H-5 of Gal b), 3.49–3.42 (m, 1H, C*H*$_2$CH$_2$SiMe$_3$), 3.18 (br. s, 1H, 6-O*H* of Gal b), 2.13 (s, 3H, COC*H*$_3$), 0.88–0.67 (m, 2H, CH$_2$C*H*$_2$SiMe$_3$), −0.14 (s, 9H, CH$_2$CH$_2$Si*Me*$_3$); ^{13}C NMR (100 MHz, $CDCl_3$): δ 170.78, 165.9, 165.6, 165.3, 165.2, 133.3, 133.2, 133.1, 129.8, 129.69, 129.66, 129.5, 129.1, 128.9, 128.4, 128.4, 128.3, 128.2, 101.2 (C-1 of Gal b), 100.8 (C-1 of Gal a), 74.4, 73.9, 72.3, 72.1, 69.7, 69.6, 68.4, 68.0, 67.7, 67.2, 62.6, 10.7, 17.7, −1.54.

HR-FABMS: calcd for $C_{47}H_{52}O_{16}SiNa$: *m/z* 923.2983; found: *m/z* 923.2922 $[M+Na]^+$.

4.5. 2-(Trimethylsilyl)ethyl 2-*O*-benzoyl-4,6-*O*-benzylidene-3-*O*-chloroacetyl-β-D-galactopyranosyl-(1→6)-2,3-di-*O*-benzoyl-β-D-galactopyranosyl-(1→6)-4-*O*-acetyl-2,3-di-*O*-benzoyl-β-D-galactopyranoside (9)

A mixture of acceptor **8** (1.44 g, 1.60 mmol), donor **4** (0.950 g, 1.76 mmol) and 4Å MS (2.00 g) in dry CH_2Cl_2 (16.0 mL) was stirred for 1.5 h at room temperature, then cooled to –60°C. NIS (593 mg, 2.63 mmol) and TfOH (23.6 μL, 0.263 mmol) was added, and the mixture was stirred for 1 h at −60°C, then neutralized with Et_3N. The precipitates were filtrated off and washed with $CHCl_3$. The combined filtrate and washings were successively washed with sat. aq. $Na_2S_2O_3$, sat. aq. $NaHCO_3$, brine, dried ($MgSO_4$), and concentrated. The product was purified by flash column chromatography (Ultra pack B) using 4:3 hexane-AcOEt to give **9** (1.65 g, 78%) as an amorphous powder.

$[\alpha]_D^{25}$ +49.7 (*c* = 1.0, $CHCl_3$). ^{1}H NMR (400 MHz, $CDCl_3$): δ 8.99–7.15 (m, 30H, 6 x Ph), 5.70–5.63 (m, 2H, H-2 of Gal b, H-2 of Gal c), 5.60–5.56 (m, 2H, H-2, 4 of Gal a), 5.23 (s, 1H, >C*H*–Ph), 5.31–5.24 (m, 2H, H-3 of Gal a, H-3 of Gal c), 5.20 (dd, 1H, $J_{2,3}$

= 10.6 Hz, $J_{3,4}$ = 3.2 Hz, H-3 of Gal b), 4.83 (d, 1H, $J_{1,2}$ = 8.2 Hz, H-1 of Gal c), 4.67 (d, 1H, $J_{1,2}$ = 7.7 Hz, H-1 of Gal b), 4.57 (d, 1H, $J_{1,2}$ = 7.8 Hz, H-1 of Gal a), 4.47 (br. d, 1H, $J_{3,4}$ = 3.3 Hz, H-4 of Gal c), 4.39 (br. d, 1H, J = 11.5 Hz, H-6a of Gal c), 4.28 (br. s, 1H, H-4 of Gal b), 4.17–4.10 (m, 2H, H-6a of Gal b, H-6b of Gal c), 4.02 (d, 1H, J = 15.6 Hz, COCH_2Cl), 3.99–3.91 (m, 3H, H-5, 6b of Gal b, COCH_2Cl), 3.87–3.73 (m, 4H, H-5, 6 of Gal a, CH_2CH$_2$SiMe$_3$), 3.67 (br. s, 1H, H-5 of Gal c), 3.40–3.33 (m, 1H, CH_2CH$_2$SiMe$_3$), 2.85 (s, 1H, 4-O*H* of Gal b), 2.02 (s, 3H, COCH_3), 0.81–0.59 (m, 2H, CH$_2$CH_2SiMe$_3$), −0.16 (s, 9H, CH$_2$CH$_2$SiMe_3); ^{13}C NMR (100 MHz, CDCl$_3$): δ 170.0, 167.2, 165.6, 165.4, 165.3, 165.2, 165.1, 137.2, 133.5, 133.2, 133.03, 133.01, 129.8, 129.74, 129.67, 129.63, 129.58, 129.5, 129.19, 129.15, 129.0, 128.6, 128.33, 128.31, 128.29, 128.24, 128.22, 128.2, 126.3, 125.3, 101.1 (C-1 of Gal b), 101.0, 100.6 (C-1 of Gal a), 100.5 (C-1 of Gal c), 73.7, 73.5, 73.4, 73.1, 72.7, 71.9, 69.7, 69.5, 68.7, 68.6, 68.0, 67.5, 67.2, 66.8, 66.4, 66.0, 40.6, 21.4, 20.5, 17.6, −1.50.
HR-FABMS: calcd for $C_{69}H_{71}ClO_{23}SiNa$: *m/z* 1353.3661; found: *m/z* 1353.3653 $[M+Na]^+$.

4.6. 2-(Trimethylsilyl)ethyl 2-*O*-benzoyl-4,6-*O*-benzylidene-β-D-galactopyranosyl-(1→6)-2,3-di-*O*-benzoyl-β-D-galactopyranosyl-(1→6)-4-*O*-acetyl-2,3-di-*O*-benzoyl-β-D-galactopyranoside (10)

To a solution of **9** (322 mg, 0.242 mmol) in pyridine (6.0 mL) was added H_2O (1.2 mL), and the mixture was stirred for 18 h at 70°C. The mixture diluted with $CHCl_3$, washed with 10% aq. HCl, sat. aq. $NaHCO_3$, and brine, dried ($MgSO_4$) and concentrated. The residue was purified by silica gel column chromatography (ϕ30 x 150 mm) using 3:2 toluene-acetone to give **10** (280 mg, 91%) as an amorphous powder.
$[\alpha]_D^{25}$ +29.1 (*c* = 1.0, $CHCl_3$). ^{1}H NMR (400 MHz, $CDCl_3$): δ 8.06–7.16 (m, 30H, 6 x Ph), 5.70 (dd, 1H, $J_{1,2}$ = 7.8 Hz, $J_{2,3}$ = 10.3 Hz, H-2 of Gal b), 5.61–5.57 (m, 3H, H-2, 4 of Gal a, >C*H*–Ph), 5.36 (dd, 1H, $J_{1,2}$ = 8.0 Hz, $J_{2,3}$ = 9.9 Hz, H-2 of Gal c), 5.20 (dd, 1H, $J_{2,3}$ = 10.3 Hz, $J_{3,4}$ = 3.4 Hz, H-3 of Gal a), 5.22 (dd, 1H, $J_{2,3}$ = 10.3 Hz, $J_{3,4}$ = 3.2 Hz, H-3 of Gal b), 4.77 (d, 1H, $J_{1,2}$ = 8.0 Hz, H-1 of Gal c), 4.67 (d, 1H, $J_{1,2}$ = 7.8 Hz, H-1 of Gal b), 4.57 (d, 1H, $J_{1,2}$ = 8.1 Hz, H-1 of Gal a), 4.38 (br. d, 1H, J = 11.7 Hz, H-6a of Gal c), 4.28 (br. d, 2H, J = 3.0 Hz, H-4 of Gal b, H-4 of Gal c), 4.14–4.10 (m, 3H, H-6a of Gal b, H-6 of Gal c), 4.01–3.76 (m, 7H, H-5, 6 of Gal a, H-5, 6b of Gal b, H-3 of Gal c, CH_2CH$_2$SiMe$_3$), 3.61(br. s, 1H, H-5 of Gal c), 3.39–3.32 (m, 1H, CH_2CH$_2$SiMe$_3$), 2.84 (d, 1H, $J_{OH,4}$ = 5.3 Hz, 4-O*H* of Gal b), 2.66 (d, 1H, $J_{OH,3}$ = 11.0 Hz, 3-O*H* of Gal c), 2.03 (s, 3H, COCH_3), 0.81–0.59 (m, 2H, CH$_2$CH_2SiMe$_3$), −0.16 (s,

9H, $CH_2CH_2Si\mathit{Me}_3$); ^{13}C NMR (100 MHz, $CDCl_3$): δ 170.4, 166.3, 165.6, 165.4, 165.17, 165.15, 137.2, 133.2, 133.04, 133.02, 129.82, 129.76, 129.7, 129.63, 129.58, 129.5, 129.3, 129.1, 128.99, 128.95, 128.5, 128.33, 128.28, 128.22, 128.18, 126.3, 101.5, 101.1 (C-1 of Gal b), 100.6 (C-1 of Gal a), 100.4 (C-1 of Gal c), 75.5, 73.7, 72.8, 72.5, 71.9, 71.5, 69.7, 69.6, 67.8, 68.1, 67.5, 67.4, 66.9, 66.8, 66.1, 20.5, 17.6, −1.49.
HR-FABMS: calcd for $C_{67}H_{70}O_{22}SiNa$: *m/z* 1277.3873; found: *m/z* 1277.3826 $[M+Na]^+$.

4.7. 2-(Trimethylsilyl)ethyl 2,3,4,6-tetra-*O*-acetyl-α-D-mannopyranosyl-(1→3)-2-*O*-benzoyl-4,6-*O*-benzylidene-β-D-galactopyranosyl-(1→6)-2,3-di-*O*-benzoyl-β-D-galactopyranosyl-(1→6)-4-*O*-acetyl-2,3-di-*O*-benzoyl-β-D-galactopyranoside (12)

Compound **12** was prepared from **10** (1.19 g, 0.95 mmol) and **11** (459 mg, 1.04 mmol) as described for preparation of **7**. The product was purified by silica gel column chromatography (5:2 toluene-acetone) to give **12** (1.13 g, 75%).
$[\alpha]_D^{25}$ +60.8 (*c* = 1.0, $CHCl_3$). ^{1}H NMR (400 MHz, $CDCl_3$): δ 8.10–7.31 (m, 30H, 6 x Ph), 5.73 (dd, 1H, $J_{1,2}$ = 8.0 Hz, $J_{2,3}$ = 10.3 Hz, H-2 of Gal b), 5.64–5.58 (m, 4H, H-2, 4 of Gal a, H-2 of Gal c, >C*H*–Ph), 5.33 (dd, 1H, $J_{2,3}$ = 10.5 Hz, $J_{3,4}$ = 3.4 Hz, H-3 of Gal a), 5.25 (dd, 1H, $J_{2,3}$ = 10.2 Hz, $J_{3,4}$ = 2.9 Hz, H-3 of Gal b), 5.21–5.14 (m, 3H, H-2, 3, 4 of Man), 5.10 (br. s, 1H, H-1 of Man), 4.85 (d, 1H, $J_{1,2}$ = 8.0 Hz, H-1 of Gal c), 4.69 (d, 1H, $J_{1,2}$ = 8.0 Hz, H-1 of Gal b), 4.61 (d, 1H, $J_{1,2}$ = 8.0 Hz, H-1 of Gal a), 4.47–4.40 (m, 2H, H-4, 6a of Gal c), 4.33 (d, 1H, $J_{3,4}$ = 2.9 Hz, H-4 of Gal b), 4.21–4.12 (m, 3H, H-6a of Gal b, H-3, 6b of Gal c), 4.01–3.76 (m, 8H, H-5, 6 of Gal a, H-5, 6b of Gal b, H-5, 6 of Man, 4-O*H* of Gal b, CH_2CH$_2$SiMe$_3$), 3.62(br. s, 1H, H-5 of Gal c), 3.44–3.37 (m, 1H, CH_2CH$_2$SiMe$_3$), 2.13, 2.08, 2.07, 1.94, 1.77 (each s, each 3H, COCH_3), 0.85–0.63 (m, 2H, CH$_2$CH_2SiMe$_3$), −0.13 (s, 9H, $CH_2CH_2Si\mathit{Me}_3$); ^{13}C NMR (100 MHz, $CDCl_3$): δ 170.4, 170.03, 169.98, 169.5, 169.1, 165.6, 165.3, 165.2, 165.1, 164.9, 149.6, 137.2, 133.3, 133.2, 133.1, 133.0, 132.9, 129.8, 129.7, 129.63, 129.60, 129.55, 129.5, 129.2, 129.0, 128.9, 128.4, 128.3, 128.3, 128.2, 126.2, 126.1, 123.7, 101.0 (C-1 of Gal b), 100.8, 100.54 (C-1 of Gal a), 100.45 (C-1 of Gal c), 94.2 ($J_{C,H}$ = 170 Hz, C-1 of Man), 74.8, 73.7, 73.2, 72.7, 71.9, 71.6, 69.9, 69.72, 69.66, 69.6, 68.9, 68.6, 68.3, 68.0, 67.4, 67.1, 66.7, 66.6, 65.8, 65.6, 61.7, 20.8, 20.6, 20.54, 20.50, 20.4, 17.5, −1.52.
HR-FABMS: calcd for $C_{81}H_{88}O_{31}SiNa$: *m/z* 1607.4977; found: *m/z* 1607.4806 $[M+Na]^+$.

4.8. 2-(Trimethylsilyl)ethyl 2,3,4,6-tetra-*O*-acetyl-α-D-mannopyranosyl-(1→3)-4,6-di-*O*-acetyl-2-*O*-benzoyl-β-D

-galactopyranosyl-(1→6)-6-*O*-acetyl-2,3-di-*O*-benzoyl-β-D-galactopyranosyl-(1→6)-4-*O*-acetyl-2,3-di-*O*-benzoyl-α-D-galactopyranoside (13)

To a solution of **12** (156 mg, 98.1 μmol) in AcOH (2.4 mL) was added H_2O (0.6 mL) at room temperature, and the mixture was stirred for 8.0 h at 70°C. After completion of the reaction, the mixture was concentrated. To a solution of the residue in pyridine (3.0 mL) was added Ac_2O (2.0 mL), and the mixture was stirred for 18 h at room temperature. The mixture diluted with $CHCl_3$, washed with 10% aq. HCl, sat. aq. $NaHCO_3$, and brine, dried ($MgSO_4$) and concentrated. The residue was purified by silica gel column chromatography (ϕ22 x 180 mm) using 8:1 toluene-acetone to give **13** (147 mg, 92%) as an amorphous powder.

$[\alpha]_D^{25}$ +55.2 (*c* = 1.0, $CHCl_3$). ^{1}H NMR (400 MHz, $CDCl_3$): δ 8.05–7.31 (m, 25H, 5 x Ph), 5.63 (br. d, 1H, $J_{3,4}$ = 3.2, H-4 of Gal b), 5.61–5.58 (m, 2H, H-2 of Gal a, H-2 of Gal b), 5.55 (br. d, 1H, $J_{3,4}$ = 3.5 Hz, H-4 of Gal a), 5.45–5.39 (m, 2H, H-2, 4 of Gal c), 5.34 (dd, 1H, $J_{2,3}$ = 10.3 Hz, $J_{3,4}$ = 2.4 Hz, H-3 of Gal b), 5.30 (dd, 1H, $J_{2,3}$ = 10.5 Hz, $J_{3,4}$ = 3.5 Hz, H-3 of Gal a), 5.12–5.07 (m, 2H, H-2, 4 of Man), 5.01 (d, 1H, $J_{1,2}$ = 1.6 Hz, H-1 of Man), 4.97 (dd, 1H, $J_{2,3}$ = 10.4 Hz, $J_{3,4}$ = 3.4 Hz, H-3 of Man), 4.75 (d, 1H, $J_{1,2}$ = 7.8 Hz, H-1 of Gal c), 4.69 (d, 1H, $J_{1,2}$ = 8.0 Hz, H-1 of Gal b), 4.60 (d, 1H, $J_{1,2}$ = 8.0 Hz, H-1 of Gal a), 4.27 (dd, 1H, $J_{5,6a}$ = 6.6 Hz, $J_{6a,6b}$ = 11.5 Hz, H-6a of Gal c), 4.20 (dd, 1H, $J_{5,6b}$ = 6.4 Hz, $J_{6a,6b}$ = 11.5 Hz, H-6b of Gal c), 4.10 (dd, 1H, $J_{2,3}$ = 10.3 Hz, $J_{3,4}$ = 6.4 Hz, H-3 of Gal c), 4.03–3.65 (m, 11H, H-5, 6 of Gal a, H-5, 6 of Gal b, H-5 of Gal c, H-5, 6 of Man, C*H*$_2$CH$_2$SiMe$_3$), 3.42–3.36 (m, 1H, C*H*$_2$CH$_2$SiMe$_3$), 2.23, 2.10, 2.083, 2.06, 1.90, 1.67 (each s, each 3H, 6 x COC*H*$_3$), 2.078 (s, 6H, 2 x COC*H*$_3$), 0.84–0.62 (m, 2H, CH$_2$C*H*$_2$SiMe$_3$), −0.15 (s, 9H, CH$_2$CH$_2$Si*Me*$_3$); ^{13}C NMR (100 MHz, $CDCl_3$): δ 170.6, 170.4, 170.3, 169.9, 169.7, 169.31, 169.26, 165.34, 165.26, 165.11, 165.06, 164.4, 133.4, 133.2, 133.1, 133.0, 129.8, 129.62, 129.58, 129.5, 129.4, 129.3, 128.9, 128.8, 128.5, 128.3, 128.2, 128.1, 101.0 (C-1 of Gal c), 100.8 (C-1 of Gal b), 100.6 (C-1 of Gal a), 94.9 (C-1 of Man), 73.8, 72.6, 72.5, 71.9, 71.6, 70.8, 70.0, 69.5, 69.4, 68.6, 68.52, 68.45, 67.9, 67.7, 67.4, 67.0, 65.03, 65.00, 61.51, 61.47, 29.6, 20.7, 20.6, 20.5, 20.4, 20.3, 17.5, −1.55.

HR-FABMS: calcd for $C_{80}H_{90}O_{34}SiNa$: *m/z* 1645.4980; found: *m/z* 1645.4910 $[M+Na]^+$.

4.9.

2,3,4,6-tetra-*O*-acetyl-α-D-mannopyranosyl-(1→3)-4,6-di-*O*-acetyl-2-*O*-benzoyl-β-D-galactopyranosyl-(1→6)-6-*O*-acetyl-2,3-di-*O*-benzoyl-β-D-galactopyranosyl-(1→6)-4-*O*-acetyl-2,3-di-*O*-benzoyl-β-D-galactopyranosyl trichloroacetimidate (14)

To a solution of **13** (136 mg, 83.8 μmol) in CH_2Cl_2 (2.0 mL) was added CF_3CO_2H (1.0 mL) at 0°C, and the mixture was stirred for 1.5 h at 0°C. After completion of the reaction, the mixture was concentrated. To a solution of the residue in CH_2Cl_2 (2.0 mL) was added CCl_3CN (69.0 μL, 670 μmol) and DBU (18.8 μL, 126 μmol) at 0°C. The reaction mixture was stirred for 3.0 h at rt. The mixture was concentrated and purified by silica gel column chromatography (ϕ28 x 105 mm) using 20:1 chloroform-acetone to give **14** (126 mg, 90.2%) as an amorphous powder.

$[\alpha]_D^{25}$ +79.7 (*c* = 1.0, $CHCl_3$). ^{1}H NMR (400 MHz, $CDCl_3$): δ 8.23 (s, 1H, N*H*), 8.07–7.31 (m, 25H, 5 x Ph), 6.61 (d, 1H, $J_{1,2}$ = 3.2 Hz, H-1 of Gal a), 5.79 (dd, 1H, $J_{2,3}$ = 10.5 Hz, $J_{3,4}$ = 3.2 Hz, H-3 of Gal a), 5.74 (dd, 1H, $J_{1,2}$ = 3.2 Hz, $J_{2,3}$ = 10.5 Hz, H-2 of Gal a), 5.70 (br. d, 1H, $J_{4,3}$ = 3.2 Hz, H-4 of Gal a), 5.62 (br. d, 1H, $J_{3,4}$ = 3.2 Hz, H-4 of Gal b), 5.57 (dd, 1H, $J_{1,2}$ = 8.0 Hz, $J_{2,3}$ = 10.5 Hz, H-2 of Gal b), 5.44 (br. d, 1H, $J_{3,4}$ = 3.5 Hz, H-4 of Gal c), 5.40 (dd, 1H, $J_{1,2}$ = 8.0 Hz, $J_{2,3}$ = 10.0 Hz, H-2 of Gal c), 5.31 (dd, 1H, $J_{2,3}$ = 10.5 Hz, $J_{3,4}$ = 3.2 Hz, H-3 of Gal b), 5.13–5.08 (m, 2H, H-2, 4 of Man), 5.02 (d, 1H, $J_{1,2}$ = 1.4 Hz, H-1 of Man), 4.98 (dd, 1H, $J_{2,3}$ = 3.2 Hz, $J_{3,4}$ = 10.1 Hz, H-3 of Man), 4.71 (d, 2H, $J_{1,2}$ = 8.0 Hz, H-1 of Gal b, H-1 of Gal c), 4.47 (br. t, *J* = 5.5, 6.4 Hz 1H, H-6a of Gal a), 4.28–4.18 (m, 2H, H-6 of Gal c), 4.12 (dd, 1H, $J_{2,3}$ = 10.0 Hz, $J_{3,4}$ = 3.5 Hz, H-3 of Gal c), 4.02–3.82 (m, 6H, H-6b of Gal a, H-5, 6 of Gal b, H-5 of Gal c, H-6a of Man), 3.75–3.68 (m, 3H, H-5 of Gal a, H-5, 6b of Man), 2.25, 2.14, 2.10, 2.074, 2.069, 2.06, 1.91, 1.68 (each s, each 3H, 8 x COC*H*$_3$); ^{13}C NMR (100 MHz, $CDCl_3$): δ 170.6, 170.34, 170.29, 169.6, 169.5, 169.34, 169.28, 169.2, 165.5, 165.24, 165.18, 165.0, 164.4, 160.1, 133.41, 133.37, 1333.2, 133.0, 129.74, 129.66, 129.6, 129.48, 129.45, 129.2, 129.0, 128.9, 128.8, 128.6, 128.5, 128.31, 128.27, 128.2, 128.1, 101.0 (C-1 of Gal b), 100.6 (C-1 of Gal c), 94.9 (C-1 of Man), 93.3 (C-1 of Gal a), 90.5, 73.8, 72.7, 71.6, 70.7, 70.0, 69.1, 68.6, 68.5, 68.4, 68.2, 67.6, 67.5, 66.9, 65.0, 64.5, 61.4, 20.64, 20.60, 20.51, 20.48, 20.4, 20.3.

MALDI-TOFMS: calcd for $C_{77}H_{78}Cl_3NO_{34}Na$: *m/z* 1688.3; found: *m/z* 1688.7 $[M+Na]^+$.

4.10. (2*S*, 3*S*, 4*R*)-3,4-dibenzyloxy-2-(hexadecanoylamino)-octadecyl 2,3,4,6-tetra-*O*-acetyl-α-D-mannopyranosyl-(1→3)-4,6-di-*O*-acetyl-2-*O*-benzoyl-β-D-galactopyranosyl-(1→6)-6-*O*-acetyl-2,3-di-*O*-benzoyl-β-D-galactopyranosyl-(1→6)-4-*O*-acetyl-2,3-di-*O*-benzoyl-β-D-galactopyranoside (16)

A mixture of solution of acceptor (2*S*,3*R*,4*R*)-3,4-di-*O*-benzoyl-2-hexadecanamido-octadecane-1,3,4-triol (**15**) (72.2 mg,

94.4 μmol), donor **14** (105 mg, 63.0 μmol) and 4Å MS (400 mg) in dry CH_2Cl_2 (0.80 mL) was stirred for 18 h at room temperature, then cooled to 0°C. TMSOTf (9.08 μL, 50.4 μmol) was added, and the mixture was stirred for 3.0 h at 0°C, then neutralized with Et_3N. The precipitates were filtrated off and washed with $CHCl_3$. The combined filtrate and washings were successively washed with brine, dried ($MgSO_4$), and concentrated. The product was purified by flash column chromatography (Ultra Pack A) using 1:1 hexane-ethyl acetate to give **16** (80.0 mg, 56.0%) as an amorphous powder.
$[\alpha]_D^{25}$ +31.4 (*c* = 1.0, $CHCl_3$). ^{1}H NMR (400 MHz, $CDCl_3$): δ 8.06–7.30 (m, 35H, 7 x Ph), 6.05 (d, 1H *J* = 9.1 Hz, N*H*), 5.59 (d, 1H, $J_{3,4}$ = 3.2 Hz, H-4 of Gal a), 5.55–5.25 (m, 9H, H-2, 3 of Gal a, H-2, 3, 4 of Gal b, H-2, 4 of Gal c, H-3, 4 of Cer), 5.12–5.06 (m, 2H, H-2, 4 of Man), 5.02 (br. s, 1H, H-1 of Man), 4.97 (dd, 1H, $J_{2,3}$ = 3.4 Hz, $J_{3,4}$ = 10.1 Hz, H-3 of Man), 4.67 (d, 1H, $J_{1,2}$ = 8.1 Hz, H-1 of Gal c), 4.40 (d, 1H, $J_{1,2}$ = 7.3 Hz, H-1 of Gal b), 4.32–4.18 (m, 3H, H-6a of Man, H-1a, 2 of Cer), 4.13–4.08 (m, 2H, $J_{1,2}$ = 8.0 Hz , H-1 of Gal a, H-3 of Gal c), 3.95–3.65 (m, 9H, H-5 of Gal a, H-5, 6a, of Gal b, H-5, 6 of Gal c, H-5, 6b of Man, H-1b, 2 of Cer), 3.55 (dd, 1H, $J_{5,6a}$ = 4.1 Hz, $J_{6a,6b}$ = 10.5 Hz, H-6a of Gal a), 3.09 (dd, 1H, $J_{5,6b}$ = 2.5 Hz, $J_{6a,6b}$ = 9.4 Hz, H-6b of Gal b), 3.01 (dd, 1H, $J_{5,6b}$ = 7.2 Hz, $J_{6b,6a}$ = 10.5 Hz, H-6b of Gal a), 2.21, 2.10, 2.09, 2.07, 1.91, 1.67 (each s, each 3H, 6 x COC*H*$_3$), 2.06 (s, 6H, 2 x COC*H*$_3$), 2.17–0.85 (m, 60H, alkyl-H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 172.7, 170.6, 170.43, 170.36, 170.0, 169.7, 169.4, 169.3, 166.1, 165.3, 164.9, 164.5, 164.4, 133.4, 133.34, 133.25, 133.3, 133.0, 132.8, 130.3, 130.1, 129.8, 129.6, 129.5, 129.3, 129.2, 129.1, 128.9, 128.8, 128.5, 128.3, 128.2, 100.9 (C-1 of Gal a), 100.8 (C-1 of Gal c), 100.3 (C-1 of Gal b), 95.0 (C-1 of Man), 73.8, 72.5, 72.0, 71.23, 71.15, 70.9, 70.2, 70.0, 69.4, 68.64, 68.57, 68.5, 67.8, 67.59, 67.55, 66.8, 66.6, 65.1, 61.53, 61.47, 47.6, 36.3, 31.8, 59.7, 69.6, 29.5, 29.4, 29.3, 29.1, 28.6, 25.6, 25.4, 22.6, 20.70, 20.66, 20.53, 20.46, 20.3, 14.1.
MALDI-TOFMS: calcd for $C_{123}H_{153}NO_{39}Na$: *m/z* 2291; found: *m/z* 2291 $[M+Na]^+$.

4.11. (2*S*, 3*S*, 4*R*)-2-(hexadecanoylamino)-3,4-dihydroxyoctadecyl α-D-mannopyranosyl-(1→3)-β-D-galactopyranosyl-(1→6)-β-D-galactopyranosyl-(1→6)-4-β-D-galactopyranoside (1)

To a solution of **16** (68.3 mg, 30.1 μmol) in MeOH (2.0 mL) was added 1,4-dioxane (2.0 mL) and NaOMe (200 mg) at room temperature, and the mixture was stirred for 18 h at room temperature then neutralized with IR-120B (H^+). The precipitates were filtrated off and concentrated. The product was purified by gel filtration chromatography (Sephadex LH-20, ϕ20 x 1000 mm) using 1:1 chloroform-MeOH to

give **1** (30.5 mg, 84%) as a white solid.
$[\alpha]_D^{25}$ +12.8 (*c* = 0.2, 1:1 $CHCl_3$-MeOH). ^{1}H NMR (400 MHz, 1:1 $CDCl_3$-CD_3OD): δ 4.99 (d, 1H, *J* = 1.1 Hz, H-1 of Man), 4.36 (d, 1H, *J* = 7.3 Hz, H-1 of Gal c), 4.32 (d, 1H, *J* = 7.3 Hz, H-1 of Gal b), 4.27 (d, 1H, *J* = 7.3 Hz, H-1 of Gal a); ^{13}C NMR (100 MHz, $CDCl_3$): δ 175.5, 105.0 (C-1 of Gal b, c), 104.9 (C-1 of Gal a), 97.4 (C-1 of Man), 77.7, 76.0, 74.90, 74.87, 74.5, 74.3, 74.1, 73.8, 72.7, 72.2, 72.1, 72.0, 71.7, 70.5, 70.3, 69.8, 69.7, 69.6, 69.5, 68.4, 65.6, 62.6, 62.2, 51.4, 37.1, 32.8, 30.5, 30.5, 30.4, 30.3, 30.2, 26.9, 26.8, 23.5, 14.4.
HR-FABMS: calcd for $C_{58}H_{109}NO_{24}Na$: *m/z* 1226.7237; found: *m/z* 1226.7118 $[M+Na]^+$.

4.12. 2-(Trimethylsilyl)ethyl 2,3,4,6-tetra-*O*-acetyl-α-D-mannopyranosyl-(1→3)-2-*O*-benzoyl-4,6-*O*-benzylidene-β-D-galactopyranosyl-(1→6)-[2,3,4,6-tetra-*O*-benzyl-α-D-glucopyranosyl-(1→4)]-2,3-di-*O*-benzoyl-β-D-galactopyranosyl-(1→6)-4-*O*-acetyl-2,3-di-*O*-benzoyl-β-D-glucopyranoside (18α)

4.13. 2-(Trimethylsilyl)ethyl 2,3,4,6-tetra-*O*-acetyl-α-D-mannopyranosyl-(1→3)-2-*O*-benzoyl-4,6-*O*-benzylidene-β-D-galactopyranosyl-(1→6)-[2,3,4,6-tetra-*O*-benzyl-β-D-glucopyranosyl-(1→4)]-2,3-di-*O*-benzoyl-β-D-galactopyranosyl-(1→6)-4-*O*-acethyl-2,3-di-*O*-benzoyl-β-D-glucopyranoside (18β)

(Ent. 1) A mixture of acceptor **12** (207 mg, 0.130 mmol), donor **17** (247 mg, 0.390 mmol) and 4Å MS (250 mg) in dry CH_2Cl_2 (2.0 mL) was stirred for 2 h at room temperature, then cooled to −40°C. NIS (132 mg, 0.585 mmol) and TfOH (5.24 μL, 58.5 μmol) was added, and the mixture was stirred for 1 h at −40°C, then neutralized with Et_3N. The precipitates were filtrated off and washed with $CHCl_3$. The combined filtrate and washings were successively washed with sat. aq. $Na_2S_2O_3$, sat. aq. $NaHCO_3$, brine, dried ($MgSO_4$), and concentrated. The product was purified by silica gel column chromatography (ϕ30 x 170 mm) using 1:1 hexane-AcOEt to give **18β** (104 mg, 38%) and **18α** (123 mg, 45%) as amorphous powders.

(Ent. 2) A mixture of acceptor **12** (220 mg, 0.138 mmol), donor **17** (263 mg, 0.414 mmol) and 4Å MS (300 mg) in dry CH_2Cl_2 (2.0 mL) and dry diethyl ether (0.4 mL) was stirred for 4 h at room temperature, then cooled to −20°C. NIS (140 mg, 0.621 mmol) and TfOH (5.56 μL, 0.0621 mmol) was added, and the mixture was stirred for 1 h at −20°C, then neutralized with Et_3N. The precipitates were filtrated off and washed with

$CHCl_3$. The combined filtrate and washings were successively washed with sat. aq. $Na_2S_2O_3$, sat. aq. $NaHCO_3$, brine, dried ($MgSO_4$), and concentrated. The product was purified by flash column chromatography (Ultra Pack B) using 5:2 hexane-AcOEt to give **18β** (38.8 mg, 13%) and **18α** (189 mg, 65%) as amorphous powders.

(Ent. 3) A mixture of acceptor **12** (270 mg, 0.170 mmol), donor **17** (323 mg, 0.511 mmol) and 4Å MS (300 mg) in dry toluene (1.8 mL) and dry 1,4-dioxane (0.6 mL) was stirred for 4 h at room temperature, then cooled to −20°C. NIS (173 mg, 0.767 mmol) and TfOH (6.87 μL, 0.0767 mmol) was added, and the mixture was stirred for 1 h at −20°C, then neutralized with Et_3N. The precipitates were filtrated off and washed with $CHCl_3$. The combined filtrate and washings were successively washed with sat. aq. $Na_2S_2O_3$, sat. aq. $NaHCO_3$, brine, dried ($MgSO_4$), and concentrated. The product was purified by flash column chromatography (Ultra Pack B) using 5:2 hexane-AcOEt to give **18α** (277 mg, 77%) as amorphous powders.

18α: $[\alpha]_D^{25}$ +78.8 (*c* = 1.0, $CHCl_3$). ^{1}H NMR (400 MHz, $CDCl_3$): δ 8.26–7.28 (m, 50H, 10 x Ph), 5.79–5.70 (m, 5H, H-2, 4 of Gal a, H-2 of Gal b, H-2 of Gal c, >C*H*–Ph), 5.46 (dd, 1H, $J_{2,3}$ = 10.5 Hz, $J_{3,4}$ = 3.4 Hz, H-3 of Gal a), 5.38–5.31 (m, 5H, H-3 of Gal b, H-2, 3 of Man, 2 x benzyl methylene), 5.24–5.21 (m, 2H, H-1, 3 of Man), 5.14–5.10 (m, 2H, H-1 of Glc, benzyl methylene), 5.03 (d, 1H, benzyl methylene), 4.95–4.89 (m, 4H, H-1 of Gal c, 3 x benzyl methylene), 4.74 (d, 1H, $J_{1,2}$ = 8.0 Hz, H-1 of Gal b), 4.71 (d, 1H, $J_{1,2}$ = 7.6 Hz, H-1 of Gal a), 4.56–4.47 (m, 4H, H-4, 6a of Gal b, H-4 of Gal c, benzyl methylene), 4.26–4.19 (m, 4H, H-6b of Gal b, H-3, 5 of Gal c, H-3 of Glc), 4.09–3.85 (m, 8H, H-6 of Gal a, H-5 of Gal b, H-5, 6 of Man, H-4 of Glc, C*H*$_2$CH$_2$SiMe$_3$), 3.82 (br. s, 2H, H-6 of Gal c), 3.65 (dd, 1H, $J_{1,2}$ = 3.2 Hz, $J_{2,3}$ = 9.8 Hz, H-2 of Glc), 3.55–3.41 (m, 3H, H-5, 6a of Glc, C*H*$_2$CH$_2$SiMe$_3$), 3.07 (br. d, 1H, *J* = 9.8 Hz, H-6b of Glc), 2.27, 2.21, 2.19, 2.08, 1.93 (each s, each 3H, COC*H*$_3$), 0.91–0.68 (m, 2H, CH$_2$C*H*$_2$SiMe$_3$), −0.03 (s, 9H, CH$_2$CH$_2$Si*Me*$_3$); ^{13}C NMR (100 MHz, $CDCl_3$): δ 170.4, 170.1, 170.0, 169.6, 169.1, 165.8, 165.3, 165.2, 165.1, 164.8, 139.0, 138.6, 138.5, 138.0, 137.3, 133.2, 133.14, 133.09, 133.0, 132.9, 129.9, 129.8, 129.7, 129.60, 129.55, 129.3, 129.0, 128.9, 128.53, 128.47, 128.28, 128.26, 128.2, 127.9, 127.8, 127.7, 127.6, 127.5, 127.44, 127.42, 127.3, 127.2, 126.2, 100.9 (C-1 of Gal a), 100.7, 100.5 (C-1 of Gal b), 100.4 (C-1 of Gal c), 99.4 (C-1 of Glc), 94.4 (C-1 of Man), 81.5, 80.2, 77.5, 75.4, 75.2, 75.1, 74.7, 74.3, 73.5, 73.44, 73.35, 73.2, 72.7, 71.9, 71.8, 71.0, 70.5, 70.0, 69.9, 69.7, 68.6, 68.4, 68.1, 67.4, 66.5, 66.2, 65.6, 61.7, 29.7, 20.9, 20.6, 20.54, 20.46, 17.5, −1.49.

MALDI-TOFMS: calcd for $C_{115}H_{122}O_{36}SiNa$: *m/z* 2129.7; found: *m/z* 2130.1 $[M+Na]^+$.

18β: $[\alpha]_D^{25}$ +92.5 (*c* = 1.0, $CHCl_3$). ^{1}H NMR (400 MHz, $CDCl_3$): δ 8.07–7.09 (m, 50H,

10 x Ph), 5.73 (dd, 1H, $J_{1,2}$ = 8.0 Hz, $J_{2,3}$ = 10.3 Hz, H-2 of Gal b), 5.59–5.55 (m, 2H, H-2 of Gal a, >C*H*–Ph), 5.50–5.46 (m, 2H, H-4 of Gal a, H-2 of Gal c), 5.38–5.32 (m, 2H, H-3 of Gal b, benzyl methylene), 5.26 (dd, 1H, $J_{2,3}$ = 10.3 Hz, $J_{3,4}$ = 3.4 Hz, H-3 of Gal a), 5.22–5.11 (m, 3H, H-2, 3, 4 of Man), 5.04 (d, 1H, $J_{1,2}$ = 1.4 Hz, H-1 of Man), 4.90–4.83 (m, 3H, H-1 of Gal c, 2 x benzyl methylene), 4.74–4.69 (m, 2H, 2 x benzyl methylene), 4.67 (d, 1H, $J_{1,2}$ = 7.8 Hz, H-1 of Gal b), 4.58–4.47 (m, 4H, H-1 of Gal a, 3 x benzyl methylene), 4.36 (d, 1H, $J_{1,2}$ = 7.6 Hz, H-1 of Glc), 4.34 (br. d, 1H, J = 11.9 Hz, H-6a of Gal c), 4.24–4.19 (m, 3H, H-4, 6a of Gal b, H-4 of Gal c), 4.09–4.00 (m, 3H, H-6b of Gal b, H-3, 6b of Gal c), 3.89–3.70 (m, 8H, H-6 of Gal a, H-5 of Gal b, H-5 of Gal c, H-5, 6 of Man, C*H*$_2$CH$_2$SiMe$_3$), 3.65 (br. s, 2H, H-6 of Glc), 3.57–3.52 (m, 2H, H-2, 4 of Glc), 3.44 (d, 1H, $J_{2,3}$ = $J_{3,4}$ = 8.9 Hz, H-3 of Glc), 3.34–3.28 (m, 2H, H-5 of Gal a, C*H*$_2$CH$_2$SiMe$_3$), 3.22–3.18 (m, 1H, H-5 of Glc), 2.08, 2.06, 2.00, 1.89, 1.76 (each s, each 3H, COC*H*$_3$), 0.76–0.52 (m, 2H, CH$_2$C*H*$_2$SiMe$_3$), −0.18 (s, 9H, CH$_2$CH$_2$Si*Me*$_3$); ^{13}C NMR (100 MHz, CDCl$_3$): δ 170.4, 170.13, 170.07, 169.6, 169.1, 165.6, 165.4, 165.1, 164.84, 164.77, 138.8, 138.5, 138.3, 138.0, 137.4, 133.3, 133.2, 133.0, 132.9, 130.1, 129.8, 129.63, 129.56, 129.0, 128.8, 128.6, 128.5, 128.4, 128.30, 128.26, 128.2, 128.1, 127.9, 127.8, 127.7, 127.54, 127.47, 127.3, 126.2, 103.8 (C-1 of Glc), 100.9 (C-1 of Gal a), 100.7, 100.5 (C-1 of Gal c), 100.40 (C-1 of Gal b), 94.6 (C-1 of Man), 84.6, 82.3, 77.6, 75.6, 75.2, 75.1, 75.0, 74.9, 74.6, 73.9, 73.3, 72.9, 72.8, 72.1, 71.9, 70.9, 70.1, 70.0, 69.7, 69.1, 68.9, 68.6, 68.5, 68.4, 68.1, 67.5, 67.3, 66.3, 65.6, 61.6, 20.9, 20.61, 20.56, 20.53, 20.45, 17.5, −1.47.
MALDI-TOFMS: calcd for $C_{115}H_{122}O_{36}SiNa$: *m/z* 2129.7; found: *m/z* 2130.0 $[M+Na]^+$.

4.14. 2-(Trimethylsilyl)ethyl 2,3,4,6-tetra-*O*-acetyl-α-D-mannopyranosyl-(1→3)-4,6-di-*O*-acetyl-2-*O*-benzoyl-β-D-galactopyranosyl-(1→6)-[2,3,4,6-tetra-*O*-acetyl-α-D-glucopyranosyl-(1→4)]-2,3-di-*O*-benzoyl-β-D-galactopyranosyl-(1→6)-4-*O*-acethyl-2,3-di-*O*-benzoyl-β-D-glucopyranoside (19)

Compound **18α** (373 mg, 0.177 mmol) in THF-MeOH-AcOH (1:1:1, 12 mL) was hydrogenolysis under hydrogen (0.11 MPa) in the presence of Pd(OH)$_2$ /C (300 mg) for 18 h at room temperature, and the mixture was then filtered and concentrated. The residue was acetylated with acetic anhydride (4.0 mL) in pyridine (6.0 mL). The reaction mixture was poured into ice H_2O and extracted with $CHCl_3$. The extract was washed sequentially with 5% HCl, aq $NaHCO_3$, and brine, dried ($MgSO_4$), and concentrated. The residue was purified by flash column chromatography (Ultra Pack A)

using 8:1 toluene-acetone to give **19** (290 mg, 85.9%) as amorphous powders.
$[\alpha]_D^{25}$ +54.3 (*c* = 1.0, $CHCl_3$). ^{1}H NMR (400 MHz, $CDCl_3$): δ 8.04–7.31 (m, 25H, 5 x Ph), 5.61–5.50 (m, 4H, H-2, 4 of Gal a, H-2 of Gal b, H-2 of Glc), 5.45 (d, 1H, $J_{3,4}$ = 3.0 Hz, H-4 of Gal c), 5.39–5.34 (m, 1H, H-2 of Gal c), 5.30 (dd, 1H, $J_{2,3}$ = 10.3 Hz, $J_{3,4}$ = 3.2 Hz, H-3 of Gal a), 5.18–4.95 (m, 6H, H-3 of Gal b, H-1, 3, 4 of Glc, H-1, 2, 3, 4 of Man), 4.73 (d, 1H, $J_{1,2}$ = 8.0 Hz, H-1 of Gal c), 4.66 (d, 1H, $J_{1,2}$ = 7.7 Hz, H-1 of Gal b), 4.61 (d, 1H, $J_{1,2}$ = 8.0 Hz, H-1 of Gal a), 4.34 (br. d, 1H, *J* = 10.1 Hz, H-5 of Glc), 4.25–4.09 (m, 5H, H-5 of Gal a, H-4 of Gal b, H-3, 5, 6 of Gal c), 4.00–3.65 (m, 11H, H-5, 6 of Gal a, H-5, 6a of Gal b, H-6 of Glc, H-5, 6 of Man, C*H*$_2$CH$_2$SiMe$_3$), 3.57 (br. d, 1H, *J* = 11.2 Hz, H-6b of Gal b), 3.43–3.36 (m, 1H, C*H*$_2$CH$_2$SiMe), 2.24, 2.15, 2.10, 2.09, 2.07, 2.05, 2.01, 1.98, 1.94, 1.90, 1.66 (each s, each 3H, COC*H*$_3$), −0.17 (s, 9H, CH$_2$CH$_2$Si*Me*$_3$); ^{13}C NMR (100 MHz, $CDCl_3$): δ 170.6, 170.5, 170.41, 170.37, 170.04, 169.98, 169.9, 169.5, 169.41, 169.38, 169.3, 165.6, 165.3, 165.2, 165.1, 164.5, 133.6, 133.3, 133.13, 133.08, 129.9, 129.74, 129.68, 129.6, 129.5, 129.3, 129.1, 129.0, 128.8, 128.6, 128.43, 128.37, 128.3, 128.2, 101.3 (C-1 of Gal b), 100.9 (C-1 of Gal c), 100.6 (C-1 of Gal a), 97.9 (C-1 of Glc), 95.1 (C-1 of Man), 75.7, 73.8, 72.9, 72.82, 72.76, 71.9, 70.7, 70.6, 70.2, 69.6, 69.5, 68.7, 68.6, 68.5, 68.1, 68.0, 67.8, 67.6, 66.3, 65.1, 65.0, 61.5, 61.2, 61.1, 60.4, 20.8, 20.7, 20.6, 20.4, 17.6, 14.2, −1.52
MALDI-TOFMS: calcd for $C_{92}H_{106}O_{42}SiNa$: *m/z* 1933.6; found: *m/z* 1934.3 $[M+Na]^+$.

4.15.

2,3,4,6-tetra-*O*-acetyl-β-D-mannopyranosyl-(1→3)-4,6-di-*O*-acetyl-2-*O*-benzoyl-β-D-galactopyranosyl-(1→6)-[2,3,4,6-tetra-*O*-acethyl-α-D-glucopyranosyl-(1→4)]-2,3-di-*O*-benzoyl-β-D-galactopyranosyl-(1→6)-4-*O*-acetyl-2,3-di-*O*-benzoyl-α-D-glucopyranosyl trichloroacetimidate (20)

Compound **20** was prepared from **19** (271 mg, 142 μmol) as described for preparation of **14**. The product was purified by silica gel column chromatography (20:1 chloroform-acetone) to give **20** (283 mg, quant.) as amorphous powder.
$[\alpha]_D^{25}$ +94.4 (*c* = 2.0, $CHCl_3$). ^{1}H NMR (400 MHz, $CDCl_3$): δ 8.30 (s, 1H, N*H*), 8.06–7.30 (m, 25H, 5 x Ph), 6.61 (d, 1H, $J_{1,2}$ = 4.4 Hz, H-1 of Gal a), 5.81 (dd, 1H, $J_{2,3}$ = 10.8 Hz, $J_{3,4}$ = 3.3 Hz, H-3 of Gal a), 5.73–5.69 (m, 2H, H-2, 4 of Gal a), 5.54–5.48 (m, 2H, H-2 of Gal b, H-2 of Glc), 5.46 (d, 1H, $J_{3,4}$ = 3.0 Hz, H-4 of Gal c), 5.39 (t, 1H, $J_{1,2}$ = $J_{2,3}$ = 8.0 Hz, H-2 of Gal c), 5.17–4.92 (m, 8H, H-3 of Gal b, H-1, 3, 4 of Glc, H-1, 2, 3, 4, of Man), 4.75 (d, 1H, $J_{1,2}$ = 8.0 Hz, H-1 of Gal c), 4.65 (d, 1H, $J_{1,2}$ = 7.6 Hz, H-1 of Gal b), 4.45 (br. d, 1H, $J_{5,6}$ = 6.2 Hz, H-5 of Gal a), 4.35–4.32 (m, 1H, H-5 of Glc),

4.26–4.12 (m, 5H, H-6 of Gal b, H-3, 4, 5 of Gal c), 4.03–3.89 (m, 3H, H-5 of Gal b, H-6a of Gal c, H-6a of Glc), 3.82–3.64 (m, 6H, H-6 of Gal a, H-6b of Gal c, H-6b of Glc, H-5, 6 of Man), 2.25, 2.17, 2.13, 2.11, 2.00, 1.95, 1.93, 1.91, 1.67 (each s, each 3H, COC*H*$_3$), 2.08 (s, 6H, 2 x COC*H*$_3$); ^{13}C NMR (100 MHz, $CDCl_3$): δ 170.54, 170.49, 170.4, 170.3, 170.0, 169.9, 169.5, 169.41, 169.36, 169.3, 165.63, 169.58, 165.1, 165.0, 164.5, 160.3, 133.6, 133.5, 133.4, 133.2, 133.0, 129.9, 129.7, 129.6, 129.5, 129.3, 129.1, 129.0, 128.7, 128.6, 128.4, 128.2, 100.9 (C-1 of Gal b, c), 97.8 (C-1 of Glc), 95.0 (C-1 of Man), 93.5 (C-1 of Gal a), 90.6, 76.0, 73.8, 73.1, 72.9, 70.8, 70.7, 70.6, 70.1, 69.3, 68.7, 68.6, 68.5, 68.2, 68.1, 67.7, 66.9, 66.6, 65.0, 64.9, 61.5, 64.2, 61.0, 20.7, 20.7, 20.6, 20.5, 20.5, 20.3, 14.0, 10.9.
MALDI-TOFMS: calcd for $C_{89}H_{94}Cl_3NO_{42}Na$: *m/z* 1976; found: *m/z* 1976 $[M+Na]^+$.

4.16. (2*S*, 3*S*, 4*R*)-3,4-dibenzyloxy-2-(hexadecanoylamino)-octadecyl 2,3,4,6-tetra-*O*-acetyl-β-D-mannopyranosyl-(1→3)-4,6-di-*O*-acetyl-2-*O*-benzoyl-β-D-galactopyranosyl-(1→6)-[2,3,4,6-tetra-*O*-aceyl-α-D-glucopyranosyl-(1→4)]-6-*O*-acetyl-2,3-di-*O*-benzoyl-β-D-galactopyranosyl-(1→6)-4-*O*-acetyl-2,3-di-*O*-benzoyl-β-D-galactopyranoside (21)

Compound **21** was prepared from **15** (76.9 mg, 101 μmol) and **20** (131 mg, 67.1 μmol) as described for preparation of **16**. The product was purified by silica gel column chromatography (1:1 hexane-ethyl acetate) to give **21** (72.1 mg, 42.0%).
$[\alpha]_D^{25}$ +54.4 (*c* = 1.0, $CHCl_3$). ^{1}H NMR (400 MHz, $CDCl_3$): δ; 8.04–7.31 (m, 35H, 5 x Ph), 5.99 (d, 1H, *J* = 9.6 Hz, N*H* of Cer), 5.52–5.23 (m, 9H, H-2, 3 of Gal a, H-2, 3 of Gal b, H-2, 4 of Gal c, H-2 of Glc, H-3, 4 of Cer), 5.14–4.95 (m, 8H, H-4 of Gal a, H-1, 3, 4 of Glc, H-1, 2, 3, 4 of Man), 4.70 (d, 1H, $J_{1,2}$ = 8.2 Hz, H-1 of Gal c), 4.43 (d, 1H, $J_{1,2}$ = 7.5 Hz, H-1 of Gal b), 4.31–4.29 (m, 2H, H-1a, 2 of Cer), 4.22–4.09 (m, 5H, H-4 of Gal b, H-3, 6a of Gal c, H-6 of Glc), 4.04 (d, 1H, $J_{1,2}$ = 7.8 Hz, H-1 of Gal a), 3.95–3.49 (m, 11H, H-6 of Gal a, H-6 of Gal b, H-5, 6b of Gal c, H-5 of Glc, H-5, 6 of Man, H-1b of Cer), 3.15 (dd, 1H, $J_{5,6a}$ = 2.8 Hz, $J_{5,6b}$ = 9.4 Hz, H-5 of Gal a), 2.98 (dd, 1H, $J_{5,6a}$ = 6.4 Hz, $J_{5,6b}$ = 10.8 Hz, H-5 of Gal b), 2.22, 2.15, 2.11, 2.09, 2.063, 2.057, 2.00, 1.95, 1.91, 1.90, 1.66 (each s, each 3H, COC*H*$_3$), 1.78–0.85 (m, 60H, alkyl-H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 170.6, 170.50, 170.45, 170.4, 170.2, 169.9, 169.54, 169.45, 169.4, 169.3, 166.1, 165.6, 165.4, 165.2, 165.0, 164.5, 133.6, 133.5, 133.4, 133.3, 132.9, 130.3, 130.2, 129.9, 129.8, 129.7, 129.6, 129.5, 129.24, 129.17, 129.1, 129.0, 128.8, 128.6, 128.5, 128.4, 128.3, 101.4 (C-1 of Gal a), 101.0 (C-1 of Gal b), 100.3 (C-1 of Gal c), 97.7 (C-1 of Man), 95.1 (C-1 of Glc), 75.4, 73.8, 72.9, 72.7, 72.4, 72.2, 71.3,

70.8, 70.6, 70.3, 70.2, 69.6, 68.70, 68.66, 68.6, 68.1, 67.9, 67.7, 66.5, 66.0, 65.1, 65.0, 61.6, 61.2, 61.1, 47.8, 36.2, 31.9, 29.71, 29.68, 29.64, 29.59, 29.54, 29.47, 29.3, 29.2, 28.8, 25.6, 25.4, 22.7, 20.8, 20.7, 20.59, 20.55, 20.4, 14.1.
MALDI-TOFMS: calcd for $C_{135}H_{169}NO_{47}Na$: *m/z* 2579.1; found: *m/z* 2579.6 $[M+Na]^+$.

4.17 (2*S*, 3*S*, 4*R*)-2-(hexadecanoylamino)-3,4-dihydroxyoctadecyl β-D-mannopyranosyl-(1→3)-β-D-galactopyranosyl-(1→6)-[α-D-glucopyranosyl-(1→4)]-β-D-galactopyranosyl-(1→6)-4-β-D-galactopyranoside (2)

Compound 2 was prepared from **21** (72.1 mg, 28.2 μmol) as described for preparation of **1**. The product was purified by gel filtration chromatography (Sephadex LH-20, ϕ20 x 1000 mm) using 1:1 chloroform-MeOH to give **2** (33.9 mg, 88.0%).
$[\alpha]_D^{25}$ +50.3 (*c* = 0.2, 1:1 $CHCl_3$-MeOH). ^{1}H NMR (400 MHz, $CDCl_3$): δ 5.06 (d, 1H, *J* = 3.7 Hz, H-1 of Glc), 4.98 (br. s, 1H, H-1 of Man), 4.40 (d, 1H, *J* = 6.9 Hz, H-1 of Gal c), 4.33 (d, 1H, *J* = 6.8 Hz, H-1 of Gal b), 4.28 (d, 1H, *J* = 7.5 Hz, H-1 of Gal a); ^{13}C NMR (100 MHz, $CDCl_3$): δ 175.3, 104.8 (C-1 of Gal b), 104.6 (C-1 of Gal c), 104.1 (C-1 of Gal a), 101.0 (C-1 of Glc), 97.2 (C-1 of Man), 75.9, 74.1, 74.0, 73.9, 73.7, 73.5, 72.9, 71.9, 71.7, 71.4, 71.1, 70.4, 70.1, 69.8, 69.4, 68.0, 67.3, 65.7, 62.5, 62.2, 62.3, 62.1, 62.0, 50.9, 36.9, 32.5, 30.3, 30.2, 30.1, 30.0, 29.9, 26.7, 26.5, 24.0, 23.2, 14.3.
HR-FABMS: calcd for $C_{64}H_{110}NO_{29}Na$: *m/z* 1388.7765; found: *m/z* 1388.7743 $[M+Na]^+$.

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Stereocontrolled syntheses of two neutral glycosphingolipids from the fungus *Hirsutella rhossiliensis* have been achieved.

The synthetic methods may be useful for the synthesis of conjugation of the other glycan.