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A practical synthesis of a (1→6)-linked β-D-glucosamine nonasaccharide

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Abstract

A (1→6)-β-D-glucosamine nonasaccharide was convergently synthesized using isopropyl thioglycosides as donors. Anomeric acetylated glucosamine derivatives were proved to be good acceptors in the NIS/TMSOTf catalyzed glycosylation. The target nonasaccharide showed a mild antitumor activity against H_{22} on the preliminary mice tests.

Keywords: Glycosylation; Oligosaccharides; Glucosamine; Bioactivity

1. Introduction

2-Amino-2-deoxy-D-glucose (glucosamine) is the most common amino sugar and occurs as a constituent of glycoproteins, glycolipids, bacterial lipopolysaccharides, proteoglycans and nodulation factors associated with leguminous plants.[1] Chitin and chitosan, poly-(1→4)-β-D-glucosamine derivatives, are widely used as a bifidus factor to promote animal growth and as an elicitor to protect plants from fungal invasions.[2] Glucosamine oligosaccharides with the (1→6)-linkage have gotten less attention with respect to their β-D-(1→4)-linked counterparts.[3] A literature search suggests that (1→6)-β-D-glucosamine oligosaccharides may act as a potential antitumor and immunostimulating agents.[4] More impressively, a carbohydrate-based catalyst, containing three (1→6)-linked β-D-glucosamine units, has been designed and recently synthesized.[5] It showed a marked rate enhancement and specificity for the hydrolysis of GTP to GDP and orthophosphate (OP). We proved, in a test in mice, that the β-D-glucosamine hexamer could significantly increase the number of white blood cells and marrow cells compared to the results from chemotherapy (CTX).[6] Herein, we report the first synthesis of a (1→6)-β-D-glucosamine nonasaccharide and preliminary results of its anticancer activity against the H_{22} tumor.

2. Results and discussion

The convergent synthesis of the target nonasaccharide is outlined in Scheme 1. As we have observed in previous work that the rapid consumption of 3,4,6-tri-*O*-acetyl-2-deoxy-2-phthalimido-α-D-glucopyranosyl trichloroacetimidate during its glycosylation afforded a low yield of product,[7] we decided to use isopropyl 3,4-di-*O*-acetyl-2-deoxy-2-phthalimido-1-thio-β-D-glucopyranoside (**7**) as the basic building block for preparing the elongation synthon. Thus, the β isomer of **4**,[8] re-crystallized from its α,β mixture, was reacted with 2-propanethiol under the promotion of $BF_3{\cdot}Et_2O$ in CH_2Cl_2 at room temperature to give thioglycoside **5** in 86% yield. Using the α,β mixture of **4**, we could also get a good yield of **5** in CH_2Cl_2 under reflux. Saponification of **5** with NaOMe in MeOH, followed by 6-*O*-silylation with *tert*-butylchlorodimethylsilane in pyridine and subsequent in situ acetylation furnished key synthon **7**.

We were gratified to find that the coupling of donor **7** with the acetyl acceptor, 1,3,4-tri-*O*-acetyl-2-deoxy-2-phthalimido-α,β-D-glucopyranose (**3**), in CH_2Cl_2 in the

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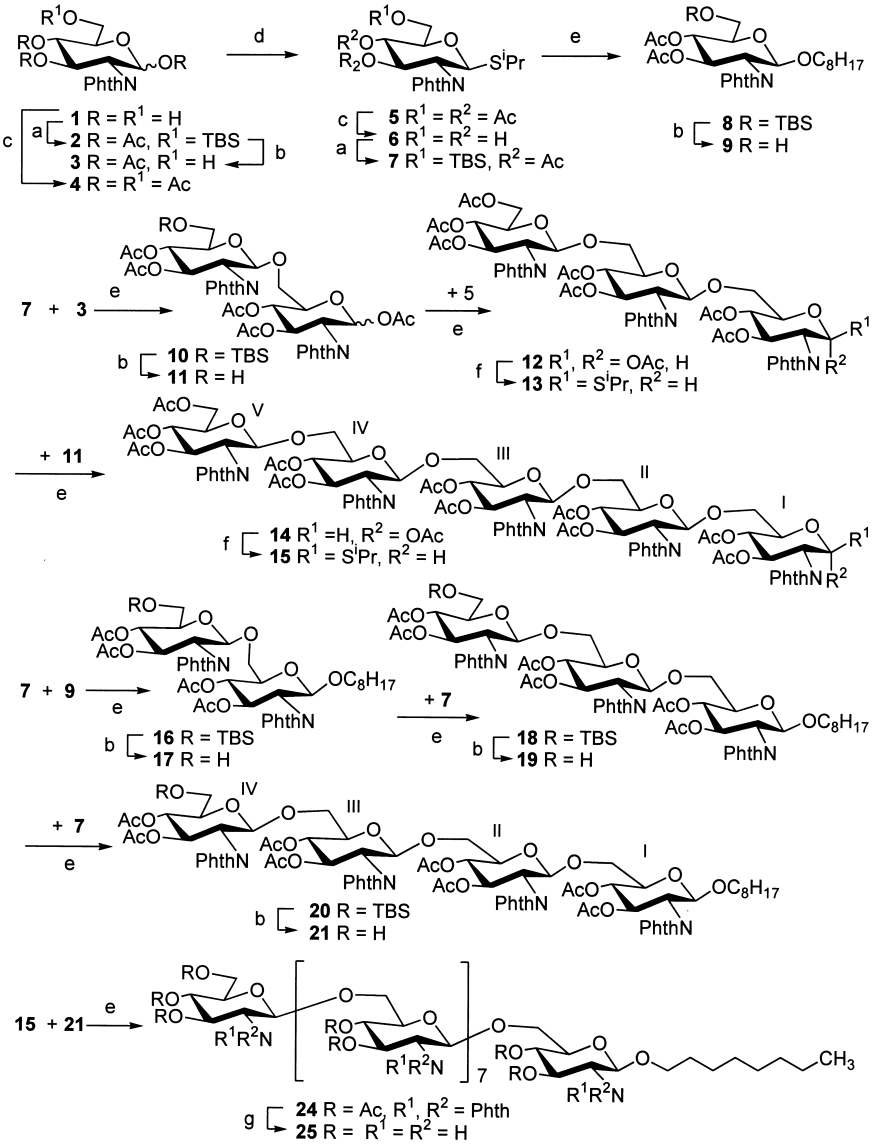
presence of NIS/TMSOTf at −20 °C gave an excellent yield of disaccharide **10**. This result significantly simplified our synthesis towards the target. Removal of the silyl group from **10** with $BF_3{\cdot}Et_2O$ (→**11**), followed by glycosylation with thioglycoside **5**, afforded fully *O*-acetylated triglucosamine derivative **12**. It should be noted that the TBAF-desilylation caused acyl migration from C-4 to C-6 in this case.[9] A modified Helfrich reaction of **12** and 2-propanethiol in CH_2Cl_2 under reflux gave isopropyl thioglycoside **13** in 73% yield. If the above reaction was carried out at room temperature, compound **13** was obtained in 53% yield, and the α isomer of **12** was recovered. Condensation of trisaccharide donor **13** with disaccharide acceptor **11** gave pentasaccharide **14** with the predominant α configuration on the reducing end (sugar unit I). Pure α product was obtained in a yield of 78% after a silica gel column separation. Again, a modified Helfrich reaction of pentasaccharide **14** and 2-propanethiol in CH_2Cl_2 under reflux gave isopropyl thioglycoside **15** (60%). No reaction was observed at 0 °C in 2 h.

Convergently, glycosylation of **7** with octanol in CH_2Cl_2 using NIS/TMSOTf catalysts gave glycoside **8**, which was further desilylated with 2 equiv of $BF_3{\cdot}Et_2O$ to give acceptor **9** (85% from **7**). Reiterative coupling and desilylation of **7** and **9** finally gave a tetrasaccharide acceptor **21** in 28% overall yield (from **9** to **21**). With pentasaccharide donor **15** and tetrasaccharide acceptor **21** in hand, we tried condensation of these two species in CH_2Cl_2 at −10 °C using NIS/TMSOTf pro-



Scheme 1. Reagents and conditions: (a) TBSCl, Pyr; Ac_2O; 70% for **2**; 78% for **7**; (b) $BF_3{\cdot}Et_2O$, CH_2Cl_2; 99.5% for **3**; 89% for **9**; 84.6% for **11**; 78% for **17**; 86.5% for **19**; 84% for **21**; (c) Ac_2O, Pyr; (d) $BF_3{\cdot}Et_2O$, CH_2Cl_2, 86%; (e) NIS, TMSOTf, CH_2Cl_2; 95.5% for **8**; 94% for **10**; 86% for **12**; 78% for **14**; 80% for **16**; 92% for **18**; 67.5% for **20**; 47.4% for **24**; (f) $BF_3{\cdot}Et_2O$, CH_2Cl_2, reflux; 73% for **13**; 60% for **15**; (g) MeOH satd with NH_3; 72%.

moters, and 47.4% of nonasaccharide **24** was obtained. Full deprotection of **24** in ammonia-saturated methanol afforded nonasaccharide **25** in good yield (72%).

The antitumor activity of nonasaccharide **25** was preliminarily studied according to the method described by Sasaki and co-workers.[10] Balb/c mice weighing about 20 g and H_{22} (2.5×10^7 cells) were used for the bioassay. Lentinan (imported from Japan for medical usage) and Cisplatin® (CDDP) were selected as the positive controls in parallel tests. The samples were injected daily for 9 days, while CDDP was given every other day. The tumor inhibition ratios for **25**, lentinan and CDDP were 36.8–43.1% (dosage: 0.5–2.0 mg/kg/day), 37.3% (dosage: 1 mg/kg/day) and 55.4–56.1% (dosage: 3 mg/kg/every other day), respectively.

In conclusion, we have described a practical convergent synthesis of the linear (1→6)-β-D-glucosamine nonasaccharide. The reiterative usage of 6-*O*-silylated isopropyl thioglycoside and C-1 acetylated acceptor simplified the whole procedure. Moreover, the synthetic target compound showed a mild antitumor activity towards liver cancer model H_{22}.

3. Experimental

3.1. General methods

Optical rotations were determined at 25 °C with a Perkin–Elmer Model 241-Mc automatic polarimeter. ^{1}H NMR, ^{13}C NMR and ^{1}H–^{1}H, ^{1}H–^{13}C COSY spectra were recorded with a Bruker ARX 400 spectrometers for solutions in $CDCl_3$ or D_2O. Chemical shifts are given in ppm downfield from internal Me_4Si. Mass spectra were measured using MALDITOF-MS with α-cyano-4-hydroxycinnamic acid (CCA) as matrix. Thin-layer chromatography (TLC) was performed on silica gel HF_{254} with detection by charring with 30% (v/v) H_2SO_4 in MeOH, or in some cases by a UV detector.

3.2. 1,3,4-Tri-*O*-acetyl-2-deoxy-2-phthalimido-D-glucopyranose (3)

To a pre-cooled solution of compound **1**[8a] (2.0 g, 6.467 mmol) in pyridine (10 mL) was added *tert*-butylchlorodimethylsilane (1.065 g, 7.1 mmol) and DMAP (20 mg). The mixture was stirred at room temperature (rt) for 24 h, and then a premixed solution of acetic anhydride (6 mL) and pyridine (6 mL) was added. After 4 h, the mixture was co-evaporated to dryness with the help of toluene. The above crude product was treated with $BF_3{\cdot}Et_2O$ (1.0 mL, 7.96 mmol) in CH_2Cl_2 (25 mL) at rt for 75 min, then poured into cold satd aq $NaHCO_3$, and extracted with CH_2Cl_2. The organic phase was concentrated, and the crude product was subjected to column chromatography (1:1 EtOAc–petroleum ether) to give syrupy **3** (1.97 g, 70%) as an α,β mixture (3:2): ^{1}H NMR for β isomer: δ 1.87, 2.00, 2.08 (3 s, 9 H, Ac), 3.62–3.85 (m, 3 H, H-6a, H-6b, H-5), 4.45 (dd, 1 H, *J* 10.4, 8.8 Hz, H-2), 5.17 (dd, 1 H, *J* 9.2, 5.8 Hz, H-4), 5.93 (dd, 1 H, *J* 10.4, 9.2 Hz, H-3), 6.53 (d, 1 H, *J* 8.8 Hz, H-1), 7.25–7.87 (m, 4 H, Ph); ^{1}H NMR for α isomer: δ 1.89, 2.09, 2.10 (3 s, 9 H, Ac), 3.62–3.84 (m, 2 H, H-6a, H-6b), 4.12–4.14 (m, 1 H, H-5), 4.70 (dd, 1 H, *J* 11.6, 3.4 Hz, H-2), 5.15 (dd, 1 H, *J* 9.2, 3.0 Hz, H-4), 6.30 (d, 1 H, *J* 3.4 Hz, H-1), 6.61 (dd, 1 H, *J* 11.6, 9.2 Hz, H-3), 7.26–8.02 (m, 4 H, Ph). MALDITOF-MS: Calcd for $C_{20}H_{21}NO_{10}$: 435 [M]; Found 458.3 $[M + Na]^+$.

3.3. Isopropyl 3,4,6-tri-*O*-acetyl-2-deoxy-2-phthalimido-1-thio-β-D-glucopyranoside (5)

To a mixture of β anomer of **4** (9.53 g, 20 mmol) and 2-propanethiol (2.43 mL, 26 mmol) in CH_2Cl_2 (50 mL) was added $BF_3{\cdot}Et_2O$ (3.25 mL, 26 mmol). The mixture was stirred at rt for 2 h, then poured into cold satd aq $NaHCO_3$, and extracted with CH_2Cl_2. The organic phase was concentrated, and the crude product was subjected to column chromatography (2:5 EtOAc–petroleum ether) to give syrupy **5** (8.47 g, 86%): $[\alpha]_D$ + 42° (*c* 1, $CHCl_3$); ^{1}H NMR: δ 1.24 (t, 6 H, *J* 7.2 Hz, $SCH(CH_3)_2$), 1.87, 2.05, 2.11 (3 s, 9 H, Ac), 3.13–3.17 (m, 1 H, $SCH(CH_3)_2$), 3.90–3.92 (m, 1 H, H-5), 4.17 (dd, 1 H, *J* 12.0, 2.2 Hz, H-6a), 5.31 (dd, 1 H, *J* 12.0, 4.3 Hz, H-6b), 4.37 (t, 1 H, *J* 10.0 Hz, H-2), 5.17 (t, *J* 10.0 Hz, H-4), 5.57 (d, 1 H, *J* 10.0 Hz, H-1), 5.83 (t, 1 H, *J* 10.0 Hz, H-3), 7.74–7.88 (m, 4 H, Ph). Anal. Calcd for $C_{23}H_{27}NO_9S$: C, 55.97; H, 5.51. Found: C, 55.80; H, 5.67.

3.4. Isopropyl 3,4-di-*O*-acetyl-6-*O*-*tert*-butyldimethylsilyl-2-deoxy-2-phthalimido-1-thio-β-D-glucopyranoside (7)

Compound **5** (10 g, 20.26 mmol) in MeOH (120 mL) was treated with 1 M NaOMe (5 mL) at rt for 2 h and then neutralized with Amberlite IR-120 (H^+) resin. After filtration, the filtrate was concentrated. The crude **6** gave the following ^{1}H NMR: δ 1.18 (2 t, 6 H, *J* 6.4 Hz, CH_3), 3.09–3.13 (m, 1 H, C*H*), 3.48–3.50 (m, 1 H, H-5), 3.68 (t, 1 H, *J* 10.0 Hz, H-4), 3.88 (d, 2 H, *J* 2.8 Hz, H-6), 4.11 (t, 1 H, *J* 10.0 Hz, H-2), 4.33 (t, 1 H, *J* 10.0 Hz, H-3), 5.42 (d, 1 H, *J* 10.0 Hz, H-1), 7.69–7.82 (m, 4 H, Ph). To the above residue was added *tert*-butylchlorodimethylsilane (3.45 g, 23 mmol) and DMAP (30 mg). The mixture was stirred at rt for 10 h, then was added a premixed solution of acetic anhydride (8 mL) and pyridine (8 mL). The mixture was stirred at rt for 4 h and then co-evaporated with toluene. The residue was subjected to the column chromatography (1:1 EtOAc–petroleum ether) to give **7** (8.93 g, 78%) as

a foam: $[\alpha]_D$ + 53° (*c* 1, $CHCl_3$); ^1H NMR: δ 0.06, 0.08 (2 s, 6 H, $Si(CH_3)_2$), 0.90 (s, 9 H, *t*-Bu), 1.22, 1.26 (2 s, 6 H, $SCH(CH_3)_2$), 1.85, 2.03 (2 s, 6 H, Ac), 3.13–3.16 (m, 1 H, SC*H*), 3.69–3.72 (m, 3 H, 2 H-6, H-5), 4.34 (t, *J* 10.0 Hz, H-2), 5.09 (t, 1 H, *J* 10.0 Hz, H-4), 5.53 (d, 1 H, *J* 10.0 Hz, H-1), 5.82 (t, 1 H, *J* 10.0, H-3), 7.27–7.87 (m, 4 H, Ph); ^{13}C NMR: δ − 5.40, 18.27, 20.48, 20.71, 23.76, 24.12, 25.81, 35.23, 54.04 (C-2), 62.81 (C-6), 69.63 (C-4), 71.97 (C-3), 78.99 (C-5), 80.45 (C-1), 123.60, 123.64, 131.28, 131.67, 134.17, 134.28, 167.17, 167.80, 169.43, 170.23. MALDITOF-MS: Calcd for $C_{27}H_{39}NO_8SSi$: 565 [M]; Found 588.3 $[M + Na]^+$.

3.5. General procedure for NIS/TMSOTf-catalyzed coupling reaction

To a solution of isopropyl thioglycoside donor (1 mmol) and alcohol acceptor (0.98 mmol or as claimed specifically) in anhyd CH_2Cl_2 at − 20 °C was added NIS (1.5 mmol) and TMSOTf (0.05 mmol), respectively, under N_2 protection. The mixture was stirred under these conditions for 60 min, neutralized with Et_3N and then concentrated. The residue was subjected to silica gel column chromatography (EtOAc–petroleum ether) to give the desired product.

3.6. Octyl 3,4-di-*O*-acetyl-6-*O*-*tert*-butyldimethylsilyl-2-deoxy-2-phthalimido-β-D-glucopyranoside (8)

Compound **7** (4.16 g, 7.35 mmol) was reacted with octanol (1.87 mL, 11.5 mmol) as described in general procedure to give **8** (4.35 g, 95.5%) as a syrup: $[\alpha]_D$ + 23° (*c* 1, $CHCl_3$); ^1H NMR: δ 0.06, 0.07 (2 s, 6 H, $Si(CH_3)_2$), 0.79 (t, 3 H, *J* 7.2 Hz, CH_2CH_3), 0.89 (s, 9 H, *t*-Bu), 0.98–1.40 (m, 12 H, 6 CH_2), 1.84, 2.01 (2 s, 6 H, Ac), 3.42 (m, 1 H, OCH_aH_b), 3.67–3.75 (m, 3 H, H-5, H-6a, H-6b), 3.79–3.81 (m, 1 H, OCH_aH_b), 4.53 (dd, 1 H, *J* 10.8, 8.4 Hz, H-2), 5.09 (t, 1 H, *J* 9.4 Hz, H-4), 5.31 (d, 1 H, *J* 8.4 Hz, H-1), 5.79 (dd, 1 H, *J* 10.8, 9.4 Hz, H-3), 7.71–7.85 (m, 4 H, Ph); ^{13}C NMR: δ − 5.47, 13.88, 18.16, 20.33, 20.57, 22.41, 25.69, 28.94, 29.12, 31.48, 54.71, 62.53, 69.59, 69.64, 71.07, 74.61, 97.73, 123.35, 131.36, 134.06, 167.56, 169.30, 170.11. Anal. Calcd for $C_{32}H_{49}NO_9Si$: C, 62.01; H, 7.97. Found: C, 61.79; H, 8.05.

3.7. Octyl 3,4-di-*O*-acetyl-2-deoxy-2-phthalimido-β-D-glucopyranoside (9)

Compound **8** (4.0 g, 6.45 mmol) was treated with $BF_3{\cdot}Et_2O$ (1.6 mL, 12.7 mmol) in CH_2Cl_2 (40 mL) for 15 min at rt, then poured into cold satd aq $NaHCO_3$, and extracted with CH_2Cl_2. The organic phase was concentrated, and the crude product was subjected to column chromatography (1:1 EtOAc–petroleum ether) to give syrupy **9** (2.9 g, 89%): $[\alpha]_D$ + 30° (*c* 1, $CHCl_3$); ^1H NMR: δ 0.81 (t, 3 H, *J* 7.2 Hz, CH_2CH_3), 0.88–1.43 (m, 12 H, 6 CH_2), 1.88, 2.01 (2 s, 6 H, Ac), 3.42–3.45 (m, 1 H, OCH_aH_b), 3.64–3.82 (m, 3 H, H-5, H-6a, H-6b), 3.82–3.85 (m, 1 H, OCH_aH_b), 4.29 (dd, 1 H, *J* 10.8, 8.4 Hz, H-2), 5.12 (t, 1 H, *J* 9.3 Hz, H-4), 5.39 (d, 1 H, *J* 8.4 Hz, H-1), 5.84 (dd, 1 H, *J* 10.8, 9.3 Hz, H-3), 7.34–7.87 (m, 4 H, Ph). Anal. Calcd for $C_{26}H_{35}NO_9$: C, 61.77; H, 6.98. Found: C, 61.54; H, 7.09.

3.8. 3,4-Di-*O*-acetyl-6-*O*-*tert*-butyldimethylsilyl-2-deoxy-2-phthalimido-β-D-glucopyranosyl-(1 → 6)-1,3,4-tri-*O*-acetyl-2-deoxy-2-phthalimido-D-glucopyranose (10)

Compound **7** (885 mg, 1.56 mmol) and **3** (620 mg, 1.42 mmol) was coupled as described in general procedure to give **10** (1.24 g, 94%): ^1H NMR: δ 0.08, 0.09 (2 s, 6 H, $Si(CH_3)_2$), 0.91 (s, 9 H, *t*-Bu), 1.77, 1.82, 1.84, 1.88, 2.02 (5 s, 5 × 1.2 H, β-$COCH_3$), 1.71, 1.78, 1.85, 1.93, 2.02 (5 s, 5 × 1.8 H, α-$COCH_3$), 3.59–3.78 (m, 4 H, 4 H-6), 3.82–3.84 (m, 0.4 H, H_β-5), 3.90 (t, 1 H, *J* 12.6 Hz, H-5′), 4.12–4.14 (m, 0.6 H, H_α-5), 4.30–4.33 (m, 1.4 H, H-2′, H_β-2), 5.54 (dd, 0.6 H, *J* 11.6, 3.4 Hz, H_α-2), 4.90 (t, 0.6 H, *J* 9.2 Hz, H_α-4), 5.02 (t, 0.4 H, *J* 10.0 Hz, H_β-4), 5.11 (t, 1 H, *J* 9.6 Hz, H-4′), 5.41 (d, 1 H, *J* 8.8 Hz, H-1′), 5.75 (br t, 1.4 H, *J* 10.0 Hz, H-3′, H_β-3), 5.94 (d, 0.6 H, *J* 3.6 Hz, H_α-1), 6.34 (d, 0.4 H, *J* 8.8 Hz, H_β-1), 6.39 (dd, 0.6 H, *J* 11.6, 9.2 Hz, H_α-3), 7.69–7.86 (m, 8 H, Ph). MALDITOF-MS: Calcd for $C_{44}H_{52}N_2O_{18}Si$: 924 [M]; Found 947.1 $[M + Na]^+$.

3.9. 3,4-Di-*O*-acetyl-2-deoxy-2-phthalimido-β-D-glucopyranosyl-(1 → 6)-1,3,4-tri-*O*-acetyl-2-deoxy-2-phthalimido-D-glucopyranose (11)

Compound **10** (1.47 g, 1.59 mmol) was treated with $BF_3{\cdot}Et_2O$ (0.4 mL, 3.2 mmol) as described in preparation of **9** to give **11** (1.09 g, 84.6%) as a foamy solid; ^1H NMR: δ 1.80, 1.85, 1.93, 1.94, 2.05 (5 s, 5 × 1.2 H, β-$COCH_3$), 1.79, 1.86, 1.93, 1.96, 2.06 (5 s, 5 × 1.8 H, α-$COCH_3$), 3.64–3.92 (m, 5.4 H, 4 H-6, H_β-5, H-5′), 4.14–4.16 (m, 0.6 H, H_α-5), 4.31 (dd, 1 H, *J* 10.0, 8.4 Hz, H-2′), 4.36 (dd, 0.4 H, *J* 10.0, 8.8 Hz, H_β-2), 5.58 (dd, 0.6 H, *J* 12.0, 3.4 Hz, H_α-2), 5.00 (t, 0.6 H, *J* 9.2 Hz, H_α-4), 5.10 (t, 1.4 H, *J* 10.0 Hz, H_β-4, H-4′), 5.56 (d, 0.4 H, *J* 8.4 Hz, H_β-1′), 5.41 (d, 0.6 H, *J* 8.4 Hz, H_α-1′), 5.78 (t, 1.4 H, *J* 10.0 Hz, H-3′, H_β-3), 6.00 (d, 0.6 H, *J* 3.4 Hz, H_α-1), 6.38 (d, 0.4 H, *J* 8.8 Hz, H_β-1), 6.42 (dd, 0.6 H, *J* 12.0, 9.2 Hz, H_α-3), 7.7–7.86 (m, 8 H, Ph). MALDITOF-MS: Calcd for $C_{38}H_{38}N_2O_{18}$: 810 [M]; Found 833.3 $[M + Na]^+$.

3.10. Isopropyl 3,4,6-tri-*O*-acetyl-2-deoxy-2-phthalimido-β-D-glucopyranosyl-(1→6)-3,4-di-*O*-acetyl-2-deoxy-2-phthalimido-β-D-glucopyranosyl-(1→6)-3,4-di-*O*-acetyl-2-deoxy-2-phthalimido-1-thio-β-D-glucopyranoside (13)

Compound **5** (665 mg, 1.35 mmol) and **11** (1.07 g, 1.32 mmol) was coupled as described in general procedure to give **12** (1.39 g, 86%), which was transformed into the thioglycoside as described in the preparation of **5** to give **13** (748 mg, 53%): $[\alpha]_D$ +43° (*c* 1, $CHCl_3$); ^1H NMR: δ 1.04, 1.09 (2 s, 6 H, *J* 6.0 Hz, $SCH(CH_3)_2$), 1.78, 1.80, 1.86, 1.93, 1.95, 2.04, 2.16 (7 s, 21 H, $COCH_3$), 2.97 (m, 1 H $SCH(CH_3)_2$), 3.47 (dd, 1 H, *J* 9.2, 6.8 Hz, H-6a), 3.57–3.60 (m, 1 H, H-5), 3.73–3.85 (m, 3 H, H-6a′, H-5′, H-6b), 3.87–4.10 (m, 2 H, H-5″, H-6b′), 4.18–4.23 (m, 3 H, H-2, H-2′, H-6a″), 4.35 (dd, 1 H, *J* 10.6, 8.4 Hz, H-2″), 4.36 (dd, 1 H, H-6b″), 4.82 (t, 1 H, *J* 9.2 Hz, H-4), 4.94 (t, 1 H, *J* 10.4 Hz, H-4′), 5.19 (t, 1 H, *J* 9.2 Hz, H-4″), 5.32 (d, 1 H, *J* 8.8 Hz, H-1′), 5.39 (d, 1 H, *J* 10.6 Hz, H-1), 5.52 (d, 1 H, *J* 8.4 Hz, H-1″), 5.62 (dd, 1 H, *J* 10.4, 8.8 Hz, H-3′), 5.68 (dd, 1 H, *J* 10.0, 9.2 Hz, H-3), 5.77 (dd, 1 H, *J* 10.6, 9.2 Hz, H-3″), 7.71–7.93 (m, 12 H, Ph); ^{13}C NMR: δ 20.29, 20.34, 20.34, 20.43, 20.49, 20.56, 20.74, 23.46, 23.86, 34.90, 53.78, 54.38, 61.97, 67.84, 68.21, 68.90, 69.57, 69.61, 70.69, 70.80, 71.40, 72.02, 72.09, 76.76, 80.20, 97.54, 97.93, 123.52, 123.55, 131.70, 131.17, 131.47, 134.117, 134.37, 167.57, 169.26, 169.29, 169.44, 169.49, 169.97, 169.99, 170.03, 170.68. MALDITOF-MS: Calcd for $C_{59}H_{61}N_3O_{25}S$: 1243 [M]; Found 1266.76 $[M+Na]^+$. Anal. Calcd for $C_{59}H_{61}N_3O_{25}S$: C, 56.96; H, 4.94. Found: C, 56.81; H, 5.02.

3.11. 3,4,6-Tri-*O*-acetyl-2-deoxy-2-phthalimido-β-D-glucopyranosyl-(1→6)-3,4-di-*O*-acetyl-2-deoxy-2-phthalimido-β-D-glucopyranosyl-(1→6)-3,4-di-*O*-acetyl-2-deoxy-2-phthalimido-β-D-glucopyranosyl-(1→6)-3,4-di-*O*-acetyl-2-deoxy-2-phthalimido-β-D-glucopyranosyl-(1→6)-1,3,4-tri-*O*-acetyl-2-deoxy-2-phthalimido-α-D-glucopyranose (14)

Coupling of **13** (1.611 g, 1.29 mmol) and **11** (1.02 g, 1.26 mmol) as described in general procedure to give **14** as a foamy solid (1.94 g, 78%): $[\alpha]_D$ +61° (*c* 1, $CHCl_3$); ^1H NMR: δ 1.77 (×2), 1.78, 1.79, 1.86, 1.89, 1.92, 1.93, 1.94, 1.97, 2.04, 2.16 (11 s, 36 H, $COCH_3$), 3.42–3.58 (m, 5 H, H-6a^{III}, H-6a^{I}, H-6a^{II}, H-5^{II}, H-5^{III}), 3.62 (d, 1 H, *J* 12.0 Hz, H-6b^{II}), 3.70–3.85 (m, 3 H, H-6a^{IV}, H-5^{IV}, H-6b^{III}), 3.90–3.96 (m, 3 H, H-5^{V}, H-6b^{IV}, H-6b^{I}), 4.08–4.20 (m, 4 H, H-5^{I}, H-2^{II}, H-6a^{V}, H-2^{III}), 4.23 (dd, 1 H, *J* 10.8, 8.4 Hz, H-2^{IV}), 4.32–4.40 (m, 2 H, H-2^{V}, H-6b^{V}), 4.54 (dd, 1 H, *J* 11.6, 3.6 Hz, H-2^{I}), 4.76 (t, 1 H, *J* 9.2 Hz, H-4^{II}), 4.80 (dd, 1 H, *J* 10.0, 9.2 Hz, H-4^{III}), 4.89 (dd, 1 H, *J* 10.0, 9.2 Hz, H-4^{I}), 4.95 (t, 1 H, *J* 9.2 Hz, H-4^{IV}), 5.19 (t, 1 H, *J* 9.2 Hz, H-4^{V}), 5.23 (d, 1 H, *J* 8.4 Hz, H-1^{II}), 5.29 (d, 1 H, *J* 8.4 Hz, H-1^{III}), 5.30 (d, 1 H, *J* 8.4 Hz, H-1^{IV}), 5.49 (d, 1 H, *J* 8.4 Hz, H-1^{V}), 5.57 (dd, 1 H, *J* 10.6, 9.2 Hz, H-3^{II}), 5.61 (dd, 1 H, *J* 10.6, 9.2 Hz, H-3^{III}), 5.66 (dd, 1 H, *J* 10.8, *J* 9.2 Hz, H-3^{IV}), 5.79 (dd, 1 H, *J* 10.6, 9.2 Hz, H-3^{V}), 5.86 (d, 1 H, *J* 3.6 Hz, H-1^{I}), 6.39 (dd, 1 H, *J* 11.6, 9.2 Hz, H-3^{I}), 7.71–7.92 (m, 20 H, Ph); Selected ^{13}C NMR: δ 20.09, 20.12, 20.21, 20.30, 20.34, 20.50, 20.57, 20.72, 52.57, 53.94, 54.15, 61.67, 66.17, 66.97, 67.54, 67.61, 67.85, 68.68, 69.18, 69.26, 69.38, 70.32, 70.47, 70.76, 71.71, 72.40, 72.76, 72.93, 90.05, 97.17, 97.41, 97.72, 97.76, 168.90, 169.01, 169.10, 169.19, 169.22, 169.70, 169.80, 170.41. MALDITOF-MS: Calcd for $C_{94}H_{91}N_5O_{43}$: 1977.5 [M]; Found 2001.3 $[M+Na]^+$. Anal. Calcd for $C_{94}H_{91}N_5O_{43}$: C, 57.06; H, 4.64. Found: C, 56.92; H, 4.67.

3.12. Isopropyl 3,4,6-tri-*O*-acetyl-2-deoxy-2-phthalimido-β-D-glucopyranosyl-(1→6)-3,4-di-*O*-acetyl-2-deoxy-2-phthalimido-β-D-glucopyranosyl-(1→6)-3,4-di-*O*-acetyl-2-deoxy-2-phthalimido-β-D-glucopyranosyl-(1→6)-3,4-di-*O*-acetyl-2-deoxy-2-phthalimido-β-D-glucopyranosyl-(1→6)-3,4-di-*O*-acetyl-2-deoxy-2-phthalimido-1-thio-β-D-glucopyranose (15)

To a mixture of **14** (1.24 g, 0.627 mmol) and 2-propanethiol (0.08 mL, 0.86 mmol) in CH_2Cl_2 (10 mL) was added $BF_3{\cdot}Et_2O$ (0.1 mL, 0.8 mmol). The mixture was stirred under reflux for 1 h, then poured into cold satd aq $NaHCO_3$, and extracted with CH_2Cl_2. The organic phase was concentrated, and the crude producr was subjected to column chromatography (5:4 EtOAc–petroleum ether) to give syrupy **15** (750 mg, 60%): $[\alpha]_D$ +44° (*c* 1, $CHCl_3$); ^1H NMR: δ 0.99, 1.06 (2 d, 6 H, *J* 4.6 Hz, $SCH(CH_3)_2$), 1.78 (s, 9 H, 3 Ac), 1.79, 1.86, 1.93, 1.94, 1.95, 2.04, 2.17 (7 s, 24 H, 8 Ac), 2.93–2.96 (m, 1 H, $SCH(CH_3)_2$), 3.43–3.52 (m, 5 H, H-6a^{II}, H-6a^{I}, H-6a^{III}, H-5^{II}, H-5^{III}), 3.56–3.62 (m, 2 H, H-6b^{I}, H-5^{I}), 3.70–3.80 (m, 4 H, H-6a^{IV}, H-5^{IV}, H-6b^{II}, H-6b^{I}), 3.90–3.97 (m, 2 H, H-6b^{IV}, H-5^{V}), 4.12–4.24 (m, 5 H, H-2^{II}, H-2^{III}, H-2^{IV}, H-2^{I}, H-6a^{V}), 4.35–4.41 (m, 2 H, H-6b^{V}, H-2^{V}), 4.79–4.85 (m, 3 H, H-4^{II}, H-4^{III}, H-4^{IV}), 4.93 (t, 1 H, *J* 9.2 Hz, H-4^{I}), 5.20 (t, 1 H, *J* 9.2 Hz, H-4^{V}), 5.25 (d, 1 H, *J* 8.4 Hz, H-1^{II}), 5.30 (d, 1 H, *J* 8.4 Hz, H-1^{III}), 5.31 (d, 1 H, *J* 8.4 Hz, H-1^{IV}), 5.36 (d, 1 H, *J* 10.4 Hz, H-1^{I}), 5.50 (d, 1 H, *J* 8.4 Hz, H-1^{V}), 5.61 (dd, 1 H, *J* 10.6, 9.2 Hz, H-3^{II}), 5.63 (dd, 1 H, *J* 10.6, 9.2 Hz, H-3^{III}), 5.67 (t, 2 H, *J* 9.2 Hz, H-3^{IV}, H-3^{V}), 5.79 (dd, 1 H, *J* 10.6, 9.2 Hz, H-3^{I}), 7.71–7.92 (m, 20 H, Ph); Selected ^{13}C NMR: δ 20.39, 20.43, 20.55, 20.66, 20.82, 23.43, 23.90, 34.81, 53.78 (C-2^{I}), 54.42 (C-2^{II},C-2^{III},C-2^{IV},C-2^{V}), 62.64 (C-6^{V}), 67.19 (C-6^{II}), 67.85 (C-6^{III}), 67.99 (C-6^{IV}), 68.23 (C-6^{I}), 68.99 (C-4^{V}), 68.48 (C-4^{II}), 69.61 (C-4^{III}, C-4^{IV}), 69.68 (C-4^{I}), 70.66 (C-3^{II}, C-3^{III}, C-3^{IV}), 70.72 (C-3^{V}), 70.82 (C-3^{I}), 71.45 (C-5^{I}), 72.08 (C-5^{V}), 72.59 (C-5^{IV}), 72.65 (C-5^{III}),

73.03 (C-5^{II}), 80.19 (C-1^{I}), 97.43 (C-1^{IV}), 97.56 (C-1^{III}), 97.79 (C-1^{II}), 98.12 (C-1^{V}), 170.77. MALDITOF-MS: Calcd for $C_{95}H_{95}N_5O_{41}S$: 1993.5 [M]; Found 2016.82 $[M + Na]^+$.

3.13. Octyl 3,4-di-*O*-acetyl-6-*O*-*tert*-butyldimethylsilyl-2-deoxy-2-phthalimido-β-D-glucopyranosyl-(1 → 6)-3,4-di-*O*-acetyl-2-deoxy-2-phthalimido-β-D-glucopyranoside (16)

Coupling of **7** (1.7 g, 3 mmol) and **9** (1.44 g, 2.85 mmol) as described in general procedure to give **16** as a syrup (2.268 g, 80%): $[\alpha]_D$ +37° (*c* 1, $CHCl_3$); ^{1}H NMR: δ 0.08, 0.10 (2 s, 6 H, $Si(CH_3)_2$), 0.81 (t, 3 H, *J* 7.2 Hz, CH_2CH_3), 0.92 (s, 9 H, *t*-Bu), 0.88–1.30 (m, 12 H, 6 CH_2), 1.78, 1.84, 1.92, 2.02 (4 s, 12 H, $COCH_3$), 3.12–3.15 (m, 1 H, OCH_aH_b), 3.43–3.46 (m, 1 H, OCH_aH_b), 3.63 (dd, 1 H, *J* 10.8, 6.8 Hz, H-6a), 3.66–3.84 (m, 4 H, H-5, H-5′, H-6a′, H-6b), 3.90 (dd, 1 H, *J* 10.8, 3.2 Hz, H-6b′), 4.16 (dd, 1 H, *J* 10.8, 8.4 Hz, H-2), 4.29 (dd, 1 H, *J* 10.8, 8.4 Hz, H-2′), 4.88 (t, 1 H, *J* 9.2 Hz, H-4), 5.14 (t, 1 H, *J* 9.2 Hz, H-4′), 5.17 (d, 1 H, *J* 8.4 Hz, H-1), 5.44 (d, 1 H, *J* 8.4 Hz, H-1′), 5.67 (dd, 1 H, *J* 10.8, 9.0 Hz, H-3), 5.77 (dd, 1 H, *J* 10.8, 9.2 Hz, H-3′), 7.70–7.85 (m, 8 H, Ph); ^{13}C NMR: δ −5.36, 13.96, 18.26, 20.34, 20.40, 20.42, 20.65, 22.50, 25.71, 25.79, 29.00, 29.02, 29.06, 31.55, 54.59 (C-2′), 54.62 (C-2), 62.29 (C-6), 68.07 (C-6′), 69.35 (OCH_2), 69.35 (C-4′), 69.72 (C-4), 71.70 (C-3), 71.07 (C-3′), 73.03 (C-5′), 74.66 (C-5), 97.59, 97.66 (C-1′, C-1), 123.40, 123.44, 131.37, 131.49, 134.08, 167.25, 167.56, 167.70, 167.80, 169.29, 170.02, 170.19. Anal. Calcd for $C_{50}H_{66}N_2O_{17}Si$: C, 60.35; H, 6.68. Found: C, 60.56; H, 6.61.

3.14. Octyl 3,4-di-*O*-acetyl-2-deoxy-2-phthalimido-β-D-glucopyranosyl-(1 → 6)-3,4-di-*O*-acetyl-2-deoxy-2-phthalimido-β-D-glucopyranoside (17)

Compound **16** (2.2 g, 2.21 mmol) was desilylated as described in the preparation of **9** to give **17** (1.53 g, 78%) as a syrup: $[\alpha]_D$ +37° (*c* 1, $CHCl_3$); ^{1}H NMR: δ 0.81 (t, 3 H, *J* 7.2 Hz, CH_2CH_3), 0.88–1.28 (m, 12 H, 6 CH_2), 1.82, 1.86, 1.98, 2.06 (4 s, 12 H, Ac), 3.20–3.22 (m, 1 H, OCH_aH_b), 3.51–3.53 (m, 1 H, OCH_aH_b), 3.64–3.73 (m, 4 H, H-5, H-5′, H-6a′, H-6a), 3.83 (dd, 1 H, *J* 12.0, 3.2 Hz, H-6b′), 3.90–3.92 (m, 1 H, H-6b), 4.18 (dd, 1 H, *J* 10.8, 8.4 Hz, H-2), 4.29 (dd, 1 H, *J* 10.8, 8.8 Hz, H-2′), 4.97 (t, 1 H, *J* 9.6 Hz, H-4), 5.14 (t, 1 H, *J* 9.4 Hz, H-4′), 5.20 (d, 1 H, *J* 8.4 Hz, H-1), 5.49 (d, 1 H, *J* 8.8 Hz, H-1′), 5.69 (dd, 1 H, *J* 10.8, 9.6 Hz, H-3), 5.81 (dd, 1 H, *J* 10.8, 9.4 Hz, H-3′), 7.70–7.87 (m, 8 H, Ph); ^{13}C NMR: δ 13.96, 20.36, 20.60, 20.69, 22.50, 25.70, 29.00, 29.02, 29.09, 31.55, 54.48 (C-2′), 54.62 (C-2), 62.20 (C-6), 68.46 (C-6′), 69.23 (C-4′), 69.64 (OCH_2), 70.26 (C-4), 70.64 (C-3), 70.68 (C-3′), 72.62 (C-5′), 74.19 (C-5), 97.64 (C-1′), 97.78 (C-1), 123.44, 123.54, 131.37, 131.46, 134.12, 134.18, 169.88, 170.06, 170.10. MALDITOF-MS: Calcd for $C_{44}H_{52}N_2O_{17}$: 880 [M]; Found 903.34 $[M + Na]^+$.

3.15. Octyl 3,4-di-*O*-acetyl-2-deoxy-2-phthalimido-β-D-glucopyranosyl-(1 → 6)-3,4-di-*O*-acetyl-2-deoxy-2-phthalimido-β-D-glucopyranosyl-(1 → 6)-3,4-di-*O*-acetyl-2-deoxy-2-phthalimido-β-D-glucopyranoside (19)

Coupling of **7** (1.87 g, 3.31 mmol) and **17** (2.65 g, 3.01 mmol) as described in general procedure gave **18** as a foamy solid (3.8 g, 92%); ^{1}H NMR: δ 0.10, 0.11 (2 s, 6 H), 0.81 (t, 3 H, *J* 7.2 Hz), 0.93 (s, 9 H), 0.85–1.28 (m, 12 H), 1.77, 1.79, 1.85, 1.91, 1.93, 2.02 (6 s, 18 H), 3.19–3.21 (m, 1 H), 3.46 (dd, 1 H, *J* 10.8, 6.4 Hz), 3.49–3.52 (m, 2 H), 3.66–3.84 (m, 6 H), 3.91 (d, 1 H), 4.13 (dd, 1 H, *J* 10.4, 8.4 Hz), 4.20 (dd, 1 H, *J* 10.8, 8.4 Hz), 4.30 (dd, 1 H, *J* 10.8, 8.4 Hz), 4.79 (t, 1 H, *J* 9.2 Hz), 4.92 (t, 1 H, *J* 9.2 Hz), 5.13 (d, 1 H, *J* 8.4 Hz), 5.15 (t, 1 H, *J* 9.2 Hz), 5.30 (d, 1 H, *J* 8.4 Hz), 5.45 (d, 1 H, *J* 8.4 Hz), 5.62 (dd, 2 H, *J* 10.8, 9.0 Hz), 5.77 (dd, 1 H, *J* 10.8, 9.2 Hz), 7.77–7.92 (m, 12 H); ^{13}C NMR: δ −5.36, −5.37, 13.96, 18.28, 20.29, 20.35, 20.39, 20.46, 20.66, 20.94, 22.50, 25.73, 25.81, 29.00, 29.04, 29.08, 31.55, 54.41, 54.53, 54.57, 62.33, 67.67, 67.90, 69.39, 69.43, 69.54, 69.64, 70.65, 70.70, 71.06, 72.72, 73.11, 74.64, 97.54, 97.62, 97.71, 123.40, 123.45, 123.61, 131.38, 131.46, 134.07, 131.46, 134.29, 169.23, 169.34, 170.00, 170.06, 171.18. Compound **18** (1.77 g, 1.29 mmol) was desilylated as described in the preparation of **9** to give **19** (1.40 g, 86.5%) as a foam: $[\alpha]_D$ +38° (*c* 1, $CHCl_3$); ^{1}H NMR: δ 0.81 (t, 3 H, *J* 7.2 Hz, CH_2CH_3), 0.85–1.26 (m, 12 H, 6 CH_2), 1.79, 1.80, 1.86, 1.92, 1.97, 2.06 (6 s, 18 H, $COCH_3$), 3.20–3.22 (m, 1 H, OCH_aH_b), 3.48–3.51 (m, 1 H, OCH_aH_b), 3.53 (dd, 1 H, *J* 10.8, 6.4 Hz, H-6a), 3.60–3.63 (m, 1 H, H-5), 3.66 (dd, 1 H, *J* 10.8, 6.4 Hz, H-6a″), 3.71–3.85 (m, 5 H, H-5″, H-5′, H-6a′, H-6b, H-6b″), 3.95–3.97 (m, 1 H, H-6b′), 4.15 (dd, 1 H, *J* 10.4, 8.4 Hz, H-2), 4.23 (dd, 1 H, *J* 10.4, 8.4 Hz, H-2′), 4.31 (dd, 1 H, *J* 10.0, 8.4 Hz, H-2″), 4.84 (t, 1 H, *J* 9.2 Hz, H-4), 5.03 (t, 1 H, *J* 9.2 Hz, H-4′), 5.15 (t, 1 H, *J* 10.0 Hz, H-4″), 5.16 (d, 1 H, *J* 8.4 Hz, H-1), 5.35 (d, 1 H, *J* 8.4 Hz, H-1′), 5.51 (d, 1 H, *J* 8.4 Hz, H-1″), 5.65 (dd, 2 H, *J* 10.4, 9.2 Hz, H-3, H-3′), 5.80 (t, 1 H, *J* 10.0 Hz, H-3″), 7.71–7.90 (m, 12 H, Ph); ^{13}C NMR: δ 13.91, 20.25, 20.30, 20.30, 20.47, 20.50, 20.54, 22.43, 25.66, 28.95, 28.97, 29.02, 31.49, 54.36 (C-2″, C-2′), 54.55 (C-2), 61.15 (C-6″), 67.92 (C-6′), 68.35 (C-6), 69.16 (C-4″), 69.44 (OCH_2), 69.85 (C-4′), 69.87 (C-4), 70.56 (C-3, C-3′), 70.75 (C-3″), 72.51 (C-5′), 72.69 (C-5), 74.22 (C-5″), 97.48 (C-1″), 97.61 (C-1), 97.72 (C-1′), 123.38, 123.42, 123.55, 131.29, 131.34, 131.46, 134.08, 134.22, 169.54, 169.58, 169.88, 169.93, 169.96, 169.96. MALDITOF-MS: Calcd for

$C_{62}H_{69}N_3O_{25}$: 1255.4 [M]; Found 1278.9 $[M+Na]^+$. Anal. Calcd for $C_{62}H_{69}N_3O_{25}$: C, 59.28; H, 5.54. Found: C, 59.02; H, 5.63.

3.16. Octyl 3,4-di-*O*-acetyl-2-deoxy-2-phthalimido-β-D-glucopyranosyl-(1→6)-3,4-di-*O*-acetyl-2-deoxy-2-phthalimido-β-D-glucopyranosyl-(1→6)-3,4-di-*O*-acetyl-2-deoxy-2-phthalimido-β-D-glucopyranosyl-(1→6)-3,4-di-*O*-acetyl-2-deoxy-2-phthalimido-β-D-glucopyranoside (21)

Coupling of **7** (1.212 g, 2.14 mmol) and **19** (2.56 g, 2.04 mmol) as described in general procedure gave **20** as a foamy solid (2.403 g, 67.5%); ^{1}H NMR: δ 0.09, 0.11 (2 s, 6 H, 2 SiCH_3), 0.80 (t, 3 H, *J* 7.2 Hz, CH_2CH_3), 0.83–1.28 (m, 12 H, 6 CH_2), 1.76, 1.78, 1.80, 1.85, 1.92, 1.93, 1.95, 2.05 (8 s, 24 H, $COCH_3$), 3.16 (m, 1 H, OCH_aH_b), 3.35–3.46 (m, 4 H, H-6a^{II}, H-6a^{III}, H-5^{III}, OCH_aH_b), 3.57–3.59 (m, 1 H, H-5^{II}), 3.61–3.65 (m, 2 H, H-6b^{II}, H-6^{III}), 3.73–3.85 (m, 5 H, H-5^{I}, H-5^{IV}, H-6a^{I}, H-6a^{IV}, H-6b^{IV}), 3.93 (dd, 1 H, *J* 11.2, 2.4 Hz, H-6b^{I}), 4.11–4.19 (m, 3 H, H-2^{II}, H-2^{III}, H-2^{I}), 4.30 (dd, 1 H, *J* 11.6, 8.4 Hz, H-2^{IV}), 4.75 (t, 1 H, *J* 9.2 Hz, H-4^{III}), 4.82 (t, 1 H, *J* 9.2 Hz, H-4^{II}), 4.90 (t, 1 H, *J* 9.2 Hz, H-4^{I}), 5.14 (d, 1 H, *J* 8.4 Hz, H-1^{III}), 5.16 (t, 1 H, *J* 9.2 Hz, H-4^{IV}), 5.23 (d, 1 H, *J* 8.4 Hz, H-1^{II}), 5.29 (d, 1 H, *J* 8.4 Hz, H-1^{I}), 5.43 (d, 1 H, *J* 8.4 Hz, H-1^{IV}), 5.56 (dd, 1 H, *J* 11.6, 9.2 Hz, H-3^{III}), 5.64 (dd, 1 H, *J* 11.6, 9.2 Hz, H-3^{II}), 5.65 (dd, 1 H, *J* 11.6, 9.2 Hz, H-3^{I}), 5.79 (dd, 1 H, *J* 11.6, 9.2 Hz, H-3^{IV}), 7.70–7.79 (m, 16 H, Ph); Selected ^{13}C NMR: δ −5.36, 13.95, 18.27, 22.49, 25.72, 25.80, 28.99, 29.02, 29.03, 31.53, 54.35, 54.40, 54.54, 54.60 (4 C-2), 62.28 (C-6^{IV}), 67.26 (C-6^{III}), 67.93 (C-6^{I}, C-6^{II}), 69.32, 69.40, 69.50, 69.57, 69.58 (5C), 70.57, 70.61, 70.69, 71.04 (4 C-3), 72.64 (C-5^{III}), 72.69 (C-5^{II}), 72.95 (C-5^{IV}), 74.58 (C-5^{I}), 97.48 (C-1^{I}), 97.60 (C-1^{II}), 97.61 (C-1^{III}), 97.74 (C-1^{IV}), 169.22, 169.30, 169.37, 169.45, 169.95, 169.99, 170.05, 170.16. Compound **20** (480 mg, 0.275 mmol) was desilylated as described in the preparation of **9** to give **21** (377 mg, 84%) as a foam: $[\alpha]_D$ +40° (*c* 1, $CHCl_3$); ^{1}H NMR: δ 0.81 (t, 3 H, *J* 7.2 Hz, CH_2CH_3), 0.83–1.26 (m, 12 H, 6 CH_2), 1.78, 1.79, 1.80, 1.87, 1.91, 1.95, 1.97, 2.06 (8 s, 24 H, $COCH_3$), 3.05 (br s, 1 H, OH), 3.17–3.19 (m, 1 H, OCH_aH_b), 3.45–3.85 (m, 12 H), 3.95 (m, 1 H, H-6b^{I}), 4.11–4.24 (m, 3 H, H-2^{II}, H-2^{III}, H-2^{I}), 4.33 (dd, 1 H, *J* 11.6, 8.4 Hz, H-2^{IV}), 4.82 (t, 1 H, *J* 9.2 Hz, H-4^{III}), 4.85 (t, 1 H, *J* 9.2 Hz, H-4^{II}), 5.03 (t, 1 H, *J* 9.2 Hz, H-4^{I}), 5.14 (d, 1 H, *J* 8.4 Hz, H-1^{III}), 5.17 (t, 1 H, *J* 9.2 Hz, H-4^{IV}), 5.29 (d, 1 H, *J* 8.4 Hz, H-1^{II}), 5.36 (d, 1 H, *J* 8.4 Hz, H-1^{I}), 5.52 (d, 1 H, *J* 8.4 Hz, H-1^{IV}), 5.58 (dd, 3 H, *J* 11.6, 9.2 Hz, 3 H-3), 5.82 (dd, 1 H, *J* 11.6, 9.2 Hz, H-3^{IV}), 7.71–7.93 (m, 16 H, Ph). Selected ^{13}C NMR: δ 14.04, 22.58, 25.80, 29.08, 29.10, 29.12, 31.62, 54.40, 54.42, 54.51, 54.69 (4 C-2), 61.24 (C-6^{IV}), 67.99 (C-6^{I}, C-6^{II}), 68.08 (C-6^{III}), 69.31, 69.48, 69.74, 69.95, 69.99, 70.60, 70.70, 70.75, 70.90 (4 C-3), 72.58, 72.77, 72.87 (C-5^{III}, C-5^{II}, C-5^{IV}), 74.34 (C-5^{I}), 97.58 (C-1^{I}), 97.61 (C-1^{II}), 97.69 (C-1^{III}), 97.74 (C-1^{IV}), 169.58, 169.65, 169.73, 170.73, 170.01, 170.04, 170.06, 170.12, 170.15. MALDITOF-MS: Calcd for $C_{80}H_{86}N_4O_{33}$: 1630.5 [M]; Found 1654.0 $[M+Na]^+$. Anal. Calcd for $C_{80}H_{86}N_4O_{33}$: C, 58.89; H, 5.31. Found: C, 58.68; H, 5.39.

3.17. Octyl 3,4-di-*O*-acetyl-2-deoxy-2-phthalimido-β-D-glucopyranosyl-(1→6)-3,4-di-*O*-acetyl-2-deoxy-2-phthalimido-β-D-glucopyranosyl-(1→6)-3,4-di-*O*-acetyl-2-deoxy-2-phthalimido-β-D-glucopyranosyl-(1→6)-3,4-di-*O*-acetyl-2-deoxy-2-phthalimido-β-D-glucopyranosyl-(1→6)-3,4-di-*O*-acetyl-2-deoxy-2-phthalimido-β-D-glucopyranosyl-(1→6)-3,4-di-*O*-acetyl-2-deoxy-2-phthalimido-β-D-glucopyranosyl-(1→6)-3,4-di-*O*-acetyl-2-deoxy-2-phthalimido-β-D-glucopyranosyl-(1→6)-3,4-di-*O*-acetyl-2-deoxy-2-phthalimido-β-D-glucopyranosyl-(1→6)-3,4-di-*O*-acetyl-2-deoxy-2-phthalimido-β-D-glucopyranoside (24)

Coupling of **15** (528 mg, 0.264 mmol) and **21** (572 mg, 0.352 mmol) at −10 °C as described in general procedure gave **24** as a foamy solid (443 mg, 47.4%): $[\alpha]_D$ +41° (*c* 1, $CHCl_3$); ^{1}H NMR: δ 0.81 (t, 3 H, *J* 7.6 Hz, CH_2CH_3), 0.85–1.28 (m, 12 H, 6 CH_2), 1.77–2.16 (m, 57 H, 19 $COCH_3$), 3.14–3.16 (m, 1 H, OCH_aH_b), 3.35–3.60 (m, 16 H), 3.61–3.80 (m, 8 H), 3.87–3.95 (m, 2 H), 3.41–3.43 (m, 9 H), 4.37–4.44 (m, 2 H), 4.74–4.83 (dd, 7 H), 4.93 (t, 1 H, *J* 9.2 Hz), 5.12 (d, 1 H, $J_{1,2}$ 8.4 Hz, H-1), 5.21 (t, 1 H, *J* 9.2 Hz), 5.22–5.26 (m, 6 H, 6 H-1), 5.31 (d, 1 H, *J* 8.4 Hz, H-1), 5.50 (d, 1 H, *J* 8.4 Hz, H-1), 5.58–5.66 (m, 8 H), 5.80 (dd, 1 H, *J* 10.6, 9.2 Hz), 7.71–7.92 (m, 36 H, Ph); Selected ^{13}C NMR: δ 13.96, 20.31, 22.49, 25.72, 28.99, 29.02, 29.03, 31.53, 54.37, 54.58, 61.94, 67.18, 67.37, 67.47, 67.48, 67.57, 67.76, 67.92, 68.15, 68.13, 68.90, 69.32, 69.44, 69.62, 70.50, 70.63, 70.73, 71.98, 72.56, 72.93, 97.51, 97.58, 97.59, 97.63, 97.68, 98.01, 169.36, 169.43, 169.46, 169.89, 170.03, 171.06. MALDITOF-MS: Calcd for $C_{172}H_{173}N_9O_{74}$: 3548 [M]; Found 3572.2 $[M+Na]^+$.

3.18. Octyl 2-amino-2-deoxy-β-D-glucopyranosyl-(1→6)-2-amino-2-deoxy-β-D-glucopyranosyl-(1→6)-2-amino-2-deoxy-β-D-glucopyranosyl-(1→6)-2-amino-2-deoxy-β-D-glucopyranosyl-(1→6)-2-amino-2-deoxy-β-D-glucopyranosyl-(1→6)-2-amino-2-deoxy-β-D-glucopyranosyl-(1→6)-2-amino-2-deoxy-β-D-glucopyranosyl-(1→6)-2-amino-2-deoxy-β-D-glucopyranosyl-(1→6)-2-amino-2-deoxy-β-D-glucopyranoside (25)

To NH_3-satd MeOH (150 mL) was added **24** (350 mg, 0.099 mmol). The mixture was stirred at rt for 9 days, then concentrated. The residue was dissolved in H_2O (1 mL) and then passed through a Bio-Gel P-2 column to

give **25** (112 mg, 72%) as a white solid: $[\alpha]_D$ −21° (*c* 0.5, $CHCl_3$); ^{13}C NMR (100 MHz, D_2O): δ 102.96, 103.08, 103.54 (3 C), 103.60 (2 C), 103.66, 103.72 (9 C-1). MALDITOF-MS: Calcd for $C_{62}H_{117}N_9O_{37}$: 1579.8 [M]; Found 1603.2 $[M + Na]^+$.

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