Supporting information

Orthogonal cleavage of 2-naphthylmethyl group in the presence of p-methoxy phenyl-protected anomeric position and its use in carbohydrate synthesis

Vittorio Cattaneo*, Davide Oldrini*, Alessio Corrado*, Francesco Berti*, Roberto Adamo*

* GSK Vaccines, Via Fiorentina 1, 53100 Siena (Italy).
* e-mail_roberto.x.adamo@gsk.com

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General methods for chemical synthesis of oligosaccharides

All chemicals were of reagent grade, and were used without further purification. Reactions were monitored by thin-layer chromatography (TLC) on Silica Gel 60 F254 (Sigma Aldrich); after examination under UV light, compounds were visualized by heating with 10% (v/v) ethanolic H2SO4. In the work up procedures, organic solutions were washed with the amounts of the indicated aqueous solutions, then dried with anhydrous Na2SO4, and concentrated under reduced pressure at 30-50°C on a water bath. Column chromatography was performed on pre-packed silica cartridges RediSep (Teledyne-Isco, 0.040–0.063 nm) or Biotage SNAP Ultra (0.050 nm irregular silica). Unless otherwise specified, a gradient 0 → 100% of the elution mixture was applied in a Combiflas hR (Teledyne-Isco) or Isolera (Biotage) instrument. Solvent mixtures less polar than those used for TLC were used at the onset of separation. 1H NMR spectra were measured at 400 MHz and 298 K with a Bruker AvanceIII spectrometer; δH values were reported in ppm, relative to the internal standard Me4Si (δH = 0.00, CDCl3) or the water signal (δH = 4.79 ppm, D2O). 13C NMR spectra were measured at 100 MHz and 298 K with a Bruker AvanceIII spectrometer; δC values are reported in ppm relative to the signal of CDCl3 (δC = 77.0, CDCl3). NMR signals were assigned by homonuclear and heteronuclear 2-dimensional correlation spectroscopy. When reporting assignments of NMR signals, sugar residues in oligosaccharides are indicated with capital letters, uncertain attributions are denoted “/”. Nuclei associated with the linker are denoted with a prime. Exact masses were measured by electron spray ionization cut-off spectroscopy, using a Q-Tof microMacromass (Waters) instrument. Optical rotation was measured with a P-2000 Jasco polarimeter at 25°C.

4-Methoxyphenyl 2,6-di-O-benzoyl-3-O-naphthylmethyl-β-D-galactopyranoside 1a: Compound 1b (2.57 g, 5.2 mmol) and Bu2SnO (1.55 g, 6.2 mmol) were refluxed in toluene (50 ml) for 2 h using a Dean Stark apparatus. Then temperature was lowered to 50 °C, NAPBr (1.3 g, 6.2 mmol) and TBAI (2.3 g, 6.2 mmol) were added, and stirring was continued for 12 h. Chromatography (cyclohexane-EtOAc) provided 3.03 g of product 1a (92%).

1H NMR (CDCl3): δ 8.07–6.61 (m, 22H, H-Ar), 5.75 (t, J = 8.8 Hz, 1H, H-2), 4.89 (d, J = 7.3 Hz, H-1), 4.89, 4.72 (2 d, J = 12.2 Hz, 1H, CH2NAP), 4.77–4.65 (m, 2H, H-6), 4.24 (d, J = 2.3 Hz, 1H, H-4), 3.98–3.95 (m, 1H, H-5), 3.79 (dd, 1H, H-3), 3.66 (s, 3H, OCH3).

13C NMR (CDCl3): δ 166.3, 165.4 (2 CO), 155.4–113.4 (C-Ar), 100.8 (C-1), 78.0 (C-3), 72.7 (C-5), 71.7 (CH2NAP), 70.9 (C-2) 66.1 (C-4), 63.6 (C-6), 55.5 (OCH3). HR ESI MS C38H34O9: [M+Na]+ calc 657.2101; found 657.2116.
4-Methoxyphenyl 2,4,6-tri-O-benzoyl-3-O-naphtylmethyl-β-D-galactopyranoside 2a: Compound 1b (500 mg, 0.79 mmol) was dissolved in 4:1 CH₂Cl₂-Pyridine (10 ml), and BzCl (0.5 ml, 4 mmol) was added at 0°C. After stirring overnight, allowing reaching room temperature, the mixture was concentrated and the residue was purified on silica gel to afford product 2a in theoretically quantitative yield. [α]D 20 = +79.4° (c 0.40, CHCl₃).

H NMR (CDCl₃): δ 8.10–6.56 (m, 19H, H-Ar), 5.73 (d, J = 3.2 Hz, 1H, H-4), 5.55 (t, J = 8.7 Hz, 1H, H-2), 5.08 (d, J = 8.0 Hz, H-1), 4.53–4.46 (m, 2H, H-6), 4.22–4.18 (m, 1H, H-5), 4.16 (dd, 1H, H-3), 3.64 (s, 3H, OCH₃).

C NMR (CDCl₃): δ 166.8, 166.2, 166.0 (3 CO), 155.6–112.3 (C-Ar), 100.7 (C-1), 73.8 (C-2), 71.8 (C-3, 5), 70.3 (C-4), 62.4 (C-6), 55.5 (OCH₃). HR ESI MS C₄₅H₃₈O₁₀: [M+Na⁺] calc 761.2363; found 761.2346.

4-Methoxyphenyl 2,4,6-tri-O-benzoyl-β-D-galactopyranoside 2b: Yield 78%. [α]D 25 = +17.3° (c 0.40, CHCl₃).

H NMR (CDCl₃): δ 8.10–6.58 (m, 19H, H-Ar), 5.73 (d, J = 3.1 Hz, 1H, H-4), 5.55 (t, J = 8.6 Hz, 1H, H-2), 5.07 (d, J = 7.9 Hz, H-1), 4.53–4.44 (m, 2H, H-6), 4.22–4.18 (m, 1H, H-5), 4.16 (dd, 1H, H-3), 3.64 (s, 3H, OCH₃).

C NMR (CDCl₃): δ 166.8, 166.2, 166.0 (3 CO), 155.6–112.3 (C-Ar), 100.7 (C-1), 73.3 (C-2), 71.8, 70.8 (C-3, 4), 70.3 (C-5), 62.6 (C-6), 55.6 (OCH₃). HR ESI MS C₃₄H₃₆O₁₀: [M+H⁺] calc 599.1997; found 599.1995.

2,4,6-Tri-O-benzoyl-3-O-naphtylmethyl-α,β-D-galactopyranoside 2c: Yield 68%. H NMR (CDCl₃): δ 8.18–7.40 (m, H-Ar), 5.81 (d, J = 2.7 Hz, H-4), 5.81 (d, J = 2.8 Hz, H-3), 5.75 (d, J = 3.5 Hz, H-1), 5.43 (dd, J = 9.0 Hz, H-2), 5.31 (dd, J = 7.9, 9.9 Hz, H-2), 4.94 (d, H-1), 4.73–4.38 (m, H-5, H-6), 4.26–4.20 (m, H-3). C NMR (CDCl₃): δ 166.8, 165.5, 166.2 (3 CO), 133.7–128.3 (C-Ar), 96.0 (C-1), 91.1 (C-1), 75.5 (C-2), 72.2 (C-2), 71.7 (C-4), 71.6 (C-4), 70.7 (C-5), 67.1 (C-3), 68.0 (C-3), 66.0 (C-5), 62.7 (C-6), 62.6 (C-6). HR ESI MS C₃₄H₃₆O₁₀: [M+H⁺] calc 632.2046; found 632.2035.

4-Methoxyphenyl 2,6-di-O-benzoyl-4-O-levulinoyl-3-O-naphtylmethyl-β-D-galactopyranoside 3a: Compound 1a (500 mg, 0.79 mmol) was dissolved in CH₂Cl₂ (10 ml), to which levulinic acid (140 mg, 1.2 mmol), DCC (247 mg, 1.2 mmol) and DMAP (146 mg, 1.2 mmol) were added. After stirring overnight the mixture was concentrated and the residue was purified on silica gel to afford 512 mg of product 3a (89%), as a white solid (m.p 119–121°C from ethyl acetate). [α]D 25 = +48.7° (c 0.43, CHCl₃).

H NMR (CDCl₃): δ 8.08–6.59 (m, 22H, H-Ar), 5.73 (d, J = 2.3 Hz, 1H, H-4), 5.68 (t, J = 9.0 Hz, 1H, H-2), 4.91 (d, J = 7.8 Hz, H-1), 4.82, 4.58 (2 d, J = 12.3 Hz, 1H, CH₂NAP), 4.57–4.50 (m, 2H, H-6, 4.11–4.08 (m, 1H, H-5), 3.79 (dd, 1H, H-3), 3.67 (s, 3H, OCH₃), 2.93–2.78 (m, 4H, CH₂CH₃), 2.19 (s, 3H, CH₃).

C NMR (CDCl₃): δ 206.3, 172.3, 166.1, 165.2 (4 CO), 155.5–114.3 (C-Ar), 101.0 (C-1), 75.9 (C-3), 71.4 (C-5), 71.2 (CH₂Nap), 70.8 (C-2), 66.1 (C-4), 62.3 (C-6), 55.5 (OCH₃), 38.1, 29.71 (2 CH₂Lev), 28.2 (CH₃). HR ESI MS C₄₅H₄₀O₁₁: [M+H⁺] calc 733.2649; found 733.2646.
2,6-Di-O-benzyol-4-O-levulinoyl-β-D-galactopyranoside 3b: Yield 76%. [α]_D^{25} = +25.1° (c 0.23, CHCl₃).

1H NMR (CDCl₃): δ 8.03–6.58 (m, 14H, H-Ar), 5.54 (d, J = 2.9 Hz, 1H, H-4), 5.45 (t, J = 8.8 Hz, 1H, H-2), 5.00 (d, J = 7.6 Hz, H-1), 4.54–4.40 (m, 2H, H-6), 4.14–4.11 (m, 1H, H-5), 4.04 (dd, 1H, H-3), 3.66 (s, 3H, OCH₃), 2.86–2.72 (m, 4H, CH₂CH₂), 2.19 (s, 3H, CH₃).

13C NMR (CDCl₃): δ 204.7, 172.4, 166.5, 166.1 (4 CO), 155.6–114.3 (C-Ar), 100.8 (C-1), 73.0 (C-3), 71.5 (C-4,5), 70.1 (C-2), 62.4 (C-6), 55.5 (OCH₃), 38.4, 29.71 (2 CH₂), 28.2 (CH₃). HR ESI MS C₃₂H₃₁O₁₁: [M+H]⁺ calc 592.1945; found 592.1955.

2,6-Di-O-benzyol-4-O-levulinoyl-3-O-naphthylmethyl-α,β-D-galactopyranoside 3c: Yield 61%, α/β anomers in ~3:2 ratio. 1H NMR (CDCl₃): δ 8.07–7.27 (m, H-Ar), 5.81 (d, J = 2.1 Hz, H-4α), 5.78 (d, J = 2.3 Hz, H-4β), 5.61 (d, J = 2.6 Hz, H-1α), 5.38 (dd, J = 10.2 Hz, H-2α), 5.35 (t, J = 8.7 Hz, H-2β), 4.82 (t, J = 11 Hz, H-6α), 4.70 (d, H-1β), 4.71–4.33 (m, H-5α,5β,6α,6β), 4.46 (dd, H-3α), 4.05 (dd, H-3β), 3.77 (br. s, OH), 2.85–2.68 (m, CH₂CH₂), 2.10, 2.04 (2x s, 2 x CH₃). HR ESI MS C₃₉H₃₄O₁₀: [M+H]⁺ calc 627.2230; found 627.2245.

4-Methoxyphenyl 2-O-benzyol-4,6-O-benzylidene-3-O-naphthylmethyl-β-D-galactopyranoside 4a: Compound 28 was prepared from 1a (730 mg, 1 mmol) by deacylation with NaOMe in MeOH (5 ml) at pH 12 for 48 h. The reaction crude was neutralized with Dowex H⁺, then filtered and concentrated. The material was dissolved in CH₃CN (5 ml) and benzylidene dimethyl acetal (1 ml) was added in the presence of catalytic p-TsOH (100 mg). After stirring for 6 h, the reaction was quenched by addition of TEA, concentrated and rapidly purified on silica gel (cyclohexane-EtOAc). Fractions containing sugar were concentrated and dissolved in DMF (5 ml) and 60% NaH in mineral oil (2 equiv) followed by BnBr (0.5 ml) was added at 0°C under nitrogen. After stirring overnight at r.t., the mixture was partitioned with water, and combined organic layers were concentrated. Purification on silica gel of the residue gave 450 mg of product (73%), as a white solid (m.p. 139–140°C from cyclohexane-EtOAc). [α]_D^{25} = +3.7° (c 0.15, CHCl₃).

1H NMR (CDCl₃): δ 8.00–6.70 (m, 22H, H-Ar), 5.90 (dd, J = 8.0, 9.9 Hz, 1H, H-2), 5.56 (s, 1H, CHPh), 4.99 (d, 1H, H-1), 4.88, 4.79 (2 d, J = 12.0 Hz, 2H, CH₂NAP), 4.92, 4.11 (2 d, J = 12.1 Hz, 2H, H-6), 4.32 (d, J = 2.5 Hz, 1H, H-4), 3.84 (dd, 1H, H-3), 3.71 (s, 3H, OCH₃), 3.49 (br. s 1H, H-5). HR ESI MS C₃₈H₃₄O₉: [M+H]⁺ calc 619.2332; found 619.2334.
4-Methoxyphenyl 2-O-benzoyl-4,6-O-benzylidene-D-galactopyranoside 4b: Yield 82%. \([\alpha]_{D}^{25} = -2.2^\circ\) (c 0.15, CHCl₃).

\(^1\)H NMR (CDCl₃): \(\delta\) 8.13–6.80 (m, 14H, H-Ar), 5.65 (s, 1H, CHPh), 5.45 (dd, \(J = 8.0, 9.2\) Hz, 1H, H-2), 5.18 (d, 1H, H-1), 4.47–4.44 (m, 1H, H-6a), 4.21 (d, \(J = 3.5\) Hz, 1H, H-4), 4.15 (t, \(J = 10.0\) Hz, 1H, H-6b), 3.98 (dd, 1H, H-3), 3.77 (s, 3H, OCH₃), 3.71–3.68 (br. s 1H, H-5). \(^13\)C NMR (CDCl₃): \(\delta\) 166.1 (CO), 133.6–114.6 (C-Ar), 102.1 (PhCH), 100.2 (C-1), 80.7 (C-3), 74.8 (C-4), 72.7 (C-2), 68.6 (C-6), 66.4 (C-5), 55.6 (OCH₃). HR ESI MS C₂₇H₂₆O₅: [M+H]⁺ cal 501.1525; found 501.1531.

2-O-Benzoyl-4,6-O-benzylidene-3-O-napthylmethyl-\(\beta\)-D-galactopyranoside 4c:

Yield 45%, \(\alpha/\beta\) anomers in \(~3:2\) ratio. \(^1\)H NMR (CDCl₃): \(\delta\) 8.06–6.89 (m, H-Ar), 5.69 (d, \(J = 3.6\) Hz, H-1), 5.61 (dd, \(J = 10.2\) Hz, H-2), 5.54 (d, \(J = 8.0\) Hz, H-1), 5.52 (s, CHPh), 4.89–4.81 (m, CHPh, H-2), 3.42 (m, H-3), 3.41–3.40 (m, H-4), 3.88–3.85 (m, H-5), 3.92 (d, \(J = 2.3, 9.9\) Hz, H-4), 3.48 (d, \(J = 2.3\) Hz, H-4).

\(^13\)C NMR (CDCl₃): \(\delta\) 167.1, 166.0, 137.7–125.2 (C-Ar), 101.2 (CHPh, C-1), 92.6 (CHPh), 97.8 (C-1), 91.3 (C-1), 74.2, 73.5, 73.1, 71.8, 70.8, 69.4, 62.5, 60.4. HR ESI MS C₃₁H₂₈O₇: [M+H]⁺ cal 513.1913; found 513.1925.

4-Methoxyphenyl 2-O-benzyl-4,6-O-benzylidene-3-O-napthylmethyl-\(\beta\)-D-galactopyranoside 5a: This compound was prepared from 1a (730 mg, 1 mmol) by deacylation with NaOMe in MeOH (5 ml) at pH 12 for 48 h. The reaction crude was neutralized with Dowex H⁺, then filtered and concentrated. The residue was dissolved in DMF (5 ml) and 60% NaH in mineral oil (2 equiv) and BnBr (0.5 ml) was added under nitrogen. After stirring overnight the mixture was partitioned with water, and combined organic layers were concentrated. Purification on silica gel of the residue gave 510 mg of product (84%). \). \([\alpha]_{D}^{25} = -0.3^\circ\) (c 2.1, CHCl₃).

\(^1\)H NMR (CDCl₃): \(\delta\) 7.90–6.86 (m, 22H, H-Ar), 5.55 (s, 1H, CHPh), 5.10, 4.91 (2 d, \(J = 10.9\) Hz, 2H, CH₂Ar), 5.11, 4.97 (2 d, \(J = 12.0\) Hz, 2H, CH₂Ar), 4.92 (d, \(J = 7.6\) Hz H-1), 4.32, 4.01 (2 d, \(J = 12.1\) Hz, 2H, H-6), 4.22–4.18 (m, 2H, H-2,5), 3.80 (s, 3H, OCH₃), 3.72 (dd, \(J = 3.2\) Hz, 1H, H-3), 3.33 (s, 1H, H-4).

\(^13\)C NMR (CDCl₃): \(\delta\) 155.5–114.1 (C-Ar), 103.2 (CHPh), 100.2 (C-1), 79.2 (C-3), 78.2 (C-5), 75.5 (CH₂Ar), 73.8 (C-4), 72.1 (C-2), 69.1 (C-6), 55.6 (OCH₃). HR ESI MS C₃₈H₃₆O₇: [M+Na]⁺ cal 627.2359; found 627.2363.

4-Methoxyphenyl 2-O-benzyl-4,6-O-benzylidene-D-galactopyranoside: The product of NAP removal from 5a was identical to the compound described in literature.²

2-O-Benzyl-4,6-O-benzylidene-3-O-napthylmethyl-\(\beta\)-D-galactopyranoside 5c:

Yield 68%, \(\alpha/\beta\) anomers in \(~3:2\) ratio. \(^1\)H NMR (CDCl₃): \(\delta\) 7.93–7.33 (m, H-Ar), 5.52 (s, CHPh), 5.51 (s, CHPh), 5.41 (d, \(J = 3.5\) Hz, H-1), 5.09–4.75 (m, CH₂Ar), 4.72 (d, \(J = 7.5\) Hz, H-1), 4.25 (br. s, H-4), 4.25–4.22 (m, H-6a), 4.18–4.15 (m, H-6b), 4.14–4.00 (m, H-2), 3.87 (br. s, H-5), 3.84 (dd, \(J = 7.0, 9.3\) Hz, H-2), 3.67 (dd, \(J = 2.3, 9.7\) Hz, H-3), 3.40 (d, \(J = 2.3\) Hz, H-4).
13C NMR (CDCl3): δ 129.9–125.2 (C-Ar), 101.3 (CHPh), 101.1 (CHPh), 97.5 (C-1β), 92.5 (C-1α), 79.2, 77.2, 75.8, 75.3, 73.9, 72.1, 69.5, 66.8, 62.8. HR ESI MS C31H29NO6: [M+Na]+ calc 521.1940; found 521.1955.

4-Methoxyphenyl 2-O-Benzoyl-4,6-O-benzylidene-3-O-naphtylmethyl-β-D-glucopyranoside 6a:
Compound 293 (800 mg, 1.4 mmol) was reacted with p-methoxy phenol (620 mg, 5 mmol), NIS (450 mg, 2.5 mmol) and TIOH (28 ul, 0.32 mmol) and CH2Cl2 (5 ml) at -10°C to room temperature, under nitrogen. After stirring overnight the mixture was quenched with TEA, and filtered. The filtrate was concentrated and purified on silica gel (cyclohexane-EtOAc) to give 514 mg of product 6a (74%), as a white solid (m.p. 133–135°C from EtOAc). [α]D 25 = +7.5° (c 0.17, CHCl3).

1H NMR (CDCl3): δ 7.89–5.39 (m, 22H, H-Ar), 5.62 (s, 1H, CHPh), 5.53 (t, J = 7.2 Hz, 1H, H-2), 5.00 (d, J = 8.0 Hz H-1), 4.97, 4.86 (2d, J = 11.6 Hz, 2H, CH2NAP), 4.37 (dd, J = 4.5, 9.5 Hz, 1H, H-6a), 3.97–3.96 (m, 2H, H-3, 4), 3.86 (t, J = 9.5 Hz, 1H, H-6b), 3.67 (s, 3H, OCH3), 3.57–3.51 (m, 1H, H-5).

13C NMR (CDCl3): δ 165.1 (CO), 155.6–114.5 (C-Ar), 101.4 (CHPh, C-1), 81.5 (C-4), 77.6 (C-3), 74.05 (CH2NAP), 73.3 (C-2), 68.7 (C-6), 66.4 (C-5), 55.6 (OCH3). HR ESI MS C31H29O6: [M+H]+ calc 513.1878; found 520.1913.

4-Methoxyphenyl 2-O-Benzoyl-4,6-O-benzylidene-β-D-glucopyranoside 6b:
Yield 82%. [α]D 25 = +18.7° (c 0.41, CHCl3).

1H NMR (CDCl3): δ 7.57–6.07 (m, 14H, H-Ar), 5.55 (s, 1H, CHPh), 5.36 (t, J = 7.6 Hz, 1H, H-2), 5.08 (d, J = 7.5 Hz H-1), 4.38 (dd, J = 4.6, 9.5 Hz, 1H, H-6a), 4.07 (t, J = 8.0 Hz, 1H, H-3), 3.83 (t, J = 9.5 Hz, 1H, H-6b), 3.73 (t, J = 9.1 Hz, 1H, H-4), 3.69 (s, 3H, OCH3), 3.61–3.55 (m, 1H, H-5).

13C NMR (CDCl3): δ 151.3 (CO), 133.7–114.5 (C-Ar), 102.0 (CHPh), 101.2 (C-1), 80.7 (C-4), 74.8 (C-2), 72.5 (C-3), 68.6 (C-6), 66.4 (C-5), 55.6 (OCH3). HR ESI MS C27H26O6: [M+H]+ calc 479.1712; found 479.1706.

2-O-Benzoyl-4,6-O-benzylidene-3-O-naphtylmethyl-α,β-D-glucopyranoside 6c:
Yield 78%, α/β anomers in ~2:1 ratio. 1H NMR (CDCl3): δ 8.14–7.35 (m, H-Ar), 5.70 (s, CHPh), 5.60 (d, J = 3.9 Hz, H-1α), 5.34 (s, CHPh), 5.13 (dd, J = 8.5 Hz, H-2α), 5.09–4.83 (m, CH2Ar, H-2β), 4.70 (d, J = 7.5 Hz, H-1β), 4.17 (t, J = 11.0 Hz, H-6α), 4.06–3.51 (m, H-3α, 4α, 6b), 3.30–3.20 (m, 5αβ). HR ESI MS C31H28O7: [M+H]+ calc 535.1733; found 535.1716.
4-Methoxyphenyl 2,3-O-isopropylidene-α-d-mannopyranoside 31: Mannoside 30 (2 g, 4.1 mmol) was deacetylated with NaOMe in 20 of MeOH at pH strongly basic. After neutralization with Dowex H⁺, the mixture was filtered. The filtrate was concentrated and re-dissolved in 20 ml of 1:1 acetone:dimethyl acetone, containing catalytic p-TsOH (200 mg, 0.4 mmol) and stirred for 1 h at r.t. Then water was added (50 ml) and the mixture was stirred for 2 h until the faster moving spot (cyclohexane–EtOAc 1:1) disappeared. The mixture was concentrated and chromatographed (cyclohexane–EtOAc) to give 0.88 g of product 30 (67%). [α]D²⁵ = +74.9° (c 0.97, CHCl₃).

¹H NMR (CDCl₃): δ 7.67–6.78 (m, 27H, H-Ar), 5.62 (s, 1H, H-1), 4.31 (d, J = 5.0 Hz, 1H, H-2), 4.26 (t, J = 5.0 Hz, 1H, H-3), 3.80–3.69 (m, 7H, H-4,5,6, OCH₃), 3.53 (br. s, 1H, OH-2), 2.65 (br. s, 1H, OH-3), 1.67, 1.48 (2 s, 3H each, 2 x CH₃).

¹³C NMR (CDCl₃): δ 170.1 (CO), 155.1–114.7 (C-Ar), 109.8 (C(OCH₃)₂), 96.5 (C-1), 78.5 (C-3), 75.6 (C-2), 70.2 (C-4,5), 69.2 (C-6), 55.7 (OCH₃), 27.0, 26.2 (2 x CH₃). HR ESI MS C₁₆H₂₂O₇: [M+H]⁺ calc 327.1416; found 327.1444.

4-Methoxyphenyl 4-O-benzyl-2,3-O-isopropylidene-6-O-tertbutyldiphenylsilyl-α-D-mannopyranoside 32: Diol 31 (500 mg, 1.5 mmol) was dissolved in pyridine (5 ml) and treated with TBDPSCI (600 µl, 2.3 mmol) in the presence of DMAP (40 µg, 0.2 mmol) at r.t. After stirring for 6 h (TLC, 4:1 cyclohexane-EtOAc) the reaction was complete. The reaction crude was concentrated and purified on silica gel (cyclohexane-EtOAc) to give the 6-TBDPS mannoside, which was dissolved in dry THF (5 ml) and treated with NaH in mineral oil (150 mg, 4.5 mmol) for 15 min at °C. The BnBr (0.53 ml, 4.5 mmol) was added and stirring was continued overnight at r.t. After TLC (9:1 cyclohexane-EtOAc) showed complete reaction, the mixture was diluted with CH₂Cl₂ and partitioned with water. Combined organic layers were concentrated and chromatographed on silica gel (cyclohexane-EtOAc) to yield compound 32 (780 mg, 78% over two steps). [α]D²⁵ = +24.3° (c 1.6, CHCl₃).

¹H NMR (CDCl₃): δ 7.77–6.79 (m, 19H, H-Ar), 5.73 (s, 1H, H-1), 4.99, 4.70 (2 d, J = 11.3 Hz, 2H, CH₂Ph), 4.55 (t, J = 6.5 Hz, 1H, H-4), 4.42 (d, J = 5.3 Hz, 1H, H-2), 3.99–3.96 (m, 1H, H-6a), 3.92–3.82 (m, 3H, H-3,5,6b), 3.77 (br. s, 3H, OCH₃), 1.66, 1.49 (2 s, 3H each, 2 x CH₃).

¹³C NMR (CDCl₃): δ 155.0–114.6 (C-Ar), 109.6 (C(OCH₃)₂), 96.3 (C-1), 78.9 (C-4), 75.9 (C-2), 75.4 (C-3), 73.2 (CH₂Ph), 72.2 (C-5), 62.9 (C-6), 55.8 (OCH₃), 28.0 (CH₃), 26.6 (tBuSi), 26.2 (CH₃). HR ESI MS C₃₉H₄₆O₇Si: [M+Na]⁺ calc 677.2911; found 677.2864.
4-Methoxyphenyl 2-O-acetyl-4-O-benzyl-3-O-napthylmethyl-6-O-tertbutyldiphenylsilyle-α,δ-mannopyranoside 7a: Compound 32 (1.95 g, 3 mmol) was stirred overnight in 15 ml of 9:1 AcOH-H2O at 50°C. The reaction crude was concentrated and purified on silica gel to give 550 mg of the diol which was used for the following step. The material (1.55 g, 3 mmol) and Bu2SnO (830 mg, 3.3 mmol) were suspended in toluene (30 ml) and refluxed for 2 h at the Dean Stark apparatus. The temperature was lowered to 50°C, then NAPBr (680 mg, 3.3 mmol) and TBAI (1.2 g, 3.3 mmol) were added. After stirring overnight, TLC (4:1 cyclohexane-ETOAc) showed complete reaction. The mixture was concentrated and re-dissolved in 1:1 Ac2O-pyridine (10 ml). After 6 h, TLC (9:1 cyclohexane-ETOAc) showed formation of a faster moving spot. The reagents were evaporated and the residue was purified on silica gel to yield the product 7a (1.55 g, 65% over three steps). [α]D25 = +2.8° (c 1.74, CHCl3).

1H NMR (CDCl3): δ 7.67-6.78 (m, 27H, H-Ar), 5.66 (br. s, 1H, H-2), 5.50 (s, 1H, H-1), 5.06, 4.76 (2 d, J = 10.9 Hz, 2H, CH2Ar), 5.00, 4.85 (2 d, J = 11.3 Hz, 2H, CH2Ar), 4.33 (dd, J = 2.9, 9.6 Hz, H-3), 4.22 (t, J = 9.6 Hz, 1H, H-4), 4.22 (dd, J = 3.4, 10.6 Hz, H-6a), 3.93-3.88 (m, 2H, H-5,6b), 3.79 (m, 3H, OCH3), 2.19 (s, 3H, CH3CO), 1.15 (s, 9H, tBuSi).

13C NMR (CDCl3): δ 170.1 (CO), 155.5-114.7 (C-Ar), 96.9 (C-1), 78.1 (C-3), 75.5 (CH2Ar), 74.1 (C-4), 73.1 (C-5), 75.3 (CH2Ar), 70.9 (C-2), 70.0 (C-6), 55.7 (OCH3), 26.8 (tBuSi), 21.2 (CH3CO). HR ESI MS C40H52O6Si: [M+Na]+ calc 819.3329; found 819.3347.

4-Methoxyphenyl 2-O-acetyl-4-O-benzyl-6-O-tertbutyldiphenylsilyle-α-D-mannopyranoside 7b: Yield 88%. [α]D25 = +36.1° (c 0.52, CHCl3).

1H NMR (CDCl3): δ 7.67-6.78 (m, 19H, H-Ar), 5.53 (br. s, 1H, H-2), 5.39 (s, 1H, H-1), 4.99, 4.84 (2 d, J = 11.3 Hz, 2H, CH2Ph), 4.44 (dd, J = 2.9, 9.6 Hz, H-3), 4.14 (t, J = 9.6 Hz, 1H, H-4), 4.09 (dd, J = 3.4, 10.6 Hz, H-6a), 3.96 (d, J = 10.8 Hz, H-6b), 3.87-3.85 (m, 1H, H-5), 3.80 (m, 3H, OCH3), 2.26 (s, 3H, CH3CO), 1.19 (s, 9H, tBuSi).

13C NMR (CDCl3): δ 170.9 (CO), 155.3-114.0 (C-Ar), 97.4 (C-1), 75.4 (C-4), 75.2 (CH2Ar), 73.0 (C-2), 73.8 (C-5), 70.1 (C-3), 62.7 (C-6), 55.7 (OCH3), 26.9 (tBuSi), 21.3 (CH3CO). HR ESI MS C38H44O6Si: [M+Na]+ calc 679.2703; found 679.2787.

2-O-Acetyl-4-O-benzyl-3-O-napthylmethyl-6-O-tertbutyldiphenylsilyle-α,β-D-mannopyranoside 7c: Yield, 58%. Yield 77%, 3:1 α/β mixture. 1H NMR (CDCl3): δ 8.30-7.05 (m, 23H, H-Ar), 5.42 (dd, J = 1.3, 2.3 Hz, H-2β), 5.31 (br. s, H-2α), 5.28 (d, H-1β), 5.19 (d, J = 2.5 Hz, H-1α), 4.89-4.603 (m, CH2Ar), 4.27 (dd, H-3α), 4.16 (dd, H-3β), 4.09-3.87 (m, H-4αβ, 5αβ, 6αβ), 2.20, 2.18 (2 x s, 2 x CH3CO), 1.27 (s, tBuSi). HR ESI MS C42H32O2Si: [M+Na]+ calc 713.2911; found 713.2918.

4-Methoxyphenyl 2,4-di-O-benzyl-3-O-napthylmethyl-6-O-tertbutyldiphenylsilyle-α-D-mannopyranoside 8a: This compound was prepared from compound 32 (1.95 g, 3 mmol) as described for 20, except that after 3-ONAP introduction the material was dissolved in 10 ml of dry THF and treated with NaH in mineral oil (300 mg, 9 mmol) at 0°C, followed by Br2 (1 ml, 9 mmol) at 0°C. The mixture was stirred overnight at r.t., when TLC (9:1 cyclohexane-ETOAc) showed complete reaction. The mixture was diluted with CH2Cl2 and partitioned
with water. Combined organic layers were concentrated and chromatographed on silica gel (cyclohexane-EtOAc) to give compound 8a (1.8 g, 72% over two steps). [α]D25 = +81.5° (c 0.80, CHCl3).

1H NMR (CDCl3): δ 7.64–6.78 (m, 32H, H-Ar), 5.51 (s, 1H, H-1), 5.01–4.72 (m, 6H, 3 x CH2Ar), 4.25 (br. s, 1H, H-2), 4.41–4.34 (m, 2H, H-2,4), 4.19–4.12 (m, 2H, H-3,6a), 4.01–3.95 (m, 2H, H-5,6b), 3.84 (s, 3H, OCH3), 1.21 (s, 9H, tBuSi).

13C NMR (CDCl3): δ 155.3–114.6 (C-Ar), 97.2 (C-1), 80.2 (C-4), 75.5, 75.4, 74.8 (3 x CH2Ar), 73.7 (C-2), 73.0 (C-5), 72.6 (C-3), 63.2 (C-6), 55.7 (OCH3), 26.9 (tBuSi). HR ESI MS C59H62O7Si: [M+Na]+ calc 844.3795; found 844.3793.

4-Methoxyphenyl 2,4-di-O-benzyl-6-O-tertbutyldiphenylsilyl-α-D-mannopyranoside 8b: Yield 81%. [α]D25 = +21.2° (c 0.43, CHCl3).

1H NMR (CDCl3): δ 7.75–6.78 (m, 24H, H-Ar), 5.52 (s, 1H, H-1), 4.99, 4.67 (2 d, J = 11.0 Hz, 2H, CH2Ph), 4.83, 4.71 (2 d, J = 11.3 Hz, 2H, CH2Ph), 4.24–4.22 (m, 1H, H-3), 3.99–3.87 (m, 4H, H-2,4,6), 3.79–3.77 (m, 1H, H-5), 3.77 (s, 3H, OCH3), 1.09 (s, 9H, tBuSi).

13C NMR (CDCl3): δ 158.8–114.3 (C-Ar), 95.9 (C-1), 78.6 (C-4), 76.3 (C-2), 75.0, 73.1 (2 x CH2Ar), 72.6 (C-5), 71.7 (C-3), 62.9 (C-6), 55.7 (OCH3), 26.8 (tBuSi). HR ESI MS C43H48O7Si: [M+Na]+ calc 727.3067; found 727.3091.

2,4-Di-O-benzyl-3-O-napthylmethyl-6-O-tertbutyldiphenylsilyl-α,β-D-mannopyranoside 8c: Yield 77%, almost exclusively α-anomer. 1H NMR (CDCl3): δ 7.55–7.16 (m, 28H, H-Ar), 5.47 (s, 1H, H-1), 5.02–4.63 (m, 6H, 3 x CH2Ph), 4.21 (t, J = 7.6 Hz, 1H, H-4), 4.13 (dd, J = 3.5, 8 Hz, 1H, H-3), 4.00–3.95 (m, 2H, H-2,6), 3.88–3.85 (m, 1H, H-5), 1.28 (s, 9H, tBuSi).

13C NMR (CDCl3): δ 168.4 (CO), 138.1–122.7 (C-Ar), 99.9 (C-1), 80.4 (C-3), 75.3 (CH2Ar), 75.1 (C-4), 74.4, 74.1 (2 x CH2Ar), 73.2 (C-2), 72.7 (C-5), 62.9 (C-6), 26.7 (tBuSi). HR ESI MS C47H50O8Si: [M+Na]+ calc 761.3274; found 761.3261.

4-Methoxyphenyl 4-O-benzyl-α-D-mannopyranoside 11: Compound 7a (1 g, 1.25 mmol) was first desilylated by treatment with 1 M TBAF (300 ul) in 10 ml of THF. After fast purification on a silica gel pad eluting with CH2Cl2, the material was concentrated and then treated with DDQ according to the general procedure for NAP removal. Chromatography on silica gel (cyclohexane-EtOAc) gave compound 11 (370 mg, 71% over two steps). [α]D25 = +15.1° (c 0.21, CHCl3).

1H NMR (CDCl3): δ 7.67–6.78 (m, 9H, H-Ar), 5.43 (s, 1H, H-1), 5.32 (br. s, 1H, H-2), 4.92, 4.88 (2 d, J = 10.8 Hz, 2H, CH2Ph), 4.38 (dd, J = 3.0, 7.6 Hz, H-3), 4.32–4.27 (m, 1H, H-5), 3.87–3.84 (m, 3H, H-4,6), 3.78 (s, 3H, OCH3), 2.20 (s, 3H, CH3CO).

13C NMR (CDCl3): δ 170.8 (CO), 155.2–114.6 (C-Ar), 96.7 (C-1), 72.4 (C-4, CH2Ar), 72.2 (C-2), 70.1 (C-3,5), 70.1 (C-3), 61.7 (C-6), 55.4 (OCH3), 21.1 (CH3CO). HR ESI MS C21H25O6: [M+Na]+ calc 441.1525; found 441.1533.
2,3,4,6-tetra-O-acetyl-α-D-fucopyranoside 34 and 2,3,4,6-tetra-O-acetyl-β-D-fucopyranoside 35:
To a solution of D-fucose peracetate 33 (2 g, 6 mmol) and p-methoxyphenol (2.2 g, 18 mmol) in CH₂Cl₂ (30 ml) containing preactivated 4 Å MS, BF₃Et₂O (3.7 ml, 30 mmol) was added and the mixture was stirred for 2 h at r.t., at which time TLC (3:2 cyclohexane-ethyl acetate) showed disappearance of the starting material. After stirring, TLC (3:2 toluene-ethyl acetate) showed that the reaction was complete. The reaction was quenched with TEA, the crude mixture was concentrated and purified on silica gel to give the α-product 34 (1.25 g, 52%) and the β-product 35 (1.1 g, 45%). The β-anomer 35 was identical to the compound described in literature; α-anomer 34, [α]D²⁵ = +113.0° (c 3.50, CHCl₃).

¹H NMR (CDCl₃): δ 6.92–6.72 (m, 4H, H-Ar), 5.52 (d, J = 4.5 Hz H-1, 1H), 5.66 (dd, J = 3.1, 10.9 Hz, 1H, H-3), 5.27 (d, 1H, H-4), 5.15 (dd, 1H, H-2), 4.07 (t, J = 8.0 Hz, 1H, H-3), 4.23–4.19 (m, 1H, H-5), 3.66 (s, 3H, OCH₃), 2.08, 1.98, 1.92 (3 x s, 3H each, 3 x CH₂CO), 1.03 (d, J = 6.7 Hz, 3H, H-6).

¹³C NMR (CDCl₃): δ 170.6, 710.4, 170.1 (CO), 155.7, 114.3 (C-Ar), 95.7 (C-1), 71.0 (C-4), 67.9 (C-2,3), 65.2 (C-5), 55.6 (OCH₃), 20.7, 20.6, 20.5 (C-5), 15.8 (C-6). HR ESI MS C₁₉H₂₃O₆: [M+Na]⁺ calc 419.1318; found 419.1328.

4-Methoxyphenyl 2,3-O-isopropylidene-α-D-fucopyranoside 36: α-Fucoside 34 (1 g, 2.5 mmol) was deacetylated by treatment with NaOMe in 10 ml of MeOH at pH strongly basic. After neutralization with Dowex H⁺, the resin was filtered off. The filtrate was concentrated and re-dissolved in acetone dimethyl acetal (30 ml) containing p-TsOH (100 mg) as catalyst. After stirring overnight at r.t., the mixture was neutralized with TEA, concentrated and purified on silica gel (cyclohexane-ethyl acetate) to afford 36 (660 mg, 85%). [α]D²⁵ = +17.2° (c 0.41, CHCl₃).

¹H NMR (CDCl₃): δ 6.98–6.77 (m, 4H, H-Ar), 5.32 (d, J = 3.6 Hz H-1, 1H), 5.30 (t, J = 5.6 Hz, 1H, H-3), 4.24–4.19 (m, 1H, H-5), 4.06 (d, J = 6.0 Hz, 1H, H-4), 3.87–3.82 (m, 1H, H-2), 3.71 (s, 3H, OCH₃), 1.48, 1.32 (2 x s, 3H each, 2 x CH₃), 1.25 (d, J = 6.7 Hz, 3H, H-6).

¹³C NMR (CDCl₃): δ 155.5–114.5 (C-Ar), 109.3 (C(CH₃)₂), 97.5 (C-1), 76.2 (C-3), 74.6 (C-4), 69.6 (C-2), 64.5 (C-5), 55.6 (OCH₃), 27.9, 26.0 (2 x CH₃), 16.2 (C-6). HR ESI MS C₁₉H₂₃O₆: [M+Na]⁺ calc 333.1314; found 333.1318.

4-Methoxyphenyl 3,4-di-O-benzyl-2-O-naphtylmethyl-α-D-fucopyranoside 9a: To a solution of compound 36 (600 mg, 1 mmol) in THF (5 ml), 60% NaH in mineral oil (117 mg, 3 mmol) was added at 0°C under nitrogen. After 15 min, NAPBr (660 mg, 3 mmol) was added and the mixture was stirred overnight at r.t. After washing with water, combined organic layers were concentrated and purified on silica gel (cyclohexane-ethyl acetate). Fractions containing the product were concentrated and dissolved in 10 ml of 9:1 AcOH-H₂O and kept at 50°C
overnight, and then it was concentrated. The mixture was washed with ad NaHCO₃, and organic layers were combined and concentrated. The residue was dissolved in THF (10 ml) and treated with 60% NaH in mineral oil (235 mg, 6 mmol) and BnBr (0.71 ml, 6 mmol). After stirring overnight, the mixture was concentrated and purified on silica gel (cyclohexane-EtOAc) to afford 9a (407 mg, 69% over three steps), as a white solid (m.p. 133–135°C from EtOAc). [α]D²⁵ = +7.5° (c 0.17, CHCl₃).

¹H NMR (CDCl₃): δ 7.77–6.77 (m, 22H, H-Ar), 5.43 (d, J = 3.6 Hz H-1,1H), 5.06–4.69 (m, 6H, 3 x CH₂Ar), 4.27 (dd, J = 9.8 Hz, 1H, H-5), 4.32 (dd, J = 2.6 Hz, H-3), 4.10–4.06 (m, 1H, H-5), 3.80 (s, 3H, OCH₃), 3.77 (d, 1H, H-4), 1.13 (d, J = 6.3 Hz, 3H, H-6).

¹³C NMR (CDCl₃): δ 155.5–114.5 (C-Ar), 97.3 (C-1), 79.3 (C-3), 77.7 (C-4), 76.6 (C-3), 75.2 (CH₂Ar), 73.4 (2 x CH₂Ar), 67.1 (C-5), 55.6 (OCH₃), 16.6 (C-6). HR ESI MS C₈₈H₇₉O₈; [M+K]⁺ calc 629.2195; found 629.2305.

4-Methoxyphenyl 3,4-di-O-benzyl-α-D-fucopyranoside 9b: Yield 94%. [α]D²⁵ = +38.7° (c 0.42, CHCl₃).

¹H NMR (CDCl₃): δ 7.40–6.37 (m, 14H, H-Ar), 5.41 (d, J = 3.8 Hz H-1,1H), 4.92, 4.61 (2 d, J = 12.0 Hz, 2H, CH₂Ph), 4.74 (s, 2H, CH₂Ph), 4.28–4.22 (m, 1H, H-2), 4.00–3.94 (m, 1H, H-5), 3.83 (dd, J = 2.3, 9.9 Hz, H-3), 3.70–3.68 (m, 4H, H-4, OCH₃), 3.77 (d, 1H, H-4), 1.10 (d, J = 6.7 Hz, 3H, H-6b).

¹³C NMR (CDCl₃): δ 155.5–114.6 (C-Ar), 98.7 (C-1), 79.9 (C-5), 76.7 (C-4), 74.9 (CH₂Ar), 72.6 (CH₂Ar), 68.7 (C-2), 67.5 (C-3), 55.6 (OCH₃), 16.7 (C-6). HR ESI MS C₂₁H₃₀O₆; [M+Na]⁺ calc 473.1940; found 473.1917.

3,4-Di-O-benzyl-2-O-naphtylmethyl-α,β-D-fucopyranoside 9c: ¹H NMR (CDCl₃) showed α/β anomers in ratio 2:3. δ 7.79–6.58 (m, H-Ar), 5.27 (d, J = 3.7 Hz, H-1), 5.00–4.61 (m, 6 x CH₂Ph, incl. d, 4.61, J = 8.0 Hz, H-1β), 4.11–4.04 (m, H-2α,3β), 4.00–3.94 (m, 1H, H-5), 3.92 (dd, J = 2.3, 9.9 Hz, H-3β), 3.80 (dd, J = 7.0, 8.9 Hz, H-2β), 3.62 (d, 1H, H-4α), 3.51–3.42 (m, H-4β,5β), 1.19 (d, J = 6.6 Hz, H-6β), 1.11 (d, J = 6.6 Hz, H-6α).

¹³C NMR (CDCl₃): δ 133.0–116.1 (C-Ar), 97.8 (C-1β), 91.8 (C-1α), 82.5, 80.7, 77.4, 76.5, 75.1, 74.9, 74.8, 73.5, 73.1, 70.8, 66.8, 16.9 (C-6β), 16.8 (C-6α). HR ESI MS C₁₃₁H₁₃₂O₆; [M+H]⁺ calc 485.2328; found 485.2358.

4-Methoxyphenyl 3,4-O-isopropylidene-2-O-naphtylmethyl-β-D-fucopyranoside 10a: Compound 35 (1 g, 2.5 mmol) was first deacetylated by treatment with NaOMe in 10 ml of MeOH at pH strongly basic. After neutralization with Dowex H⁺, the resin was filtered off. The filtrate was concentrated and re-dissolved in acetone dimethyl acetal (30 ml) containing p-TsOH (100 mg) as catalyst. After stirring overnight at r.t., the mixture was quenched with TEA and concentrated. The residue was dissolved in THF (10 ml) and treated with 60% NaH in mineral oil (195 mg, 5 mmol) at 0°C under nitrogen. After 15 min, NAPBr (1.1 g, 5 mmol) and stirred overnight at r.t. After TLC (4:1 cyclohexane-EtOAc) showed complete reaction, the mixture was concentrated and chromatography of the residue on silica gel (cyclohexane-EtOAc) gave compound 10a (630 mg, 81%). [α]D²⁵ = +76.0° (c 0.70, CHCl₃).

¹H NMR (CDCl₃): δ 7.81–6.79 (m, 12H, H-Ab), 5.04, 5.12 (2 d, J = 12.0 Hz, 2H, CH₂NAP), 4.76 (d, J = 8.1 Hz, 1H, H-1), 4.12 (t, J = 6.2 Hz, 1H, H-3), 3.98 (d, J = 1.0, 5.0 Hz, 1H, H-4), 3.90–3.83 (m, 1H, H-5), 3.73 (s, 3H, OCH₃), 3.64 (t, J = 7.0 Hz, 1H, H-2), 1.37 (d, J = 6.4 Hz, 3H, H-6), 1.32, 1.31 (2 x s, 3H each, 2 x CH₃).
$^{13}$C NMR (CDCl$_3$): δ 152.3–115.5 (C-Ar), 102.1 (C-1), 79.3 (C-3), 71.2 (C-2), 76.3 (C-4), 73.7 (CH$_2$Ar), 68.9 (C-5), 55.6 (OCH$_3$), 27.8, 26.4 (2 x CH$_3$), 16.7 (C-6). HR ESI MS C$_{27}$H$_{59}$O$_6$: [M+H]$^+$ calc 468.2351; found 468.2386.

4-Methoxyphenyl β-D-fucopyranoside 10b: Yield 45%. $^1$H NMR (CDCl$_3$): δ 7.03–6.71 (m, 4H, H-Ar), 4.72 (d, J = 8.0 Hz, 1H, H-1), 3.84 (t, J = 8.2 Hz, 1H, H-2), 3.80–3.68 (m, 6H, H-3,4,5, incl. 3.77 s, OCH$_3$), 1.39 (d, J = 6.3 Hz, 3H, H-6). $^{13}$C NMR (CDCl$_3$): δ 118.2–114.5 (C-Ar), 102.1 (C-1), 77.2 (C-3), 73.7 (C-2), 71.2 (C-4), 70.8 (C-5), 55.6 (OCH$_3$), 16.3 (C-6). HR ESI MS C$_{13}$H$_{18}$O$_6$: [M+H]$^+$ calc 293.1003; found 293.1001.

2-O-Naphthylmethyl α,β-D-fucopyranoside 10c: Yield 41%, α/β anomers in 2:1 ratio. $^1$H NMR (CDCl$_3$): δ 7.78–7.10 (m, H-Ar), 5.25 (d, J = 2.5 Hz, 1H, H-1α), 4.88–4.71 (m, CH$_2$NAP), 4.66 (d, J = 7.5 Hz, 1H, H-1β), 4.17–4.05 (m, H-5α,β), 3.96 (dd, J = 7.7 Hz, 1H, H-2α), 3.75 (d, J = 3.2 Hz, 1H, H-4α,β), 3.70–3.63 (m, H-3α,4β), 3.59–3.58 (m, H-3β), 3.41 (t, J = 8.5 Hz, H-2β), 1.28 (d, J = 6.0 Hz, H-6β), 1.21 (d, J = 6.3 Hz, H-6α). HR ESI MS C$_{17}$H$_{26}$O$_5$: [M+Na]$^+$ calc 327.1188; found 327.1208.

3,4-Di-O-benzyl-α,β-D-fucopyranosyl trichloroacetimidate 14: The 1-OH fucoside 9c (110 mg, 0.22 mmol) was dissolved in 5 ml of CH$_2$Cl$_2$ and CCl$_3$CN (0.1 ml, 1.1 mmol) followed by DBU (7 μl, 0.044 mmol) was added. The reaction was complete in 30 min (7:3 cyclohexane-ETOAc). The mixture was concentrated and purified on silica gel to give 85 mg of product 34 (62%) as α/β anomers in 3:2 ratio.

$^1$H NMR (CDCl$_3$): δ 8.45 (NH), 7.76–6.51 (m, 14H, H-Ar), 6.51 (d, J = 2.3 Hz, H-1α), 5.35 (d, J = 10.0 Hz, H-1β), 4.79–4.61 (m, 6 x CH$_2$Ph), 4.35 (dd, J = 3.3, 10.5 Hz, H-3β), 4.27 (dd, J = 8.0, 9.9 Hz, H-2β), 4.11–4.04 (m, H-2α,5β), 4.06–4.03 (m, 1H, H-5α), 4.00 (dd, J = 2.3, 9.3 Hz, H-3α), 3.80 (dd, J = 7.0, 8.9 Hz, H-2β), 3.79–3.55 (m, H-4α,4β,5β), 1.15 (d, J = 6.6 Hz, H-6β), 1.11 (d, J = 6.6 Hz, H-6α).

$^{13}$C NMR (CDCl$_3$): δ 161.5 (CNH), 138.5–126.4 (C-Ar), 102.0 (C-1β), 95.4 (C-1α), 82.9, 82.1, 81.9, 78.2, 77.4, 76.5, 74.9, 74.8, 73.2, 72.9, 70.4, 69.6, 68.4, 16.7 (C-6β), 14.9 (C-6α). HR ESI MS C$_{31}$H$_{32}$O$_5$: [M+H]$^+$ calc 650.1244; found 650.1248.

3-(Benzyloxycarbonyl)aminopropyl 2,4-di-O-benzyl-3-O-naphthylmethyl-6-O-tertbutyldiphenylsilyl-α-D-mannopyranoside 19: Compound 8c (500 mg, 0.65 mmol) was dissolved in 20 ml of CH$_2$Cl$_2$ and Et$_3$CCN (0.35 ml, 3.25 mmol) followed by DBU (30 μl, 0.2 mmol) was added. After stirring for 3 h the mixture was concentrated and purified on silica gel (cyclohexane-ETOAc with 0.1% TEA) to give the trichloroacetimide 18 (344 mg, 67%). $^1$H NMR (CDCl$_3$): δ 8.70 (s 1H, NH), 7.88–7.18 (m, 28H, H-Ar), 6.63 (d, J = 3.5 Hz, H-1), 5.04–4.66 (m, 3 x CH$_2$Ph), 4.21 (t, J = 8.5 Hz, 1H, H-4), 4.18–4.09 (m, 4H, H-3,5,6), 3.98 (br. s, 1H, H-2).

To a solution of donor 18 (400 mg, 0.5 mmol) and 3-(benzyloxycarbonylamino)-1-propanol (151 mg, 0.72 mmol) in CH$_2$Cl$_2$ (5 ml) containing preactivated 4 Å MS, NIS (162 mg, 0.72 mmol) followed by TiOH (13 μl, 0.14 mmol) was added at -20°C. The mixture was stirred for 30 min when TLC (7:3 cyclohexane-ETOAc) showed complete reaction. The mixture was neutralized with TEA, filtered and
concentrated. Purification of the residue on silica gel (cyclohexane-EtOAc) gave the product 19 (340 mg, 73%). [α]D25 = +4.1° (c 0.55, CHCl3).

1H NMR (CDCl3): δ 7.89–7.21 (m, 33H, H-Ar), 5.15, 5.08 (2 d, J = 11.7 Hz, 2H, CH2Cbz), 4.99–4.62 (m, 7H, 3 x CH2Ph, incl., s, 4.82, H-1), 4.11 (t, J = 8.8 Hz, 1H, H-4), 4.03–3.96 (m, 3H, H-5,6), 3.83 (br. s, 1H, H-2), 3.82–3.77 (m, 1H, H-1’a), 3.71 (dd, J = 3.2, 9.1 Hz, 1H, H-3), 3.47–3.42 (s, 1H, H-1’b), 3.31–3.22 (m, 2H, H-3’), 1.88–1.75 (m, 2H, H-2’), 1.10 (s, 9H, tBuSi).

13C NMR (CDCl3): δ 156.3 (CONH), 138.2–125.5 (C-Ar), 97.8 (C-1), 80.3 (C-2), 75.5, 75.1, 74.7 (CH2Ar), 73.8 (C-3), 72.8 (C-5), 72.4 (C-5), 66.6 (CH2Cbz), 65.4 (C-6), 63.3 (C-1’), 38.9 (C-3’), 29.4 (C-2’), 26.7 (tBuSi). HR ESI MS C58H83NO5Si: [M+Na]+ calc 952.4221; found 952.4234.

3-(Benzyloxycarbonyl)aminopropyl 2,4-di-O-benzyl-6-O-
tertbutyldiphenylsilyl-α-D-mannopyranoside 20: The general procedure for NAP removal was followed, yield 78%. [α]D25 = +9.6° (c 0.78, CHCl3).

1H NMR (CDCl3): δ 7.82–7.30 (m, 24H, H-Ar), 5.31 (br. s, 2H, CH2Cbz), 4.96, 4.64 (2 d, J = 11.9 Hz, 2H, CH2Ph), 4.95 (s, 1H, H-1), 4.82, 4.70 (2 d, J = 11.0 Hz, 2H, CH2Ph), 4.07–3.97 (m, 3H, H-1’a,3,6a), 3.87–3.79 (m, 3H, H-4,5,6b), 3.68 (d, J = 7.8 Hz, 1H, H-2), 3.48–3.45 (s, 1H, H-1’b), 3.35–3.27 (m, 2H, H-3’), 1.87–1.77 (m, 2H, H-2’), 1.13 (s, 9H, tBuSi).

13C NMR (CDCl3): δ 156.3 (CONH), 138.6–127.5 (C-Ar), 96.9 (C-1), 78.8 (C-2), 76.4 (C-4), 74.8, 72.5 (CH2Ar), 72.3 (C-3), 71.7 (C-5), 63.5 (CH2Cbz), 61.5 (C-6), 63.2 (C-1’), 38.6 (C-3’), 29.2 (C-2’), 27.4 (tBuSi). HR ESI MS C47H85NO7Si: [M+Na]+ calc 794.3489; found 794.3492.
Compound 1a
Compound 2b
Compound 2c
Compound 3a
Compound 3b
Compound 3c
Compound 4a
Compound 4c
Compound 5a
Compound 5c
Compound 6a
Compound 6b
Compound 7a
Compound 7b
Compound 8c
Compound 9a
Compound 9b
Compound 10a
Compound 11
Compound 13
Compound 15
Compound 17
Compound 19
Compound 21
Compound 22
Compound 24
Compound 25
Compound 31
Compound 32
Compound 34
References