Synthesis of defined mono-de-N-acetylated β-(1→6)-N-acetyl-D-glucosamine oligosaccharides to characterize PgaB hydrolase activity

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Supplementary Information

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Supplementary figures and tables

Figure S1  TLC plate imaged in Fig. 3A.

Figure S2  TLC plate from Fig. S1 visualized by fluorescence imaging (exposure time of 80 ms). **Disaccharide 44 labelled by DBCO-Cy5.
Figure S3  Negative control experiment (no enzyme present) for heptasaccharide 4 (5 mM), incubated in 100 mM HEPES, pH 7.0. Time point aliquots were labelled with DBCO-Cy5 for 1 h by diluting the 1 μL aliquots with 1 μL of 1 mM DBCO-Cy5, then analyzed by TLC (1:1:2 H₂O/AcOH/nBuOH) and visualized by fluorescence imaging (exposure time 80 ms). **Disaccharide 44 labelled by DBCO-Cy5.

Figure S4  TLC plate imaged in Fig. 4.
**Table S1** Yield of products 35 and 36.\(^{1,2}\)

<table>
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<th>Temp.(^a) (°C)</th>
<th>Time(^a) (h)</th>
<th>35 (%)</th>
<th>36 (%)</th>
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<td>2</td>
<td>83</td>
<td>-</td>
</tr>
<tr>
<td>50</td>
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<tr>
<td>60</td>
<td>20</td>
<td>-</td>
<td>64</td>
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\(^a\) Conditions for the deprotection of 34 using aq. NaOH.

**Table S2** Raw fluorescence integration values from Fig. 5, calculated from TLC plates with an exposure time of 80ms (as seen in Fig. S2).

<table>
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<th>Replicate 2</th>
<th>Average Turnover (%)</th>
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<td>4</td>
<td></td>
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<td>Turnover (%)</td>
<td>Turnover (%)</td>
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<td>36</td>
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<td>37.1</td>
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**Synthesis**

1,3,4,6-Tetra-O-acetyl-2-trifluoroacetamido-2-deoxy-D-glucopyranose (5)

Known\(^3,^4\) trifluoroacetamido tetraacetate 5 (2:1 \(\alpha/\beta\)) was synthesized as described previously.\(^5\) \(^1\)H NMR (400 MHz, Chloroform-\(d\)) \(\delta_H\) 7.03 (d, \(J = 9.6\) Hz, 1H, N-H\(\beta\)), 6.57 (d, \(J = 8.7\) Hz, 1H, N-H\(\alpha\)), 6.25 (d, \(J = 3.7\) Hz, 1H, H-1\(\alpha\)), 5.75 (d, \(J = 8.7\) Hz, 1H, H-1\(\beta\)), 5.27 (dd, \(J = 10.6, 9.4\) Hz, 1H, H-3\(\alpha\)), 5.23 (t, \(J = 9.6\) Hz, 1H, H-4\(\alpha\)), 5.14 (t, \(J = 9.6\) Hz, 1H, H-4\(\beta\)), 4.44 (ddd, \(J = 10.7, 8.7, 3.7\) Hz, 1H, H-2\(\alpha\)), 4.34 (q, \(J = 9.7\) Hz, 1H, H-3\(\beta\)), 4.28 (dd, \(J = 12.5, 4.2\) Hz, 2H, H-6\(a\)\(\alpha\), H-6\(a\)\(\beta\)), 4.14 (dd, \(J = 12.6, 2.3\) Hz, 1H, H-6\(b\)\(\beta\)), 4.07 (s, 3H, 1 × Ac\(\alpha\)), 2.20 (s, 3H, 1 × Ac\(\beta\)), 2.12 (s, 3H, 1 × Ac\(\alpha\)), 1.79 (s, 6H, 1 × Ac\(\beta\)).

\(p\)-Tolyl 3,4,6-tri-O-acetyl-2-trifluoroacetamido-2-deoxy-\(\beta\)-1-thio-D-glucopyranoside (6)

Known\(^3,^4\) trifluoroacetamido tetraacetate 5 (9.67 g, 21.8 mmol, 2:1 \(\alpha/\beta\)) and \(p\)-thiocresol (8.13 g, 65.5 mmol, 3 equiv.) was dissolved in freshly distilled CH\(_2\)Cl\(_2\) (97 mL). BF\(_3\)Et\(_2\)O (13.7 mL, 109.1 mmol, 5 equiv.) was added at room temperature. The reaction was stirred under Ar for 40 h (TLC in 3:7 EtOAc/pentanes, \(R_f = 0.4\)). The solution was diluted with CH\(_2\)Cl\(_2\) (80 mL) then washed carefully with sat. aq. NaHCO\(_3\) (2 × 120 mL). The aqueous layers were re-extracted with CH\(_2\)Cl\(_2\) (2 × 30 mL). The organic layers were dried over Na\(_2\)SO\(_4\) and concentrated. Column chromatography (EtOAc/pentanes, 2:8 → 4:6) gave thioglycoside 6 (9.32 g, 84%) as a white/pale yellow flaky solid.

\(p\)-Tolyl 2-trifluoroacetamido-2-deoxy-\(\beta\)-1-thio-D-glucopyranoside (7)

Known\(^3,^4\) trifluoroacetamido tetraacetate 5 (9.67 g, 21.8 mmol, 2:1 \(\alpha/\beta\)) and \(p\)-thiocresol (8.13 g, 65.5 mmol, 3 equiv.) was dissolved in freshly distilled CH\(_2\)Cl\(_2\) (97 mL). BF\(_3\)Et\(_2\)O (13.7 mL, 109.1 mmol, 5 equiv.) was added at room temperature. The reaction was stirred under Ar for 40 h (TLC in 3:7 EtOAc/pentanes, \(R_f = 0.4\)). The solution was diluted with CH\(_2\)Cl\(_2\) (80 mL) then washed carefully with sat. aq. NaHCO\(_3\) (2 × 120 mL). The aqueous layers were re-extracted with CH\(_2\)Cl\(_2\) (2 × 30 mL). The organic layers were dried over Na\(_2\)SO\(_4\) and concentrated. Column chromatography (EtOAc/pentanes, 2:8 → 4:6) gave thioglycoside 6 (9.32 g, 84%) as a white/pale yellow flaky solid.
Thioglycoside 6 (5.60 g, 11.0 mmol) was suspended in MeOH (110 mL). Sodium (85 mg, 3.7 mmol, 0.33 equiv.) was added. The reaction was stirred at RT for 2.5 h (TLC in 10:1 CH₂Cl₂/MeOH, Rᵣ = 0.3), then quenched with Dowex 50WX8 cation exchange resin (hydrogen form, 50-100 mesh). The resin was filtered and washed with MeOH (3 × 40 mL). The filtrate was concentrated giving triol 7 (4.30 g, quant.) as a white flaky solid.

\[
\text{H NMR (400 MHz, Methanol-}^d_4\text{) } \delta H 7.39 (d, J = 8.2 Hz, 2H, 2 × Ar), 7.12 (d, J = 8.0 Hz, 2H, 2 × Ar), 4.75 (d, J = 10.4 Hz, 1H, H-1), 3.87 (dd, J = 12.2, 2.0 Hz, 1H, H-6a), 3.75 (t, J = 10.1 Hz, 1H, H-2), 3.69 (dd, J = 12.1, 5.2 Hz, 1H, H-6b), 3.52 (dd, J = 9.9, 8.0 Hz, 1H, H-3), 3.35 (t, J = 9.7 Hz, 1H, H-4), 3.31 (m, 1H, H-5), 2.30 (s, 3H, CH₃).
\]

\[
\text{C NMR (100 MHz, Methanol-}^d_4\text{) } \delta C 139.06 (1 × 4° Ar), 133.57 (2 × Ar), 130.97 (1 × 4° Ar), 130.61 (2 × Ar), 87.92 (C-1), 82.25 (C-5), 76.76 (C-3), 71.78 (C-4), 62.83 (C-6), 56.75 (C-2), 21.14 (CH₃).
\]

m/z (ESI) calculated for C₁₅H₁₈NO₅F₃NaS [M+Na]+ 404.07, found 404.1.

**p-Tolyl 3,4-di-O-benzoyl-6-tert-butyldiphenylsilyl-2-trifluoroacetamido-2-deoxy-β-1-thio-D-glucopyranoside (8)**

Triol 7 (4.30 g 11.3 mmol) and DMAP (140 mg, 1.15 mmol, 0.1 equiv.) were dissolved in dry pyridine (130 mL). TBDPSCl (5.9 mL, 22.7 mmol, 2 equiv.) was added. The reaction was stirred at RT under Ar for 24 h (TLC in 1:1 CH₂Cl₂/MeOH, Rᵣ = 0.7), then BzCl (7.9 mL, 68.1 mmol, 6 equiv.) was added, and stirring continued under the same conditions for an additional 23 h (TLC in 2:8 EtOAc/pentanes, Rᵣ = 0.6). The solution was co-concentrated with toluene. The residue was dissolved in CH₂Cl₂ (250 mL) then washed with 1 M HCl (2 × 200 mL) then aq. NaHCO₃ (200 mL). The aqueous layers were re-extracted with CH₂Cl₂ (2 × 50 mL each). The organic layers were dried over Na₂SO₄ and concentrated. Column chromatography (EtOAc/pentanes, 1:9 → 3:7) gave 8 (9.30 g, quant.) as a white amorphous solid. ¹H NMR (400 MHz, Chloroform-d) δH 7.88 (dd, J = 8.4, 1.3 Hz, 2H, 2 × SiPh), 7.80 (dd, J = 8.4, 1.3 Hz, 2H, 2 × Bz), 7.73 (dd, J = 8.0, 1.5 Hz, 2H, 2 × SiPh), 7.57 (dd, J = 8.0, 1.4 Hz, 2H, 2 × Bz), 7.49 – 7.44 (m, 4H, 2 × SAr, 2 × SiPh), 7.40 – 7.27 (m, 8H, 4 × Bz, 4 × SiPh), 7.15 (t, J = 7.9 Hz, 2H, 2 × Bz), 7.05 (d, J = 8.0 Hz, 2H, 2 × SAr), 6.88 (d, J = 9.3 Hz, 1H, N-H), 5.72 (t, J = 9.8 Hz, 1H, H-3), 5.66 (t, J = 9.3 Hz, 1H, H-4), 4.96 (d, J = 10.3 Hz, 1H, H-1), 4.27 (q, J = 9.8 Hz, 1H, H-2), 3.93 – 3.77 (m, 3H, H-5, H-6a, H-6b), 2.32 (s, 3H, ArCH₃), 1.05 (s, 9H, Si(CH₃)₃). ¹³C NMR (100 MHz, Chloroform-d) δC 167.30, 164.84 (2 × COPh), 157.14 (d, J = 37.8 Hz, COCF₃), 138.73 (1 × 4° SAr), 135.68 (2 × Bz), 135.51 (2 × SiPh), 133.78 (2 × SAr), 133.76, 133.35 (2 × 4° Bz), 132.79 (2 × SiPh), 129.95 (2 × SiPh), 129.88 (2 × SAr), 129.71, 129.63 (2 × Bz), 129.57 (2 × SiPh), 129.04 (1 × 4° SiPh), 128.51 (2 × SiPh), 128.42 (2 × SiPh), 128.26 (1 × 4° SiPh), 127.73 (2 × Bz), 127.63 (2 × Bz), 127.55 (1 × 4° SAr), 115.54 (d, J = 288.2 Hz, CF₃), 86.31 (C-1), 79.30 (C-5), 74.48 (C-3), 68.47 (C-4), 62.50 (C-6), 53.84 (C-2), 26.65 (CH₃), 21.23 (ArCH₃). m/z (ESI) calculated for C₄₅H₄₈N₂O₂F₃SiS [M+NH₄]^+ 845.29, found 845.3.
p-Tolyl 3,4-di-O-benzoyl-2-trifluoroacetamido-2-deoxy-β-1-thio-D-glucopyranoside (9)

![Structural diagram of compound 9]

The di-O-benzoyl ester 8 (6.50 g, 7.9 mmol) was dissolved in dry THF (110 mL). AcOH (4.5 mL, 78.6 mmol, 10 equiv.) was added, followed by TBAF (1.0 M in THF, 39 mL, 39.0 mmol, 5 equiv.). The reaction was stirred at RT under \( \text{N}_2 \) for 18 h (TLC in 3:7 EtOAc/pentanes, \( R_f = 0.5 \)). The solution was diluted with EtOAc (150 mL) then washed with sat. aq. \( \text{NH}_4 \)Cl (200 mL). The aqueous layer was re-extracted with EtOAc (2 × 50 mL). The organic layers were dried over \( \text{Na}_2\text{SO}_4 \) and concentrated. Column chromatography (CH\(_2\)Cl\(_2\)/MeOH, 100:1 → 40:1) gave acceptor 9 (4.5 g, 97%) as a white powder. ¹H NMR (400 MHz, DMSO-\( \text{d}_6 \)) \( \delta \)H 9.84 (d, \( J = 9.1 \) Hz, 1H, N-H), 7.84 (dd, \( J = 8.5, 1.5 \) Hz, 2H, 2 × Bz), 7.75 (dd, \( J = 8.5, 1.4 \) Hz, 2H, 2 × Bz), 7.65 – 7.57 (m, 2H, 2 × Bz), 7.51 – 7.40 (m, 6H, 4 × Bz, 2 × SAr), 7.20 (d, \( J = 7.9 \) Hz, 2H, 2 × SAr), 5.64 (t, \( J = 9.7 \) Hz, 1H, N-H), 5.34 (t, \( J = 9.7 \) Hz, 1H, N-H), 5.21 (d, \( J = 10.3 \) Hz, 1H, H-1), 4.98 (t, \( J = 4.8 \) Hz, 1H, H-5), 4.11 (q, \( J = 9.9 \) Hz, 1H, H-2), 3.92 (ddd, \( J = 10.0, 4.8, 2.3 \) Hz, 1H, H-5), 3.63 (ddd, \( J = 12.3, 4.9, 2.3 \) Hz, 1H, H-6a), 3.54 (m, 1H, H-6b). ¹³C NMR (100 MHz, DMSO-\( \text{d}_6 \)) \( \delta \)C 165.67, 165.01 (2 × C-OPh), 156.54 (d, \( J = 36.8 \) Hz, C-OCF\(_3\)), 138.04 (1 × 4° SAr), 134.11 (2 × Bz), 132.49 (2 × SAr), 130.20 (2 × SAr), 129.61 (2 × Bz), 129.50 (2 × Bz), 129.27 (1 × 4° Bz), 129.21 (2 × Bz), 129.15 (2 × Bz), 128.98 (1 × 4° Bz), 128.65 (2 × 4° SAr), 116.07 (d, \( J = 288.3 \) Hz, C-OCF\(_3\)), 84.91 (C-1), 78.71 (C-5), 74.81 (C-3), 69.55 (C-4), 60.60 (C-6), 53.25 (C-2), 21.10 (ArCH\(_3\)). m/z (ESI) calculated for C\(_{29}\)H\(_{30}\)N\(_2\)O\(_7\)F\(_3\)S \([\text{M+NH}_4]^+\) 607.17, found 607.2.

p-Tolyl 3,4-di-O-benzoyl-6-chloroacetyl-2-trifluoroacetamido-2-deoxy-β-1-thio-D-glucopyranoside (10)

![Structural diagram of compound 10]

Acceptor 9 (3.70 g 6.3 mmol) was dissolved in CH\(_2\)Cl\(_2\) (63 mL). Pyridine (2.0 mL, 24.7 mmol, 4 equiv.) was added, followed by chloroacetyl chloride (1.0 mL, 12.6 mmol, 2 equiv.). The reaction was stirred at RT for 15 min (TLC in 3:7 EtOAc/pentanes, \( R_f = 0.7 \)). The solution was diluted with CH\(_2\)Cl\(_2\) (30 mL) then washed with 1 M HCl (2 × 75 mL) then aq. NaHCO\(_3\) (75 mL). The aqueous layers were re-extracted with CH\(_2\)Cl\(_2\) (2 × 15 mL each). The organic layers were dried over \( \text{Na}_2\text{SO}_4 \) and concentrated, giving chloroacetate 10 (4.30 g, quant.) as white crystals/pale yellow flakes. ¹H NMR (400 MHz, Chloroform-\( \text{d}_2 \)) \( \delta \)H 7.84 (ddd, \( J = 9.9, 8.3, 1.3 \) Hz, 4H, 4 × Bz), 7.51 (t, \( J = 7.5 \) Hz, 1H, 1 × Bz), 7.46 (t, \( J = 7.5 \) Hz, 1H, 1 × Bz), 7.42 (d, \( J = 8.1 \) Hz, 2H, 2 × SAr), 7.34 (dd, \( J = 8.3, 7.4 \) Hz, 2H, 2 × Bz), 7.28 (dd, \( J = 8.5, 7.7 \) Hz, 2H, 2 × Bz), 7.20 (d, \( J = 9.3 \) Hz, 1H, N-H), 7.12 (d, \( J = 7.9 \) Hz, 2H, 2 × SAr), 5.87 (dd, \( J = 10.3, 9.6 \) Hz, 1H, H-3), 5.50 (t, \( J = 9.8 \) Hz, 1H, H-4), 5.04 (d, \( J = 10.3 \) Hz, 1H, H-1), 4.41 (dd, \( J = 12.2, 3.1 \) Hz, 1H, H-6a), 4.37 (dd, \( J = 12.2, 4.8 \) Hz, 1H, H-6b), 4.32 (q, \( J = 10.1 \) Hz, 1H, H-2), 4.08 (ddd, \( J = 10.0, 4.8, 3.0 \) Hz, 1H, H-5), 3.96 (d, \( J = 24.5, 15.2 \) Hz, 2H, CH\(_2\)Cl), 2.34 (s, 3H, ArCH\(_3\)). ¹³C NMR (100 MHz, Chloroform-\( \text{d}_2 \)) \( \delta \)C 167.14 (COCH\(_2\)Cl), 166.96, 165.10 (2 × COPh), 157.26 (d, \( J = 37.9 \) Hz, COCF\(_3\)), 139.20 (1 × 4° SAr), 134.14 (2 × SAr), 133.97, 133.74 (2 × Bz), 129.88 (2 × Bz), 129.61 (2 × Bz), 129.50 (2 × Bz), 129.27 (1 × 4° Bz), 129.21 (2 × Bz), 129.15 (2 × Bz), 128.98 (1 × 4° Bz), 128.65 (2 × 4° SAr), 116.07 (d, \( J = 288.3 \) Hz, CF\(_3\)), 84.91 (C-1), 78.71 (C-5), 74.81 (C-3), 69.55 (C-4), 60.60 (C-6), 53.25 (C-2), 21.10 (ArCH\(_3\)). m/z (ESI) calculated for C\(_{29}\)H\(_{30}\)N\(_2\)O\(_7\)F\(_3\)S [M+NH\(_4\)]\(^+\) 607.17, found 607.2.
SAr), 129.85 (2 × Bz), 129.60 (2 × Bz), 128.57 (2 × Bz), 128.51 (2 × Bz), 128.36, 127.92 (2 × 4° Bz), 126.83 (1 × 4° SAr), 115.44 (d, $J = 288.1$ Hz, CF$_3$), 86.11 (C-1), 75.89 (C-5), 73.71 (C-3), 68.83 (C-4), 63.97 (C-6), 53.60 (C-2), 40.54 (CH$_2$Cl), 21.21 (ArCH$_3$). $m/z$ (ESI) calculated for C$_{31}$H$_{31}$N$_2$O$_8$F$_3$SCl $[M+NH_4]^+$ 683.14, found 683.1.

3,4-Di-O-benzoyl-6-chloroacetyl-2-trifluoroacetamido-2-deoxy-α-D-glucopyranosyl bromide (11)

![Structure of 3,4-Di-O-benzoyl-6-chloroacetyl-2-trifluoroacetamido-2-deoxy-α-D-glucopyranosyl bromide (11)](attachment:image)

Thioglycoside 10 (3.40 g, 5.10 mmol) was dissolved in dry CH$_2$Cl$_2$ (50 mL). Br$_2$ (300 μL, 5.86 mmol, 1.15 equiv.) was added. The reaction was stirred at RT under Ar in the dark for 1.5 h (TLC in 2:8 EtOAc/pentanes, $R_f = 0.6$). The solution was diluted with CH$_2$Cl$_2$ (30 mL) then washed with 20% aq. Na$_2$S$_2$O$_3$ (40 mL), then H$_2$O (40 mL). The aqueous layers were re-extracted with CH$_2$Cl$_2$ (2 × 10 mL). The organic layers were dried over Na$_2$SO$_4$ and concentrated under reduced pressure, giving crude bromide donor 11 (3.52 g, quant.) as a yellow amorphous solid.

$^1$H NMR (400 MHz, Chloroform-$d$) $\delta$H 7.95 (dd, $J = 8.5, 1.5$ Hz, 2H, 2 × Bz), 7.90 (dd, $J = 8.4, 1.3$ Hz, 2H, 2 × Bz), 7.58 – 7.51 (m, 2H, 2 × Bz), 7.39 (m, 4H, 4 × Bz), 7.12 (d, $J = 7.3$ Hz, 1H, N-H), 6.69 (d, $J = 3.7$ Hz, 1H, H-1), 5.80 (t, $J = 9.5$ Hz, 1H, H-3), 5.76 (t, $J = 9.6$ Hz, 1H, H-4), 4.58 – 4.50 (m, 2H, 2 × Bz), 4.47 (dd, $J = 12.6, 4.1$ Hz, 1H, H-6a), 4.40 (dd, $J = 12.6, 2.5$ Hz, 1H, H-6b), 4.15 (d, $J = 2.1$ Hz, 2H, CH$_2$Cl).

3,4-Di-O-benzoyl-6-chloroacetyl-2-trifluoroacetamido-2-deoxy-β-D-glucopyranosyl-(1→6)-p-Tolyl 3,4-di-O-benzoyl-2-trifluoroacetamido-2-deoxy-β-1-thio-D-glucopyranoside (12)

![Structure of 3,4-Di-O-benzoyl-6-chloroacetyl-2-trifluoroacetamido-2-deoxy-β-D-glucopyranosyl-(1→6)-p-Tolyl 3,4-di-O-benzoyl-2-trifluoroacetamido-2-deoxy-β-1-thio-D-glucopyranoside (12)](attachment:image)

Acceptor 9 (2.00 g, 3.39 mmol) and glycosyl bromide 11 (3.17 g, 5.10 mmol, 1.5 equiv; 3.52 g crude) were dissolved in freshly distilled CH$_2$Cl$_2$ (76 mL) containing freshly activated powdered 4Å MS (5.0 g). The mixture was cooled to -45 °C under Ar in the dark for 1 h. AgOTf (1.74 g, 6.77 mmol, 2 equiv.) in dry toluene (10 mL) was added, and the reaction was stirred for 2 h (TLC in 2:8 acetone/pentanes, $R_f = 0.2$) and then quenched with NEt$_3$. The mixture was diluted with CH$_2$Cl$_2$ (80 mL) and filtered through celite. The solids were washed with CH$_2$Cl$_2$ (3 × 80 mL). The filtrate was washed with sat. aq. NaCl (2 × 250 mL). The aqueous layers were re-extracted with CH$_2$Cl$_2$ (2 × 100 mL). The organic layers were dried over Na$_2$SO$_4$ and concentrated. Column chromatography (acetone/hexanes, 2:8 → 3:7) gave disaccharide 12 (3.45 g, 90%) as a pale yellow amorphous solid. $^1$H NMR (400 MHz, Chloroform-$d$) $\delta$H 7.96 – 7.87 (m, 6H under Ar in the dark for 1 h. AgOTf (1.74 g, 6.77 mmol, 2 equiv.) in dry toluene (10 mL) was added, and the reaction was stirred for 2 h (TLC in 2:8 acetone/pentanes, $R_f = 0.2$) and then quenched with NEt$_3$. The mixture was diluted with CH$_2$Cl$_2$ (80 mL) and filtered through celite. The solids were washed with CH$_2$Cl$_2$ (3 × 80 mL). The filtrate was washed with sat. aq. NaCl (2 × 250 mL). The aqueous layers were re-extracted with CH$_2$Cl$_2$ (2 × 100 mL). The organic layers were dried over Na$_2$SO$_4$ and concentrated. Column chromatography (acetone/hexanes, 2:8 → 3:7) gave disaccharide 12 (3.45 g, 90%) as a pale yellow amorphous solid. $^1$H NMR (400 MHz, Chloroform-$d$) $\delta$H 7.96 – 7.87 (m, 6H, 6 × Bz), 7.82 (dd, $J = 8.6, 1.5$ Hz, 2H, 2 × Bz), 7.51 (m, 5H, N-H', 4 × Bz), 7.44 (d, $J = 8.1$ Hz, 2H, 2 × SAr), 7.35 (m, 8H, 8 × Bz), 7.20 (d, $J = 8.0$ Hz, 2H, 2 × SAr), 6.92 (d, $J = 8.7$ Hz, 1H, N-H), 5.92 (t, $J = 9.9$ Hz, 1H, H-3), 5.65 (t, $J = 9.7$ Hz, 1H, H-3'), 5.58 (t, $J = 9.6$ Hz, 1H, H-4'), 5.42 (t, $J = 9.7$ Hz, 1H, H-4), 5.14 (d, $J = 10.2$ Hz, 1H, H-1), 4.69 (d, $J = 8.4$ Hz, 1H, H-2), 4.44 (dd, $J = 12.6, 4.1$ Hz, 1H, H-6a), 4.40 (dd, $J = 12.6, 2.5$ Hz, 1H, H-6b), 4.15 (d, $J = 2.1$ Hz, 2H, CH$_2$Cl).
H-1'), 4.53 (q, J = 9.2 Hz, 1H, H-2'), 4.34 (d, J = 3.7 Hz, 2H, H-6a, H-6b), 4.25 (dd, J = 12.0, 2.0 Hz, 1H, H-6a'), 3.97 (dd, J = 12.0, 2.0 Hz, 1H, H-6a'), 3.95 – 3.88 (m, 3H, H-2, H-5, H-5'), 3.60 (dd, J = 11.9, 4.1 Hz, 1H, H-6b'), 2.37 (s, 3H, ArCH3). 13C NMR (100 MHz, Chloroform-d) δC 167.06 (COCH2Cl), 166.45, 166.33, 165.91, 165.12 (4 × COPh), 157.65 (d, J = 37.9 Hz, 1 × COCF3), 157.09 (d, J = 38.0 Hz, 1 × COCF3), 139.40 (1 × 4° SAr), 134.07 (1 × Bz), 133.95 (2 × SAr), 133.68 (2 × Bz), 133.64 (1 × Bz), 130.14 (2 × SAr), 129.91 (2 × Bz), 129.86 (2 × Bz), 129.75 (2 × Bz), 129.72 (2 × Bz), 128.59 (1 × Bz), 128.50 (2 × Bz), 128.49 (2 × Bz), 128.47, 128.45 (2 × Bz), 128.35, 128.20, 128.06 (3 × 4° Bz), 126.35 (1 × 4° SAr), 115.89 (d, J = 287.8 Hz, 1 × CF3), 115.68 (d, J = 288.0 Hz, 1 × CF3), 101.44 (C-1'), 84.85 (C-1), 77.19 (C-5), 72.88 (C-3), 72.61 (C-3'), 72.07 (C-5'), 68.94 (C-4), 68.88 (C-4'), 68.13 (C-6'), 63.58 (C-6), 54.58 (C-2'), 53.83 (C-2), 40.55 (CH2Cl), 21.15 (ArCH3). m/z (ESI) calculated for C53H49N3O15F6SCl [M+NH4]+ 1148.25, found 1148.2.

3,4-Di-O-benzoyl-6-chloroacetyl-2-trifluoroacetamido-2-deoxy-β-D-glucopyranosyl-(1→6)-3,4-di-O-benzoyl-2-trifluoroacetamido-2-deoxy-α-D-glucopyranosyl bromide (13)

Disaccharide thioglycoside 12 (2.00 g, 1.77 mmol) was dissolved in dry CH2Cl2 (18 mL). Br2 (118 μL, 2.30 mmol, 1.3 equiv.) was added. The reaction was stirred at RT under Ar in the dark for 1.5 h (TLC in 7:13 EtOAc/pentanes, Rf = 0.4). The solution was diluted with CH2Cl2 (12 mL) then washed with 20% aq. Na2S2O3 (30 mL) then H2O (30 mL). The aqueous layers were re-extracted with CH2Cl2 (2 × 7 mL). The organic layers were dried over Na2SO4 and concentrated under reduced pressure, giving crude glycosyl bromide 13 (2.00 g, quant.) as a yellow amorphous solid. 1H NMR (400 MHz, Chloroform-d) δH 8.01 (dd, J = 8.5, 1.4 Hz, 2H, 2 × Bz), 7.95 – 7.84 (m, 6H, 6 × Bz), 7.59 (t, J = 7.0 Hz, 1H, 1 × Bz), 7.52 (t, J = 7.5 Hz, 3H, 3 × Bz), 7.44 (t, J = 7.8 Hz, 2H, 2 × Bz), 7.40 – 7.33 (m, 7H, N-H', 6 × Bz), 7.04 (d, J = 7.6 Hz, 1H, N-H), 6.72 (d, J = 3.6 Hz, 1H, H-1), 5.84 (t, J = 9.4 Hz, 1H, H-3), 5.72 (t, J = 9.7 Hz, 1H, H-3'), 5.68 (t, J = 9.4 Hz, 1H, H-4), 5.56 (t, J = 9.6 Hz, 1H, H-4'), 4.67 (d, J = 8.4 Hz, 1H, H-1'), 4.46 (q, J = 8.2 Hz, 1H, H-2'), 4.43 – 4.34 (m, 2H, H-5, H-5', H-6a, H-6b), 4.30 (dd, J = 12.0, 2.1 Hz, 1H, H-6a'), 4.04 (d, J = 1.0 Hz, 2H, CH2Cl), 3.94 (dt, J = 9.6, 3.7 Hz, 1H, H-2), 3.57 (dd, J = 11.8, 2.8 Hz, 1H, H-6b').

3,4-Di-O-benzoyl-6-chloroacetyl-2-trifluoroacetamido-2-deoxy-β-D-glucopyranosyl-(1→6)-chloropropl 3,4-di-O-benzoyl-2-trifluoroacetamido-2-deoxy-β-D-glucopyranoside (14)
Crude glycosyl bromide 13 (1.92 g, 1.76 mmol; 2.00 g crude) and 3-chloropropanol (1.5 mL, 17.9 mmol, 10 equiv.) were dissolved in freshly distilled CH$_2$Cl$_2$ (25 mL) containing freshly activated powdered 4Å MS (2.5 g). The mixture was cooled to 0 °C under Ar in the dark for 1 h. AgOTf (0.59 g, 2.30 mmol, 1.3 equiv.) in dry toluene (3 mL) was added, and the reaction was stirred under the same conditions for 2 h (TLC in 1:3 acetone/pentanes, R$_f$ = 0.2), then quenched with NEt$_3$. The mixture was diluted with CH$_2$Cl$_2$ (20 mL) and filtered through celite. The solids were washed with CH$_2$Cl$_2$ (3 × 20 mL). The filtrate was washed with sat. aq. NaCl (2 × 80 mL). The aqueous layers were re-extracted with CH$_2$Cl$_2$ (2 × 20 mL). The organic layers were dried over Na$_2$SO$_4$ and concentrated. Column chromatography (EtOAc/pentanes, 28:72 → 4:6) gave disaccharide 14 (1.72 g, 89%) as a white amorphous solid. $^1$H NMR (400 MHz, Acetone-$_d_6$) $\delta$H 8.78 (d, $J$ = 9.0 Hz, 1H, N-H'), 8.68 (d, $J$ = 9.2 Hz, 1H, N-H), 7.95 (dd, $J$ = 8.4, 1.3 Hz, 2H, 2 × Bz), 7.92 – 7.84 (m, 6H, 6 × Bz), 7.66 – 7.53 (m, 4H, 4 × Bz), 7.51 – 7.38 (m, 8H, 8 × Bz), 5.84 (dd, $J$ = 10.6, 9.3 Hz, 1H, H-3), 5.81 (dd, $J$ = 10.7, 9.3 Hz, 1H, H-3'), 5.49 (t, $J$ = 9.6 Hz, 1H, H-4), 5.48 (t, $J$ = 9.8 Hz, 1H, H-4'), 5.16 (d, $J$ = 8.4 Hz, 1H, H-1), 5.10 (d, $J$ = 8.4 Hz, 1H, H-1'), 4.41 (dd, $J$ = 12.2, 5.2 Hz, 1H, H-6a'), 4.37 – 4.31 (m, 2H, H-2, H-6b'), 4.31 – 4.14 (m, 6H, H-2, H-5, H-5', H-6a, COCH$_2$Cl), 4.07 (dt, $J$ = 10.9, 5.5 Hz, 1H, OC$_2$H$_2$CH$_2$), 3.87 (dd, $J$ = 11.8, 6.1 Hz, 1H, H-6b), 3.79 (ddd, $J$ = 12.7, 7.6, 5.0 Hz, 1H, OCHFCH$_2$), 3.69 (t, $J$ = 6.5 Hz, 2H, CH$_2$CH$_2$Cl), 2.16 – 1.97 (m, 2H, CH$_2$CH$_2$Cl). $^{13}$C NMR (100 MHz, Acetone-$_d_6$) $\delta$C 167.68 (C$_{OCH_2Cl}$), 166.42 (2 × C$_{OPh}$), 166.00, 165.87 (2 × C$_{OPh}$), 134.49, 134.45, 134.37, 134.35 (4 × Bz), 130.52 (2 × Bz), 130.40 (2 × Bz), 130.32 (2 × Bz), 130.14, 130.06, 130.03 (4 × 4° Bz), 129.48 (2 × Bz), 129.44 (2 × Bz), 129.40 (2 × Bz), 129.37 (2 × Bz), 101.16 (C-1), 100.97 (C-1'), 73.87 (C-5), 73.76 (C-3), 73.73 (C-3'), 72.58 (C-5'), 70.83 (C-4), 70.46 (C-4'), 69.08 (C-6), 67.01 (OCH$_2$CH$_2$), 64.45 (C-6'), 55.78 (C-2'), 55.59 (C-2), 42.21 (CH$_2$CH$_2$Cl), 41.45 (COCH$_2$Cl), 33.30 (CH$_2$CH$_2$CH$_2$). m/z (ESI) calculated for C$_{49}$H$_{48}$N$_3$O$_{16}$F$_6$Cl$_2$[M+NH$_4$]$^+$ 1128.23, found 1118.24.

3,4-Di-O-benzoyl-2-trifluoroacetamido-2-deoxy-β-D-glucopyranosyl-(1→6)-chloropropyl 3,4-di-O-benzoyl-2-trifluoroacetamido-2-deoxy-β-D-glucopyranoside (15)

Disaccharide 14 (2.08 g, 1.89 mmol) and thiourea (0.72 g, 9.46 mmol, 5 equiv) were dissolved in a 1:1 mixture of pyridine/EtOH (190 mL). The solution was stirred at 70 °C for 18 h (TLC in 4:6 EtOAc/pentanes, R$_f$ = 0.3), then co-concentrated with toluene. The residue was dissolved in CH$_2$Cl$_2$ (300 mL) then washed with 1 M HCl (2 × 300 mL) then sat. aq. NaHCO$_3$ (300 mL). The aqueous layers were re-extracted with CH$_2$Cl$_2$ (2 × 60 mL each), and the organic layers were dried over Na$_2$SO$_4$ and concentrated. Column chromatography (EtOAc/pentanes, 7:13 → 1:1) gave disaccharide acceptor 15 (1.01 g, 52%) as a pale yellow amorphous solid. $^1$H NMR (400 MHz, Chloroform-d) $\delta$H 7.95 – 7.84 (m, 8H, 8 × Bz), 7.53 – 7.44 (m, 5H, N-H', 4 × Bz), 7.41 – 7.28 (m, 9H, N-H, 8 × Bz), 5.81 (dd, $J$ = 10.7, 9.5 Hz, 1H, H-3), 5.69 (dd, $J$ = 10.6, 9.6 Hz, 1H, H-3'), 5.52 (t, $J$ = 9.5 Hz, 1H, H-4), 5.39 (d, $J$ = 9.6 Hz, 1H, H-4'), 4.86 (d, $J$ = 8.3 Hz, 1H, H-1), 4.76 (d, $J$ = 8.4 Hz, 1H, H-1'), 4.36 (dd, $J$ = 9.9, 9.3 Hz, 1H, H-2'), 4.24 (dd, $J$ = 11.3, 2.4 Hz, 1H, H-6a), 4.13 (dd, $J$ = 10.6, 8.5 Hz, 1H, H-2), 4.04 – 3.99 (m, 1H, OCFHCH$_2$), 3.95 (ddd, $J$ = 9.5, 7.6, 6.1 Hz, 1H, H-6b), 3.79 (ddd, $J$ = 12.7, 7.6, 5.0 Hz, 1H, OCFHCH$_2$), 3.69 (t, $J$ = 6.5 Hz, 2H, CH$_2$CH$_2$Cl), 2.16 – 1.97 (m, 2H, CH$_2$CH$_2$Cl).
9.7, 4.1, 2.6 Hz, 1H, H-5), 3.84 – 3.74 (m, 1H, H-6a'), 3.71 – 3.57 (m, 6H, H-5', H-6b, H-6b'), OCH2CH2, CH2Cl). 13C NMR (125 MHz, Chloroform-d) δC 166.80, 166.70, 166.04, 165.82 (4 × COPh), 157.62 (d, J = 37.6 Hz, 1 × COCF3), 157.51 (d, J = 37.7 Hz, 1 × COCF3), 134.06, 133.84, 133.75, 133.67 (4 × Bz), 129.89 (2 × Bz), 129.85 (2 × Bz), 129.83 (2 × Bz), 129.81 (2 × Bz), 128.66 (2 × Bz), 128.54 (2 × Bz), 128.52 (2 × Bz), 128.49 (2 × Bz), 128.47, 128.34, 128.27, 128.12 (4 × 4° Bz), 115.67 (q, J = 289.8 Hz, 1 × CF3), 115.47 (q, J = 287.6 Hz, 1 × CF3), 100.91 (C-1'), 100.55 (C-1), 74.80 (C-5'), 72.98 (C-5), 72.65 (C-3'), 72.09 (C-3), 69.53 (C-4'), 69.00 (C-4), 67.99 (C-6), 66.25 (OCH2CH2), 61.05 (C-6'), 55.14 (C-2), 54.65 (C-2'), 41.42 (CH2Cl), 31.98 (CH2CH2).


p-Tolyl 3,4-di-O-benzoyl-6-chloroacetyl-2-phthalimido-2-deoxy-β-D-glucopyranoside (16)

Known 6 phthalimido-protected thioglycoside 16 was synthesized as described previously. 7 1H NMR (400 MHz, Chloroform-d) δH 7.92 – 7.85 (m, 3H, 2 × Bz, 1 × Phth), 7.74 – 7.67 (m, 5H, 2 × Bz, 3 × Phth), 7.49 (tt, J = 6.8, 1.2 Hz, 1H, 1 × Bz), 7.41 (tt, J = 7.0, 1.2 Hz, 1H, 1 × Bz), 7.37 – 7.32 (m, 4H, 2 × SAr, 2 × Bz), 7.24 (t, J = 7.9 Hz, 2H, 2 × Bz), 7.12 (d, 2H, 2 × SAr), 6.25 (dd, J = 10.3, 9.3 Hz, 1H, H-3), 5.81 (d, J = 10.5 Hz, 1H, H-1), 5.54 (dd, J = 10.1, 9.3 Hz, 1H, H-4), 4.55 (t, J = 10.4 Hz, 1H, H-2), 4.42 (d, J = 4.3 Hz, 2H, H-6a, H-6b), 4.14 (ddd, 1H, H-5), 4.08 (d, J = 1.8 Hz, 2H, H2Cl), 2.35 (s, 3H, ArC3H3). 13C NMR (100 MHz, Chloroform-d) δC 166.92 (COCH2Cl), 165.60, 165.20 (2 × COPh), 138.92 (1 × 4° SAr), 134.32, 134.21 (2 × Phth), 134.06 (2 × SAr), 133.56, 133.29 (2 × Bz), 129.80 (2 × Bz), 129.72 (2 × SAr), 129.71 (2 × Bz), 128.56 (1 × 4° Bz), 128.44 (2 × Bz), 128.27 (2 × Bz), 126.84 (1 × 4° SAr), 123.67 (2 × Phth), 83.44 (C-1), 75.81 (C-5), 71.85 (C-3), 69.44 (C-4), 64.00 (C-6), 53.76 (C-2), 40.68 (CH2Cl), 21.21 (ArC3H3). m/z (ESI) calculated for C37H30N9O9NaSCl [M+Na]+ 722.12, found 722.13.

3,4-di-O-benzoyl-6-chloroacetyl-2-phthalimido-2-deoxy-β-D-glucopyranosyl bromide (17)

Known 6 thioglycoside 16 (423 mg, 0.604 mmol) was dissolved in dry CH2Cl2 (6 mL). Br2 (36 μL, 0.703 mmol, 1.15 equiv.) was added. The reaction was stirred at RT under Ar in the dark for 1.5 h (TLC in 2:8 EtOAc/pentanes, Rf = 0.3). The solution was diluted with CH2Cl2 (4 mL) then washed with 20% aq. Na2S2O3 (10 mL) then H2O (10 mL). The aqueous layers were re-extracted with CH2Cl2 (2 × 2 mL). The organic layers were dried and concentrated, giving crude glycosyl bromide 17 (438 mg, quant.) as a white amorphous solid. 1H NMR (400 MHz, Chloroform-d) δH 7.89 (dd, J = 8.4, 1.3 Hz, 2H, 2 × Bz), 7.83 (bs, 2H, 2 × Phth), 7.77 – 7.69 (m, 4H, 2 × Bz, 2 × Phth), 7.51 (tt, J = 7.0, 1.3 Hz, 1H, 1 × Bz), 7.44 (tt, J = 7.1, 1.3 Hz, 1H, 1 × Bz), 7.39 – 7.34 (m, 2H, 2 × Bz), 7.30 – 7.24 (m, 2H, 2 × Bz), 6.56 (d, J = 9.6 Hz, 1H, H-1), 6.22 (dd, J = 10.4, 9.3 Hz, 1H, H-3), 5.69 (dd, J = 10.1, 9.4 Hz, 1H, H-4), 4.86 (dd, J = 10.4, 9.6 Hz, 1H, H-2), 4.46
(dd, $J = 12.5, 4.7$ Hz, 1H, H-6a), 4.41 (dd, $J = 12.5, 2.7$ Hz, 1H, H-6b), 4.22 (ddd, $J = 10.2, 4.6, 2.7$ Hz, 1H, H-5), 4.16 (d, $J = 1.7$ Hz, 2H, CH$_2$Cl).

3,4-Di-O-benzoyl-6-chloroacetyl-2-phthalimido-2-deoxy-β-D-glucopyranosyl-(1→6)-3,4-di-O-benzoyl-2-trifluoroacetamido-2-deoxy-β-D-glucopyranosyl-(1→6)-chloropropyl 3,4-di-O-benzoyl-2-trifluoroacetamido-2-deoxy-β-D-glucopyranoside (18)

![Disaccharide structure](image)

Disaccharide acceptor 15 (310 mg, 0.302 mmol) and glycosyl bromide 17 (397 mg, 0.604 mmol, 2 equiv; 438 mg crude) were dissolved in freshly distilled CH$_2$Cl$_2$ (9 mL) containing freshly activated powdered 4Å MS (0.90 g). The mixture was cooled to -45 °C under Ar in the dark for 1 h. AgOTf (210 mg, 0.817 mmol, 2.7 equiv.) in dry toluene (1.8 mL) was added, and the reaction was stirred under the same conditions for 2 h (TLC in 4:6 EtOAc/pentanes, $R_f = 0.5$), then quenched with NEt$_3$. The mixture was diluted with CH$_2$Cl$_2$ (30 mL) and filtered through celite. The solids were washed with CH$_2$Cl$_2$ (3 × 30 mL). The filtrate was washed with sat. aq. NaCl (2 × 90 mL). The aqueous layers were re-extracted with CH$_2$Cl$_2$ (2 × 15 mL). The organic layers were dried over Na$_2$SO$_4$ and concentrated. Column chromatography (EtOAc/pentanes, 3:7 → 4:6) gave trisaccharide 18 (435 mg, 90%) as a white/pale yellow amorphous solid.

$^{1}H$ NMR (600 MHz, Chloroform-d) $\delta_H$ 8.01 (dd, $J = 8.4, 1.2$ Hz, 2H, 2 × Bz), 7.92 (dt, $J = 8.4, 1.3$ Hz, 4H, 4 × Bz), 7.85 – 7.78 (m, 6H, 6 × Bz), 7.74 – 7.67 (m, 2H, 2 × Phth), 7.66 – 7.63 (m, 2H, 2 × Phth), 7.58 (d, $J = 9.4$ Hz, 1H, N-H), 7.55 – 7.41 (m, 6H, 6 × Bz), 7.38 – 7.29 (m, 8H, 8 × Bz), 7.19 – 7.13 (m, 2H, 2 × Bz), 7.09 (d, $J = 8.8$ Hz, 1H, N-H'), 6.32 (dd, $J = 10.7, 9.1$ Hz, 1H, H-3''), 5.97 (dd, $J = 10.7, 9.5$ Hz, 1H, H-3), 5.65 (dd, $J = 10.1, 9.2$ Hz, 1H, H-4''), 5.64 (dd, $J = 10.5, 9.3$ Hz, 1H, H-3'), 5.53 (d, $J = 8.4$ Hz, 1H, H-1''), 5.40 (t, $J = 9.7$ Hz, 1H, H-4), 5.19 (t, $J = 9.8$ Hz, 1H, H-4'), 4.85 (d, $J = 8.4$ Hz, 1H, H-1), 4.67 (d, $J = 8.4$ Hz, 1H, H-1'), 4.64 (dd, $J = 10.8, 8.4$ Hz, 1H, H-2''), 4.37 (dd, $J = 12.2, 6.0$ Hz, 1H, H-6a''), 4.32 – 4.23 (m, 3H, H-2, H-2', H-6b''), 4.17 – 4.10 (m, 2H, H-5, H-5''), 4.08 (dt, $J = 10.0, 5.0$ Hz, 1H, OCH$_2$CH$_2$Cl), 4.03 – 3.86 (m, 5H, H-5', H-6a, H-6a', COCH$_2$Cl), 3.84 (dd, $J = 12.5, 6.4$ Hz, 1H, H-6b), 3.79 (dd, $J = 12.2, 2.1$ Hz, 1H, H-6b'), 3.70 (dd, $J = 13.0, 8.9, 4.2$ Hz, 1H, OCH$_2$CH$_2$), 3.62 (dd, $J = 7.1, 5.4$ Hz, 2H, CH$_2$CH$_2$Cl), 2.11 (ddq, $J = 13.7, 10.1, 5.1$ Hz, 1H, CH$_2$CH$_2$CH$_2$), 1.96 (dddd, $J = 14.6, 11.7, 7.0, 4.9$ Hz, 1H, CH$_3$CH$_2$CH$_2$). $^{13}$C NMR (125 MHz, Chloroform-d) $\delta_C$ 167.92 (2 × COPhth), 167.03 (COCH$_2$Cl), 166.39, 166.36, 166.08, 165.60, 165.32, 165.15 (6 × COPh), 157.63 (d, $J = 37.6$ Hz, 1 × COCl$_2$), 157.41 (d, $J = 37.6$ Hz, 1 × COCl$_2$), 157.41 (d, $J = 37.6$ Hz, 1 × COCl$_2$), 134.45 (2 × Phth), 133.94, 133.70, 133.63, 133.57, 133.54, 133.46 (6 × Bz), 131.25 (2 × 4° Phth), 130.06 (2 × Bz), 129.89 (2 × Bz), 129.85 (2 × Bz), 129.84 (2 × Bz), 129.81 (2 × Bz), 129.78 (2 × Bz), 128.77 (2 × Bz), 128.61 (1 × 4° Bz), 128.53 (2 × Bz), 128.50 (2 × Bz, 2 × 4° Bz), 128.49 (4 × Bz), 128.47 (2 × Bz), 128.42 (2 × Bz), 128.41, 128.36 (2 × 4° Bz), 128.24 (2 × Bz), 123.69 (2 × Phth), 115.68 (q, $J = 288.2$ Hz, 1 × CF$_3$), 115.62 (q, $J = 288.2$ Hz, 1 × CF$_3$), 101.62 (C-1'), 100.54 (C-1), 99.43 (C-1''), 73.81 (C-5'), 73.03 (C-5), 72.42 (C-5''), 72.38 (C-3'), 72.01 (C-3), 70.38 (C-3''), 70.23 (C-4), 70.16 (C-6'), 70.14 (C-6), 69.79 (C-4', C-4''), 66.31 (OCH$_2$CH$_2$), 64.01 (C-6''), 55.06 (C-2), 54.96 (C-2'), 54.94
(C-2'), 41.55 (CH$_2$CH$_2$Cl), 40.64 (COCH$_2$Cl), 32.04 (CH$_2$CH$_2$CH$_2$). $m/z$ (ESI) calculated for C$_{77}$H$_{69}$N$_4$O$_{24}$F$_6$Cl$_2$ [M+NH$_4$]$^+$ 1617.36, found 1617.35.

3,4-Di-O-benzoyl-2-phthalimido-2-deoxy-β-D-glucopyranosyl-(1→6)-3,4-di-O-benzoyl-2-trifluoroacetamido-2-deoxy-β-D-glucopyranosyl-(1→6)-chloropropyl 3,4-di-O-benzoyl-2-trifluoroacetamido-2-deoxy-β-D-glucopyranoside (19)

Trisaccharide 18 (424 mg, 0.265 mmol) and thiourea (101 mg, 1.33 mmol, 5 equiv) were dissolved in a 1:1 mixture of pyridine/EtOH (28 mL). The solution was stirred at 70 °C for 18 h (TLC in 4:6 EtOAc/pentanes, $R_f = 0.2$), then co-concentrated with toluene. The residue was dissolved in CH$_2$Cl$_2$ (70 mL) then washed with 1 M HCl (2 × 70 mL) then sat. aq. NaHCO$_3$ (70 mL). The aqueous layers were re-extracted with CH$_2$Cl$_2$ (2 × 15 mL), and the organic layers were dried over Na$_2$SO$_4$ and concentrated. Column chromatography (EtOAc/pentanes, 4:6) gave trisaccharide acceptor 19 (225 mg, 56%) as a white amorphous solid.

$^1$H NMR (600 MHz, Chloroform-$d$) δ $^1$H 7.96 (dd, $J = 8.3$, 1.1 Hz, 2H, 2 × Bz), 7.92 (dd, $J = 8.4$, 1.2 Hz, 2H, 2 × Bz), 7.87 (dd, $J = 8.4$, 1.2 Hz, 2H, 2 × Bz), 7.76 (dd, $J = 8.4$, 1.2 Hz, 2H, 2 × Bz), 7.70 (dd, $J = 5.5$, 3.0 Hz, 2H, 2 × Phth), 7.66 (dd, $J = 8.3$, 1.2 Hz, 2H, 2 × Bz), 7.63 (dd, $J = 5.5$, 3.0 Hz, 2H, 2 × Phth), 7.58 (d, $J = 9.0$ Hz, 1H, N-H), 7.55 – 7.45 (m, 6H, 6 × Bz), 7.42 – 7.41 (m, 1H, H-5'), 7.03 (d, $J = 8.7$ Hz, 1H, N-H'), 6.32 (dd, $J = 10.7$, 9.2 Hz, 1H, H-3''), 5.80 (dd, $J = 10.7$, 9.5 Hz, 1H, H-3), 5.58 (dd, $J = 10.7$, 9.5 Hz, 1H, H-3'), 5.55 (d, $J = 8.4$ Hz, 1H, H-1''), 4.87 (d, $J = 8.4$ Hz, 1H, H-1), 4.67 (d, $J = 8.4$ Hz, 1H, H-1'), 4.53 (dd, $J = 10.8$, 8.4 Hz, 1H, H-2''), 4.26 – 4.17 (m, 2H, H-2, H-2'), 4.14 – 4.08 (m, 2H, H-5, H-6a'), 3.97 (q, $J = 288.2$ Hz, 1 × CF$_3$), 3.93 – 3.89 (m, 2H, H-6a, OC$_2$H$_4$), 3.75 – 3.64 (m, 3H, OCH$_2$CH$_2$CH$_2$Cl), 2.18 – 2.12 (m, 1H, CH$_2$OCH$_2$CH$_2$), 2.07 – 1.98 (m, 1H, CH$_2$CH$_2$OCH$_2$CH$_2$).

$^{13}$C NMR (125 MHz, Chloroform-$d$) $\delta$ $^1$C 170.86, 166.42, 166.40, 165.90, 165.64, 165.07 (6 × COPh), 157.60 (d, $J = 37.5$ Hz, 1 × COCF$_3$), 157.39 (d, $J = 37.7$ Hz, 1 × COCF$_3$), 134.14 (2 × Phth), 133.89, 133.79, 133.58, 133.51, 133.49, 133.34 (6 × Bz), 131.49 (2 × 4° Phth), 129.98 (2 × Bz), 129.96 (2 × Bz), 129.85 (2 × Bz), 129.78 (4 × Bz), 129.71 (2 × Bz), 128.68 (2 × Bz), 128.57 (1 × 4° Bz), 128.50 (2 × Bz), 128.49 (2 × 4° Bz), 128.45 (2 × Bz), 128.42 (2 × Bz, 1 × 4° Bz), 128.42 (1 × 4° Bz), 128.39 (2 × Bz, 1 × 4° Bz), 128.30 (2 × Bz), 123.53 (2 × Phth), 115.66 (q, $J = 288.2$ Hz, 1 × CF$_3$), 115.58 (q, $J = 288.3$ Hz, 1 × CF$_3$), 101.67 (C-1'), 100.56 (C-1), 98.28 (C-1''), 74.35 (C-5'), 73.36 (C-5), 72.40 (C-3'), 72.20 (C-3), 70.44 (C-3''), 70.13 (C-4'), 70.03 (C-4), 70.01 (C-6), 69.27 (C-4'), 68.36 (C-6''), 66.46 (C-6), 61.06 (OCH$_2$CH$_2$), 55.20 (C-2), 54.93 (C-2'), 54.76 (C-2''), 41.58 (CH$_2$Cl), 32.12 (CH$_2$CH$_2$CH$_2$). $m/z$ (ESI) calculated for C$_{75}$H$_{69}$N$_4$O$_{23}$F$_6$Cl$_2$ [M+NH$_4$]$^+$ 1541.39, found 1541.38.

3,4-Di-O-benzoyl-6-chloroacetyl-2-trifluoroacetamido-2-deoxy-β-D-glucopyranosyl-(1→6)-3,4-di-O-benzoyl-2-trifluoroacetamido-2-deoxy-β-D-glucopyranosyl-(1→6)-3,4-di-O-
benzoyl-2-phthalimido-2-deoxy-β-D-glucopyranosyl-(1→6)-3,4-di-O-benzoyl-2-trifluoroacetamido-2-deoxy-β-D-glucopyranosyl-(1→6)-chloropropyl 3,4-di-O-benzoyl-2-trifluoroacetamido-2-deoxy-β-D-glucopyranoside (20)

Trisaccharide acceptor 19 (165 mg, 0.108 mmol) and glycosyl bromide 13 (236 mg, 0.217 mmol, 2 equiv; 237 mg crude) were dissolved in freshly distilled CH₂Cl₂ (3 mL) containing freshly activated powdered 4Å MS (300 mg). The mixture was cooled to -45 °C under Ar in the dark for 1 h. AgOTf (75 mg, 0.292 mmol, 2.7 equiv.) in dry toluene (0.6 mL) was added, and the reaction was stirred for 2 h (TLC in 4:6 EtOAc/pentanes, Rₑ = 0.4), then quenched with NEt₃. The mixture was diluted with CH₂Cl₂ (7 mL) and filtered through celite. The solids were washed with CH₂Cl₂ (3 × 7 mL). The filtrate was washed with sat. aq. NaCl (2 × 25 mL). The aqueous layers were re-extracted with CH₂Cl₂ (2 × 5 mL). The organic layers were dried over Na₂SO₄ and concentrated. Column chromatography (EtOAc/hexanes, 3:7 → 4:6) gave pentasaccharide 20 (216 mg, 79%) as a white amorphous solid.
(2 × Bz), 130.21 (2 × Bz), 130.16 (2 × Bz), 129.90 (2 × Bz), 129.83 (2 × Bz), 129.80 (2 × Bz), 129.70 (2 × Bz), 129.08 (2 × Bz), 129.05 (4° Bz), 128.93 (2 × Bz), 128.87 (1 × 4° Bz), 128.57 (2 × Bz), 128.40 (2 × Bz), 128.38 (2 × Bz), 128.35 (2 × Bz), 128.30 (2 × Bz), 128.23 (2 × Bz), 128.22, 128.13 (2 × 4° Bz), 124.36, 123.48 (2 × Phth), 115.96 (q, J = 288.0 Hz, 1 × CF₃), 115.59 (q, J = 287.8 Hz, 1 × CF₃), 115.36 (q, J = 288.4 Hz, 1 × CF₃), 115.04 (q, J = 287.1 Hz, 1 × CF₃), 104.09, 101.65, 100.72 (3 × C-1), 100.42 (1 × C-1), 74.65 (1 × C-5), 73.90, 73.55 (C-6", 1 × C-6), 73.50 (C-5"), 72.59 (1 × C-6), 72.53 (1 × C-3, 1 × C-5), 72.51 (1 × C-5), 72.28 (2 × C-3, 1 × C-5, 1 × C-6), 71.74 (1 × C-4), 71.70 (C-4"), 71.56, 69.91 (1 × C-4), 69.87 (1 × C-4), 69.43 (C-3"), 66.45 (OCH₂CH₂), 63.67 (1 × C-6), 63.67 (1 × C-6), 58.01, 55.44 (2 × C-2), 55.29 (C-2"), 54.70, 54.43 (2 × C-2), 41.61 (CH₂CH₂), 40.54 (COCH₂Cl), 32.12 (CH₂CH₂CH₂).

m/z (MALDI) calculated for C₁₂₁H₁₀₁N₅O₃₈F₁₂Cl₂Na [M+Na]⁺ 2552.52, found 2552.13.

2-Acetamido-3,4,6-tri-O-acetyl-2-deoxy-β-D-glucopyranosyl-(1→6)-2-acetamido-3,4-di-O-acetyl-2-deoxy-β-D-glucopyranosyl-(1→6)-3,4-di-O-acetyl-2-phthalimido-2-deoxy-β-D-glucopyranosyl-(1→6)-chloropropyl 2-acetamido-3,4-di-O-acetyl-2-deoxy-β-D-glucopyranoside (21)

Pentasaccharide 20 (206 mg, 0.081 mmol) was dissolved in a 2:4:1 mixture of 0.5 M NaOH (16.2 mL, 8.1 mmol, 100 equiv.), THF (32.4 mL), and MeOH (8.1 mL). The reaction was stirred at 40 °C for 3 h. The solution was concentrated and dried under high vacuum. The residue was dissolved in a 1:1 mixture of pyridine (20 mL, 211.6 mmol, 2612 equiv.) and Ac₂O (20 mL, 247.3 mmol, 3052 equiv.). The reaction was stirred at 50 °C for 2 h, then left to attain RT for 16 h (TLC in 17:3 EtOAc/EtOH, Rₓ = 0.5). The solution co-concentrated with toluene. The residue was dissolved in CH₂Cl₂ (60 mL) then washed with 1 M HCl (60 mL) then aq. NaHCO₃ (60 mL). The aqueous layers were re-extracted with CH₂Cl₂ (2 × 15 mL). The organic layers were dried over Na₂SO₄ and concentrated. Column chromatography (EtOAc/EtOH, 19:1 → 8:2) gave pentasaccharide 21 (101 mg, 75%) as a white amorphous solid. ¹H NMR (600 MHz, Acetone-d₆) δH 7.94 – 7.90 (m, 4H, 4 × Phth), 7.56 (d, J = 9.5 Hz, 1H, 1 × N-H), 7.31 (d, J = 9.3 Hz, 1H, 1 × N-H), 7.31 (d, J = 9.7 Hz, 1H, 1 × N-H), 7.15 (d, J = 9.5 Hz, 1H, 1 × N-H), 5.85 (dd, J = 10.7, 8.9 Hz, 1H, H-3"), 5.43 (d, J = 8.4 Hz, 1H, H-1"), 5.35 (dd, J = 10.4, 9.4 Hz, 1H, 1 × H-3), 5.26 (dd, J = 10.4, 9.4 Hz, 1H, 1 × H-3), 5.22 – 5.17 (m, 3H, 1 × H-1, 2 × H-3), 5.04 (dd, J = 10.2, 8.9 Hz, 1H, H-4"), 4.98 (t, J = 10.4 Hz, 1H, 1 × H-4), 4.92 (dd, J = 10.0, 9.4 Hz, 1H, 1 × H-4), 4.84 (t, J = 9.8 Hz, 1H, 1 × H-4), 4.76 (d, J = 8.5 Hz, 1H, 1 × H-1), 4.72 – 4.65 (m, 3H, 2 × H-1, 1 × H-4), 4.40 (td, J = 10.5, 9.7, 2.5 Hz, 1H, 1 × H-5), 4.31 (dd, J = 10.8, 8.4 Hz, 1H, H-2").
4.20 (m, 2H, 1 × H-2, H-5"), 4.17 (q, J = 9.3 Hz, 1H, 1 × H-2), 4.13 – 4.05 (m, 2H, 1 × H-5, 1 × H-6a), 4.03 – 3.97 (m, 4H, 2 × H-2, 1 × H-5, H-6a"), 3.95 – 3.85 (m, 5H, 1 × H-6a, H-6b", 2 × H-6b, OCHHCH₂), 3.84 – 3.80 (m, 2H, 1 × H-5, 1 × H-6a), 3.74 (dd, J = 11.7, 2.6 Hz, 1H, 1 × H-6a), 3.68 (dd, J = 12.4, 7.8, 4.6 Hz, 1H, OCHHCH₂), 3.67 – 3.62 (m, 3H, 1 × H-6b, CH₂Cl), 3.59 (dd, J = 11.7, 8.2 Hz, 1H, 1 × H-6b), 2.11, 2.09, 2.06, 2.05 (4 s, 12H, 4 × Ac), 2.03 – 2.01 (m, 1H, CH₂CHHCH₂), 1.99, 1.98, 1.96, 1.96, 1.95 (5 s, 15H, 5 × Ac), 1.96 – 1.93 (m, 4H, CH₂CHHCH₂, 1 × Ac), 1.92, 1.89, 1.84, 1.84, 1.83 (5 s, 15H, 5 × Ac).

13C NMR (125 MHz, Acetone-d₆) δC 171.18, 170.93, 170.71 (3 × COCH₃), 170.65 (2 × COCH₃), 170.54 (2 × COCH₃), 170.49, 170.45, 170.41, 170.33, 170.23, 170.12, 170.10, 170.06 (8 × COCH₃), 135.88 (2 × Phth), 132.27 (2 × 4° Phth), 124.27 (2 × Phth), 103.99, 102.36, 101.14 (4 × C-1), 100.04 (C-1"), 74.66 (1 × C-3), 74.54 (1 × C-5), 74.32, 73.87 (2 × C-3), 73.61 (C-5"), 73.22 (1 × C-3), 73.15 (1 × C-3), 72.69 (1 × C-5), 72.00 (1 × C-5, C-6"), 71.82 (1 × C-6), 71.57 (C-4"), 71.45 (1 × C-4), 71.26 (C-3"), 71.21 (1 × C-4), 70.90 (1 × C-6), 70.50, 69.96 (2 × C-4), 66.90 (OCH₂CH₂), 66.58, 63.03 (2 × C-6), 56.21 (C-2"), 54.97, 54.84, 54.70, 52.88 (4 × C-2), 42.63 (CH₂Cl), 33.31 (CH₂CH₂CH₂), 23.29, 23.25, 23.16, 23.09 (4 × NCOCH₃), 21.05, 20.99, 20.98, 20.90, 20.73 (5 × COCH₃), 20.71 (2 × COCH₃), 20.67 (2 × COCH₃), 20.55, 20.46 (2 × COCH₃). m/z (ESI) calculated for C₇₁H₉₈N₆O₃₈Cl [M+NH₄]⁺ 1677.56, found 1677.56.

2-Acetamido-3,4,6-tri-O-acetyl-2-deoxy-β-D-glucopyranosyl-(1→6)-2-acetamido-3,4-di-O-acetyl-2-deoxy-β-D-glucopyranosyl-(1→6)-3,4-di-O-acetyl-2-phthalimido-2-deoxy-β-D-glucopyranosyl-(1→6)-azidopropyl 2-acetamido-3,4-di-O-acetyl-2-deoxy-β-D-glucopyranoside (22)

Pentasaccharide 21 (97.0 mg, 0.058 mmol) and NaN₃ (114 mg, 1.75 mmol, 30 equiv.) were dissolved in dry DMF (5.8 mL). The reaction was stirred at 80 °C for 24 h (TLC in 17:3 EtOAc/EtOH, Rf = 0.5). The solution was diluted with EtOAc (90 mL) then washed with H₂O (90 mL). The aqueous layer was re-extracted with EtOAc (2 × 45 mL). The organic layers were dried over Na₂SO₄ and concentrated. Column chromatography (EtOAc/EtOH, 19:1 → 8:2) gave azidopropyl glycoside 22 (74.4 mg, 76%) as a white amorphous solid. 1H NMR (600 MHz, Acetone-d₆) δH 7.99 – 7.88 (m, 4H, 4 × Phth), 7.54 (d, J = 9.4 Hz, 1H, 1 × N-H), 7.31 (d, J = 9.4 Hz, 2H, 2 × N-H), 7.14 (d, J = 9.5 Hz, 1H, 1 × N-H), 5.85 (dd, J = 10.7, 8.9 Hz, 1H, H-3"), 5.43 (d, J = 8.5 Hz, 1H, H-1"), 5.34 (dd, J = 10.4, 9.4 Hz, 1H, 1 × H-3), 5.26 (dd, J = 10.5, 9.4 Hz, 1H, 1 × H-3), 5.22 – 5.18 (m, 3H, 1 × H-1, 2 × H-3), 5.05 (dd, J = 10.2, 8.9 Hz, 1H, H-4"), 4.98 (t, J = 9.8 Hz, 1H, 1 × H-4), 4.93 (dd, J = 10.0, 9.5 Hz, 1H, 1 × H-4), 4.84 (t, J = 9.8 Hz, 1H, 1 × H-4), 4.77 (d, J = 8.6 Hz, 1H, 1 × H-1), 4.72 – 4.66 (m, 3H, 2 × H-1, 1 × H-4), 4.39 (td, J = 9.9, 2.3 Hz, 1H, 1 × H-5), 4.31 (dd, J = 10.7, 8.5 Hz, 1H, H-2"), 4.28 – 4.20 (m, 2H, 1 × H-2, H-5"),
4.17 (q, J = 9.4 Hz, 1H, 1 × H-2), 4.11 (dd, J = 12.4, 5.6 Hz, 1H, 1 × H-6a), 4.07 (ddd, J = 10.4, 8.2, 2.7 Hz, 1H, 1 × H-5), 4.03 – 3.97 (m, 4H, 2 × H-2, 1 × H-5, 1 × H-6a), 3.94 (dd, J = 10.4, 1.9 Hz, 1H, 1 × H-6a), 3.91 – 3.85 (m, 4H, H-6b", 2 × H-6b, OCH2HCH3), 3.84 – 3.79 (m, 2H, 1 × H-5, 1 × H-6a), 3.75 (dd, J = 11.7, 2.6 Hz, 1H, 1 × H-6a), 3.65 (dd, J = 12.5, 9.7 Hz, 1H, 1 × H-6b), 3.62 (ddd, J = 12.7, 7.3, 5.6 Hz, 1H, OCH2HCH2), 3.58 (dd, J = 11.8, 8.2 Hz, 1H, 1 × H-6b), 3.40 (td, J = 6.8, 1.4 Hz, 2H, CH3N3), 2.11, 2.09, 2.07, 2.05, 1.99, 1.98, 1.96 (7 s, 21H, 7 × CH3), 1.95 (s, 6H, 2 × CH3), 1.94, 1.92, 1.89, 1.84, 1.83 (6 s, 18H, 6 × CH3), 1.83 – 1.79 (m, 2H, CH2CH2CH2). 13C NMR (125 MHz, Acetone-d6) δ C 171.18, 170.94, 170.73, 170.67, 170.67 (5 × COCH3), 170.57 (2 × COCH3), 170.51, 170.48, 170.44, 170.33, 170.21, 170.15, 170.12, 170.00 (8 × COCH3), 135.91 (2 × Phth), 132.31 (2 × 4° Phth), 124.59, 124.33 (2 × Phth), 103.98, 102.36, 101.64, 101.18 (4 × C-1), 100.04 (C-1"), 74.67 (1 × C-3), 74.54 (1 × C-5), 74.38, 73.92 (2 × C-3), 73.64 (C-5"), 73.23 (1 × C-5), 73.20 (1 × C-3), 72.75 (1 × C-5), 72.05 (1 × C-5), 71.95 (C-6"), 71.76 (1 × C-6), 71.56 (C-4"), 71.46 (1 × C-4), 71.30 (C-3"), 71.22 (1 × C-4), 70.83 (1 × C-6), 70.52, 69.97 (2 × C-4), 66.90 (OCH2CH2), 66.62, 63.05 (2 × C-6), 56.22 (C-2"), 55.00, 54.84, 54.72, 52.91 (4 × C-2), 49.00 (CH3N3), 29.59 (CH2CH2CH2), 23.29, 23.26, 23.18, 23.09 (4 × NCOCH3), 21.06 (1 × OCOCH3), 20.99 (2 × OCOCH3), 20.90, 20.74 (2 × OCOCH3), 20.72 (2 × OCOCH3), 20.67 (2 × OCOCH3), 20.53, 20.46 (2 × OCOCH3). m/z (ESI) calculated for C71H98N9O38 [M+NH4]+ 1684.60, found 1684.60.

3,4-Di-O-benzoyl-6-chloroacetyl-2-trifluoroacetamido-2-deoxy-β-D-glucopyranosyl-(1→6)-3,4-di-O-benzoyl-2-trifluoroacetamido-2-deoxy-β-D-glucopyranosyl-(1→6)-3,4-di-O-benzoyl-2-trifluoroacetamido-2-deoxy-β-D-glucopyranosyl-(1→6)-chloropropyl 3,4-di-O-benzoyl-2-trifluoroacetamido-2-deoxy-β-D-glucopyranoside (23)

Disaccharide acceptor 15 (1.00 g, 0.98 mmol) and glycosyl bromide 13 (1.59 g, 1.46 mmol, 1.5 equiv; 1.77 g crude) were dissolved in freshly distilled CH2Cl2 (25 mL) containing freshly activated powdered 4Å MS (2.5 g). The mixture was cooled to -45 °C under Ar in the dark for 1 h. AgOTf (0.50 mg, 1.95 mmol, 2 equiv.) in dry toluene (3 mL) was added, and the reaction was stirred under the same conditions for 2 h (TLC in 3:7 acetone/pentanes, Rf = 0.2), then quenched with NEt3. The mixture was diluted with CH2Cl2 (20 mL) and filtered through celite. The solids were washed with CH2Cl2 (3 × 20 mL). The filtrate was washed with sat. aq. NaCl (2 × 80 mL). The aqueous layers were re-extracted with CH2Cl2 (2 × 15 mL). The organic layers were dried over Na2SO4 and concentrated. Column chromatography (acetone/pentanes, 3:7 → 7:13) gave tetrasaccharide 23 (1.52 g, 77%) as a pale yellow amorphous solid, and recovered acceptor 15 (0.11 g, 11%). Analytical Data for 23: 1H NMR (600 MHz, Chloroform-d) δH 8.12 (d, J = 7.7 Hz, 1H, 1 × N-H), 8.05 (ddd, J = 10.4, 8.4, 1.3 Hz, 4H, 4 × Bz), 8.02 – 7.98 (m, 2H, 2 × Bz), 7.99 – 7.93 (m, 9H, 1 × N-H, 8 × Bz), 7.60 – 7.44 (m, 10H, 1 × N-H, 9 × Bz), 7.45 – 7.28 (m,
1H, 1 × N-H, 13 × Bz), 7.25 (s, 2H, 2 × Bz), 7.15 – 7.11 (m, 2H, 2 × Bz), 5.95 (t, J = 9.9 Hz, 1H, 1 × H-3), 5.92 (t, J = 10.3 Hz, 1H, 1 × H-3), 5.84 (t, J = 9.6 Hz, 1H, 1 × H-3), 5.79 (dd, J = 10.6, 9.0 Hz, 1H, 1 × H-3), 5.70 (dd, J = 12.8, 6.8 Hz, 1H, 1 × H-4), 5.65 (t, J = 9.6 Hz, 1H, 1 × H-4), 5.35 (t, J = 9.7 Hz, 1H, 1 × H-5), 5.20 (t, J = 9.8 Hz, 1H, 1 × H-5), 4.99 (d, J = 8.4 Hz, 1H, 1 × H-1), 4.82 (d, J = 8.2 Hz, 1H, 1 × H-1), 4.77 (d, J = 8.4 Hz, 1H, 1 × H-1), 4.70 – 4.47 (m, 7H, 1 × H-1, 4 × H-2, 1 × H-5), 4.42 (dd, J = 12.3, 6.8 Hz, 1H, 1 × H-6a), 4.18 – 4.05 (m, 5H, 1 × H-5, 2 × H-6a, 1 × H-6b, OCCH₂Cl), 3.99 – 3.83 (m, 5H, 1 × H-5, 1 × H-6a, 1 × H-6b, COCH₂Cl), 3.82 – 3.77 (m, 1H, OCH₂CH₂), 3.66 – 3.48 (m, 2 × H-6b, CH₂CH₂Cl), 2.04 (dt, J = 20.1, 6.2 Hz, 2H, CH₂CH₂Cl₂).

13C NMR (125 MHz, Chloroform-d) δC 167.02 (C OCH₂Cl), 166.81, 166.70, 166.48, 166.41, 166.29, 165.21, 165.08 (8 × COPh), 158.33 (d, J = 38.0 Hz, 1 × COCF₃), 158.31 (d, J = 38.5 Hz, 1 × COCF₃), 158.17 (d, J = 37.8 Hz, 1 × COCF₃), 157.91 (d, J = 37.3 Hz, 1 × COCF₃), 133.98 (1 × Bz), 133.84 (2 × Bz), 133.75, 133.69 (2 × Bz), 133.43 (2 × Bz), 133.38 (1 × Bz), 130.14 (2 × Bz), 130.08 (2 × Bz), 130.00 (2 × Bz), 129.92 (2 × Bz), 129.85 (6 × Bz), 129.69 (2 × Bz), 128.89 (2 × Bz), 128.81 (2 × 4° Bz), 128.72 (2 × Bz), 128.68 (4 × 4° Bz), 128.64 (2 × Bz), 128.41 (4 × Bz), 128.38 (4 × Bz), 128.35 (2 × Bz), 128.19, 128.05 (2 × 4° Bz), 115.56 (q, J = 287.9 Hz, 2 × CF₃), 115.40 (q, J = 287.2 Hz, 1 × CF₃), 115.16 (q, J = 287.2 Hz, 1 × CF₃), 103.78, 103.31, 101.77, 99.96 (4 × C-1), 73.93, 73.30 (2 × C-5), 73.24 (1 × C-6), 73.01 (1 × C-5), 72.61, 72.45 (2 × C-3), 72.22 (1 × C-6), 71.77 (1 × C-3), 71.37, 71.33, 71.21, 70.23 (4 × C-4), 68.81 (1 × C-3), 66.53 (OCH₂CH₂), 64.17 (1 × C-6), 55.35, 55.16, 54.52, 53.76 (4 × C-2), 41.47 (CH₂CH₂Cl), 40.69 (COCH₂Cl), 31.95 (CH₂CH₃). m/z (ESI) calculated for C₉₃H₈₄N₅O₃₀F₁₂Cl₂ [M+NH₄]⁺ 2048.44, found 2048.43.

3,4-Di-O-benzoyl-2-trifluoroacetamido-2-deoxy-β-D-glucopyranosyl-(1→6)-3,4-di-O-benzoyl-2-trifluoroacetamido-2-deoxy-β-D-glucopyranosyl-(1→6)-3,4-di-O-benzoyl-2-trifluoroacetamido-2-deoxy-β-D-glucopyranosyl-(1→6)-chloropropyl 3,4-di-O-benzoyl-2-trifluoroacetamido-2-deoxy-β-D-glucopyranoside (24)

![Tetrasaccharide structure](image)

Tetrasaccharide 23 (1.22 g, 0.60 mmol) and thiourea (230 mg, 3.02 mmol, 5 equiv) were dissolved in a 1:1 mixture pyridine/EtOH (60 mL). The solution was stirred at 70 °C for 18 h (TLC in 1:1 EtOAc/pentanes, Rf = 0.6), then co-concentrated with toluene. The residue was dissolved in CH₂Cl₂ (150 mL) then washed with 1 M HCl (2 × 150 mL) then sat. aq. NaHCO₃ (150 mL). The aqueous layers were re-extracted with CH₂Cl₂ (2 × 30 mL), and the organic layers were dried over Na₂SO₄ and concentrated. Column chromatography (EtOAc/pentanes, 4:6 → 9:11) gave tetrasaccharide acceptor 24 (0.72 g, 62%) as a white/pale yellow amorphous solid. ¹H NMR (600 MHz, Chloroform-d) δH 8.04 (d, J = 7.3 Hz, 2H, 2 × Bz), 8.00 – 7.88 (m, 16H, 2 × N-H, 14 × Bz), 7.53 (q, J = 7.0 Hz, 3H, 2 × Bz), 7.50 – 7.40 (m, 7H, 7 × Bz), 7.41 – 7.34 (m, 7H, 1 × N-H, 6 × Bz), 7.33 – 7.26 (m, 7H, 1 × N-H, 6 × Bz), 7.20 (t, J = 7.9 Hz, 2H, 2 × Bz), 5.94 (t, J =...
= 10.2 Hz, 1H, 1 × H-3), 5.88 (t, J = 10.2 Hz, 1H, 1 × H-3), 5.81 – 5.71 (m, 2H, 1 × H-3), 5.67 (t, J = 9.5 Hz, 1H, 1 × H-4), 5.53 (t, J = 9.4 Hz, 1H, 1 × H-4), 5.40 (t, J = 9.7 Hz, 1H, 1 × H-4), 5.26 (t, J = 9.7 Hz, 1H, 1 × H-4), 4.95 (d, J = 8.2 Hz, 1H, 1 × H-1), 4.83 (d, J = 8.2 Hz, 1H, 1 × H-1), 4.75 (d, J = 8.3 Hz, 1H, 1 × H-1), 4.64 – 4.55 (m, 3H, 1 × H-1, 2 × H-2), 4.51 (t, J = 9.7 Hz, 1H, 1 × H-5), 4.46 (q, J = 9.7 Hz, 1H, 1 × H-2), 4.42 – 4.33 (m, 2H, 1 × H-2, 1 × H-5), 4.24 – 4.19 (m, 1H, 1 × H-5), 4.12 – 3.98 (m, 3H, 2 × H-6a, OCH2HCH2), 3.89 – 3.82 (m, 2H, 1 × H-6a, 1 × H-6b), 3.79 – 3.68 (m, 4H, 1 × H-6a, 2 × H-6b, OCH2HCH2), 3.67 – 3.63 (m, 1H, 1 × H-5), 3.60 (dd, J = 12.7, 4.0 Hz, 1H, 1 × H-6b), 3.55 (t, J = 7.0 Hz, 2H, CH2Cl), 2.11 – 2.01 (m, 1H, CH2CH2CH2), 2.02 – 1.93 (m, 1H, CH2CH2CHH2), 2.02 – 1.93 (m, 1H, CH2CH2CHH2). 13C NMR (125 MHz, Chloroform-d) δC 166.94, 166.66, 166.53, 166.30 (4 × COPh), 166.20 (2 × COPh), 166.16, 165.33 (2 × COPh), 158.17 (d, J = 38.1 Hz, 1 × COCF3), 158.15 (d, J = 38.2 Hz, 1 × COCF3), 158.10 (d, J = 37.7 Hz, 1 × COCF3), 157.87 (d, J = 37.7 Hz, 1 × COCF3), 134.04, 133.86, 133.82, 133.80, 133.71, 133.56, 133.42, 133.41 (8 × Bz), 130.11 (2 × Bz), 130.00 (2 × Bz), 129.97 (2 × Bz), 129.91 (4 × Bz), 129.84 (2 × Bz), 129.80 (4 × Bz), 128.73 (2 × Bz), 128.70, 128.70 (2 × 4° Bz), 128.67 (4 × Bz), 128.65 (2 × 4° Bz), 128.63 (2 × Bz), 128.55 (2 × 4° Bz), 128.43 (2 × Bz), 128.41 (4 × Bz), 128.38 (2 × Bz), 128.24 (2 × 4° Bz), 115.61 (q, J = 288.0 Hz, 1 × CF3), 115.54 (q, J = 287.8 Hz, 1 × CF3), 115.41 (q, J = 287.5 Hz, 1 × CF3), 115.26 (q, J = 287.6 Hz, 1 × CF3), 103.15, 102.73, 101.70, 100.17 (4 × C-1), 75.05, 73.97, 73.22, 72.76 (4 × C-5), 72.39 (1 × C-3, 1 × C-6), 72.29, 72.00 (1 × C-3), 71.51 (1 × C-3, 1 × C-6), 71.21 (1 × C-4, 1 × C-6), 70.76, 69.76, 69.32 (3 × C-4), 66.64 (OCH2CH2), 61.27 (1 × C-6), 55.37, 55.36, 54.66, 54.64 (4 × C-2), 41.50 (CH2Cl), 32.02 (CH2CH2CH2). m/z (MALDI) calculated for C91H79N4O29F12NaCl [M+Na]+ 1977.42, found 1977.65.


Tetrasaccharide acceptor 24 (0.59 g, 0.30 mmol) and glycosyl bromide 17 (0.59 g, 0.90 mmol, 3 equiv.) were dissolved in freshly distilled CH2Cl2 (9 mL) containing freshly activated powdered 4Å MS (0.90 g). The mixture was cooled to -45 °C under Ar in the dark for 1 h. AgOTf (105 mg, 0.409 mmol, 4 equiv.) in dry toluene (0.6 mL) was added, and the reaction was stirred under the same conditions for 2 h (TLC in 4:6 EtOAc/pentanes, Rf = 0.4), then quenched with NEt3. The mixture was diluted with CH2Cl2 (25 mL) and filtered through celite. The solids were washed with CH2Cl2 (3 × 25 mL). The filtrate was washed with sat. aq. NaCl (2 × 75 mL). The aqueous
layers were re-extracted with CH₂Cl₂ (2 × 15 mL). The organic layers were dried over Na₂SO₄ and concentrated. Column chromatography (EtOAc/pentanes, 7:13 → 9:11) gave pentasaccharide 25 (0.68 g, 89%) as a pale yellow amorphous solid. ¹H NMR (600 MHz, Chloroform-d) δ H 8.49 (d, J = 10.1 Hz, 1H, 1 × N-H), 8.44 (d, J = 9.5 Hz, 1H, 1 × N-H), 8.20 (d, J = 7.2 Hz, 2H, 2 × Bz), 8.16 – 8.11 (m, 2H, 2 × Bz), 8.08 – 8.03 (m, 3H, 1 × N-H, 2 × Bz), 8.03 (d, J = 7.3 Hz, 2H, 2 × Bz), 8.00 – 7.92 (m, 12H, 12 × Bz), 7.83 – 7.78 (m, 3H, 3 × Phth), 7.67 – 7.64 (m, 1H, 1 × Phth), 7.60 – 7.53 (m, 5H, 5 × Bz), 7.51 – 7.39 (m, 12H, 12 × Bz), 7.38 – 7.26 (m, 8H, 8 × Bz), 7.18 – 7.13 (m, 5H, 5 × Bz), 6.91 (d, J = 8.6 Hz, 1H, 1 × N-H), 6.34 (dd, J = 10.7, 8.9 Hz, 1H, H-3IV), 6.25 (dd, J = 10.9, 9.4 Hz, 1H, 1 × H-3), 6.01 (t, J = 10.3 Hz, 1H, 1 × H-3), 5.86 (t, J = 10.3 Hz, 1H, 1 × H-3), 5.76 – 5.63 (m, 4H, 1 × H-3, H-4IV, 2 × H-4), 5.33 (t, J = 9.8 Hz, 1H, 1 × H-4), 5.15 (d, J = 8.5 Hz, 1H, H-1IV), 5.07 (d, J = 8.5 Hz, 1H, 1 × H-1), 5.00 (t, J = 9.8 Hz, 1H, 1 × H-4), 4.92 (q, J = 10.2 Hz, 1H, 1 × H-2), 4.87 (d, J = 8.4 Hz, 1H, 1 × H-1), 4.80 – 4.67 (m, 3H, 1 × H-1, 2 × H-5), 4.66 – 4.55 (m, 6H, 1H-1, H-2IV, 3 × H-2, 1 × H-5), 4.37 (dd, J = 12.3, 7.3 Hz, 1H, H-6aIV), 4.25 (dd, J = 12.9, 10.8 Hz, 1H, 1 × H-6a), 4.21 – 4.09 (m, 3H, 1H, 1 × H-5, 1 × H-6a, OCH₂HCl₂), 4.06 (dd, J = 12.2, 2.0 Hz, 1H, H-6bIV), 4.04 – 4.00 (m, 1H, H-5IV), 3.90 (d, J = 15.4 Hz, 1H, COCH₂Cl), 3.84 – 3.79 (m, 2H, OCH₂CH₂, COCH₂Cl), 3.75 (t, J = 13.3, 10.5 Hz, 1H, 1 × H-66), 3.71 – 3.59 (m, 5H, 1H-6a, 2 × H-6b, CH₂CH₂Cl), 3.38 (dd, J = 13.0, 1.7 Hz, 1H, 1H-6a), 3.23 (d, J = 11.4 Hz, 1H, 1 × H-6b), 2.21 – 2.12 (m, 1H, CH₂CH₂HCl₂), 2.11 – 2.01 (m, 1H, CH₂CH₂HCl₂). ¹C NMR (125 MHz, Chloroform-d) δ C 168.80, 167.37 (2 × COPh), 167.15 (COCH₂Cl), 166.71, 166.60, 166.55, 166.53, 166.44, 166.17, 165.81, 165.65, 164.96, 164.94 (10 × COPh), 158.52 (d, J = 38.1 Hz, 1 × COCF₃), 158.43 (d, J = 38.4 Hz, 1 × COCF₃), 158.27 (d, J = 37.9 Hz, 1 × COCF₃), 158.01 (d, J = 37.6 Hz, 1 × COCF₃), 135.12, 135.00 (2 × Phth), 133.83 (2 × Bz), 133.78, 133.65 (2 × Bz), 133.54 (2 × Bz), 133.37 (3 × Bz), 133.20 (1 × Bz), 130.69, 130.50 (2 × 4° Phth), 130.22 (2 × Bz), 130.11 (2 × Bz), 129.94 (2 × Bz), 129.92 (4 × Bz), 129.90 (4 × Bz), 129.89 (2 × Bz), 129.69 (2 × Bz), 129.31 (2 × Bz), 129.30 (4° Bz), 128.98 (2 × Bz, 4° Bz), 128.80 (2 × 4° Bz), 128.73 (2 × Bz), 128.71 (2 × Bz), 128.69 (2 × Bz), 128.67 (1 × 4° Bz), 128.59 (2 × Bz), 128.56 (1 × 4° Bz), 128.37 (4 × Bz, 1 × 4° Bz), 128.32 (4 × Bz), 128.26 (1 × 4° Bz), 128.22 (2 × Bz), 128.19, 128.09 (2 × 4° Bz), 124.04, 123.68 (2 × Phth), 115.82 (q, J = 287.8 Hz, 1 × CF₃), 115.70 (q, J = 287.1 Hz, 1 × CF₃), 115.58 (q, J = 287.8 Hz, 1 × CF₃), 115.01 (q, J = 287.0 Hz, 1 × CF₃), 103.95, 103.34, 101.50 (3 × C-1), 100.94 (C-1IV), 100.14 (1 × C-1), 74.33 (1 × C-6), 74.00 (1 × C-5), 73.68 (1 × C-6), 73.62 (1 × C-5), 73.57 (1 × C-6), 73.09 (C-5IV), 72.75 (1 × C-3), 72.52 (1 × C-5), 72.37 (1 × C-6), 72.36 (1 × C-3), 72.17 (1 × C-5), 72.05 (1 × C-4), 71.98 (1 × C-3), 71.74, 71.54 (2 × C-4), 71.32 (1 × C-3), 70.22 (1 × C-4), 69.97 (C-4IV), 69.78 (C-3IV), 66.81 (OCH₂CH₂), 64.14 (C-6IV), 55.36, 55.28, 55.09 (3 × C-2), 54.65 (C-2IV), 54.42 (1 × C-2), 41.70 (CH₂CH₂Cl), 40.60 (COCH₂Cl), 32.34 (CH₂CH₂CH₂). m/z (MALDI) calculated for C₁₂₁H₁₀₁N₅O₃₈F₁₂NaCl₂ [M+Na]+ 2552.52, found 2552.41.

3,4-Di-O-benzoyl-2-phthalimido-2-deoxy-β-D-glucopyranosyl-(1→6)-3,4-Di-O-benzoyl-2-trifluoroacetamido-2-deoxy-β-D-glucopyranosyl-(1→6)-3,4-di-O-benzoyl-2-trifluoroacetamido-2-deoxy-β-D-glucopyranosyl-(1→6)-3,4-di-O-benzoyl-2-trifluoroacetamido-2-deoxy-β-D-glucopyranosyl-(1→6)-chloropropyl 3,4-di-O-benzoyl-2-trifluoroacetamido-2-deoxy-β-D-glucopyranoside (26)
Pentasaccharide 25 (0.79 g, 0.31 mmol) and thiourea (120 mg, 1.58 mmol, 5 equiv) were dissolved in a 1:1 mixture pyridine/EtOH (30 mL). The solution was stirred at 70 °C for 18 h (TLC in 1:1 EtOAc/pentanes, Rf = 0.6), then co-concentrated with toluene. The residue was dissolved in CH2Cl2 (75 mL) then washed with 1 M HCl (2 × 75 mL) then sat. aq. NaHCO3 (75 mL). The aqueous layers were re-extracted with CH2Cl2 (2 × 15 mL), and the organic layers were dried over Na2SO4 and concentrated. Column chromatography (EtOAc/hexanes, 4:6 → 1:1) gave pentasaccharide acceptor 26 (0.44 g, 57%) as a white/pale yellow amorphous solid. 

1H NMR (600 MHz, Chloroform-d) δH 8.51 (d, J = 10.0 Hz, 1H, 1 × N-H), 8.42 (d, J = 9.5 Hz, 1H, 1 × N-H), 8.15 (dd, J = 8.1, 1.1 Hz, 2H, 2 × Bz), 8.09 (dd, J = 8.4, 1.4 Hz, 2H, 2 × Bz), 8.07 (d, J = 9.7 Hz, 1H, 1 × N-H), 8.05 – 8.00 (m, 4H, 4 × Bz), 8.01 – 7.92 (m, 8H, 8 × Bz), 7.93 (dd, J = 8.1, 1.0 Hz, 2H, 2 × Bz), 7.82 – 7.74 (m, 3H, 3 × Phth), 7.60 – 7.52 (m, 7H, 7 × Bz), 7.49 – 7.37 (m, 14H, 13 × Bz, 1 × Phth), 7.35 – 7.28 (m, 6H, 6 × Bz), 7.25 (t, J = 7.9 Hz, 2H, 2 × Bz), 7.21 (t, J = 7.9 Hz, 2H, 2 × Bz), 7.16 (t, J = 7.9 Hz, 2H, 2 × Bz), 7.08 (d, J = 9.1 Hz, 1H, 1 × N-H), 6.37 (dd, J = 10.6, 9.1 Hz, 1H, H-3IV), 6.18 (dd, J = 10.7, 9.6 Hz, 1H, 1 × H-3), 5.99 (t, J = 9.8 Hz, 1H, 1 × H-3), 5.76 – 5.69 (m, 2H, 1 × H-3, 1 × H-4), 5.57 (dd, J = 10.7, 9.0 Hz, 1H, 1 × H-4), 5.41 – 5.31 (m, 2H, H-4IV, 1 × H-4), 5.23 (d, J = 8.5 Hz, 1H, H-1IV), 5.04 (d, J = 8.5 Hz, 1H, 1 × H-1), 5.04 (t, J = 9.8 Hz, 1H, 1 × H-4), 4.86 (q, J = 10.3 Hz, 1H, 1 × H-2), 4.85 (d, J = 8.2 Hz, 1H, 1 × H-1), 4.77 – 4.53 (m, 8H, 2 × H-1, 3 × H-2, 3 × H-5), 4.51 (dd, J = 10.6, 8.7 Hz, 1H, H-2IV), 4.26 – 4.15 (m, 3H, 1 × H-5, 2 × H-6a), 4.13 – 4.03 (m, 3H, 1 × H-5, 2 × H-6a), 3.83 – 3.76 (m, 2H, H-5IV, OCH2CH2), 3.77 – 3.70 (m, 2H, H-6aIV, 1 × H-6a), 3.65 – 3.53 (m, 5H, H-6bIV, 2 × H-6b, CH2Cl), 3.41 (dd, J = 11.9, 0.8 Hz, 1H, 1 × H-6b), 2.14 – 2.09 (m, 1H, CH2CH2CH2), 2.06 – 1.99 (m, 1H, CH2CH2CH2). 13C NMR (125 MHz, Chloroform-d) δC 168.61, 167.53 (2 × COPh), 167.09, 166.59, 166.53, 166.52, 166.42, 166.25, 166.10, 165.73, 165.46, 164.89 (10 × COPh), 158.72 (d, J = 38.1 Hz, 1 × COCF3), 158.41 (d, J = 38.7 Hz, 1 × COCF3), 158.29 (d, J = 37.8 Hz, 1 × COCF3), 158.01 (d, J = 37.6 Hz, 1 × COCF3), 134.93 (2 × Phth), 133.87, 133.81, 133.76 (3 × Bz), 133.68 (2 × Bz), 133.52 (2 × Bz), 133.38, 133.28, 133.20 (3 × Bz), 130.84, 130.52 (2 × 4° Phth), 130.17 (2 × Bz), 130.14 (2 × Bz), 130.09 (2 × Bz), 130.04 (2 × Bz), 129.99 (2 × Bz), 129.93 (2 × Bz), 129.91 (2 × Bz), 129.87 (2 × Bz), 129.81 (2 × Bz), 129.48 (2 × Bz), 129.01, 128.97 (2 × Bz), 128.94 (2 × Bz), 128.86 (2 × Bz), 128.79 (1 × 4° Bz), 128.73 (2 × 4° Bz), 128.72 (1 × 4° Bz), 128.69 (2 × Bz), 128.62 (2 × Bz), 128.59 (2 × Bz, 1 × 4° Bz), 128.42 (1 × 4° Bz), 128.40 (2 × Bz), 128.39 (2 × Bz), 128.33 (2 × Bz, 1 × 4° Bz), 128.32 (2 × Bz), 128.30 (2 × Bz), 128.11 (1 × 4° Bz), 123.94, 123.48 (2 × Phth), 115.76 (q, J = 287.7 Hz, 1 × CF3), 115.67 (q, J = 287.1 Hz, 1 × CF3), 115.59 (q, J = 287.8 Hz, 1 × CF3), 115.02 (q, J = 287.0 Hz, 1 × CF3), 104.20, 103.43, 101.61, 100.11 (4 × C-1), 100.09 (C-1IV), 75.12 (C-5IV), 74.64 (1 × C-5), 74.25, 73.71 (2 × C-6), 73.64 (1 × C-5), 72.74 (1 × C-3), 72.67 (1 × C-5), 72.41 (1 × C-6), 72.37 (1 ×
C-3), 72.23 (1 × C-5), 71.89, 71.67 (2 × C-4), 71.62 (1 × C-4, 1 × C-6), 71.52, 71.50 (2 × C-2), 70.36 (C-4), 70.03 (C-2), 54.56, 54.39 (2 × C-2), 41.66 (CH<sub>2</sub>Cl), 32.24 (CH<sub>2</sub>C<sub>2</sub>H), 66.73 (OCH<sub>2</sub>CH<sub>2</sub>, 1 × C-4, 1 × C-6), 55.22, 55.10 (2 × C-2), 55.03 (C-2), 41.66 (CH<sub>2</sub>Cl), 32.24 (CH<sub>2</sub>C<sub>2</sub>H), 66.73 (OCH<sub>2</sub>CH<sub>2</sub>, 1 × C-4, 1 × C-6), 55.22, 55.10 (2 × C-2), 55.03 (C-2), 41.66 (CH<sub>2</sub>Cl), 32.24 (CH<sub>2</sub>C<sub>2</sub>H), 66.73 (OCH<sub>2</sub>CH<sub>2</sub>, 1 × C-4, 1 × C-6), 55.22, 55.10 (2 × C-2), 55.03 (C-2), 41.66 (CH<sub>2</sub>Cl), 32.24 (CH<sub>2</sub>C<sub>2</sub>H).

3,4-Di-O-benzoyl-6-chloroacetyl-2-phthalimido-2-deoxy-β-D-glucopyranosyl-(1→6)-3,4-di-O-benzoyl-2-trifluoroacetamido-2-deoxy-β-D-glucopyranosyl-(1→6)-3,4-di-O-benzoyl-2-trifluoroacetamido-2-deoxy-β-D-glucopyranosyl-(1→6)-3,4-di-O-benzoyl-2-trifluoroacetamido-2-deoxy-β-D-glucopyranosyl-(1→6)-chloropropyl 3,4-di-O-benzoyl-2-trifluoroacetamido-2-deoxy-β-D-glucopyranoside (27)

[Diagram of molecule]

Pentasaccharide acceptor 26 (430 mg, 0.175 mmol) and glycosyl bromide 13 (381 mg, 0.350 mmol, 2 equiv; 388 mg crude) were dissolved in freshly distilled CH<sub>2</sub>Cl<sub>2</sub> (5.2 mL) containing freshly activated powdered 4Å MS (520 mg). The mixture was cooled to -45 °C under Ar in the dark for 1 h. AgOTf (121 mg, 0.471 mmol, 2.7 equiv.) in dry toluene (1.0 mL) was added, and the reaction was stirred under the same conditions for 2 h (TLC in 4:6 EtOAc/pentanes, R<sub>f</sub> = 0.3), then quenched with NEt<sub>3</sub>. The mixture was diluted with CH<sub>2</sub>Cl<sub>2</sub> (15 mL) and filtered through celite. The solids were washed with CH<sub>2</sub>Cl<sub>2</sub> (3 × 15 mL). The filtrate was washed with sat. aq. NaCl (2 × 45 mL). The aqueous layers were re-extracted with CH<sub>2</sub>Cl<sub>2</sub> (2 × 10 mL). The organic layers were dried over Na<sub>2</sub>SO<sub>4</sub> and concentrated. Column chromatography (acetone/hexanes, 7:13 → 9:11) gave a crude mixture containing heptasaccharide 27 and pentasaccharide acceptor 26. The crude mixture was dissolved in CH<sub>2</sub>Cl<sub>2</sub> (1.8 mL). Pyridine (28.4 μL, 0.351 mmol) was added, followed by chloroacetyl chloride (13.7 μL, 0.176 mmol). The reaction was stirred at RT for 30 min. The solution was diluted with CH<sub>2</sub>Cl<sub>2</sub> (5 mL) then washed with 1 M HCl (2 × 5 mL) then sat. aq. NaHCO<sub>3</sub> (5 mL). The aqueous layers were re-extracted with CH<sub>2</sub>Cl<sub>2</sub> (2 × 1 mL). The organic layers were dried over Na<sub>2</sub>SO<sub>4</sub> and concentrated. Column chromatography (acetone/pentanes, 32:68 → 1:1) gave heptasaccharide 27 (284 mg, 47%) as a pale yellow amorphous solid, and chloroacetylated pentasaccharide 25 (68 mg, 15%) as a pale yellow amorphous solid. Analytical Data for 27: 1H NMR (600 MHz, Chloroform-d) δ<sub>H</sub> 8.47 (d, J = 9.9 Hz, 1H, 1 × N-H), 8.32 (d, J = 7.0 Hz, 1H, 1 × N-H), 8.26 – 8.23 (m, 2H, 2 × Bz), 8.21 (d, J = 9.3 Hz, 1H, 1 × N-H), 8.18 – 8.12 (m, 5H, 1 × N-H, 4 × Bz), 8.10 – 8.08 (m, 2H, 2 × Bz), 8.06 – 8.00 (m, 6H, 6 × Bz), 7.97 (d, J = 9.4 Hz, 1H, 1 × N-H), 7.95 – 7.87 (m, 12H, 12 × Bz), 7.74 – 7.70 (m, 4H, 2 × Bz, 2 × Phth), 7.66 – 7.23 (m, 37H, 36 × Bz, 1 × Phth), 7.21 – 7.16 (m, 2H, 2 × Bz), 7.11 (t, J = 7.9 Hz, 2H, 2 × Bz), 7.03 (d, J = 9.6 Hz, 1H, 1 × N-H), 7.00 (t, J = 7.6 Hz, 3H, 2 × Bz, 1 × Phth), 6.51 (dd, J = 11.0, 9.1 Hz, 1H, H-3<sup>IV</sup>), 6.25 – 6.21 (m, 2H, 2 × H-3), 6.07 (t, J = 10.1 Hz, 1H, 1 × H-3), 5.99 (t, J = 10.1 Hz, 1H, 1 × H-3), 5.94 (t,
10.3 Hz, 1H, 1 × H-3), 5.68 – 5.64 (m, 1H, 1 × H-3), 5.61 (t, J = 9.7 Hz, 1H, 1 × H-4), 5.53 (t, J = 9.8 Hz, 1H, 1 × H-4), 5.48 – 5.38 (m, 4H, H-4IV, 3 × H-4), 5.33 (d, J = 8.8 Hz, 1H, 1 × H-1), 5.15 (t, J = 9.8 Hz, 1H, 1 × H-4), 5.07 (t, J = 8.9 Hz, 2H, H-1IV, 1 × H-1), 4.93 – 4.80 (m, 4H, 2 × H-1, 1 × H-2, 1 × H-5), 4.79 – 4.67 (m, 5H, 1 × H-1, H-2IV, 1 × H-2, 2 × H-5), 4.64 – 4.52 (m, 5H, 1 × H-1, 3 × H-2, 1 × H-5), 4.30 – 4.24 (m, 2H, 2 × H-6a), 4.21 – 4.10 (m, 5H, H-5IV, 1 × H-6a, 1 × H-6b, OCH₂H₃), 3.98 (dd, J = 13.00, 11.25 Hz, 1H, 1 × H-6a), 3.95 – 3.85 (m, 4H, 1 × H-2, 2 × H-5, 1 × H-6a), 3.83 – 3.73 (m, 3H, H-6bIV, OCH₂H₂Cl), 3.69 – 3.60 (m, 3H, 1 × H-6a, CH₂CH₂Cl), 3.57 (d, J = 8.8 Hz, 1H, 1 × H-1), 3.53 (d, J = 15.4 Hz, 1H, COCH₂HCl), 3.50 – 3.46 (m, 1H, 1 × H-6b), 3.44 – 3.37 (m, 2H, 2 × H-6b), 3.32 – 3.28 (m, 1H, 1 × H-6b), 2.14 – 2.07 (m, 1H, CH₂CH₂CH₂), 2.05 – 1.98 (m, 1H, CH₂CH₂HCH₂).

13C NMR (125 MHz, Chloroform-d) δC 168.64, 168.38 (2 × COPth), 167.25 (COC₂H₅), 166.85, 166.84, 166.53, 166.50, 166.38, 166.26, 166.18, 165.95, 165.85, 165.72, 165.60, 165.16, 165.04, 164.88 (14 × COPh), 158.75 (d, J = 38.2 Hz, 1 × COCF₃), 158.52 (d, J = 37.7 Hz, 1 × COCF₃), 158.48 (d, J = 38.4 Hz, 1 × COCF₃), 158.11 (d, J = 37.4 Hz, 1 × COCF₃), 135.11, 134.92 (2 × Phth), 133.99, 133.89, 133.87, 133.75, 133.63, 133.62, 133.56, 133.43, 133.28 (9 × Bz), 133.24 (2 × Bz), 133.15 (1 × Bz), 133.12 (2 × Bz), 130.56 (2 × Bz), 130.32 (2 × Bz), 130.31 (2 × Bz), 130.19 (2 × Bz), 130.05 (2 × Bz), 129.96 (2 × Bz), 129.87 (4 × Bz), 129.84 (2 × Bz), 129.75 (2 × Bz), 129.70 (2 × Bz), 129.67 (2 × Bz), 129.59 (2 × Bz), 129.03 (1 × 4° Bz), 129.00 (2 × 4° Bz), 128.99 (2 × Bz), 128.96 (2 × Bz), 128.95, 128.91, 128.88, 128.78, 128.77 (5 × 4° Bz), 128.72 (2 × Bz), 128.70, 128.66 (2 × 4° Bz), 128.62 (2 × Bz), 128.58 (2 × 4° Bz), 128.57 (2 × Bz), 128.49 (2 × Bz), 128.44 (1 × 4° Bz), 128.40 (2 × Bz), 128.38 (2 × Bz), 128.35 (6 × Bz), 128.26 (4 × Bz), 128.23 (2 × Bz), 128.14 (1 × 4° Bz), 124.33, 123.52 (2 × Phth), 115.78 (q, J = 287.6 Hz, 2 × CF₃), 115.71 (q, J = 287.8 Hz, 1 × CF₃), 115.40 (q, J = 288.5 Hz, 1 × CF₃), 115.20 (q, J = 286.9 Hz, 1 × CF₃), 115.19 (q, J = 287.0 Hz, 1 × CF₃), 103.92, 103.26, 102.65, 101.38 (4 × C-1), 100.80 (C-1IV), 100.43, 100.20 (2 × C-1), 74.32 (C-5IV), 74.00, 73.67, 73.43, 72.97, 72.88, 72.75, 72.67, 72.49, 72.47, 72.34, 72.15, 72.09, 71.87, 71.48, 71.27, 70.88, 70.28 (C-4IV), 69.97, 69.54, 69.30 (C-3IV), 66.76 (OCH₂CH₂), 63.67 (C-6IV), 57.88, 55.44, 55.30 (3 × C-2), 55.18 (C-2IV), 55.08, 54.83 (3 × C-2), 41.67 (CH₂CH₂Cl), 40.52 (COCH₂Cl), 32.30 (CH₂CH₂CH₂). m/z (MALDI) calculated for C₁₆₅H₁₃₇N₇O₅₂F₁₈Cl₂Na [M+Na]+ 3482.73, found 3482.12.

Heptasaccharide 27 (271 mg, 0.078 mmol) was dissolved in a 2:4:1 mixture of 0.5 M NaOH (22 mL, 11.0 mmol, 140 equiv.), THF (44 mL), and MeOH (11 mL). The reaction was stirred at 40 °C for 3 h. The solution was concentrated and dried under high vacuum. The residue was dissolved in a 1:1 mixture of pyridine (25 mL, 309.1 mmol, 3968 equiv.) and Ac₂O (25 mL, 264.5 mmol, 3395 equiv.). The reaction was stirred at 50 °C for 2 h, then left to attain RT for 16 h (TLC in 8:2 EtOAc/EtOH, Rₜ = 0.3). The solution co-concentrated with toluene. The residue was dissolved in CHCl₃ (120 mL) then washed with 1 M HCl (60 mL) then aq. NaHCO₃ (60 mL). The aqueous layers were re-extracted with CHCl₃ (3 × 30 mL). The organic layers were dried over Na₂SO₄ and concentrated. Column chromatography (EtOAc/EtOH, 19:1 → 9:1) gave heptasaccharide 28 (60 mg, 34%) as a white amorphous solid.

1H NMR (600 MHz, Acetone-d₆) δH 8.12 (d, J = 10.0 Hz, 1H, 1 × N-H), 8.01 – 7.99 (m, 1H, 1 × Phth), 7.98 – 7.91 (m, 3H, 3 × Phth), 7.87 (d, J = 10.0 Hz, 1H, 1 × N-H), 7.85 (d, J = 9.8 Hz, 1H, 1 × N-H), 7.51 (d, J = 10.1 Hz, 1H, 1 × N-H), 7.47 (d, J = 9.8 Hz, 1H, 1 × N-H), 7.46 (d, J = 9.5 Hz, 1H, 1 × N-H), 5.92 (dd, J = 10.7, 8.8 Hz, 1H, H-3 IV), 5.48 – 5.41 (m, 2H, H-1 IV, 1 × H-3), 5.41 – 5.33 (m, 3H, 3 × H-3), 5.28 – 5.16 (m, 3H, 1 × H-1, 2 × H-3), 5.13 (dd, J = 10.3, 9.0 Hz, 1H, 1 × H-4), 5.05 – 4.91 (m, 5H, H-4 IV, 4 × H-4), 4.81 – 4.72 (m, 4H, 2 × H-1, 1 × H-5), 4.70 – 4.61 (m, 4H, 2 × H-2, 1 × H-4, 1 × H-5), 4.55 (td, J = 10.4, 3.2 Hz, 1H, 1 × H-5), 4.49 – 4.41 (m, 4H, H-2 IV, 2 × H-2, H-5 IV), 4.35 (dt, J = 10.2, 9.1 Hz, 1H, 1 × H-2), 4.25 (q, J = 9.6 Hz, 1H, 1 × H-2), 4.20 (dd, J = 12.5, 4.7 Hz, 1H, 1 × H-6a), 4.14 – 4.04 (m, 5H, 2 × H-2, 2 × H-5, H-6aIV), 4.01 – 3.92 (m, 3H, 2 × H-2, 2 × H-5, H-6aIV), 3.75 – 3.66 (m, 2 × H-2, 2 × H-5, H-6aIV, 1 × H-6b), 3.91 – 3.78 (m, 6H, 1 × H-5, 1 × H-6a, H-6bIV, 1 × H-6b, OCH₃CH₂OCH₃, OCH₃CH₂OCH₃), 3.75 – 3.66 (m, 6H, 2 × H-6a, 2 × H-6b, CH₂Cl₂), 3.59 – 3.52 (m, 2H, 2 × H-6b), 3.48 (dd, J = 12.5, 2.7 Hz, 1H, 1 × H-6b), 2.20, 2.15, 2.12 (3 s, 9H, 3 × Ac), 2.11 (s, 6H, 2 × Ac), 2.07 (s, 3H, 1 × Ac), 2.05 (m, 1H, CH₂CH₂H₂CH₂O), 2.03, 2.02 (2 s, 6H, 2 × Ac), 2.00 (m, 1H, CH₂CH₂H₂CH₂), 1.98, 1.98, 1.97, 1.96, 1.95, 1.95, 1.92, 1.89, 1.87, 1.86, 1.86, 1.82, 1.77 (13 s, 39H, 13 × Ac).

13C NMR (125 MHz, Acetone-d₆) δC 171.62, 171.43, 171.21, 171.08, 170.98, 170.78, 170.72, 170.69, 170.68, 170.64, 170.61, 170.60, 170.54, 170.45, 170.34, 170.33, 170.32, 170.12, 170.08, 169.84, 169.54 (21 × COCH₃), 169.31, 169.04 (2 × COPhth), 163.30, 163.05 (2 × Phth), 132.06 (2 × 4° Phth), 124.85, 124.22 (2 × Phth), 104.73, 104.32, 104.19, 103.06, 101.25, 100.74 (6 × C-1), 100.69 (C-1 IV), 75.31, 75.14 (2 × C-3), 74.70 (1 × C-5), 73.89 (1 × C-3), 73.70 (C-5 IV), 73.55 (1 × C-4), 73.43, 73.42 (2 × C-3), 73.39 (2 × C-5), 73.27 (C-6 IV), 73.13, 73.01 (2 × C-6), 72.79 (1 × C-3), 72.42 (1 × C-6), 72.27 (1 × C-4), 72.23, 72.20 (2 × C-5), 72.15, 71.97 (2 × C-4), 71.51 (1 × C-5), 71.12 (1 × C-4), 70.93 (C-3 IV), 70.59 (C-4 IV), 69.80(1 × C-4), 66.73 (OCH₃CH₂), 65.43 (1 × C-6), 62.66 (1 × C-6), 56.61 (C-2 IV), 55.75, 55.30, 55.21, 54.91, 54.74, 52.06 (6 × C-2), 42.91 (CH₂Cl₂), 33.19 (CH₂CH₂CH₂), 23.51, 23.32, 23.20, 23.18 (4 × NCOCH₃), 22.98 (2 × NCOCH₃), 21.27, 21.07, 21.02 (3 × OCOCH₃), 20.89 (2 × OCOCH₃), 20.73 (3 × OCOCH₃), 20.70 (2 × OCOCH₃), 20.64 (3 × OCOCH₃), 20.60, 20.47 (2 × OCOCH₃). m/z (ESI) calculated for C₉₂H₁₂₀N₇O₅₂Cl [M+H]+ 2234.73, found 2234.72.

Heptasaccharide 28 (55.0 mg, 0.025 mmol) and NaN₃ (48.0 mg, 0.738 mmol, 30 equiv.) were dissolved in dry DMF (2.5 mL). The reaction was stirred at 80 °C for 45 h (TLC in 8:2 EtOAc/EtOH, Rf = 0.3). The solution was diluted with EtOAc (40 mL) then washed with H₂O (40 mL). The aqueous layer was re-extracted with EtOAc (5 × 20 mL). The organic layers were dried over Na₂SO₄ and concentrated. Column chromatography (EtOAc/EtOH, 99:1 → 9:1) gave azidopropyl glycoside 29 (35.5 mg, 64%) as a white amorphous solid.

**1H NMR (600 MHz, Acetone-d₆)**  δ H 8.11 (d, J = 10.1 Hz, 1H, 1 × N-H), 8.01 – 7.99 (m, 1H, 1 × Phth), 7.98 – 7.94 (m, 3H, 3 × Phth), 7.87 (d, J = 9.7 Hz, 1H, 1 × N-H), 7.83 (d, J = 9.8 Hz, 1H, 1 × N-H), 7.51 (d, J = 10.2 Hz, 1H, 1 × N-H), 7.46 (d, J = 9.5 Hz, 2H, 2 × N-H), 5.92 (dd, J = 10.7, 8.7 Hz, 1H, H-3 IV), 5.46 – 5.42 (m, 2H, H-1 IV, 1 × H-3), 5.41 – 5.33 (m, 3H, 3 × H-3), 5.27 – 5.17 (m, 3H, 1 × H-1, 2 × N-H), 4.80 – 4.72 (m, 4H, 2 × H-1, 1 × H-5), 4.70 – 4.62 (m, 4H, 2 × H-1, 1 × H-4), 4.55 (td, J = 10.4, 9.0 Hz, 1H, 1 × H-4), 4.50 – 4.41 (m, 4H, H-4 IV, 4 × H-4), 4.35 – 4.22 (m, 4H, 3 × H-1, 1 × H-5), 4.25 (q, J = 9.6 Hz, 1H, 1 × H-2), 4.19 (dd, J = 12.5, 4.6 Hz, 1H, 1 × H-6a), 4.15 – 4.04 (m, 5H, 2 × H-2, 2 × H-5, H-6a IV), 3.89 – 3.81 (m, 5H, 1 × H-5, 1 × H-6a, H-6b IV), OC₂H₂N₃, 2.20, 2.15, 2.11, 2.11, 2.07, 0.03, 2.02, 1.98, 1.98, 1.97, 1.96, 1.95 (14 s, 39H, 13 × Ac), 1.94 – 1.93 (m, 1H, CH₂CH₂CH₂), 1.91, 1.89, 1.87 (3 s, 9H, 3 × Ac), 1.86 (s, 6H, 2 × Ac), 1.81 (s, 3H, 1 × Ac), 1.81 – 1.80 (m, 1H, CH₂CH₂CH₂), 1.77 (s, 3H, 1 × Ac). 

**13C NMR (125 MHz, Acetone-d₆)** δ C 171.61, 171.42, 171.19, 171.08, 170.98, 170.71, 170.68, 170.67, 170.64, 170.62, 170.60, 170.54, 170.45 (14 × COCH₃), 170.33 (2 × COCH₃), 170.17, 170.08, 170.05, 169.84, 169.54 (5 × COCH₃), 169.32, 169.04 (2 × COPhth), 163.31, 136.07 (2 × Phth), 132.17, 132.03 (2 × 4° Phth), 124.86, 124.22 (2 × Phth), 104.74, 104.32, 104.20, 103.04, 101.09, 100.73 (6 × C-1), 100.70 (C-1 IV), 75.36, 75.14 (2 × C-3), 74.71 (1 × C-5), 73.88 (1 × C-3), 73.70 (C-5 IV), 73.57 (1 × C-4), 73.45, 73.42 (2 × C-3), 73.40 (2 × C-5), 73.29 (C-6 IV), 73.12, 73.00 (2 × C-6), 72.79 (1 × C-3), 72.42 (1 × C-6), 72.23 (1 × C-4, 1 × C-5), 72.21 (1 × C-5), 72.16, 71.98 (2 × C-4), 71.50 (1 × C-5), 71.11 (1 × C-4), 70.93 (C-3 IV), 70.59 (C-4 IV), 69.82 (1 × C-4), 66.69 (OCH₂CH₂), 65.44, 62.68 (2 × C-6), 56.62 (C-2 IV), 55.77, 55.29, 55.23, 54.92, 54.74, 52.06 (6 × C-2), 49.30 (CH₂N₃), 29.26 (CH₂CH₂CH₂), 23.43, 23.30, 23.20,
23.17, 23.00, 22.98 (6 × NCOCH₃), 21.25, 21.07, 21.02 (3 × OCOCH₃), 20.89 (2 × OCOCH₃), 20.73 (2 × OCOCH₃), 20.70 (2 × OCOCH₃), 20.68 (1 × OCOCH₃), 20.64 (3 × OCOCH₃), 20.60, 20.47 (2 × OCOCH₃). m/z (ESI) calculated for C₉₅H₁₃₀N₁₀O₅₂ [M+2H]²⁺ 1121.89, found 1121.89.

3,4-Di-O-benzoyl-6-chloroacetyl-2-phthalimido-2-deoxy-β-D-glucopyranosyl-(1→6)-3,4-di-O-benzoyl-2-trifluoroacetamido-2-deoxy-β-D-glucopyranosyl-(1→6)-3,4-Di-O-benzoyl-2-trifluoroacetamido-2-deoxy-β-D-glucopyranosyl(1→6)-3,4-di-O-benzoyl-2-trifluoroacetamido-2-deoxy-β-D-glucopyranosyl-(1→6)-chloroethyl 3,4-di-O-benzoyl-2-trifluoroacetamido-2-deoxy-β-D-glucopyranoside (30)

Chloroethyl heptasaccharide 30 was synthesized using the same methods as chloropropyl heptasaccharide 27. ¹H NMR (600 MHz, Chloroform-d) δH 8.54 (d, J = 9.7 Hz, 1H, 1 × N-H), 8.36 – 8.28 (m, 3H, 3 × N-H), 8.22 – 8.19 (m, 2H, 2 × Bz), 8.18 – 8.16 (m, 2H, 2 × Bz), 8.12 (d, J = 7.3 Hz, 2H, 2 × Bz), 8.08 – 8.04 (m, 9H, 1 × N-H, 8 × Bz), 8.03 – 8.01 (m, 2H, 2 × Bz), 7.98 – 7.88 (m, 12H, 12 × Bz), 7.78 – 7.70 (m, 4H, 2 × Bz, 2 × Phth), 7.66 – 7.22 (m, 28H, 27 × Bz, 1 × Phth), 7.18 (t, J = 7.1 Hz, 2H, 2 × Bz), 7.15 – 7.11 (m, 3H, 1 × N-H, 2 × Bz), 7.03 – 6.97 (m, 3H, 2 × Bz, 1 × Phth), 6.54 (dd, J = 11.0, 9.4 Hz, 1H, H-3⁴), 6.28 (t, J = 10.6 Hz, 1H, 1 × H-3), 6.26 (t, J = 10.2 Hz, 1H, 1 × H-3), 6.12 (t, J = 10.0 Hz, 1H, 1 × H-3), 6.07 (t, J = 10.2 Hz, 1H, 1 × H-3), 6.01 (t, J = 10.2 Hz, 1H, 1 × H-3), 5.71 (dd, J = 10.4, 9.3 Hz, 1H, 1 × H-3), 5.59 (t, J = 9.7 Hz, 1H, 1 × H-4), 5.54 (t, J = 9.8 Hz, 1H, 1 × H-4), 5.53 – 5.43 (m, 2H, 2 × H-1), 5.42 (t, J = 9.5 Hz, 1H, 1 × H-4, 5.39 (t, J = 9.6 Hz, 1H, H-4⁴), 5.35 (d, J = 8.2 Hz, 1H, 1 × H-1), 5.21 (t, J = 9.8 Hz, 1H, 1 × H-4), 5.17 (d, J = 8.5 Hz, 1H, 1 × H-1), 5.08 (d, J = 8.4 Hz, 1H, H-1⁴), 4.98 – 4.58 (m, 13H, 3 × H-1, H-2⁴, 5 × H-2, H-5⁴, 3 × H-5), 4.56 (d, J = 8.4 Hz, 1H, 1 × H-1), 4.34 – 4.14 (m, 5H, 1H, 1 × H-5, 3 × H-6a, 1 × H-6b), 4.10 – 4.05 (m, 1H, OCHCH₂CH₂), 4.04 – 3.81 (m, 6H, 2 × H-5, H-6a⁴, 1 × H-6a, OCHCH₂CH₂, CH₂CHHCl), 3.80 – 3.72 (m, 2H, 1 × H-6a, COCH₂HCl), 3.69 – 3.61 (m, 2H, 1 × H-6a, CH₂CHHCl), 3.59 (d, J = 11.2 Hz, 1H, 1 × H-6b), 3.55 (d, J = 15.4 Hz, 1H, COCH₂HCl), 3.50 (d, J = 11.6 Hz, 1H, 1 × H-6a), 3.47 – 3.39 (m, 3H, H-6b⁴, 2 × H-6b), 3.33 (d, J = 11.3 Hz, 1H, 1 × H-6b). ¹³C NMR (125 MHz, Chloroform-d) δC 168.62, 168.46 (2 × COPhth), 167.20 (COCH₂Cl), 166.86 (2 × COPh), 166.53, 166.50, 166.30, 166.23, 166.17, 165.94, 165.80, 165.73, 165.62, 165.17, 165.04, 164.91 (12 × COPh), 158.84 (d, J = 38.6 Hz, 1H, COCH₂F₃), 158.67 (d, J = 38.0 Hz, 1 × COCH₂F₃), 158.52 (d, J = 38.6 Hz, 1 × COCH₂F₃), 158.30 (d, J = 37.7 Hz, 1 × COCH₂F₃), 158.19 (d, J = 37.7 Hz, 1 × COCH₂F₃), 157.60 (d, J = 37.6 Hz, 1 × COCH₂F₃), 157.07, 156.95 (2 × Phth), 133.97, 133.92, 133.89, 133.74 (4 × Bz), 133.66 (2 × Bz), 133.45, 133.35 (2 × Bz), 133.25 (2 × Bz), 133.16 (1 × Bz), 133.13 (2 × Bz), 130.86 (4° Phth), 130.35 (2 × Bz), 130.31 (4° Phth), 130.21 (2 × Bz), 130.19 (2 × Bz), 130.09 (2 × Bz),
130.06 (2 × Bz), 129.94 (2 × Bz), 129.88 (2 × Bz), 129.85 (4 × Bz), 129.74 (4 × Bz), 129.68 (2 × Bz), 129.59 (2 × Bz), 129.99 (6 × Bz), 128.97, 128.93, 128.90, 128.87, 128.79 (5 × 4° Bz), 128.74 (2 × Bz), 128.72, 128.68 (2 × 4° Bz), 128.64 (2 × Bz), 128.62, 128.57 (2 × 4° Bz), 128.56 (2 × Bz), 128.49 (2 × Bz), 128.47 (4° Bz), 128.44 (2 × Bz), 128.37 (4° Bz), 128.34 (6 × Bz), 128.26 (2 × Bz), 128.25 (4 × Bz), 128.18 (4° Bz), 124.29, 123.55 (2 × Phth), 115.79 (q, \( J = 287.2 \) Hz, 1 × CF₃), 115.72 (q, \( J = 287.7 \) Hz, 2 × CF₃), 115.41 (q, \( J = 288.5 \) Hz, 1 × CF₃), 115.22 (q, \( J = 286.7 \) Hz, 1 × CF₃), 103.98, 103.36, 102.81, 101.51 (4 × C-1), 100.90 (C-1IV), 100.87, 100.41 (2 × C-1), 74.33 (1 × C-5), 74.07 (1 × C-6), 73.75 (C-6IV), 73.70, 73.49 (2 × C-6), 72.99 (C-5IV), 72.89 (1 × C-3, 1 × C-5), 72.78 (1 × C-5), 72.68 (1 × C-3), 72.64 (1 × C-4), 72.42 (C-4IV, 1 × C-4, 2 × C-5), 72.29 (1 × C-5), 72.21 (1 × C-4), 72.05 (1 × C-3), 71.88, 71.53 (2 × C-6), 71.46 (1 × C-4), 71.32, 70.77 (2 × C-3), 70.57 (OCH₂CH₂), 70.34 (1 × C-4), 69.98 (1 × C-3), 69.54 (1 × C-4), 69.31 (C-3IV), 63.69 (1 × C-6), 57.92, 55.53, 55.30 (3 × C-2), 55.18 (C-2IV), 55.05 (1 × C-2), 54.92 (2 × C-), 41.82 (CH₂CH₂Cl), 40.52 (COCH₂Cl). m/z (MALDI) calculated for C₁₆₄H₁₃₅N₇O₅₂F₁₈Cl₂Na [M+Na]⁺ 3468.71, found 3468.41.


Chloroethyl heptasaccharide 30 (105 mg, 0.030 mmol) was dissolved in a 2:4:1 mixture of 4 M NaOH (1.0 mL, 4.0 mmol, 131 equiv.), THF (2.0 mL), and MeOH (0.5 mL). The reaction was stirred at 50 °C for 5 h. The solution was concentrated and dried under high vacuum. The residue was dissolved in a 1:1 mixture of pyridine (4 mL, 49.5 mmol, 1624 equiv.) and Ac₂O (4 mL, 42.3 mmol, 1390 equiv.). The reaction was stirred at RT for 16 h (TLC in 8:2 EtOAc/EtOH, \( R_f = 0.2 \)). The solution co-concentrated with toluene. The residue was dissolved in CHCl₃ (40 mL) then washed with 1 M HCl (20 mL) then sat. aq. NaHCO₃ (20 mL). The aqueous layers were re-
extracted with CHCl₃ (3 × 10 mL). The organic layers were dried over Na₂SO₄ and concentrated. Column chromatography (EtOAc/EtOH, 19:1 → 7:3) gave an inseparable mixture (49.6 mg) containing peracetylated heptasaccharide 31 and cyclized compound 32 as a white solid. Analytical data for 31: m/z (MALDI) calculated for C₉₄H₁₂₆N₇O₅₂NaCl [M+Na]⁺ 2242.70, found 2242.73. Analytical data for 32: m/z (MALDI) calculated for C₉₄H₁₂₅N₇O₅₂Na [M+Na]⁺ 2206.72, found 2206.51.

3,4,6-Tri-O-acetyl-2-trifluoroacetamido-2-deoxy-α-D-glucopyranosyl chloride (33)

![Chemical structure of 33](image)

Known⁸ compound 33 was synthesized partly based on the methods by Joseph et al.⁵ and Horton.⁹ ¹H NMR (400 MHz, Chloroform-d) δH 6.71 (d, J = 8.2 Hz, 1H, N-H), 6.23 (d, J = 3.8 Hz, 1H, H-1), 5.38 (m, 1H, H-3), 5.25 (t, J = 9.8 Hz, 1H, H-4), 4.50 (ddd, J = 10.7, 8.5, 3.6 Hz, 1H, H-2), 4.35 – 4.27 (m, 2H, H-5, H-6a), 4.15 (m, 1H, H-6b), 2.11, 2.07, 2.06 (3 s, 9H, 3 × Ac). The NMR data are in agreement with those reported in the literature.⁸

Chloroethyl 3,4,6-tri-O-acetyl-2-trifluoroacetamido-2-deoxy-β-D-glucopyranoside (34)

![Chemical structure of 34](image)

Chloride donor 33 (1.19 g, 2.84 mmol) and 2-chloroethanol (1.9 mL, 28.3 mmol, 10 equiv.) were dissolved in freshly distilled CH₂Cl₂ (40 mL) containing freshly activated powdered 4Å MS (2.4 g). The mixture was stirred at 0 °C under Ar in the dark for 1 h. AgOTf (0.95 g, 3.70 mmol, 1.3 equiv.) in dry toluene (5 mL) was added, and the reaction was stirred under the same conditions for 2 h (TLC in 7:13 EtOAc/pentanes, Rf = 0.3), then quenched with NEt₃. The mixture was diluted with CH₂Cl₂ (30 mL) and filtered through celite. The solids were washed with CH₂Cl₂ (3 × 30 mL). The filtrate was washed with sat. aq. NaCl (2 × 125 mL). The aqueous layers were re-extracted with CH₂Cl₂ (2 × 25 mL). The organic layers were dried over Na₂SO₄ and concentrated. Column chromatography (EtOAc/pentanes, 3:7 → 6:4) gave chloroethyl glycoside 34 (0.94 g, 72%) as white crystals. ¹H NMR (400 MHz, Chloroform-d) δH 6.77 (d, J = 9.1 Hz, 1H, N-H), 5.33 (dd, J = 10.7, 9.3 Hz, 1H, H-3), 5.09 (dd, J = 10.0, 9.3 Hz, 1H, H-4), 4.77 (d, J = 8.3 Hz, 1H, H-1), 4.27 (dd, J = 12.3, 4.9 Hz, 1H, H-6a), 4.16 (dd, J = 12.4, 2.5 Hz, 1H, H-6b), 4.11 (dt, J = 11.2, 4.8 Hz, 1H, OCH₂HCH₂), 4.02 (dt, J = 10.8, 8.6 Hz, 1H, H-2), 3.81 – 3.72 (m, 2H, H-5, OCH₂HCH₂), 3.62 (dd, J = 6.5, 4.8 Hz, 2H, CH₂Cl), 2.09, 2.03, 2.03 (3 s, 9H, 3 × Ac). ¹³C NMR (100 MHz, Chloroform-d) δC 171.03, 170.67, 169.29 (3 × COCH₃), 157.48 (d, J = 37.9 Hz, COCF₃), 115.53 (d, J = 288.2 Hz, CF₃), 100.55 (C-1), 72.07 (C-5), 71.53 (C-3), 69.89 (OCH₂CH₂), 68.34 (C-4), 61.90 (C-6), 54.79 (C-2), 42.70 (CH₂Cl), 20.69, 20.54, 20.37 (3 × CH₃). m/z (ESI) calculated for C₁₆H₂₅N₂O₃F₃Cl [M+NH₄]⁺ 481.12, found 481.12.

Chloroethyl 3,4,6-tri-O-acetyl-2-acetamido-2-deoxy-β-D-glucopyranoside (35) & Compound (36)
Chloroethyl glycoside 34 (50 mg, 0.108 mmol) was dissolved in a 2:4:1 mixture of 0.5 M NaOH (4.3 mL, 2.15 mmol, 20 equiv.), THF (8.6 mL), and MeOH (2.1 mL). The reaction was stirred at 40-60 °C for 2-20 h (Table 1). The solution was concentrated and dried under high vacuum. The residue was dissolved in a 1:1 mixture of pyridine (5 mL, 61.8 mmol, 572 equiv.) and Ac₂O (5 mL, 52.9 mmol, 490 equiv.). The reaction was stirred at RT for 2h (TLC in 8:2 EtOAc/pentanes, Rᵣ = 0.3, 0.1). The solution co-concentrated with toluene. The residue was dissolved in CH₂Cl₂ (30 mL) then washed with 1 M HCl (2 × 30 mL) then sat. aq. NaHCO₃ (30 mL). The aqueous layers were re-extracted with CH₂Cl₂ (2 × 7 mL). The organic layers were dried over Na₂SO₄ and concentrated. Column chromatography (8:2 → 1:0 EtOAc/pentanes) gave known 1,2-chloroethyl glycoside 35 as a white amorphous solid, and bicyclic compound 36 as a pale yellow amorphous solid (see Table 1 for yields). **Analytical data for 35:** ¹H NMR (400 MHz, Chloroform-d) δH 5.72 (d, J = 8.6 Hz, 1H, N-H), 5.31 (dd, J = 10.5, 9.4 Hz, 1H, H-3), 5.05 (t, J = 9.6 Hz, 1H, H-4), 4.78 (d, J = 8.4 Hz, 1H, H-1), 4.25 (dd, J = 12.3, 4.8 Hz, 1H, H-6a), 4.13 (dd, J = 12.2, 2.4 Hz, 1H, H-6b), 4.08 (dt, J = 11.2, 4.9 Hz, 1H, OCH/HCH₂), 3.86 (dt, J = 10.5, 8.6 Hz, 1H, H-2), 3.78 (dt, J = 11.5, 6.3 Hz, 1H, OCH/HCH₂), 3.72 (ddd, J = 9.9, 4.8, 2.4 Hz, 1H, H-5), 3.64 – 3.61 (m, 2H, CH₂Cl), 2.08, 2.02, 2.01 (3 s, 9H, 3 × OCOCH₃), 1.95 (s, 3H, NCOCH₃). The NMR data are in agreement with those reported in the literature.** Analytical data for 36:** ¹H NMR (400 MHz, Chloroform-d) δH 6.31 (dd, J = 10.9, 9.1 Hz, 1H, H-3), 4.94 (dd, J = 10.0, 9.2 Hz, 1H, H-4), 4.65 (d, J = 8.2 Hz, 1H, H-1), 4.27 (dd, J = 12.4, 4.7 Hz, 1H, H-6a), 4.13 (dd, J = 12.3, 2.1 Hz, 1H, H-6b), 4.03 (dt, J = 11.5, 3.2 Hz, 1H, OCH/HCH₂), 3.89 (ddd, J = 10.1, 4.7, 2.1 Hz, 1H, H-5), 3.73 (td, J = 11.6, 11.0, 3.1 Hz, 1H, OCH/HCH₂), 3.63 (dt, J = 14.6, 3.2 Hz, 1H, CH₂N), 3.40 (ddd, J = 13.8, 10.5, 3.2 Hz, 1H, CH/HN), 3.22 (dd, J = 11.2, 8.2 Hz, 1H, H-2), 2.09 (s, 3H, NAc), 2.05, 2.00, 1.95 (3 s, 9H, 3 × OAc). ¹³C NMR (100 MHz, Chloroform-d) δC 170.62, 170.51, 169.93, 169.45 (4 × COCH₃), 96.39 (C-1), 72.65 (C-5), 70.86 (C-3), 69.71 (C-4), 65.89 (OCH₂CH₂), 63.73 (C-2), 61.95 (C-6), 47.75 (CH₂N), 23.42 (NCOCH₃), 20.88, 20.70, 20.68 (3 × OCOCH₃). m/z (DART) calculated for C₁₆H₂₄Nₒ₉ [M+H]+ 374.14, found 374.1. 3,4-Di-O-benzoyl-6-chloroacetly-2-trifluoroacetamido-2-deoxy-β-D-glucopyranosyl-(1→6)-3,4-di-O-benzoyl-2-trifluoroacetamido-2-deoxy-β-D-glucopyranosyl-(1→6)-3,4-di-O-benzoyl-2-phthalimido-2-deoxy-β-D-glucopyranosyl-(1→6)-3,4-di-O-benzoyl-2-trifluoroacetamido-2-deoxy-β-D-glucopyranosyl-(1→6)-azidoethyl 3,4-di-O-benzoyl-2-trifluoroacetamido-2-deoxy-β-D-glucopyranoside (37)
Azidoethyl pentasaccharide 37 was synthesized using similar methods to chloropropyl pentasaccharide 20. \(^1\)H NMR (600 MHz, Chloroform-\(d\)) \(\delta_{H} 8.42 (d, J = 6.8\) Hz, 1H, 1 × N-H), 8.36 (d, \(J = 10.1\) Hz, 1H, 1 × N-H), 8.12 – 8.04 (m, 9H, 1 × N-H, 8 × Bz), 8.02 – 7.96 (m, 10H, 10 × Bz), 7.92 (dd, \(J = 8.4, 1.3\) Hz, 2H, 2 × Bz), 7.72 (dd, \(J = 7.4, 1\) Hz, 1H, 1 × Phth), 7.67 (t, \(J = 7.1\) Hz, 1H, 1 × Phth), 7.63 – 7.61 (m, 2H, 2 × Bz), 7.60 – 7.39 (m, 16H, 15 × Bz, 1 × Phth), 7.38 – 7.31 (m, 7H, 7 × Bz), 7.21 (dt, \(J = 7.6, 1.5\) Hz, 2H, 2 × Bz), 7.17 (dt, \(J = 7.6, 1.6\) Hz, 2H, 2 × Bz), 7.13 (dt, \(J = 7.8, 1.9\) Hz, 3H, 2 × Bz, 1 × Phth), 6.99 (d, \(J = 8.4\) Hz, 1H, 1 × N-H), 6.56 (dd, \(J = 11.0, 9.0\) Hz, 1H, H-3), 6.31 (dd, \(J = 10.5, 9.1\) Hz, 1H, 1 × H-3), 6.06 (dd, \(J = 10.0\) Hz, 1H, 1 × H-3), 5.91 (dd, \(J = 10.2\) Hz, 1H, 1 × H-3), 5.77 – 5.68 (m, 3H, 1 × H-3, H-4, 1 × H-4), 5.55 (dd, \(J = 10.1, 9.4\) Hz, 1H, 1 × H-4), 5.41 – 5.35 (m, 2H, 1 × H-1, 1 × H-4), 5.30 (d, \(J = 8.5\) Hz, 1H, H-1), 5.10 (t, \(J = 9.9\) Hz, 1H, 1 × H-4), 5.04 (d, \(J = 8.4\) Hz, 1H, 1 × H-1), 4.91 (d, \(J = 8.4\) Hz, 1H, 1 × H-1), 4.84 (dd, \(J = 11.1, 8.6\) Hz, 1H, H-2), 4.79 – 4.62 (m, 6H, 1 × H-1, 2 × H-2, H-5, 2 × H-5), 4.57 (q, \(J = 9.4\) Hz, 1H, 1 × H-2), 4.33 (dd, \(J = 12.3, 2.4\) Hz, 1H, 1 × H-6a), 4.26 (dd, \(J = 13.1, 10.9\) Hz, 1H, 1 × H-6a), 4.23 – 4.14 (m, 3H, 1 × H-5, 1 × H-6b, OCH\(\text{HCH}_2\)), 4.12 (dd, \(J = 13.1, 10.4\) Hz, 1H, H-6a), 4.08 (dd, \(J = 13.0, 1.2\) Hz, 1H, 1 × H-6a), 3.98 – 3.90 (m, 2H, 1 × H-2, 1 × H-5), 3.87 (dd, \(J = 12.9, 9.7\) Hz, 1H, 1 × H-6b), 3.82 (d, \(J = 15.5\) Hz, 1H, CHCHCl), 3.73 (ddd, \(J = 11.6, 8.7, 3.6\) Hz, 1H, OCH\(\text{HCH}_2\)), 3.67 – 3.62 (m, 2H, 1 × H-6a, H-6b), 3.59 (d, \(J = 15.5\) Hz, 1H, CHCHCl), 3.59 – 3.53 (m, 2H, 1 × H-6b, CH\(\text{HN}_3\)), 3.47 (dd, \(J = 12.6, 1.7\) Hz, 1H, 1 × H-6b), 3.32 (dt, \(J = 13.3, 4.0\) Hz, 1H, CH\(\text{HN}_3\)). \(^{13}\)C NMR (125 MHz, Chloroform-\(d\)) \(\delta_{C} 169.17, 167.98 (2 \times CO\text{Pth}), 167.30 (\text{COCH}_2\text{Cl}), 166.87, 166.83, 166.51, 166.50, 166.45, 165.72, 165.58, 165.34, 165.14, 164.94 (10 × CO\text{Ph}), 158.13 (d, \(J = 36.0\) Hz, 1 × CO\text{CF}_3), 158.10 (d, \(J = 38.0\) Hz, 1 × CO\text{CF}_3), 158.00 (d, \(J = 36.3\) Hz, 1 × CO\text{CF}_3), 157.57 (d, \(J = 37.3\) Hz, 1 × CO\text{CF}_3), 153.03, 134.92 (2 × Phth), 133.93, 133.86, 133.85, 133.77, 133.74, 133.54, 133.39, 133.35, 133.35, 133.21 (10 × Bz), 130.69, 130.52 (2 × 4° Phth), 130.21 (2 × Bz), 130.20 (2 × Bz), 130.16 (2 × Bz), 130.08 (2 × Bz), 129.93 (2 × Bz), 129.90 (4 × Bz), 129.83 (2 × Bz), 129.81 (2 × Bz), 129.70 (2 × Bz), 129.08 (2 × Bz), 129.04 (1 × 4° Bz), 128.93 (2 × Bz), 128.85, 128.81, 128.69, 128.67 (4 × 4° Bz), 128.64 (2 × Bz), 128.62 (2 × 4° Bz), 128.57 (2 × Bz), 128.46 (2 × Bz), 128.40 (1 × 4° Bz), 128.38 (4 × Bz), 128.35 (2 × Bz), 128.31 (2 × Bz), 128.24 (2 × Bz), 128.19, 128.12 (2 × 4° Bz), 124.31, 123.49 (2 × Phth), 115.88 (q, \(J = 288.2\) Hz, 1 × CF\(_3\)), 115.58 (q, \(J = 287.7\) Hz, 1 × CF\(_3\)), 115.36 (q, \(J = 288.5\) Hz, 1 × CF\(_3\)), 115.06 (q, \(J = 286.9\) Hz, 1 × CF\(_3\)), 104.10, 101.70, 100.68 (3 × C-1), 100.53 (C-1), 100.27 (1 × C-1), 74.65 (1 × C-5), 73.88 (C-6), 73.56 (1 × C-6), 73.48 (C-5), 72.65 (1 × C-3), 72.52 (1 × C-6), 72.50 (1 × C-5), 72.40 (1 × C-4), 72.33 (1 × C-5), 72.32 (1 × C-6), 72.31 (1 × C-5), 72.24 (1 × C-3), 71.75 (C-4), 71.69, 71.52 (2 × C-4), 69.90 (2 × C-3), 69.60 (1 × C-4), 69.40 (C-3), 68.93 (OCH\(_2\)CH\(_2\)), 63.64 (1 × C-6),
2-Acetamido-3,4,6-tri-O-acetyl-2-deoxy-β-D-glucopyranosyl-(1→6)-2-acetamido-3,4-di-O-acetyl-2-deoxy-β-D-glucopyranosyl-(1→6)-2-acetamido-3,4-di-O-acetyl-2-deoxy-β-D-glucopyranosyl-(1→6)-azidoethyl 2-acetamido-3,4-di-O-acetyl-2-deoxy-β-D-glucopyranoside (38)

Azidoethyl pentasaccharide 37 (46.5 mg, 0.018 mmol) was dissolved in a 2:4:1 mixture of 0.5 M NaOH (3.6 mL, 1.8 mmol, 100 equiv.), THF (7.2 mL), and MeOH (1.8 mL). The reaction was stirred at 40 °C for 2 h. The solution was concentrated and dried under high vacuum. The residue was dissolved in a 1:1 mixture of pyridine (4.5 mL, 55.6 mmol, 3089 equiv.) and Ac₂O (4.5 mL, 47.6 mmol, 2644 equiv.). The reaction was stirred at 50 °C for 1 h, then left to attain RT for 18 h (TLC in 9:1 EtOAc/EtOH, Rᵣ = 0.2). The solution co-concentrated with toluene. The residue was dissolved in CH₂Cl₂ (20 mL) then washed with 1 M HCl (20 mL) then aq. NaHCO₃ (20 mL). The aqueous layers were re-extracted with CH₂Cl₂ (2 × 5 mL). The organic layers were dried over Na₂SO₄ and concentrated. Column chromatography (EtOAc/EtOH, 19:1 → 17:3) gave pentasaccharide 38 (17.1 mg, 56%) as a white amorphous solid.

1H NMR (600 MHz, Chloroform-d) δH 7.85 – 7.72 (m, 4H, 4 × Phth), 7.39 (d, J = 8.9 Hz, 1H, 1 × N-H), 6.84 (d, J = 7.9 Hz, 1H, 1 × N-H), 6.21 (d, J = 9.2 Hz, 1H, 1 × N-H), 6.74 (d, J = 9.7 Hz, 1H, 1 × N-H), 5.77 (dd, J = 10.9, 8.9 Hz, 1H, H-3"), 5.65 (dd, J = 9.9 Hz, 1H, H-3), 5.28 – 5.21 (m, 3H, H-1", 1 × H-1, 1 × H-3), 5.20 (dd, J = 10.6, 9.2 Hz, 1H, 1 × H-3), 5.15 (dd, J = 10.8, 9.2 Hz, 1H, 1 × H-3), 5.00 (dd, J = 10.3, 8.9 Hz, 1H, H-4"), 4.92 – 4.85 (m, 3H, 3 × H-4), 4.73 – 4.68 (dd, J = 10.0, 9.2 Hz, 1H, 1 × H-4), 4.58 (d, J = 8.5 Hz, 2H, 2 × H-1), 4.48 (d, J = 8.5 Hz, 1H, 1 × H-1), 4.41 – 4.31 (m, 4H, H-2", H-5", 1 × H-5, 1 × H-6a), 4.29 – 4.19 (m, 3H, 2 × H-2, 1 × H-5), 4.06 (q, J = 9.1 Hz, 1H, 1 × H-2), 4.02 – 3.96 (m, 2H, H-6a", OCH₂HCH₂), 3.92 (dd, J = 12.1, 2.1 Hz, 1H, 1 × H-6b), 3.89 – 3.84 (m, 2H, 2 × H-5), 3.81 – 3.68 (m, 4H, 1 × H-2, 2 × H-6a, 1 × H-6b), 3.67 – 3.60 (m, 3H, 1 × H-6a, H-6b", OCH₂HCH₂), 3.58 (dd, J = 12.3, 2.8 Hz, 1H, 1 × H-6b), 3.54 – 3.51 (m, 1H, 1 × H-6b), 3.49 – 3.42 (m, 1H, CH₂N₃), 3.21 (dd, J = 13.5, 4.7, 3.3 Hz, 1H, CH₂N₃), 2.13, 2.11, 2.08, 2.07, 2.06 (6 s, 18H, 6 × OAc), 2.06, 2.05 (2 s, 6H, 2 × NAc), 2.04, 2.01, 2.00 (3 s, 9H, 3 × OAc), 1.97 (s, 3H, 1 × NAc), 1.95 (s, 3H, 1 × OAc), 1.91 (s, 3H, 1 × NAc), 1.90 (s, 3H, 1 × OAc). 13C NMR (125 MHz, Chloroform-d) δC 171.72, 171.05, 170.88, 170.78, 170.64, 170.45, 170.36, 170.30, 170.18, 169.94, 169.84, 169.78, 169.72, 169.66 (15 × COCH₃), 134.90 (2 × Phth), 131.03 (2 × 4° Phth), 124.00, 123.50 (2 × Phth), 103.83, 101.93 (2 × C-1), 100.61 (C-1", 1 × C-1), 99.65 (1 × C-1), 73.80 (1 × C-5), 73.31, 73.21 (2 × C-3), 72.80 (C-5"), 72.27 (1 × C-5), 72.05 (1 × C-3, 1 × C-6), 71.46 (1 × C-5), 71.33 (1 × C-3),
71.12 (1 × C-6), 71.03 (1 × C-5), 70.82, 70.77 (2 × C-4), 70.67 (C-4''), 70.04 (C-3''), 69.51, 69.17 (2 × C-4), 68.97 (1 × C-6), 68.27 (C-6'', OCH_{2}CH_{2}), 62.37 (1 × C-6), 55.44 (1 × C-2), 55.20 (C-2''), 54.36, 54.14, 53.85 (3 × C-2), 50.38 (1 × NCOCH_{3}), 23.40 (2 × NCOCH_{3}), 22.99 (1 × NCOCH_{3}), 20.83, 20.78 (2 × OCOCH_{3}), 20.76 (2 × OCOCH_{3}), 20.73, 20.67, 20.66, 20.64, 20.57, 20.54, 20.40 (7 × OCOCH_{3}).

\[ m/z \text{ (ESI) calculated for C}_{70}H_{92}NO_{38}Na^{+} \text{[M+Na]} = 1675.54, \text{found 1675.5}. \]

3,4-Di-O-benzoyl-2-phthalimido-2-deoxy-β-D-glucopyranosyl-(1→6)-3,4-Di-O-benzoyl-2-trifluoroacetamido-2-deoxy-β-D-glucopyranosyl-(1→6)-3,4-di-O-benzoyl-2-trifluoroacetamido-2-deoxy-β-D-glucopyranosyl-(1→6)-3,4-di-O-benzoyl-2-trifluoroacetamido-2-deoxy-β-D-glucopyranosyl-(1→6)-azidoethyl 3,4-di-O-benzoyl-2-trifluoroacetamido-2-deoxy-β-D-glucopyranoside (39)

Azidoethyl pentasaccharide 39 was synthesized using similar methods to chloropropyl pentasaccharide 26. 1H NMR (600 MHz, Chloroform-d) δ_H 8.51 (d, J = 9.9 Hz, 1H, 1 × N-H), 8.45 (d, J = 9.6 Hz, 1H, 1 × N-H), 8.16 (dd, J = 8.6, 1.3 Hz, 2H, 2 × Bz), 8.13 (d, J = 9.7 Hz, 1H, 1 × N-H), 8.10 (dd, J = 8.5, 9.6 Hz, 2H, 2 × Bz), 8.06 – 7.94 (m, 16H, 16 × Bz), 7.84 – 7.76 (m, 3H, 3 × Phth), 7.61 – 7.52 (m, 6H, 6 × Bz), 7.50 – 7.26 (m, 21H, 20 × Bz, 1 × Phth), 7.23 (t, J = 8.2 Hz, 2H, 2 × Bz), 7.18 (t, J = 8.1 Hz, 2H, 2 × Bz), 7.16 (d, J = 9.7 Hz, 1H, 1 × N-H), 7.10 (d, J = 9.4 Hz, 1H, 1 × N-H), 6.37 (dd, J = 10.5, 9.1 Hz, 1H, H-3 IV), 6.19 (d, J = 10.7, 9.5 Hz, 1H, 1 × H-3), 6.01 (t, J = 10.3 Hz, 1H, 1 × H-3), 5.90 (t, J = 10.6 Hz, 1H, 1 × H-3), 5.75 (t, J = 10.0 Hz, 1H, 1 × H-3), 5.73 (t, J = 10.2 Hz, 1H, 1 × H-4), 5.60 (dd, J = 10.7, 9.3 Hz, 1H, 1 × H-4), 5.41 (t, J = 9.8 Hz, 1H, 1 × H-4), 5.38 (t, J = 9.6 Hz, 1H, H-4 IV), 5.26 (d, J = 8.4 Hz, 1H, H-1 IV), 5.12 (d, J = 8.5 Hz, 1H, 1 × H-1), 5.04 (t, J = 9.8 Hz, 1H, 1 × H-4), 4.91 – 4.83 (m, 2H, 1 × H-1, 1 × H-2), 4.84 – 4.66 (m, 4H, 1 × H-1, 2 × H-2, 1 × H-5), 4.67 – 4.54 (m, 4H, 1 × H-1, 2 × H-2, 1 × H-5), 4.51 (dd, J = 10.4, 9.0 Hz, 1H, H-2 IV), 4.26 – 4.20 (m, 2H, 1 × H-5, 1 × H-6a), 4.14 – 4.06 (m, 3H, H-6a IV, 1 × H-6a, OCH_{2}CH_{2}), 3.84 – 3.79 (m, 2H, 2 × H-6a), 3.63 – 3.55 (m, 3H, 3 × H-6b), 3.49 – 3.41 (m, 2H, 2 × H-6b IV, CH_{2}N_{3}), 3.36 (dt, J = 13.3, 4.8 Hz, 1H, CH_{2}N_{3}), 3.31 (d, J = 11.7 Hz, 1H, 1 × H-6b), 2.65 (s, 1H, OH-6 IV). 13C NMR (125 MHz, Chloroform-d) δ_C 168.55, 167.50 (2 × COPth), 166.63, 166.48, 166.46, 166.41, 166.29, 166.04, 166.01, 165.74, 165.42, 164.94 (10 × COPh), 158.49 (d, J = 36.5 Hz, 1 × COCF_{3}), 158.47 (d, J = 36.4 Hz, 1 × COCF_{3}), 158.16 (d, J = 36.6 Hz, 1 × COCF_{3}), 158.14 (d, J = 36.6 Hz, 1 × COCF_{3}), 134.90 (2 × Phth), 133.82 (2 × Bz), 133.74 (2 × Bz), 133.62 (1 × Bz), 133.51 (2 × Bz), 133.40, 133.29, 133.19 (3 × Bz), 130.86 (4° Phth), 130.53 (4° Phth), 130.18 (2 × Bz), 130.15 (2 × Bz), 130.08 (2 × Bz), 130.02 (2 × Bz), 129.98 (2 × Bz), 129.92 (2 × Bz), 129.90 (2 × Bz), 129.85 (4 × Bz), 129.49 (2 × Bz), 128.99 (2 × Bz), 128.91 (1 × 4° Bz), 128.79 (2 × Bz), 128.73 (2 × Bz),
128.72, 128.66, 128.61, 128.60 (4 × 4° Bz), 128.58 (2 × 4° Bz), 128.38 (1 × 4° Bz), 128.35 (2 × Bz), 128.32 (2 × Bz), 128.30 (4 × Bz), 128.28 (2 × Bz), 127.68, 127.03 (2 × 4° Bz), 123.90, 123.51 (2 × Phth), 115.66 (q, $J = 287.1$ Hz, 1 × CF$_3$), 115.64 (q, $J = 287.8$ Hz, 1 × CF$_3$), 115.61 (q, $J = 289.9$ Hz, 1 × CF$_3$), 115.02 (q, $J = 286.2$ Hz, 1 × CF$_3$), 104.15, 103.49, 101.62, 100.08 (4 × C-1), 99.97 (C-IV), 75.18 (C-5IV), 74.62 (1 × C-5), 74.21 (1 × C-6), 73.82 (C-6IV), 73.77 (1 × C-5), 72.05 (1 × C-3), 72.67 (1 × C-5), 72.34 (1 × C-5, 1 × C-6), 72.26 (1 × C-3), 71.86 (1 × C-4), 71.60 (1 × C-3, 1 × C-4, 1 × C-6), 71.36 (1 × C-4), 70.31 (C-4IV), 70.11 (C-3IV), 69.82 (1 × C-4), 69.13 (OCH$_2$CH$_2$), 61.65 (1 × C-6), 55.17 (C-2IV), 55.13, 54.99 (2 × C-2), 54.38 (2 × C-2), 50.12 (CH$_2$N$_3$). $m/z$ (MALDI) calculated for C$_{118}$H$_{98}$N$_8$O$_{37}$F$_{12}$Na [M+Na]$^+$ 2469.57, found 2469.84.


![Structure](image)

Pentasaccharide acceptor 39 (309 mg, 0.126 mmol) and glycosyl bromide 13 (412 mg, 0.379 mmol, 3 equiv.) were dissolved in freshly distilled CH$_2$Cl$_2$ (4 mL) containing freshly activated powdered 4Å MS (400 mg). The mixture was stirred at -45 °C under Ar in the dark for 1 h. AgOTf (130 mg, 0.506 mmol, 4 equiv.) in dry toluene (1.0 mL) was added, and the reaction was stirred under the same conditions for 2 h (TLC in 4:6 acetone/pentanes, $R_f = 0.2$), then quenched with NEt$_3$. The mixture was diluted with 10 mL CH$_2$Cl$_2$ and filtered through celite. The solids were washed with CH$_2$Cl$_2$ (3 × 10 mL). The filtrate was washed with sat. aq. NaCl (2 × 30 mL).
The aqueous layers were re-extracted with CHCl\(_2\) (2 × 5 mL). The organic layers were dried over Na\(_2\)SO\(_4\) and concentrated. Column chromatography (acetone/pentanes, 4:6 \(\rightarrow\) 1:1, then EtOAc/pentanes, 1:1) gave heptasaccharide 40 with small impurities (243 mg) as a yellow solid. A portion of 40 (97 mg, 0.028 mmol) was dissolved in a 2:4:1 mixture of 0.5 M NaOH (8 mL, 4.0 mmol, 140 equiv.), THF (16 mL), and MeOH (4 mL). The reaction was stirred at 40 °C for 3 h. The solution was concentrated and dried under high vacuum. The residue was dissolved in a 1:1 mixture of pyridine (10 mL, 105.8 mmol, 3768 equiv.) and Ac\(_2\)O (10 mL, 123.6 mmol, 4414 equiv.). The reaction was stirred at 50 °C for 2 h, then left to attain RT for 16 h (TLC in 7:3 EtOAc/MeOH, \(R_f = 0.3\)). The solution co-concentrated with toluene. The residue was dissolved in CHCl\(_3\) (60 mL) then washed with 1 M HCl (30 mL) then sat. aq. NaHCO\(_3\) (30 mL). The aqueous layers were re-extracted with CHCl\(_3\) (3 × 15 mL each). The organic layers were dried over Na\(_2\)SO\(_4\) and concentrated. Column chromatography (EtOAc/MeOH, 17:3 \(\rightarrow\) 1:1) gave heptasaccharide 41 (36.2 mg, 32% over three steps) as a yellow solid. **Analytical Data for 40:**
m/z (MALDI) calculated for C\(_{164}\)H\(_{317}\)N\(_8\)O\(_{52}\)F\(_{18}\)NaCl \([M+Na]^+\) 3449.76, found 3449.86.

**Analytical Data for 41:**

\(\text{H NMR (600 MHz, Acetone-} d_6) \delta_H 8.13 (d, \(J = 10.0 \text{ Hz, 1H, } 1 \times N-H\)), 8.02 – 7.99 (m, 1H, 1 × Phth), 7.98 – 7.92 (m, 3H, 3 × Phth), 7.84 (m, J = 9.7 Hz, 1H, 1 × N-H), 7.79 (d, J = 9.6 Hz, 1H, 1 × N-H), 7.52 (d, J = 10.1 Hz, 1H, 1 × N-H), 7.51 (d, J = 9.8 Hz, 1H, 1 × N-H), 7.46 (d, J = 9.5 Hz, 1H, 1 × N-H), 6.98 (t, J = 5.2 Hz, 1H, CH\(_2\)\(\text{NAc}\)), 5.92 (dd, J = 10.7, 8.7 Hz, 1H, H-3\(^{IV}\)), 5.45 (d, J = 8.5 Hz, 1H, H-1\(^{IV}\)), 5.45 (dd, J = 10.5, 9.4 Hz, 1H, 1 × H-3), 5.41 – 5.33 (m, 3H, 1H, 1 × H-1, 2 × H-3), 5.27 – 5.17 (m, 3H, 3 × H-3), 5.05 – 4.90 (m, 5H, H-4\(^{III}\)), 4.81 – 4.76 (m, 4H, 2 × H-1, 1 × H-4, 1 × H-5), 4.74 (d, J = 8.6 Hz, 1H, 1 × H-1), 4.70 – 4.61 (m, 4H, 2 × H-1, 1 × H-4, 1 × H-5), 4.58 – 4.51 (m, 1H, 1 × H-5), 4.49 – 4.37 (m, 5H, H-2\(^{IV}\), 2 × H-2, H-5\(^{IV}\), 1 × H-5), 4.35 (dt, J = 10.4, 9.2 Hz, 1H, 1 × H-2), 4.26 (q, J = 9.4 Hz, 1H, 1 × H-2), 4.18 (dd, J = 12.4, 4.6 Hz, 1H, 1 × H-6a), 4.16 – 4.03 (m, 4H, 2 × H-2, 1 × H-5, H-6a\(^{IV}\)), 4.00 – 3.93 (m, 2H, 1 × H-6a, 1 × H-6b), 3.90 – 3.81 (m, 4H, 1 × H-5, 2 × H-6a, H-6b\(^{IV}\)), 3.79 (t, J = 5.9 Hz, 2H, OCH\(_2\)CH\(_2\)), 3.76 – 3.71 (m, 2H, 2 × H-6a, 1 × H-6b), 3.69 (dd, J = 12.5, 1.9 Hz, 1H, 1 × H-6b), 3.58 (dd, J = 7.5, 2.9 Hz, 1H, 1 × H-6b), 3.56 (dd, J = 7.7, 2.9 Hz, 1H, 1 × H-6b), 3.47 (dd, J = 12.6, 2.7 Hz, 1H, 1 × H-6b), 3.37 – 3.31 (m, 2H, CH\(_2\)N), 2.21, 2.15, 2.12, 2.11, 2.11, 2.07, 2.03, 2.02, 1.98, 1.98, 1.97, 1.96, 1.95, 1.95 (14 s, 42H, 14 × CH\(_2\)), 1.92 (s, 6H, 2 × CH\(_3\)), 1.89, 1.86, 1.86, 1.85, 1.82, 1.77 (6 s, 18H, 6 × CH\(_3\)). \(^{13}\)C NMR (125 MHz, Acetone-\(d_6\)) \(\delta_C 171.62, 171.48, 171.47, 171.07, 170.94, 170.71, 170.67, 170.66, 170.64, 170.62, 170.59, 170.55, 170.52 (13 × COCH\(_3\)), 170.46 (2 × COCH\(_3\)), 170.44, 170.43, 170.38, 170.32, 170.06, 169.88, 169.58 (7 × COCH\(_3\)), 169.28, 168.97 (2 × COPh\(_3\)), 136.27, 136.04 (2 × Phth), 132.07, 131.99 (2 × 4° Phth), 124.85, 124.17 (2 × Phth), 104.65, 104.25, 104.10, 102.98, 101.10, 100.67 (6 × C-1), 100.62 (C-1\(^{IV}\)), 75.23, 75.00 (2 × C-3), 74.61 (1 × C-5), 73.81 (1 × C-3), 73.63 (1 × C-5), 73.49 (C-6\(^{IV}\)), 73.37, 73.32 (2 × C-3), 73.28 (1 × C-5), 72.98, 72.96, 72.92 (3 × C-6), 72.76 (1 × C-3), 72.33 (1 × C-6), 72.16 (1 × C-5), 72.10 (1 × C-4), 72.09 (C-4\(^{IV}\)), 72.07 (1 × C-5), 72.05, 71.91 (2 × C-4), 71.56 (C-5\(^{IV}\), 1 × C-5), 71.15 (1 × C-4), 70.88 (C-3\(^{IV}\)), 70.53, 69.75 (2 × C-4), 68.82 (OCH\(_3\)CH\(_2\)), 65.40, 62.66 (2 × C-6), 56.54 (C-2\(^{IV}\)), 55.74, 55.21, 55.13, 54.84, 54.69, 52.02 (6 × C-2), 39.83 (CH\(_3\)N), 23.50 – 22.79 (7 × NCOCH\(_3\)), 21.25 – 20.26 (15 × OCOCH\(_3\)).
m/z (ESI) calculated for C\(_{96}\)H\(_{132}\)N\(_8\)O\(_{53}\) [M+2H\(^+\)] \(\rightarrow\) 1122.90, found 1122.90.

2-Acetamido-2-deoxy-\(\beta\)-D-glucopyranosyl-(1→6)-azidopropyl 2-acetamido-2-deoxy-\(\beta\)-D-glucopyranoside (44)
Disaccharide 47 (9.0 mg, 0.0125 mmol) was dissolved in MeOH (1.0 mL). Sodium (0.1 mg, 0.0043 mmol, 0.33 equiv.) was added. The reaction was stirred at RT for 3 h, then quenched with Dowex 50WX8 cation exchange resin (hydrogen form, 50-100 mesh). The resin was filtered and washed with MeOH. The filtrate was concentrated giving deprotected PNAG disaccharide 44 (6.1 mg, 95%) as a white powder.

1H NMR (600 MHz, Deuterium Oxide) \(\delta \)H 4.55 (d, \(J = 8.5 \text{ Hz} \), 1H, H-1), 4.50 (d, \(J = 8.5 \text{ Hz} \), 1H, H-1'), 4.22 (dd, \(J = 11.2, 1.8 \text{ Hz} \), 1H, H-6a), 3.96 – 3.92 (m, 2H, H-6a', OCH\(_2\)HCH\(_2\)), 3.79 – 3.72 (m, 3H, H-2, H-6b, H-6b'), 3.69 – 3.63 (m, 2H, H-2', OCH\(_2\)H), 3.59 – 3.52 (m, 3H, H-3, H-3', H-5), 3.48 – 3.46 (m, 2H, H-4, H-5'), 3.42 – 3.35 (m, 3H, H-4', CHN\(_3\)), 2.06, 2.06 (2s, 6H, 2 \times \text{CH}_3), 1.85 (p, \(J = 6.5 \text{ Hz} \), 2H, CH\(_2\)C\(_2\)H\(_2\)).

13C NMR (125 MHz, Deuterium Oxide) \(\delta \)C 174.46, 174.40 (2 \times \text{COCH}_3), 101.37 (C-1), 101.02 (C-1'), 75.76 (C-5'), 74.48 (C-5), 73.65 (C-3'), 73.63 (C-3), 69.91 (C-4'), 69.83 (C-4), 68.44 (C-6), 66.88 (OCH\(_2\)CH\(_2\)), 60.62 (C-6'), 55.46 (C-2'), 55.39 (C-2), 47.70 (CH\(_2\)N\(_3\)), 28.01 (CH\(_2\)C\(_2\)H\(_2\)), 22.14, 22.07 (2 \times \text{CH}_3).

m/z (ESI) calculated for C\(_{19}\)H\(_{34}\)N\(_5\)O\(_{11}\)\([M+H]^+\) 508.22, found 508.23.

3,4,6-Tri-O-benzoyl-2-trifluoroacetamido-2-deoxy-β-D-glucopyranosyl-(1→6)-chloropropyl 3,4-di-O-benzoyl-2-trifluoroacetamido-2-deoxy-β-D-glucopyranoside (45)

Disaccharide 15 (56.0 mg 0.055 mmol), DMAP (1.3 mg, 0.011 mmol, 0.2 equiv.), and pyr (17.7 μL, 0.219 mmol, 4 equiv.) were dissolved in DCM (1.0 mL). BzCl (12.7 μL, 0.109 mmol, 2 equiv.) was added. The reaction was stirred at RT for 20 h (TLC in 4:6 EtOAc/pentanes, \(R_f = 0.6\)). The solution was diluted with CH\(_2\)Cl\(_2\) (4 mL) then washed with 1 M HCl (5 mL) then aq. NaHCO\(_3\) (5 mL). The aqueous layers were re-extracted with CH\(_2\)Cl\(_2\) (2 × 1 mL each). The organic layers were dried over Na\(_2\)SO\(_4\) and concentrated. Column chromatography (EtOAc/pentanes, 3:7) gave disaccharide 45 (53.5 mg, 87%) as a white amorphous solid. 1H NMR (600 MHz, Chloroform-\(d\)) \(\delta \)H 7.94 – 7.89 (m, 6H, 6 \times Bz), 7.88 – 7.84 (m, 4H, 4 \times Bz), 7.52 – 7.46 (m, 5H, N-H'), 7.42 (t, \(J = 7.3 \text{ Hz} \), 1H, 1 \times Bz), 7.38 – 7.29 (m, 8H, 8 \times Bz), 7.27 (t, \(J = 7.8 \text{ Hz} \), 2H, 2 \times Bz), 6.91 (d, \(J = 8.7 \text{ Hz} \), 1H, H-H), 5.82 (t, \(J = 10.1 \text{ Hz} \), 1H, H-3'), 5.72 (t, \(J = 9.5 \text{ Hz} \), 1H, H-4'), 5.70 – 5.64 (m, 1H, H-3'), 5.48 (t, \(J = 9.6 \text{ Hz} \), 1H, H-4), 4.82 (d, \(J = 8.2 \text{ Hz} \), 1H, H-1'), 4.75 (d, \(J = 8.4 \text{ Hz} \), 1H, H-1'), 4.60 (q, \(J = 8.8 \text{ Hz} \), 1H, H-2'), 4.57 (dd, \(J = 12.3, 3.0 \text{ Hz} \), 1H, H-6a'), 4.40 (dd, \(J = 12.3, 4.9 \text{ Hz} \), 1H, H-6b'), 4.25 (dd, \(J = 11.6, 1.5 \text{ Hz} \), 1H, H-6a), 4.11 (q, \(J = 8.9 \text{ Hz} \), 1H, H-2), 4.08 – 4.02 (m, 2H, H-5', OCH\(_2\)H), 3.90 (ddd, \(J = 9.7, 4.5, 1.4 \text{ Hz} \), 1H, H-5), 3.67 (ddd, \(J = 10.7, 9.0, 4.9 \text{ Hz} \), 1H, OCH\(_2\)H), 3.64 – 3.59 (m, 3H, H-6b, CH\(_2\)Cl), 2.13 – 2.03 (m, 1H, CH\(_2\)CH\(_2\)H\(_2\)), 2.01 – 1.92 (m, 1H, CH\(_2\)CH\(_2\)H\(_2\)). 13C NMR (125 MHz, Chloroform-\(d\)) \(\delta \)C 166.72, 166.56, 166.08, 165.77, 165.01 (5 \times COPh), 157.68 (d, \(J = 37.4 \text{ Hz} \), 1 \times COCF\(_3\)), 157.46 (d, \(J = 37.8 \text{ Hz} \), 1 \times COCF\(_3\)), 133.94, 133.76, 133.65, 133.52,
Disaccharide 45 (50.0 mg, 0.044 mmol) and NaN₃ (28.9 mg, 0.445 mmol, 10 equiv.) were dissolved in dry DMF (4.4 mL). The reaction was stirred at 80 °C for 24 h (TLC in 4:6 EtOAc/pentanes, Rᶠ = 0.6). The solution was diluted with EtOAc (40 mL) then washed with H₂O (40 mL). The aqueous layer was re-extracted with EtOAc (2 × 20 mL). The organic layers were dried over Na₂SO₄ and concentrated. Column chromatography (EtOAc/pentanes, 3:7 → 4:6) gave azidopropyl glycoside 46 (47.0 mg, 93%) as a white amorphous solid.

1H NMR (600 MHz, Chloroform-d) δH 7.92 – 7.87 (m, 6H, 6 × Bz), 7.86 (dd, J = 8.4, 1.2 Hz, 2H, 2 × Bz), 7.83 (d, J = 7.8 Hz, 2H, 2 × Bz), 7.56 (d, J = 8.8 Hz, 1H, N-H'), 7.50 – 7.45 (m, 4H, 4 × Bz), 7.41 (t, J = 7.7 Hz, 1H, 1 × Bz), 7.35 – 7.29 (m, 8H, 8 × Bz), 7.26 (t, J = 7.5 Hz, 2H, 2 × Bz), 6.91 (d, J = 7.3 Hz, 1H, 1 × Bz), 5.81 (t, J = 10.1 Hz, 1H, H-3), 5.72 (t, J = 9.5 Hz, 1H, H-4'), 5.65 (t, J = 10.2 Hz, 1H, H-3'), 5.45 (t, J = 9.6 Hz, 1H, H-4), 4.80 (d, J = 8.2 Hz, 1H, H-1), 4.73 (d, J = 8.4 Hz, 1H, H-1'), 4.61 (q, J = 8.7 Hz, 1H, H-2'), 4.56 (dd, J = 12.3, 3.0 Hz, 1H, H-6a'), 4.39 (dd, J = 12.2, 5.0 Hz, 1H, H-6b'), 4.22 (dd, J = 11.8, 1.3 Hz, 1H, H-6a), 4.09 (q, J = 10.0, 9.2 Hz, 1H, H-2), 4.03 (ddd, J = 9.5, 4.8, 3.3 Hz, 1H, H-5'), 4.00 – 3.95 (m, 1H, OCHHCH₂), 3.87 (ddd, J = 9.5, 4.7, 1.4 Hz, 1H, H-5), 3.62 (dd, J = 11.7, 5.1 Hz, 1H, H-6b), 3.57 (ddd, J = 9.5, 7.6, 4.7 Hz, 1H, OCHHCH₂), 3.43 – 3.33 (m, 2H, CH₂N₃), 1.91 – 1.77 (m, 2H, CH₂CH₂CH₂). 13C NMR (125 MHz, Chloroform-d) δC 166.88, 166.68, 166.50, 166.08, 165.75, 165.01 (5 × COPh), 157.70 (d, J = 37.9 Hz, 1 × COCF₃), 157.45 (d, J = 37.7 Hz, 1 × COCF₃), 133.91, 133.74, 133.63, 133.51, 133.15 (5 × Bz), 129.88 (2 × Bz), 129.84 (4 × Bz), 129.77 (2 × Bz), 129.66 (2 × Bz), 129.35 (1 × 4° Bz), 128.66 (1 × 4° Bz), 128.51 (2 × Bz), 128.49 (2 × Bz), 128.45 (2 × Bz), 128.42 (2 × Bz), 128.34 (2 × Bz), 128.30 (1 × 4° Bz), 128.18 (1 × 4° Bz), 128.03 (1 × 4° Bz), 115.73 (q, J = 288.0 Hz, 1 × CF₃), 115.44 (q, J = 288.2 Hz, 1 × CF₃), 101.58 (C-1'), 100.34 (C-1), 73.38 (C-5), 72.80 (C-3'), 72.42 (C-5'), 71.84 (C-3), 69.15 (C-4'), 69.03 (C-4), 68.31 (C-6), 66.44 (OCH₂CH₂), 62.80 (C-6'), 55.25 (C-2), 54.77 (C-2'), 47.99 (CH₂N₃), 28.82 (CH₂CH₂CH₂). m/z (ESI) calculated for C₅₄H₃₁N₆O₁₆F₆ [M+NH₄]⁺ 1153.33, found 1153.32.

2-Acetamido-3,4,6-tri-O-acetyl-2-deoxy-β-D-glucopyranosyl-(1→6)-azidopropyl 2-acetamido-3,4-di-O-acetyl-2-deoxy-β-D-glucopyranoside (47)
46 (44.0 mg, 0.039 mmol) was dissolved in a 2:4:1 mixture of 0.5 M NaOH (3.1 mL, 1.55 mmol, 40 equiv.), THF (6.2 mL), and MeOH (1.5 mL). The reaction was stirred at 40 °C for 2 h. The solution was concentrated and dried under high vacuum. The residue was dissolved in a 1:1 mixture of pyridine (5 mL, 61.8 mmol, 1596 equiv.) and Ac₂O (5 mL, 52.9 mmol, 1366 equiv.). The reaction was stirred at RT for 18 h (TLC in 19:1 EtOAc/EtOH, Rₙ = 0.3). The solution co-condensed with toluene. The residue was dissolved in CH₂Cl₂ (20 mL) then washed with 1 M HCl (20 mL) then aq. NaHCO₃ (20 mL). The aqueous layers were re-extracted with CH₂Cl₂ (2 × 5 mL). The organic layers were dried over Na₂SO₄ and concentrated. Column chromatography (EtOAc/EtOH, 99:1 → 9:1) gave disaccharide 47 (13.3 mg, 48%) as a white amorphous solid. ¹H NMR (600 MHz, Chloroform-d) δH 5.86 (d, J = 8.3 Hz, 1H, N-H'), 5.47 (d, J = 8.0 Hz, 1H, N-H), 5.22 (dd, J = 10.5, 9.4 Hz, 1H, H-3), 5.17 (dd, J = 10.4, 9.4 Hz, 1H, H-3'), 5.06 (t, J = 9.6 Hz, 1H, H-4'), 5.00 (t, J = 9.5 Hz, 1H, H-4), 4.59 (d, J = 8.3 Hz, 1H, H-1), 4.50 (d, J = 8.4 Hz, 1H, H-1'), 4.25 (dd, J = 12.3, 4.7 Hz, 1H, H-6a'), 4.11 (dd, J = 12.3, 2.3 Hz, 1H, H-6b'), 4.02 – 3.96 (m, 2H, H-2', H-6a), 3.95 – 3.91 (m, 1H, OCHHCH₂), 3.84 (dt, J = 10.2, 8.6 Hz, 1H, H-2), 3.64 (m, 2H, H-5, H-5'), 3.58 – 3.54 (m, 1H, OCHHCH₂), 3.46 (dd, J = 11.3, 5.1 Hz, 1H, H-6b), 3.38 (t, J = 6.4 Hz, 2H, CH₂N₃), 2.08, 2.04, 2.02, 2.01, 2.00 (5 s, 15H, 5 × OAc), 1.95, 1.94 (2 s, 6H, 2 × NAc), 1.90 – 1.77 (m, 2H, CH₂CH₂CH₂). ¹³C NMR (125 MHz, Chloroform-d) δC 170.91, 170.86, 170.69, 170.34, 170.20, 170.00, 169.33 (7 × COCH₃), 101.36 (C-1'), 100.69 (C-1), 72.92 (C-5), 72.79 (C-3'), 72.48 (C-3), 72.04 (C-5'), 68.79 (C-4), 68.38 (C-4'), 67.84 (C-6), 65.90 (OCH₂CH₂), 61.97 (C-6'), 54.52 (C-2), 54.25 (C-2'), 48.11 (CH₂N₃), 28.90 (CH₂CH₂CH₂), 23.34, 23.15 (2 × NCOCH₃), 20.78, 20.75, 20.69, 20.66, 20.61 (5 × COCH₃). m/z (ESI) calculated for C₂₉H₄₇N₆O₁₆ [M+NH₄]⁺ 735.30, found 735.30.
$^1$H-NMR

Compound 1

Deuterium Oxide

700 MHz
$^1$H-NMR

Compound 1

Deuterium Oxide

700 MHz
COSY
Compound 1
Deuterium Oxide
500 MHz
COSY

Compound 1

Deuterium Oxide

700 MHz
TOCSY
Compound 1
Deuterium Oxide
700 MHz
$^{13}$C-NMR
Compound 1
Deuterium Oxide
125 MHz
$^1$H-NMR
Compound 2
Deuterium Oxide
600 MHz
\(^1\)H-NMR

**Compound 2**

Deuterium Oxide

600 MHz
COSY
Compound 2
Deuterium Oxide
600 MHz
$^{13}$C-NMR
Compound 2
Deuterium Oxide
125 MHz
HSQC
Compound 2
Deuterium Oxide
600 MHz
$^1$H-NMR

Compound 3

Deuterium Oxide

700 MHz
\(^1\text{H-NMR}\)

**Compound 3**

**Deuterium Oxide**

**700 MHz**
COSY
Compound 3
Deuterium Oxide
700 MHz
$^{13}$C-NMR

Compound 3

Deuterium Oxide

125 MHz
HSQC
Compound 3
Deuterium Oxide
700 MHz
HSQC-TOCSY
Compound 3
Deuterium Oxide
700 MHz
$^1$H-NMR
Compound 4
Deuterium Oxide
700 MHz
$^1$H-NMR
Compound 4
Deuterium Oxide
700 MHz
COSY
Compound 4
Deuterium Oxide
700 MHz
TOCSY
Compound 4
Deuterium Oxide
700 MHz
$^{13}$C-NMR
Compound 4
Deuterium Oxide
125 MHz
HSQC
Compound 4
Deuterium Oxide
700 MHz
$^1$H-NMR
Compound 6
Chloroform-d
400 MHz
$^{13}$C-NMR

Compound 6

Chloroform-$d$

100 MHz
$^1$H-NMR
Compound 7
Methanol-$d_4$
400 MHz
$^{13}C$-NMR
Compound 7
Methanol-$d_4$
100 MHz
$^1$H-NMR
Compound 8
Chloroform-$d$
400 MHz
$^{13}$C-NMR
Compound 8
Chloroform-$d$
100 MHz
$^1$H-NMR

Compound 9
DMSO-$d_6$
400 MHz
$^{13}$C-NMR
Compound 9
DMSO-$d_6$
100 MHz
$^1$H-NMR
Compound 10
Chloroform-$d$
400 MHz
$^{13}$C-NMR

Compound 10

Chloroform-$d$

100 MHz
$^1$H-NMR

Compound 11

Chloroform-$d$

400 MHz
$^1$H-NMR
Compound 12
Chloroform-$d$
400 MHz
$^{13}$C-NMR

Compound 12

Chloroform-\textit{d}

100 MHz
$^1$H-NMR

Compound 13

Chloroform-$d$

400 MHz
\(^1\)H-NMR

Compound 14

Acetone-\(d_6\)

400 MHz
$^{13}$C-NMR
Compound 14
Acetone-$d_6$
100 MHz
$^1$H-NMR

Compound 15

Chloroform-$d$

400 MHz
$^{13}$C-NMR
Compound 15
Chloroform-$d$
125 MHz
$^1$H-NMR
Compound 16
Chloroform-$d$
400 MHz
$^1$H-NMR
Compound 17
Chloroform-$d$
400 MHz
$^1$H-NMR
Compound 18
Chloroform-$d$
600 MHz
\(^{13}\)C-NMR
Compound 18
Chloroform-\(d^1\)
125 MHz
$^1$H-NMR
Compound 19
Chloroform-$d$
600 MHz
$^{13}$C-NMR

Compound 19

Chloroform-$d$

125 MHz
$^1$H-NMR
Compound 20
Chloroform-$d$
600 MHz
$^{13}$C-NMR

Compound 20

Chloroform-\textit{d}$'$

125 MHz
\(^1\)H-NMR
Compound 21
Acetone-\(d_6\)
600 MHz
$^{13}\text{C-NMR}$

**Compound 21**

Acetone-$d_6$

125 MHz
$^1$H-NMR
Compound 22
Acetone-$d_6$
600 MHz
$^{13}$C-NMR

Compound 22

Acetone-$d_6$

125 MHz
\(^1\)H-NMR
Compound 23
Chloroform-\(d\)
600 MHz
$^{13}$C-NMR

Compound 23

Chloroform-$d$

125 MHz
$^1$H-NMR
Compound 24
Chloroform-$d$
600 MHz
$^{13}$C-NMR

Compound 24

Chloroform-$d$

125 MHz
$^{13}$C-NMR
Compound 25
Chloroform-$d$
125 MHz
$^1$H-NMR
Compound 26
Chloroform-$d$
600 MHz
$^{13}$C-NMR
Compound 26
Chloroform-$d$
125 MHz
$^{13}$C-NMR

**Compound 27**

**Chloroform-$d'$**

**125 MHz**
$^1$H-NMR

Compound 28

Acetone-$d_6$

600 MHz
$^{13}$C-NMR

Compound 28

Acetone-$d_6$

125 MHz
$^1$H-NMR
Compound 29
Acetone-$d_6$
600 MHz
$^{13}$C-NMR
Compound 29
Acetone-$d_6$
125 MHz
$^1\text{H-NMR}$

**Compound 30**

**Chloroform-\textit{d}**

600 MHz
$^{13}$C-NMR
Compound 30
Chloroform-$d$
125 MHz
$^1$H-NMR
Compound 34
Chloroform-$d$
400 MHz
$^{13}$C-NMR
Compound 34
Chloroform-$d$
100 MHz
$^1$H-NMR
Compound 36
Chloroform-$d$
400 MHz
\(^{13}\)C-NMR

Compound 36

Chloroform-\(d^1\)

100 MHz
$^1$H-NMR
Compound 37
Chloroform-$d$
600 MHz
$^{13}$C-NMR

**Compound 37**

Chloroform-$d$

125 MHz
$^1$H-NMR
Compound 38
Chloroform-$d$
600 MHz
$^{13}$C-NMR

**Compound 38**

Chloroform-$d'$

125 MHz
$^1$H-NMR
Compound 39
Chloroform-$d$
600 MHz
$^{13}$C-NMR

**Compound 39**

Chloroform-$d$

125 MHz
$^{1}$H-NMR
Compound 41
Acetone-$d_6$
600 MHz
$^{13}$C-NMR

Compound 41

Acetone-$d_6$

125 MHz
$^1$H-NMR

Compound 44

Deuterium Oxide

600 MHz
$^{13}$C-NMR
Compound 44
Deuterium Oxide
125 MHz
$^1$H-NMR
Compound 45
Chloroform-$d$
600 MHz
$^{13}$C-NMR
Compound 45
Chloroform-$d$
125 MHz
$^1$H-NMR
Compound 46
Chloroform-$d$
600 MHz
$^{13}$C-NMR

Compound 46

Chloroform-$d$

125 MHz
$^1$H-NMR
Compound 47
Chloroform-$d$
600 MHz
$^{13}$C-NMR
Compound 47
Chloroform-$d$
125 MHz
ESI-MS
Compound 2
ESI-MS
PgaB C-Terminus
+ Compound 2
Assay
ESI-MS
PgaB C-Terminus + Compound 3
Assay
References