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Synthesis of multivalent *Streptococcus suis* adhesion inhibitors by enzymatic cleavage of polygalacturonic acid and 'click' conjugation

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A galabiose disaccharide building block was synthesized by an efficient pectinase cleavage of polygalacturonic acid and subsequent chemical functional group transformations. Besides the disaccharide, the corresponding trisaccharide was also obtained and modified. The compounds were subsequently conjugated to dendrimers with up to eight end groups using 'click' chemistry. The compounds were evaluated as inhibitors of adhesion of the pathogen *Streptococcus suis* in a hemagglutination assay and strong inhibition was observed for the tetra- and octavalent galabiose compound with MIC values in the low nanomolar range. The corresponding octavalent trisaccharide was a *ca.* 20-fold weaker inhibitor.

Introduction

The preparation of carbohydrates and their conjugates has become an important field for the study of biological processes and the development of therapeutic lead structures.[1] Many methods for selective protection schemes and for the stereoselective introduction of glycosidic bonds have been developed over the years.[2] While a synthetic strategy is often the most desired preparation method, a biocatalytic degradation of readily available natural carbohydrates or carbohydrate polymers can be advantageous. We report here on a synthetic route to a galabiose (Galα1–4Gal) and its subsequent 'click chemistry' conjugation to dendrimers. A route was used involving enzymatic degradation of polygalacturonic acid and subsequent chemical modification steps. In our research program on bacterial anti-adhesion compounds,[3,4] the galabiose derivative **1** (Chart 1a) became of interest as its azido function allows convenient conjugation to dendrimers using our microwave heated "click" protocol.[5] The galabiose sequence shows strong binding to the bacterial Gram-positive pathogen *Streptococcus suis*[6] that can cause meningitis, septicemia, and pneumonia in pigs and also meningitis in humans.[7,8] Multivalent presentation of the disaccharide sequence on dendritic scaffolds greatly enhances their binding potency.[4b,9] Other important biological targets that bind to the galabiose epitope are the uropathogenic *E. coli via* its PapG adhesin,[4d,10] the bacterium *Pseudomonas aeruginosa via* its PA-IL lectin[11] and the Shiga like Toxin, a toxin of the AB_5 family produced by *E. coli.*[12] The triazole linkage between the dendritic scaffold and the galabiose that is described here is very similar to the previously used[4b,d] amide connection. (Chart 1b).

For the synthesis of the galabiose unit a fully synthetic strategy was previously applied.[4b] While the route did produce the target product, its many steps make it less ideal for large scale synthesis. An alternative route towards galabiose based on an enzymatic cleavage of polygalacturonic acid was previously reported.[13] The present work represents an optimization and an extension describing the discovery of a widely available highly effective enzyme and easy conjugation procedures. Furthermore, besides the desired disaccharide also the α(1,4) linked galactopyranosyl trisaccharide was obtained which would require an even lengthier multistep synthetic route to prepare than the galabiose disaccharide.

Results and discussion

The procedure started with the enzymatic cleavage of commercially available pectin derived polygalacturonic acid, a polymer consisting of α(1,4)linked galacturonic acid moieties. The polymer was treated with the pectinase from *Rhizopus oryzae* and separately also with the pectinase from *Aspergillus niger* in sodium acetate buffer at pH 4.5 (Scheme 1). Both enzymes showed the expected cleavage activity but in the case of the *Rhizopus oryzae* pectinase the relative amount of the desired disaccharide **3** *versus* monosaccharide **2** and trisaccharide **4** was much higher and was estimated by TLC to be *ca.* 2:2:1 (for **3**:**2**:**4**) while for the *Aspergillus niger* pectinase this ratio was *ca.* 1:2:2. For this reason the pectinase from *Rhizopus oryzae* was chosen for further use. Optimal amounts of the disaccharide were obtained when the reaction appeared to have finished and no further conversion was taking place. Initial attempts were made to separate the obtained mixture of mono-, di and trisaccharides by ion exchange chromatography using a formic acid gradient,[13a] however on a 10 gram scale this became impractical. Better and faster separation was achieved by standard silica gel chromatography converting the free sugars **2–4** to their methyl acetals (α/β ratio ≈ 3/1) and the methyl esters **5–7**, using the crude mixture and Dowex-H^+ catalysis in MeOH. After separation, the disaccharide **6** was reduced by $NaBH_4$ and its hydroxyls were subsequently acetylated (Ac_2O, pyridine). The anomeric methoxy group was replaced with an acetate by treatment with H_2SO_4 in acetic anhydride to give **9**. The disaccharide **9** was converted to glycosyl donor **10** by selective anomeric deacetylation using hydrazine acetate followed by standard introduction of the trichloroacetimidate

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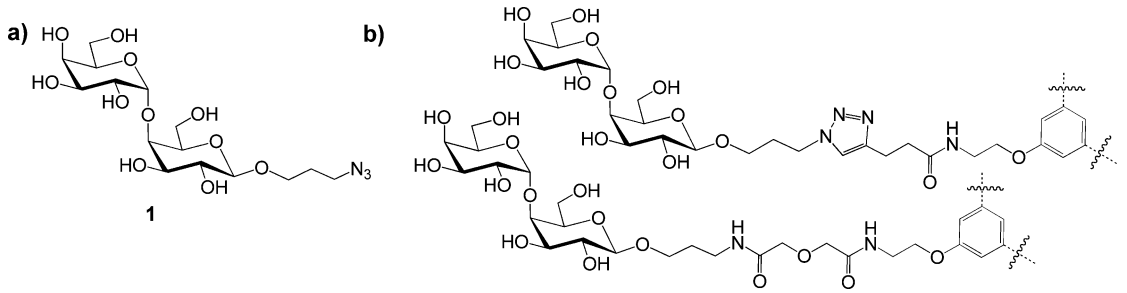
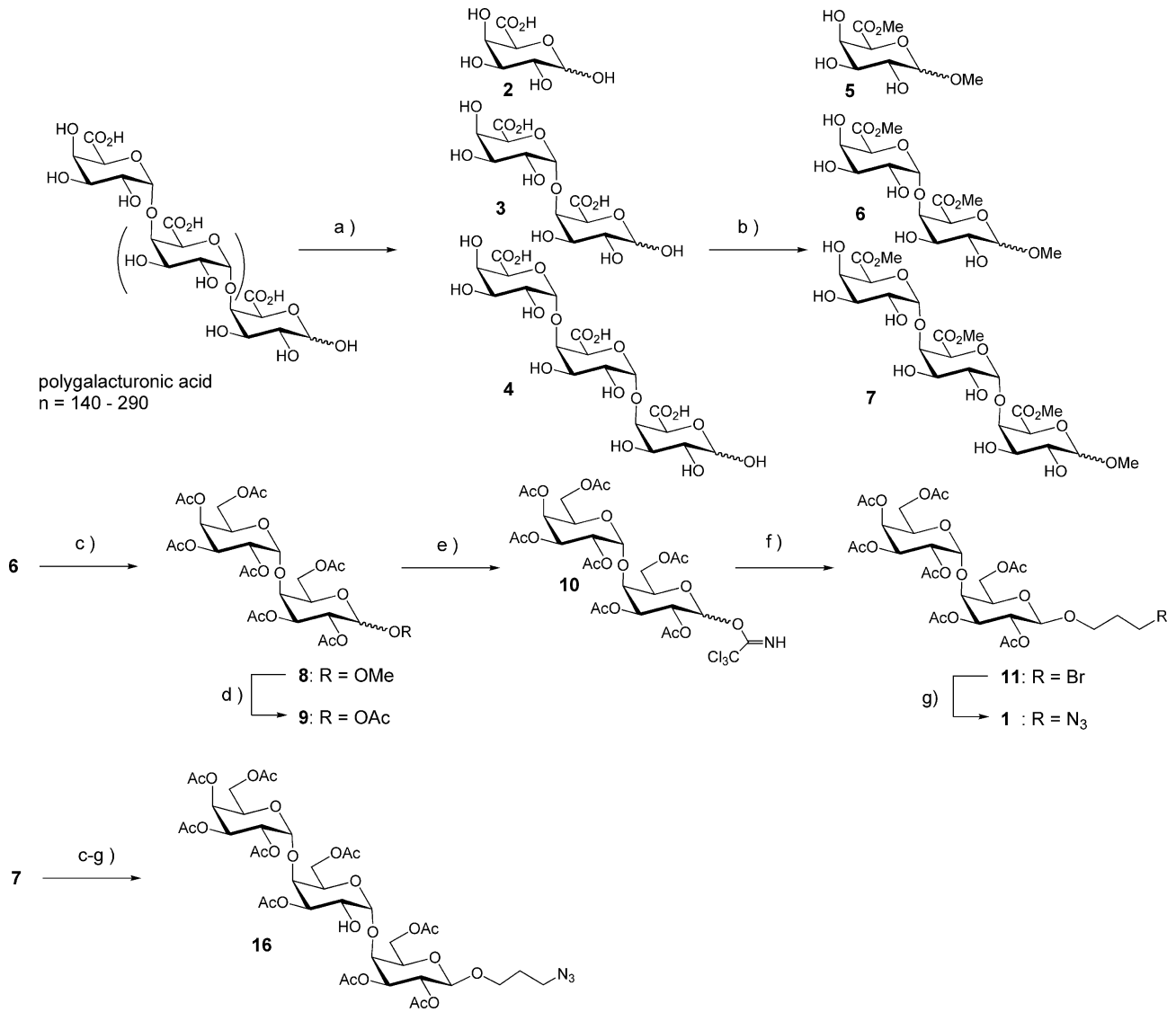


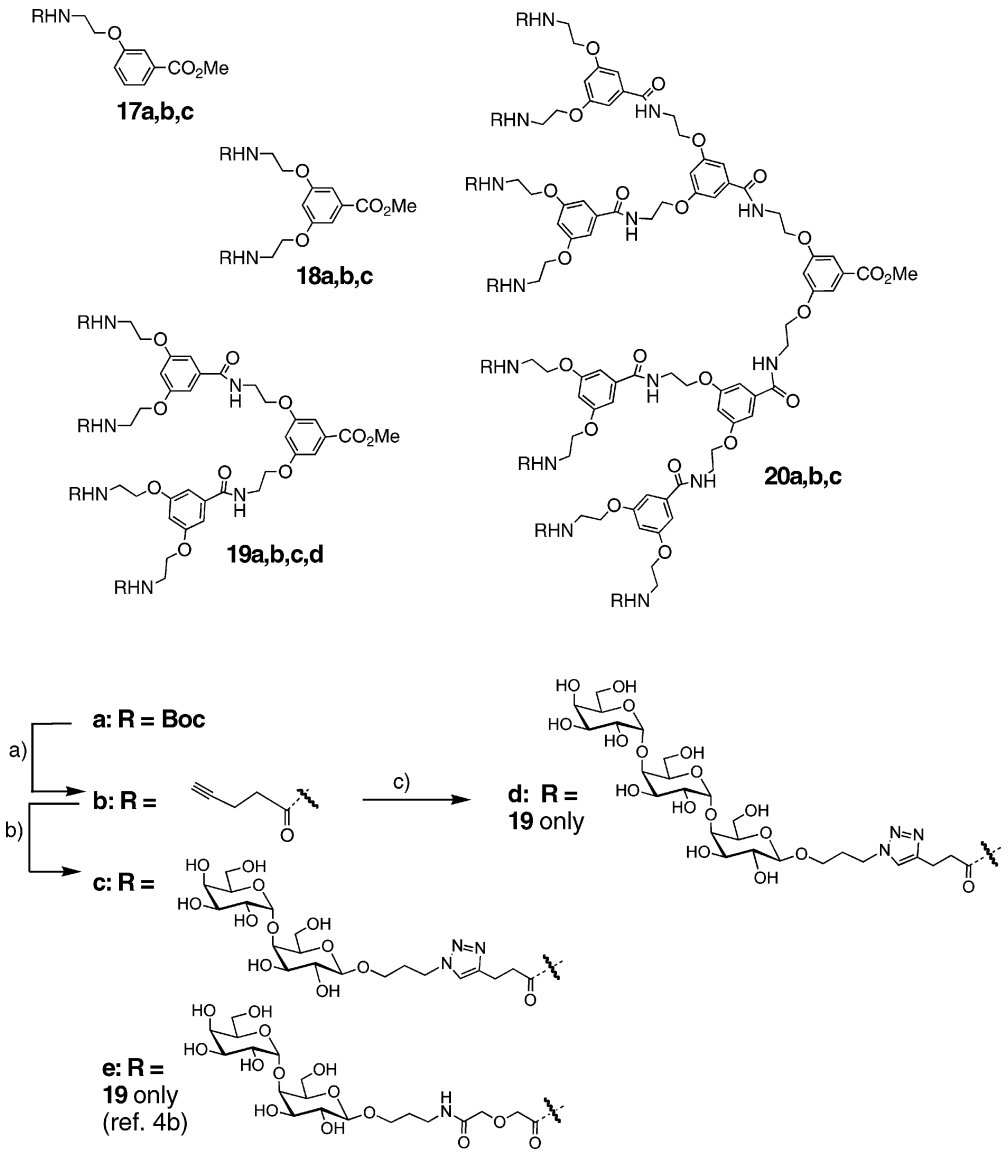
Chart 1 a) Desired galabiose building block for conjugation *via* "click" chemistry; b) top linkage to dendritic structures compared to previously used linkage (ref. 4*b*,*d*).



Scheme 1 Reagents and conditions (a) pectinase, pH = 4.5, 40 °C; (b) MeOH, Dowex-H^+, then separate on silica, 28% for **6**, 12% for **7**; (c) i. $NaBH_4$, MeOH, ii. Ac_2O, pyridine, 75% (d) H_2SO_4, Ac_2O, quant.; (e) i. N_2H_4·AcOH, DMF, ii. Cl_3CCN, DBU, CH_2Cl_2, 64% for **10**, 42% for **14**; (f) $HO(CH_2)_3Br$, TMSOTf, 58% for **11**, 55% for **15** (g) NaN_3, DMF, quant. for **1**, 94% for **16**.

moiety. Coupling of the 3-bromopropanol spacer was achieved by TMSOTf catalysis to give **11** which was subjected to a nucleophilic substitution by NaN_3 in DMF to give the desired target compound **1**. The described procedure was also applied to the galacturonic acid trisaccharide **7** to give **16** in comparable yields.

After optimizing the synthesis of the galabiose building blocks, they were conjugated to the dendritic scaffolds. For this purpose the so-called "click" reaction, the copper(I) catalyzed [3 + 2] cycloaddition between azides and alkynes,[14] was used with our previously reported conditions.[5] The dendrimers **17a–20a**[15] were



Scheme 2 Glycodendrimer synthesis. Reagents and conditions: (a) i. TFA/CH_2Cl_2; ii. 4-pentynoic acid, BOP, DiPEA, yields: 70–95%; (b) i. **1**, $CuSO_4$, sodium ascorbate, DMF, 80 °C, 20 min., yields: 66–84%, ii: NaOMe, MeOH, 35–77%; (c) i. **16**, $CuSO_4$, sodium ascorbate, DMF, 80 °C, 20 min., 79%, ii. NaOMe, MeOH, 57%.

subjected to Boc cleavage, followed by BOP mediated coupling of 4-pentynoic acid (Scheme 2). Subsequent conjugation of **17–20b** was performed with the galabiose building block **1** using Cu(I) catalysis and microwave irradiation at 80 °C. Tetravalent dendrimer **19b** was also conjugated with the trisaccharide **16** to give **19d**. The obtained dendrimers were deacetylated with NaOMe conditions to give **17c–20c** and **19d**.

Hemagglutination assay

The galabiose dendrimers were tested for their interactions with the *S. suis* adhesin by evaluating their inhibitory capacity of hemagglutination inhibition as previously described.[4b,9] The minimal inhibitory concentration (MIC) values were determined and are depicted in Table 1. From the results a clear multivalency effect was observed. The results were comparable with the previously reported data, with low nanomolar inhibition for the multivalent galabiose conjugates.[4b] The tetravalent galabiose dendrimer **19c** showed practically the same MIC value as the tetravalent reference compound **19e** with the amide linkage as it was retested in the present study, indicating no influence of the structure of the linking

Table 1 Inhibition of the *S. suis D282* mediated hemagglutination of human erythrocytes by galabiose derivatives

Compound	Valency	MIC (nM)	Rel. pot.[a] (per sugar)[b]
17c	1	400	1 (1)
18c	2	8	50 (25)
19c	4	2.4	167 (42)
19e	4	2.5	160 (40)
20c	8	3.9	100 (13)
19d	4	48	

[a] Relative potency = IC_{50}(monovalent)/IC_{50}(multivalent ligand). [b] Relative potency per sugar = relative potency/valency.

moiety. The tested tetravalent galactose trisaccharide **19d**, showed significantly reduced inhibitory potency in comparison to the tetravalent galabiose compound **19c**, *i.e.* 48 nM *vs.* 2.4 nM.

Conclusion

The preparation of derivatives of galabiose and the corresponding trisaccharide were described involving a biocatalytic polysaccharide degradation step followed by chemical modification steps. The key step in this procedure is the efficient enzymatic cleavage of the cheap polygalacturonic acid by a readily available pectinase enzyme. Methylation of the crude cleavage mixture allowed efficient separation by standard silica gel chromatography. Both disaccharide and trisaccharide were thus obtained and subsequently subjected to the range of chemical modifications leading to the galabiose building block and a galactose trisaccharide. Compared to previous reports, both the purification and ligation were optimized and this route serves as a good alternative to the fully chemical synthesis approach and it does not require expensive chemical reagents. Besides the desired disaccharide also the corresponding trisaccharide was obtained which would require many chemical steps to synthesize. Ligation of the carbohydrate building blocks to a series of alkyne functionalized dendrimers was achieved by "click" chemistry and was found to give excellent coupling yields. The newly prepared galabiose dendrimers showed comparable *S. suis* inhibition capacities as reflected in the MIC values. The tetravalent trisaccharide was found not to be as effective an inhibitor as the galabiose disaccharide. This revised partial enzymatic preparation method is attractive for the preparation of larger quantities of anti-adhesion compounds with relatively low costs and efforts. It is thus well-suited to further pursue the anti-adhesion strategy with multivalent carbohydrates,[3] as an alternative intervention method against microbial pathogens, using animal models.

Experimental section

General Remarks

Unless stated otherwise, chemicals were obtained from commercial sources and used without further purification. All solvents were purchased from Biosolve (Valkenswaard, The Netherlands) and were stored on molecular sieves (4Å). Acetic anhydride and pyridine were purchased from Acros (Geel, Belgium). Polygalacturonic acid and both pectinases from *Aspergillus niger* and *Rhizopus oryzae* were obtained from Fluka. TLC was performed on Merck precoated Silica 60 plates. Spots were visualized by dipping in 10% H_2SO_4 in MeOH followed by heating. Microwave reactions were carried out in a dedicated microwave oven, *i.e.* the Biotage Initiator. The microwave power was limited by temperature control once the desired temperature was reached. A sealed vessel of 2–5 mL was used. Preparative HPLC runs were performed on an Applied Biosystems workstation. Elution was effected using a gradient of 5% MeCN and 0.1% TFA in H_2O to 5% H_2O and 0.1% TFA in MeCN. Analytical HPLC runs were performed on a Shimadzu automated HPLC system equipped with an evaporative light scattering detector (PL-ELS 1000, Polymer Laboratories) and a UV/VIS detector operating at 220 and 254 nm. ^{1}H NMR (300 MHz) and ^{13}C NMR (75.5 MHz) were performed on a Varian G-300 spectrometer. Chemical shifts are given in ppm relative to TMS (^{1}H, 0.00 ppm), CD_3OD (^{1}H, 3.31 ppm), $CDCl_3$ (^{13}C, 77.0 ppm), D_2O (^{1}H, 4.80 ppm), CD_3OD (^{13}C, 49.2 ppm) or acetone (215.94 ppm in D_2O). Exact masses were measured by nano electro spray time-of-flight mass spectrometry on a Micromass LCToF mass spectrometer at a resolution of 5000 fwhm. Gold-coated capillaries were loaded with 1 μL of sample (concentration 20 μM) dissolved in a 1:1 (v/v) mixture of CH_3CN/H_2O with 0.1% formic acid. NaI or poly(ethylene glycol) (PEG) was added as internal standard. The capillary voltage was set between 1100 and 1350 V, and the cone voltage was set at 30 V. Matrix Assisted Laser Desorption Ionisation Time of Flight (MALDI ToF) MS was recorded on a Shimadzu Axima-CFR with α-cyano-4-hydroxycinnamic acid or sinapic acid as a matrix. Insulin and adrenocorticotropin fragment 18–39 (Acth) were used for calibration.

Enzymatic cleavage of polygalacturonic acid. A solution of polygalacturonic acid (10.0 g, ≈ 57 mmol monosaccharide) in aqueous NaOAc (0.41 M, 500 mL) was adjusted to pH = 4.5 with NaOH (4M). Pectinase (*Rhizopus oryzae*, 250 mg or *Aspergillus niger*, 250 mg) was added to the polymer suspension and the resulting mixture was allowed to stir for 24 h at 40 °C. TLC (formic acid/n-BuOH/H_2O, 6/4/1) showed the formation of the mono-, di- and tri-galacturonic acid (Rf values resp. 0.35, 0.28 and 0.23). The reaction was terminated by stirring for 5 min at 100 °C. The reaction mixture was concentrated and co-evaporated with MeOH to dryness. The crude mixture was suspended in MeOH (250 mL) and Dowex-H^+ (30 g) was added. The mixture was refluxed for 18 h, the Dowex resin was filtered off and the crude mixture was concentrated. Silica gel chromatography (EtOAc/MeOH/H_2O, 7/2/1 → 3/2/1) was used to separate the mono- di- and trigalacturonic acid methyl esters **5**, **6** and **7**.

Methyl [methyl(methyl α-D-galactopyranosyluronate)-(1→4)-α/β-D-galactopyranoside] uronate (6). Disaccharide **6** was obtained as white foam (3.26 g, 28%). ^{1}H NMR (300 MHz, CD_3OD): δ = 5.11 (1H, d, J = 1.8 Hz), 4.51 (0.66H, d, H-1 α, $J_{1,2}$ = 0.9 Hz), 4.37 (1H, d, J = 3.0 Hz), 4.20 (1H, m), 3.90 (1H, dd), 3.81 and 3.75 (2 × s, 2 × 3H, C(O)OCH_3), 3.59 (0.6H, s, OCH_3 β) and 3.42 (2.4H, s, OCH_3 α). ^{13}C NMR (CD_3OD, 75.5 MHz): δ = 171.9 and 170.9 (C-6, C-6′), 105.9 (C-1 β), 102.4 and 101.9 (C-1′, C-1 α), 80.5, 79.6, 74.7, 73.5, 73.0, 72.0, 71.3, 70.9, 70.0 and 69.9 (C-2, C-2′, C-3, C-3′, C-4, C-4′, C-5, C-5′), 58.0 and 56.6 (OCH_3 α/β), 53.2 and 52.7 (C(O)OCH_3). HRMS for $C_{15}H_{24}O_{13}$ (M, 412.1217): found $[M + Na]^+$ 435.0811, calcd. 435.1115.

Methyl [methyl(methyl α-D-galactopyranosyluronate)-(1→4)-(methyl-α-D-galactopyranosyluronate)-(1→4)-α/β-D-galactopyranoside] uronate (7). Trisaccharide **7** was obtained as an amorphous solid (1.35 g, 12%). ^{1}H NMR (300 MHz, CD_3OD): δ = 5.15 (1H, d, J = 1.8 Hz), 5.10 (1H, dd, J = 1.2 Hz), 4.51 (0.70H, s, H-1 α), 4.39–4.36 (2H, m), 4.20–4.18 (1H, m), 3.90 (1H, t), 3.87 (1H, t), 3.80, 3.78 and 3.75 (3 × 3H, 3 × s, C(O)OCH_3). 3.51 (1.0H, s, OCH_3 β) and 3.42 (2.5H, s, OCH_3 α). ^{13}C NMR (CD_3OD, 75.5 MHz): δ = 171.9, 171.3 and 170.9 (C-6, C-6′, C-6″), 105.9 (C-1 β), 102.2 and 102.0 (C-1 α, C-1′, C-1″), 80.6, 80.3, 79.7, 74.7, 72.9, 72.2, 72.0, 71.3, 70.9 and 70.1 (C-2, C-2′, C-2″, C-3, C-3′, C-3″, C-4, C-4′, C-4″, C-5, C-5′, C-5″), 58.0 and 56.6 (OCH_3

α/β), 53.1, 53.0 and 52.7 (C(O)O*C*H$_3$). HRMS for $C_{22}H_{34}O_{19}$ (M, 602.1694): found [M + Na]$^+$ 625.1316, calcd. 625.1592.

Methyl (2,3,4,6-tetra-O-acetyl-α-D-galactopyranosyl)-(1→4)-2,3,6-tri-O-acetyl-α/β-D-galactopyranoside (8). To a solution of digalacturonic acid methyl ester **6** (3.26 g) in MeOH (150 mL) was added $NaBH_4$ (4.0 g). The solution was stirred for 78 h. After neutralization with Dowex-H$^+$ the mixture was filtered and concentrated to dryness. Crude disaccharide was suspended in pyridine (100 mL) and Ac_2O (50 mL) was added. The reaction mixture was stirred for 18 h and concentrated *in vacuo* at 60 °C. Crude product was taken up in EtOAc (250 mL) and washed with aqueous NaOH (1M, 100 mL) aqueous HCl (1M, 100 mL), and brine (100 mL). The organic layer was dried over Na_2SO_4, filtered and concentrated. Silica gel chromatography (hexane/EtOAc, 1/1 → 1/2) was used to obtain pure disaccharide **6** as a white foam (3.85 g). ^{1}H NMR (300 MHz, $CDCl_3$): δ = 5.56 (1H, d, H-4′, $J_{3',4'}$ = 3.0 Hz), 5.39 (1H, dd, H-3′, $J_{2',3'}$ = 11.7 Hz, $J_{3',4'}$ = 3.3 Hz), 5.25–5.18 (3H, m, H-3, H-2, H-2′), 4.98 (2H, m, H-1, H-1′), 4.54 (1H, t, H-5, $J_{5,6}$ = 6.6 Hz), 4.17–4.06 (6H, m, H-4, H-5′, 2 × H-6, 2 × H-6′), 3.52 (0.6H, s, OCH_3 β), 3.42 (2.4H, s, OCH_3 α), 2.14, 2.13, 2.09, 2.08, 2.07, 2.03 and 1.99 (7 × 3H, 7 × s, C(O)CH_3). ^{13}C NMR ($CDCl_3$, 75.5 MHz): δ = 170.7, 170.4, 170.2, 170.1 169.9 and 169.9 (*C*(O)CH_3), 101.7 (C-1 β), 99.0 (C-1′), 97.1 (C-1 α), 72.7, 71.8, 69.4, 68.5, 68.2, 67.7, 67.3 and 66.9 (C-2, C-2′, C-3, C-3′, C-4, C-4′, C-5, C-5′), 62.3, 61.9, 60.6 and 60.4 (C-6, C-6′), 55.4 and 55.2 (OCH_3 α/β), and 20.6 (C(O)*C*H$_3$). HRMS for $C_{27}H_{38}O_{18}$ (M, 650.2058): found [M + Na]$^+$ 673.1956, calcd. 672.9821.

Acetyl (2,3,4,6-tri-O-acetyl-α-D-galactopyranosyl)-(1→4)-2,3,6-tri-O-acetyl-α/β-D-galactopyranoside (9). To a cooled solution of **8** (3.80 g, 5.84 mmol) in Ac_2O (45 mL) was added concentrated H_2SO_4 (150 μL). The solution was stirred at 0 °C for 2 h, diluted with CH_2Cl_2 (150 mL) and quenched with aqueous $NaHCO_3$ (5%, 10 mL). The reaction mixture was concentrated to dryness at 60 °C. The residue was taken up in EtOAc (200 mL) and washed with aqueous NaOH (1M, 75 mL) and brine (75 mL). The organic phase was dried over Na_2SO_4, filtered and concentrated to yield white foam **9** (3.83 g, 97%). ^{1}H NMR (300 MHz, $CDCl_3$): δ = 6.37 (1H, d, H-1α, $J_{1,2}$ = 3.6 Hz), 5.57 (1H, dd, H-4′, $J_{3',4'}$ = 3.0 Hz, $J_{4',5'}$ = 3.3 Hz), 5.43–5.35 (2H, m, H-3′ and H-3), 5.26–5.19 (2H, m, H-2′, H-2), 5.02 (H, d, H-1′, $J_{1',2'}$ = 3.6 Hz), 4.52 (1H, t, H-5, $J_{5,6}$ = 7.8 Hz), 4.38–4.05 (6H, m, H-4, H-5′, 2 × H-6′, 2 × H-6), 2.16, 2.14, 2.11, 2.11, 2.07, 2.03, 2.03 and 1.99 (8 × 3H, 8 × s, C(O)CH_3). ^{13}C NMR ($CDCl_3$, 75.5 MHz): δ = 170.5, 170.5, 170.3, 170.1, 169.8, 169.4, 169.0 and 168.8 (*C*(O)CH_3), 99.1 and 89.8 (C-1 and C-1′), 70.3, 69.2, 68.4, 68.2, 67.7, 67.2, 67.1 and 66.1 (C-2, C-2′, C-3, C-3′, C-4, C-4′, C-5, C-5′), 61.5 and 60.5 (C-6, C-6′), 20.9, 20.7 and 20.6 (C(O)*C*H$_3$). HRMS for $C_{28}H_{38}O_{19}$ (M, 678.2007): found [M + Na]$^+$ 701.1905, calcd. 701.1530.

(2,3,4,6-Tetra-O-acetyl-α-D-galactopyranosyl)-(1→4)-(2,3,6-tri-O-acetyl-α-D-galactopyranosyl) trichloroacetimidate (10). A solution of **9** (4.50 g, 6.64 mmol) and N_2H_4·HOAc (672 mg, 7.29 mmol) in dry DMF (50 mL) was stirred at r.t. for 70 h. The mixture was concentrated *in vacuo* at 60 °C, taken up in EtOAc (100 mL) and washed twice with brine (50 mL). The organic phase was dried over Na_2SO_4, filtered and concentrated. The white foam (4.24 g, quantitative) and trichloroacetonitrile (2.0 mL, 20 mmol) were dissolved in dry CH_2Cl_2 (50 mL) and the solution was cooled to 0 °C. DBU (1,8-diazabicyclo[5.4.0]undec-7-ene, 301 μL, 2.0 mmol) was added and the solution was stirred at 0 °C for 1 h followed by 20 h at r.t. The reaction mixture was concentrated and product **10** was isolated by silica gel chromatography (hex/EtOAc, 1/1) as a slightly yellow foam (3.30 g, 64%). ^{1}H NMR (300 MHz, $CDCl_3$): δ = 8.69 (1H, s, OCNHCCl_3), 6.61 (1H, d, H-1α, $J_{1,2}$ = 3.6 Hz), 5.57 (1H, d, H-4′, $J_{3',4'}$ = 3.0 Hz), 5.42 (1H, dd, H-2, $J_{1,2}$ = 3.6 Hz, $J_{2,3}$ = 11.3 Hz), 5.37–5.28 (2H, m, H-3, H-3′), 5.24 (1H, dd, H-2′, $J_{1',2'}$ = 3.6 Hz, $J_{2',3'}$ = 11.0 Hz), 5.03 (1H, m, H-1′, $J_{1',2'}$ = 3.6 Hz), 4.53 (1H, t, H-5, $J_{5,6}$ = 6.0 Hz), 4.38–4.28 (3H, m, H-4, 2 × H-6′), 4.16–4.11 (3H, m, H-5′, 2 × H-6), 2.12, 2.11, 2.04 and 2.00 (7 × 3H, 4 × s, C(O)CH_3). ^{13}C NMR ($CDCl_3$, 75.5 MHz): δ = 170.4, 170.2, 170.0, 169.8 and 168.6 (*C*(O)CH_3), 160.7 (O*C*(NH)CCl_3), 98.9 and 93.5 (C-1, C-1′), 90.8 (OCNH*C*Cl_3), 70.5, 69.3, 68.1, 67.7, 67.2, 67.1 and 66.7 (C-2, C-2′, C-3, C-3′, C-4, C-4′, C-5, C-5′), 61.8 and 60.6 (C-6, C-6′), 20.9, 20.6 and 20.4 (C(O)*C*H$_3$).

3-Bromopropyl (2,3,4,6-tetra-O-acetyl-α-D-galactopyranosyl)-(1→4)-2,3,6-tri-O-acetyl-β-D-galactopyranoside (11). A solution of **10** (1.22 g, 1.56 mmol) and 3-bromopropanol (0.68 mL, 7.8 mmol) in CH_2Cl_2 (30 mL) was stirred under N_2 at 0 °C. TMSOTf (91 μL, 0.47 mmol) was added and the mixture was stirred at 0 °C for 1 h. The mixture was warmed to r.t. and after 1 h the reaction was quenched with Et_3N and concentrated *in vacuo*. Silica gel chromatography (hex/EtOAc, 3/2 → 1/1) afforded pure **11** (0.77 g, 65%). ^{1}H NMR (300 MHz, $CDCl_3$): δ = 5.57 (1H, dd, H-4′, $J_{3',4'}$ = 3.0 Hz, $J_{4',5'}$ = 1.1 Hz), 5.39 (1H, dd, H-3′, $J_{2',3'}$ = 11.0 Hz, $J_{3',4'}$ = 3.3 Hz), 5.22–5.14 (2H, m, H-2, H-2′), 4.93 (1H, d, H-1′, $J_{1',2'}$ = 3.6 Hz), 4.82 (1H, dd, H-3, $J_{2,3}$ = 10.7 Hz, $J_{3,4}$ = 10.7 Hz), 4.48 (1H, d, H-1, $J_{1,2}$ = 8.3 Hz), 4.54–4.43 (2H, m, H-5′, H-6a), 4.20–4.10 (3H, H-6b and 2 × H-6′), 4.07 (1H, d, H-4, $J_{3,4}$ = 2.8 Hz), 4.03–4.96 and 3.73–3.65 (each 1H, 2 × m, CH_2O_{Gal}), 3.79 (1H, t, H-5, $J_{5,6}$ = 5.0 Hz), 3.50 (2H, dd, CH_2Br, *J* = 5.5 Hz, *J* = 7.4 Hz), 2.20–2.02 (2H, m, $OCH_2CH_2CH_2$Br), 2.13, 2.11, 2.08, 2.07, 2.04 and 1.99 (7 × 3H, 7 × s, C(O)CH_3). ^{13}C NMR (75.5 MHz, $CDCl_3$): δ = 170.5, 170.1, 169.8 and 169.2 (*C*(O)CH_3), 101.4 (C-1), 99.4 (C-1′), 72.6, 71.9, 68.7, 68.5, 67.8, 67.3 and 67.0 (C-2, C-2′, C-3, C-3′, C-4, C-4′, C-5, C-5′), 67.1 ($OCH_2CH_2CH_2$Br), 61.9 and 60.5 (C-6, C-6′), 32.3 (CH_2Br), 30.3 ($OCH_2CH_2CH_2$Br) and 20.6 (C(O)*C*H$_3$). HRMS for $C_{29}H_{41}BrO_{18}$ (M, 756.1476): found [M + Na]$^+$ 779.1374, calcd. 779.0682.

3-Azidopropyl (2,3,4,6-tetra-O-acetyl-α-D-galactopyranosyl)-(1→4)-2,3,6-tri-O-acetyl-β-D-galactopyranoside (1). A solution of **11** (1.21 g, 1.60 mmol) and NaN_3 (0.52 g, 8 mmol) in dry DMF (20 mL) was stirred at 100 °C for 20 h. The solution was concentrated *in vacuo* at 60 °C, taken up in EtOAc (150 mL) and washed with brine (75 mL). The organic phase was dried (Na_2SO_4), filtered and concentrated. Product **1** was lyophilized from MeCN/H_2O and was obtained as white powder (1.09 g, 95%). ^{1}H NMR (300 MHz, $CDCl_3$): δ = 5.50 (1H, dd, H-4′, $J_{3',4'}$ = 3.0 Hz, $J_{4',5'}$ = 1.1 Hz), 5.32 (1H, dd, H-3′, $J_{2',3'}$ = 11.0 Hz, $J_{3',4'}$ = 3.3 Hz), 5.15–5.08 (2H, m, H-2, H-2′), 4.93 (1H, d, H-1′, $J_{1',2'}$ = 3.6 Hz), 4.75 (1H, dd, H-3, $J_{2,3}$ = 10.7 Hz, $J_{3,4}$ = 2.8 Hz), 4.42 (1H, d, H-1, $J_{1,2}$ = 7.8 Hz), 3.91–3.88 and 3.57–3.54 (each 1H, 2 × m, CH_2O_{Gal}), 3.79 (1H, t, H-5, $J_{5,6}$ = 6.6 Hz), 3.34 (2H, t, CH_2N_3, *J* = 6.6 Hz), 2.06, 2.04, 2.01, 2.00, 1.99, 1.97 and 1.92 (7 × 3H, 7 × s, C(O)CH_3) and 1.90–1.77 (2H, m, $OCH_2CH_2CH_2N_3$). ^{13}C NMR (75.5 MHz, $CDCl_3$): δ = 170.4,

170.1, 169.8 and 169.1 (C(O)CH_3), 101.1 (C-1), 99.4 (C-1′), 72.6, 71.9, 68.6, 67.8, 67.3 and 67.0 (C-2, C-2′, C-3, C-3′, C-4, C-4′, C-5, C-5′), 66.2 (OCH$_2$CH$_2$CH$_2$N$_3$), 61.9 and 60.4 (C-6, C-6′), 48.0 (OCH$_2$), 28.9 (CH$_2$N$_3$) and 20.8 (C(O)CH$_3$). HRMS for $C_{29}H_{41}N_3O_{18}$ (M, 719.2385): found $[M + Na]^+$ 742.2283, calcd. 742.1694.

Methyl (2,3,4,6-tetra-O-acetyl-α-D-galactopyranosyl)-(1→4)-(2,3,6-tetra-O-acetyl-α-D-galactopyranosyl)-(1→4)-2,3,6-tri-O-acetyl-α/β-D-galactopyranoside (12). To a solution of trigalacturonic acid methyl ester **7** (1.35 g) in MeOH (100 mL) was added $NaBH_4$ (2.0 g). The solution was stirred for 78 h. After neutralization with Dowex-H^+ the mixture was filtered and concentrated to dryness. Crude trisaccharide was suspended in pyridine (50 mL) and Ac_2O (25 mL) was added. The reaction mixture was stirred for 18 h and concentrated *in vacuo* at 60 °C. Crude product was taken up in EtOAc (250 mL) and washed with aqueous NaOH (1M, 100 mL) aqueous HCl (1M, 100 mL), and brine (100 mL). The organic layer was dried over Na_2SO_4, filtered and concentrated. Silica gel chromatography (hexane/EtOAc, 1/2 → 1/4) was used to obtain pure trisaccharide **12** as a white foam (2.30 g). ^{1}H NMR (300 MHz, $CDCl_3$): δ = 5.56 (1H, dd, H-4″, $J_{3'',4''}$ = 3.0 Hz, $J_{4'',5''}$ = 1.4 Hz), 5.40 (1H, dd, H-3″, $J_{2'',3''}$ = 11.3 Hz, $J_{3'',4''}$ = 3.3 Hz), 5.33 (1H, dd, H-3′, $J_{2',3'}$ = 11.3 Hz, $J_{3',4'}$ = 3.3 Hz), 5.25 (1H, t, H-2″, J = 2.8 Hz), 5.21–5.16 (3H, m, H-2, H-2′, H-3), 5.00–4.98 (2H, m, H-1′, H-1″), 4.95 (1H, d, H-1, $J_{1,2}$ = 3.6 Hz), 4.54 (1H, t, H-5, $J_{5,6}$ = 6.6 Hz), 4.46–3.99 (10 H, m, H-4, H-4′, H-5′, H-5″, 2 × H-6, 2 × H-6′, 2 × H-6″), 3.51 (0.6H, s, OCH$_3$ β), 3.41 (2.2H, s, OCH$_3$ α), 2.14, 2.13, 2.10, 2.10, 2.09, 2.08, 2.07, 2.05, 2.04 and 1.99 (10 × 3H, 10 × s, C(O)CH_3). ^{13}C NMR ($CDCl_3$, 75.5 MHz): δ = 170.5, 170.2, 170.1 and 170.0 (C(O)CH_3), 101.8 (C-1 β), 99.2 and 99.1 (C-1′, C-1″), 97.1 (C-1 α), 72.5, 72.0, 69.3, 69.2, 68.8, 68.5, 68.3, 67.8, 67.7, 67.3, and 66.9 (C-2, C-2′, C-2″, C-3, C-3′, C-3″, C-4, C-4′, C-4″, C-5, C-5′, C-5″), 62.5, 62.1, 61.1 and 60.3 (C-6, C-6′, C-6″), 56.6 and 55.3 (OCH$_3$ α/β), 20.9, 20.7 and 20.6 (C(O)CH$_3$). HRMS for $C_{39}H_{54}O_{26}$ (M, 938.2903): found $[M + Na]^+$ 961.2786, calcd. 961.2801.

Acetyl (2,3,4,6-tri-O-acetyl-α-D-galactopyranosyl)-(1→4)-(2,3,6-tri-O-acetyl-α-D-galactopyranosyl)-(1→4)-2,3,6-tri-O-acetyl-α/β-D-galactopyranoside (13). To a cooled solution of **12** (2.25 g, 2.40 mmol) in Ac_2O (20 mL) was added concentrated H_2SO_4 (60 μL). The solution was stirred at 0 °C for 2 hours, diluted with CH_2Cl_2 (100 mL) and quenched with aqueous $NaHCO_3$ (5%, 5 mL). The reaction mixture was concentrated to dryness at 60 °C. Crude product was taken up in EtOAc (200 mL) and washed with NaOH (1M, 75 mL) and brine (75 mL). The organic layer was dried over Na_2SO_4, filtered and concentrated. After lyophilization **13** was obtained as white powder (2.08 g, 90%) ^{1}H NMR (300 MHz, $CDCl_3$): δ = 6.37 (1H, d, H-1α, $J_{1,2}$ = 3.6 Hz), 5.56 (1H, d, H-4″, $J_{3'',4''}$ = 2.2 Hz), 5.42–5.20 (6H, m, H-3, H-3′, H-3″, H-2, H-2′, H-2″), 5.00–4.98 (2H, 2 × d, H-1′, H-1″, $J_{1',2'}$ = 3.6 Hz, $J_{1'',2''}$ = 3.6 Hz), 4.53 (1H, t, H-5, $J_{5,6}$ = 6.6 Hz), 4.46–4.00 (10 H, m, H-4, H-4′, H-5′, H-5″, 2 × H-6, 2 × H-6′, 2 × H-6″), 2.15, 2.14, 2.13, 2.11, 2.10, 2.08, 2.07, 2.05, 2.04, 2.01 and 1.99 (11 × 3H, 11 × s, C(O)CH_3). ^{13}C NMR ($CDCl_3$, 75.5 MHz): δ = 170.7, 170.5, 170.3, 170.2, 170.1, 169.6 and 168.9 (C(O)CH_3), 99.3 and 89.8 (C-1, C-1′, C-1″), 70.5, 69.3, 69.1, 68.9, 68.3, 67.8, 67.4, 66.9 and 66.3 (C-2, C-2′, C-2″, C-3, C-3′, C-3″, C-4, C-4′, C-4″, C-5, C-5′, C-5″), 61.9, 61.0 and 60.4 (C-6, C-6′, C-6″) 20.9 and 20.6 (C(O)CH$_3$). HRMS for $C_{40}H_{54}O_{27}$ (M, 966.2852): found $[M + Na]^+$ 989.2119, calcd. 989.2750.

(2,3,4,6-Tetra-O-acetyl-α-D-galactopyranosyl)-(1→4)-(2,3,6-tri-O-acetyl-α,β-D-galactopyranosy)l-(1→4)-(2,3,6-tri-O-acetyl-α-D-galactopyranosyl) trichloroacetimidate (14). A solution of **13** (2.50 g, 2.60 mmol) and N_2H_4.HOAc (262 mg, 2.85 mmol) in dry DMF (20 mL) was stirred at r.t. for 70 h. The mixture was concentrated *in vacuo* at 60 °C, taken up in EtOAc (150 mL) and washed twice with brine (75 mL). The organic phase was dried over Na_2SO_4, filtered and concentrated. The obtained white foam (2.22 g, 93%) and trichloroacetonitrile (0.72 mL, 7.2 mmol) were dissolved in dry CH_2Cl_2 (50 mL) and the solution was cooled to 0 °C under a N_2. 1,8-Diazabicyclo[5.4.0]undec-7-ene (108 μL, 0.72 mmol) was added and the solution was stirred at 0 °C for 1 h followed by 2 h at r.t.. The reaction mixture was concentrated and product **14** was isolated by silica gel chromatography (hex/EtOAc, 2/3 → 1/3) as a white amorphous solid (1.17 g, 42%). ^{1}H NMR (300 MHz, $CDCl_3$): δ = 8.69 (1H, s, OCNHCCl$_3$), 6.60 (1H, d, H-1α, $J_{1,2}$ = 3.3 Hz), 5.56 (1H, d, H-4″, $J_{3'',4''}$ = 2.8 Hz), 5.42–5.20 (6H, m, H-2, H-2′, H-2″, H-3, H-3′, H-3″), 5.00 and 4.99 (2 × 1H, 2 × d, H-1′, H-1″, $J_{1',2'}$ = 3.0 Hz, $J_{1'',2''}$ = 2.8 Hz), 4.53 (1H, t, H-5, $J_{5,6}$ = 7.2 Hz), 4.46–4.02 (10H, m, H-4, H-4′, H-5′, H-5″, 2 × H-6, 2 × H-6′, 2 × H-6″), 2.14, 2.12, 2.10, 2.09, 2.06, 2.05, 2.04, 2.04, 2.02 and 1.99 (10 × 3H, 10 × s, C(O)CH_3). ^{13}C NMR ($CDCl_3$, 75.5 MHz): δ = 170.4, 170.2, 170.1, 169.9 and 169.6 (C(O)CH_3), 160.7 (OC(NH)CCl$_3$), 99.3 and 99.1 (C-1′, C-1″), 93.5 (C-1), 90.7 (OCNHCCl$_3$), 70.6, 69.2, 68.9, 68.2, 67.7, 67.3, 66.9 and 66.7 (C-2, C-2′, C-2″, C-3, C-3′, C-3″, C-4, C-4′, C-4″, C-5, C-5′, C-5″), 62.0, 61.2 and 60.3 (C-6, C-6′, C-6″), 20.9 and 20.5 (C(O)CH$_3$).

3-Bromopropyl (2,3,4,6-tri-O-acetyl-α-D-galactopyranosyl)-(1→4)-(2,3,6-tri-O-acetyl-α-D-galactopyranosyl)-(1→4)-2,3,6-tri-O-acetyl-β-D-galactopyranoside (15). A solution of **14** (1.17 g, 1.09 mmol) and 3-bromopropanol (0.48 mL, 5.5 mmol) in CH_2Cl_2 (25 mL) was stirred under N_2 at 0 °C. TMSOTf (63 μL, 0.33 mmol) was added and the mixture was stirred at 0 °C for 1 h. The mixture was warmed to r.t. and after 1 h the reaction was quenched with Et_3N and concentrated *in vacuo*. Silica gel chromatography (hex/EtOAc, 2/3 → 1/3) afforded pure **15** as white foam (607 mg, 55%). ^{1}H NMR (300 MHz, $CDCl_3$): δ = 5.56 (1H, dd, H-4″, $J_{3'',4''}$ = 3.3 Hz, $J_{4'',5''}$ = 1.1 Hz), 5.39 (1H, dd, H-3″, $J_{2'',3''}$ = 11.0 Hz, $J_{3'',4''}$ = 3.3 Hz), 5.33–5.21 (3H, m, H-2′, H-2″, H-3′), 5.00 and 4.98 (each 1H, 2 × d, H-1′ and H-1″, $J_{1',2'}$ = 3.6 Hz, $J_{1'',2''}$ = 3.3 Hz), 4.86 (1H, dd, H-3, $J_{2,3}$ = 10.7 Hz, $J_{3,4}$ = 2.8 Hz), 4.49 (1H, d, H-1, $J_{1,2}$ = 7.7 Hz), 4.54–4.05 (9H, m, H-4, H-5′, H-5″, 2 × H-6, 2 × H-6′, 2 × H-6″), 4.31 (1H, d, H-4′, $J_{3',4'}$ = 1.9 Hz), 4.02–3.96 and 3.75–3.66 (2 × 1H, 2 × m, CH$_2$O$_{Gal}$), 3.82 (1H, t, H-5, $J_{5,6}$ = 6.0 Hz), 3.50 (2H, dd, CH$_2$Br, J = 5.5 Hz, J = 6.6 Hz), 2.14, 2.11, 2.11, 2.10, 2.09, 2.07, 2.07, 2.06, 2.03 and 1.99 (10 × 3H, 10 × s, C(O)CH_3) and 2.20–2.05 (2H, m, OCH$_2$C$H$$_2CH_2N_3$). ^{13}C NMR (75.5 MHz, $CDCl_3$): δ = 170.4, 170.1, 170.0, 169.9, 169.8 and 168.9 (C(O)CH_3), 101.1 (C-1), 99.1 and 99.0 (C-1′, C-1″), 72.2, 71.8, 69.1, 68.7, 68.4, 68.0, 67.8, 67.5, 67.1 and 66.6 (C-2, C-2′, C-2″, C-3, C-3′, C-3″, C-4, C-4′, C-4″, C-5, C-5′, C-5″), 66.8 (OCH$_2$CH$_2$CH$_2$Br), 62.0, 60.9 and 60.2 (C-6, C-6′, C-6″), 32.1 (CH$_2$Br), 30.1 (OCH$_2$$CH_2CH_2$Br), 20.7, 20.6 and 20.4 (C(O)CH$_3$). HRMS for $C_{41}H_{57}BrO_{26}$ (M, 1044.2321): found $[M + Na]^+$ 1067.1964, calcd. 1067.2159.

3-Azidopropyl (2,3,4,6-tri-O-acetyl-α-D-galactopyranosyl)-(1→4)-(2,3,6-tri-O-acetyl-α-D-galactopyranosyl)-(1→4)-2,3,6-tri-O-acetyl-β-D-galactopyranoside (16). A solution of **15** (607 mg, 0.60 mmol) and NaN_3 (195 mg, 3 mmol) in dry DMF (20 mL) was stirred at 100 °C for 20 h. The solution was concentrated *in vacuo* at 60 °C, taken up in EtOAc (50 mL) and washed twice with brine (25 mL). The organic phase was dried (Na_2SO_4), filtered and concentrated. After lyophilization **16** was obtained as white powder (548 mg, 94%). ^{1}H NMR (300 MHz, $CDCl_3$): δ = 5.56 (1H, dd, H-4″, $J_{3'',4''}$ = 3.3 Hz), 5.39 (1H, dd, H-3″, $J_{2'',3''}$ = 11.0 Hz, $J_{3'',4''}$ = 3.3 Hz), 5.32–5.22 (3H, m, H-2′, H-2″, H-3′), 5.17 (1H, dd, H-2, $J_{1,2}$ = 7.7 Hz, $J_{2,3}$ = 10.7 Hz), 4.99 and 4.98 (each 1H, 2 × d, H-1′, H-1″, $J_{1',2'}$ = 3.6 Hz, $J_{1'',2''}$ = 3.3 Hz), 4.83 (1H, dd, H-3, $J_{2,3}$ = 10.7 Hz, $J_{3,4}$ = 2.8 Hz), 4.46 (1H, d, H-1, $J_{1,2}$ = 7.7 Hz), 4.56–4.02 (9H, m, H-4, H-5′, H-5″, 2 × H-6, 2 × H-6′, 2 × H-6″), 4.30 (1H, d, H-4′, $J_{3,4}$ = 1.7 Hz), 3.98–3.92 and 3.66–3.64 (2 × 1H, 2 × m, CH_2O_{Gal}), 3.79 (1H, t, H-5, $J_{5,6}$ = 6.6 Hz), 3.38 (2H, t, CH_2N_3, J = 6.6 Hz), 2.14, 2.11, 2.10, 2.09, 2.08, 2.07, 2.06, 2.05, 2.03 and 1.99 (10 × 3H, 10 × s, C(O)CH_3) and 1.90–1.82 (2H, m, $OCH_2CH_2CH_2N_3$). ^{13}C NMR (75.5 MHz, $CDCl_3$): δ = 170.6, 170.2, 170.0 and 169.0 (*C*(O)CH_3), 101.0 (C-1), 99.3 and 99.2 (C-1′, C-1″), 72.4, 72.0, 69.2, 68.9, 68.5, 68.2, 68.0, 67.7, 67.3 and 66.8 (C-2, C-2′, C-2″, C-3, C-3′, C-3″, C-4, C-4′, C-4″, C-5, C-5′, C-5″), 66.0 (O*C*$H_2CH_2CH_2N_3$), 62.1, 61.0 and 60.3 (C-6, C-6′, C-6″), 47.9 (CH_2N_3), 28.9 ($OCH_2CH_2CH_2N_3$) and 20.5 (C(O)*C*H_3). HRMS for $C_{41}H_{57}N_3O_{26}$ (M, 1007.3230): found [M + Na]$^+$ 1030.2924, calcd. 1030.3128.

Monovalent pentynoic acid dendrimer (17b). Compound **17a** (295 mg, 1.0 mmol) was stirred in a mixture of CH_2Cl_2/TFA (1/1, v/v, 20 mL) with a trace of water for 3 h. The reaction mixture was then concentrated to dryness and taken up in CH_2Cl_2 (10 mL). BOP (487 mg, 1.1 mmol) and 4-pentynoic acid (108 mg, 1.1 mmol) were added followed by DiPEA (0.55 mL, 3.3 mmol). The mixture was stirred for 72 h and concentrated *in vacuo*. The crude mixture was taken up in EtOAc (50 mL) and washed twice with $KHSO_4$ (1M, 15 mL), twice with NaOH (1M, 15 mL) and with brine (15 mL). Pure product was obtained as a white solid (192 mg, 70%). ^{1}H NMR (300 MHz, $CDCl_3$): δ = 7.64 (1H, m, CH_{arom}-6), 7.55 (1H, s, CH_{arom}-2), 7.35 (1H, t, CH_{arom}-5), 7.11 (1H, dd, CH_{arom}-4), 6.12 (1H, bs, C(O)NH), 4.10 (2H, t, O*C*H_2CH_2NH, J = 5.4 Hz), 3.92 (3H, s, OCH_3), 3.74–3.68 (2H, m, O*C*H_2CH_2NH), 2.59–2.53 and 2.48–2.42 (2 × 2H, 2 × m, C(O)CH_2CH_2CCH) and 1.94 (1H, t, CH_2CH_2CCH). ^{13}C NMR (75.5 MHz, $CDCl_3$): δ = 171.3 (C(O)NH), 166.8 (*C*(O)OCH_3), 158.6 (C_{arom}-3), 131.8 (C_{arom}-1), 129.8 (C_{arom}-5), 122.7 (C_{arom}-6), 119.8 (C_{arom}-4), 115.1 (C_{arom}-2), 69.6 (CH_2CH_2CCH), 67.3 (O*C*H_2CH_2NH), 52.4 (C(O)O*C*H_3), 39.2 (OCH_2CH_2NH), 35.5 (C(O)*C*H_2CH_2CCH) and 15.1 (C(O)CH_2CH_2CCH).

Divalent pentynoic acid dendrimer (18b). Divalent dendrimer **18a** (454 mg, 1.0 mmol) was stirred in a mixture of CH_2Cl_2/TFA (1/1, v/v, 16 mL) with a trace of water for 3 h. The reaction mixture was then concentrated to dryness and taken up in CH_2Cl_2 (5 mL), BOP (0.97 g, 2.2 mmol) and 4-pentynoic acid (215 mg, 2.2 mmol) were added followed by DiPEA (1.10 mL, 6.6 mmol). The reaction mixture was stirred for 18 h and concentrated. Crude product was taken up in EtOAc (100 mL) and washed with $KHSO_4$ (1M, 50 mL), NaOH (1M, 50 mL) and brine (50 mL). Dendrimer **18b** was obtained after silica gel chromatography (EtOAc) as a white solid (380 mg, 92%). ^{1}H NMR (300 MHz, $CDCl_3$): δ = 7.19 (2H, d, CH_{arom}-2,6), 6.65 (1H, s, CH_{arom}-4), 6.05 (2H, bs, C(O)NH), 4.09–4.06 (4H, m, O*C*H_2CH_2NH), 3.91 (3H, s, OCH_3), 3.73–3.67 (4H, m, OCH_2*C*H_2NH), 2.57–2.51 and 2.46–2.40 (2 × 4H, 2 × m, C(O)CH_2CH_2CCH) and 1.95 (2H, t, CH_2CH_2CCH, J = 2.1 Hz). ^{13}C NMR (75.5 MHz, $CDCl_3$): δ = 171.4 (C(O)NH), 166.7 (*C*(O)OCH_3), 159.7 (C_{arom}-3,5), 132.5 (C_{arom}-1), 108.4 (C_{arom}-2,6), 106.6 (C_{arom}-4), 69.7 (CH_2CH_2CCH), 67.4 (O*C*H_2CH_2NH), 52.6 (C(O)O*C*H_3), 39.1 (OCH_2CH_2NH), 35.5 (C(O)*C*H_2CH_2CCH) and 15.1 (C(O)CH_2CH_2CCH).

Tetravalent pentynoic acid dendrimer (19b). Tetravalent dendrimer **19a** (1099 mg, 1.0 mmol) was stirred in a mixture of CH_2Cl_2/TFA (1/1, v/v, 20 mL) with a trace of H_2O for 1 h. The reaction mixture was then concentrated to dryness and taken up in CH_2Cl_2 (10 mL), BOP (2.65 g, 6.0 mmol) and 4-pentynoic acid (589 mg, 6.0 mmol) were added followed by DiPEA (1.98 mL, 12.0 mmol). The reaction mixture was stirred for 18 h and concentrated at 60 °C. Dendrimer **19b** was obtained after silica gel chromatography (CH_2Cl_2/MeOH/DMF, 94/5/1 → 85/10/5) as white solid (826 mg, 81%, small contamination). ^{1}H NMR (300 MHz, DMSO): δ = 8.66 (2H, s, C(O)NH), 8.15 (4H, t, C(O)NH), 7.09 (2H, m, CH_{arom}-2,6), 7.04 (4H, s, CH_{arom}-2′,6′), 6.84 (1H, t, CH_{arom}-4), 6.65 (2H, t, CH_{arom}-4′), 4.16 (4H, t, O*C*H_2CH_2NH, J = 5.4 Hz), 4.01 (8H, t, O*C*H_2CH_2NH, J = 5.4 Hz), 3.83 (3H, s, OCH_3), 3.64–3.58 (4H, m, OCH_2*C*H_2NH), 3.45–3.39 (8H, m, OCH_2*C*H_2NH), 2.73 (4H, t, CH_2CH_2CCH, J = 2.1 Hz) and 2.39–2.27 (16H, m, C(O)CH_2CH_2CCH). ^{13}C NMR (75.5 MHz, DMSO): δ = 170.6 (C(O)NH), 165.9 (*C*(O)OCH_3), 159.7 (C_{arom}-3,5), 159.4 (C_{arom}-3′,5′), 136.2 (C_{arom}-1′), 131.6 (C_{arom}-1), 107.7 (C_{arom}-2,6), 106.0 (C_{arom}-2′,6′), 104.1 (C_{arom}-4′), 83.7 (CH_2CH_2CCH), 71.2 (CH_2CH_2CCH), 66.6 (O*C*H_2CH_2NH), 52.3 (C(O)O*C*H_3), 38.2 (OCH_2CH_2NH), 34.0 (C(O)*C*H_2CH_2CCH) and 14.2 (C(O)CH_2CH_2CCH).

Octavalent pentynoic acid dendrimer (20b). Octavalent dendrimer **20a** (597 mg, 0.25 mmol) was stirred in a mixture of CH_2Cl_2/TFA (1/1, v/v, 10 mL) with a trace of H_2O for 1 h. The reaction mixture was then concentrated to dryness and taken up in dry DMF (5 mL), BOP (1.33 g, 3 mmol) and 4-pentynoic acid (295 mg, 3 mmol) were added followed by DiPEA (0.99 mL, 6 mmol). The reaction mixture was stirred for 18 h and concentrated at 60 °C. Silica gel chromatography (CH_2Cl_2/MeOH/DMF, 94/5/1 → 85/10/5) was used for purification although a small impurity remains present (621 mg, ≈ quantitative). ^{1}H NMR (300 MHz, DMSO): δ = 8.69 (6H, s, C(O)NH), 8.16 (8H, t, C(O)NH), 7.07–7.04 (14H, m, CH_{arom}-2,6, 2′,6′, 2″,6″), 6.82 (1H, s, CH_{arom}-4), 6.70 (2H, bs, CH_{arom}-4′), 6.64 (4H, d, CH_{arom}-4″), 4.14 (12H, bs, O*C*H_2CH_2NH), 4.01 (16H, s, O*C*H_2CH_2NH), 3.80 (3H, s, OCH_3), 3.61 (12H, d, OCH_2*C*H_2NH), 3.42 (16H, d, OCH_2*C*H_2NH), 2.72 (8H, bs, CH_2CH_2CCH) and 2.35–2.29 (32H, m, C(O)CH_2CH_2CCH). ^{13}C NMR (75.5 MHz, DMSO): δ = 170.6 (C(O)NH), 165.9 (*C*(O)OCH_3), 159.4 (C_{arom}-3″,5″), 136.2 (C_{arom}-1″), 106.0 (C_{arom}-2″,6″), 104.1 (C_{arom}-4″), 83.7 (CH_2CH_2CCH), 71.2 (CH_2CH_2CCH), 66.6 (O*C*H_2CH_2NH), 53.4 (C(O)O*C*H_3), 40.3 (OCH_2CH_2NH), 34.0 (C(O)*C*H_2CH_2CCH) and 14.2 (C(O)CH_2CH_2CCH).

General "click" procedure

Dendrimer was mixed with the galabiose azide (1.5 eq per alkyne), $CuSO_4 \cdot 5H_2O$ (0.15 eq per alkyne) and sodium ascorbate (0.3 eq per alkyne) in 1% H_2O/DMF. The mixture was heated under microwave irradiation to 80 °C for 20 min. The reaction mixture was concentrated *in vacuo* at 60 °C and after silica gel chromatography the dendrimer was obtained.

General deacetylation procedure

A solution of the dendrimer in MeOH (5 mL) was treated with NaOMe in MeOH (30% wt solution, 50 μL) for 5 h. The solution was neutralized by Dowex-H^+, filtered and concentrated *in vacuo*. Deprotected dendrimers were purified using preparative HPLC. Pure products were obtained after lyophilisation.

Monovalent galabiose dendrimer (17c). The general "click" procedure was applied. Monovalent galabiose derivative was obtained as a white foam (179 mg, 72%). ^{1}H NMR (300 MHz, $CDCl_3$): δ = 7.65 (1H, d, CH_{arom}-6), 7.53 (1H, t, CH_{arom}-2), 7,35 (1H, t, CH_{arom}-5), 7.09 (1H, dd, CH_{arom}-4), 6.34 (1H, bs, NHCO), 5.58 (1H, dd, H-4′, $J_{3',4''}$ = 3.0 Hz, $J_{4',5'}$ = 1.1 Hz), 5.41 (1H, dd, H-3′, $J_{2',3'}$ = 11.0 Hz, $J_{3',4'}$ = 3.3 Hz), 5.23–5.16 (2H, m, H-2, H-2′), 5.00 (1H, d, H-1′, $J_{1',2'}$ = 3.9 Hz), 4.80 (1H, dd, H-3, $J_{2,3}$ = 10.7 Hz, $J_{3,4}$ = 2.7 Hz), 4.45 (1H, d, H-1, $J_{1,2}$ = 7.70 Hz), 4.55–4.35, 4.21–4.04 and 3.90–3.76 (5H, 6H, 2H, 3 × m, H-1, H-4, H-5′, H-6, H-6′, OCH_2CH_2NH, $CH_2N_{triazole}$, CH_2O_{Gal}), 3.91 (3H, s, OCH_3), 3.69–3.63 (2H, bs, OCH_2CH_2NH), 3.49–3.40 (1H, m, H-5), 3.06 and 2.67 (2 × bs, each 2H, $C(O)CH_2CH_2C_{triazole}$), 2.20–2.02 (2H, m, $OCH_2CH_2CH_2N_{triazole}$), 2.14, 2.10, 2.09, 2.08, 2.06, 2.04 and 1.99 (7 × 3H, 7 × s, $C(O)CH_3$). ^{13}C NMR (75.5 MHz, $CDCl_3$): δ = 170.5, 170.4, 170.1, 169.9 and 169.2 ($C(O)CH_3$), 166.6 ($C(O)OCH_3$), 158.3 (C_{arom}-3), 131.4 (C_{arom}-1), 129.4 (C_{arom}-5), 122.3 (C_{arom}-6), 119.6 (C_{arom}-4), 114.7 (C_{arom}-2), 101.0 (C-1), 99.4 (C-1′), 72.6, 71.9, 68.5, 67.7, 67.2 and 67.0 (C-2, C-2′, C-3, C-3′, C-4, C-4′, C-5, C-5′), 66.8 ($OCH_2CH_2CH_2N_{triazole}$), 65.6 ($OCH_2CH_2NH$), 61.9 and 60.4 (C-6, C-6′), 52.1 ($C(O)OCH_3$), 46.6 ($CH_2N_{triazole}$), 38.8 and 30.0 ($C(O)CH_2CH_2C_{triazole}$), 20.8 and 20.6 ($C(O)CH_3$). HRMS for $C_{44}H_{58}N_4O_{22}$ (M, 994.3543): found $[M + H]^+$ 995.3600, calcd. 995.3621. The general deacetylation procedure yielded compound **17c** as a clear oil (30.7 mg, 35%). ^{1}H NMR (300 MHz, D_2O): δ = 7.72 (1H, bs, $CH_{triazole}$), 7.61 (2H, s, CH_{arom}-6), 7.46–7.40 (2H, m, CH_{arom}-2,5), 7.14 (1H, d, CH_{arom}-4), 4.97 (1H, d, H-1′, $J_{1',2'}$ = 3.6 Hz), 4.39–4.27 (6H, m), 4.39–4.31 (2H, m), 4.22 (2H, t), 4.02–3.97 (4H, m), 3.94–3.67 (14H, m), 3.56–3.42 (5H, m), 2.98 and 2.60 (2 × 2H, 2 × bt, $C(O)CH_2CH_2C_{triazole}$) and 2.00 (2H, bt, $OCH_2CH_2CH_2N_{triazole}$). ^{13}C NMR (75.5 MHz, D_2O): δ = 175.6 (C(O)NH), 169.4 ($C(O)OCH_3$), 158.9 (C_{arom}-3), 131.5 (C_{arom}-1), 130.8 (C_{arom}-5), 123.1 (C_{arom}-6), 121.0 (C_{arom}-4), 115.6 (C_{arom}-2), 103.7 (C-1), 101.0 (C-1′), 77.9, 77.7, 75.7, 73.1, 71.6, 71.4, 69.8 and 69.6 (C-2, C-2′, C-3, C-3′, C-4, C-4′, C-5, C-5′), 67.5 ($OCH_2CH_2CH_2N_{triazole}$), 67.0 ($OCH_2CH_2NH$), 61.2 and 60.7 (C-6, C-6′), 53.4 ($C(O)OCH_3$), 47.7 ($CH_2N_{triazole}$), 39.4 and 35.7 ($C(O)CH_2CH_2C_{triazole}$) and 21.7 ($OCH_2CH_2CH_2N_{triazole}$). HRMS for $C_{30}H_{44}N_4O_{15}$ (M, 700.2803): found $[M + H]^+$ 701.0662, calcd. 701.2881.

Divalent galabiose dendrimer (18c). The general "click" procedure was applied. Protected divalent galabiose dendrimer was obtained as a white foam (155 mg, 84%). ^{1}H NMR (300 MHz, $CDCl_3$): δ = 7.44 (2H, bs, $CH_{triazole}$), 7.15 (2H, s, CH_{arom}-2,6), 6.67 (1H, s, CH_{arom}-4), 6.62 (2H, bs, NHCO), 5.58 (2H, dd, H-4′, $J_{3',4'}$ = 2.5 Hz), 5.41 (2H, dd, H-3′, $J_{2',3'}$ = 11.3 Hz, $J_{3',4'}$ = 3.3 Hz), 5.23–5.16 (4H, m, H-2, H-2′), 5.00 (2H, d, H-1′, $J_{1',2'}$ = 3.6 Hz), 4.81 (2H, dd, H-3, $J_{2,3}$ = 10.7 Hz, $J_{3,4}$ = 2.5 Hz), 4.47 (2H, d, H-1, $J_{1,2}$ = 7.70 Hz), 4.55–4.35, 4.17–4.00 and 3.87–3.75 (10H, 12H, 4H, 3 × m, H-1, H-4, H-5′, H-6, H-6′, OCH_2CH_2NH, $CH_2N_{triazole}$, CH_2O_{Gal}), 3.90 (3H, s, $C(O)OCH_3$), 3.65 (4H, bs, OCH_2CH_2NH), 3.50–3.42 (1H, m, H-5), 3.06 and 2.67 (2 × bs, each 4H, $C(O)CH_2CH_2C_{triazole}$), 2.20–2.02 (4H, m, $OCH_2CH_2CH_2N_{triazole}$), 2.14, 2.10, 2.09, 2.08, 2.06, 2.04 and 1.99 (7 × 6H, 7 × s, $C(O)CH_3$). ^{13}C NMR (75.5 MHz, $CDCl_3$): δ = 170.2, 170.1, 170.0, 169.8, 169.6 and 168.9 ($C(O)CH_3$), 166.1 ($C(O)OCH_3$), 159.2 (C_{arom}-3,5), 131.7 (C_{arom}-1), 107.7 (C_{arom}-2,6), 106.4 (C_{arom}-4), 100.7 (C-1), 99.1 (C-1′), 72.3, 71.6, 68.3, 67.5, 67.0 and 66.8 (C-2, C-2′, C-3, C-3′, C-4, C-4′, C-5, C-5′), 66.6 ($OCH_2CH_2CH_2N_{triazole}$), 65.4 ($OCH_2CH_2NH$), 61.7 and 60.2 (C-6, C-6′), 51.9 ($C(O)OCH_3$), 38.5 and 29.7 ($C(O)CH_2CH_2C_{triazole}$), 20.5 and 20.3 ($C(O)CH_3$). HRMS for $C_{80}H_{108}N_8O_{42}$ (M, 1852.6561): found $[M + Na]^+$ 1875.6348, calcd. 1875.6459. The general deacetylation procedure yielded compound **18c** as a white foam (66.3 mg, 49%). ^{1}H NMR (300 MHz, D_2O): δ = 7.75 (2H, bs, $CH_{triazole}$), 7.05 (2H, s, CH_{arom}-2,6), 6.62 (1H, s, CH_{arom}-4), 4.97 (2H, s, H-1′), 4.39–4.27 (6H, m), 4.02–3.70 (25H, m), 3.56–3.53 (8H, m), 2.97 and 2.60 (2 × 4H, 2 × bs, $C(O)CH_2CH_2C_{triazole}$) and 2.02 (4H, bs, $OCH_2CH_2CH_2N_{triazole}$). ^{13}C NMR (75.5 MHz, D_2O): δ = 175.7 (C(O)NH), 168.9 ($C(O)OCH_3$), 160.1 (C_{arom}-3,5), 132.3 (C_{arom}-1), 108.9 (C_{arom}-2,6), 107.5 (C_{arom}-4), 103.7 (C-1), 101.0 (C-1′), 77.9, 77.7, 75.9, 75.6, 73.2, 73.0, 71.5, 69.9 and 69.5 (C-2, C-2′, C-3, C-3′, C-4, C-4′, C-5, C-5′), 67.7 ($OCH_2CH_2CH_2N_{triazole}$), 67.1 ($OCH_2CH_2NH$), 61.3 and 60.8 (C-6, C-6′), 47.6 ($CH_2N_{triazole}$), 39.4 and 35.8 ($C(O)CH_2CH_2C_{triazole}$) and 21.9 ($OCH_2CH_2CH_2N_{triazole}$). HRMS for $C_{52}H_{80}N_8O_{28}$ (M, 1264.5082): found $[M + Na]^+$ 1287.1271, calcd. 1287.4980.

Tetravalent galabiose dendrimer (19c). The general "click" procedure was applied. Protected tetravalent galabiose dendrimer **19c** was obtained as a white foam (151 mg, 78%). ^{1}H NMR (300 MHz, $CDCl_3$): δ = 7.44 (4H, bs, $CH_{triazole}$), 7.36 (2H, bs, C(O)NH), 7.15 (2H, s, CH_{arom}-2,6), 6.94 (8H, bs, CH_{arom}-2′,6′ and C(O)NH), 6.73 (1H, bs, CH_{arom}-4), 6.52 (2H, bs, CH_{arom}-4′), 5.57 (4H, dd, H-4′, $J_{3',4'}$ = 2.2 Hz), 5.41 (4H, dd, H-3′, $J_{2',3'}$ = 11.0 Hz, $J_{3',4'}$ = 3.3 Hz), 5.23–5.15 (8H, m, H-2, H-2′), 5.00 (4H, d, H-1′, $J_{1',2'}$ = 3.7 Hz), 4.81 (4H, dd, H-3, $J_{2,3}$ = 10.7 Hz, $J_{3,4}$ = 2.4 Hz), 4.54–4.35, 4.21–4.08, 3.98 and 3.87–3.80 (22H, 22H, 8H, 12H, 3 × m, 1 × bs, H-1, H-4, H-5′, H-6, H-6′, OCH_2CH_2NH, OCH_2CH_2NH, $CH_2N_{triazole}$, CH_2O_{Gal}), 3.87 (3H, s, OCH_3), 3.57 (6H, bs, OCH_2CH_2NH), 3.45 (4H, bs, H-5) 3.03 and 2.66 (2 × bs, 2 × 8H, $C(O)CH_2CH_2C_{triazole}$), 2.20–2.00 (8H, m, $OCH_2CH_2CH_2N_{triazole}$), 2.13, 2.10, 2.08, 2.07, 2.05, 2.04 and 1.99 (7 × 12H, 7 × s, $C(O)CH_3$). ^{13}C NMR (75.5 MHz, $CDCl_3$): δ = 170.5, 170.4, 170.0, 169.9 and 169.2 ($C(O)CH_3$), 167.9 (C(O)NH), 166.4 ($C(O)OCH_3$), 159.5 (C_{arom}-3,5 and C_{arom}-3′,5′), 136.3 (C_{arom}-1′), 131.9 (C_{arom}-1), 108.1 (C_{arom}-2,6), 106.5 (C_{arom}-4), 106.0 (C_{arom}-2′,6′), 104.8 (C_{arom}-4′), 100.9 (C-1), 99.4 (C-1′), 72.5, 71.8, 68.6, 68.4, 67.7, 67.2 and 67.0 (C-2, C-2′, C-3, C-3′, C-4, C-4′, C-5, C-5′), 66.7 ($OCH_2CH_2CH_2N_{triazole}$), 65.6 ($OCH_2CH_2NH$), 61.8 and 60.4 (C-6, C-6′), 52.2 ($C(O)OCH_3$), 46.7 ($CH_2N_{triazole}$), 39.5 and

38.6 (OCH_2CH_2NH), 38.6 and 30.0 ($C(O)CH_2CH_2C_{triazole}$), 20.8 and 20.6 ($C(O)CH_3$). HRMS for $C_{170}H_{226}N_{18}O_{86}$ (M, 3895.3864): found $[M + 3Na]^{3+}$ 1321.7095, calcd. 1321.4519. The general deacetylation procedure yielded compound **19c** as a white foam (64.3 mg, 74%). ^{1}H NMR (300 MHz, D_2O): δ = 7.65 (4H, s, $CH_{triazole}$), 6.79 (6H, s, CH_{arom}-2,6, 2′,6′), 6.48 (3H, t, CH_{arom}-4, 4′), 4.95 (4H, s, H-1′), 4.37–4.27 (16H, m), 4.01–3.45 (84H, m), 2.89 and 2.52 (2 × 8H, 2 × bs, $C(O)CH_2CH_2C_{triazole}$) and 2.00 (8H, m, $OCH_2CH_2CH_2N_{triazole}$). ^{13}C NMR (75.5 MHz, D_2O): δ = 175.4 and 169.6 (C(O)NH), 168.2 ($C(O)OCH_3$), 160.0 (C_{arom}-3′,5′), 159.8 (C_{arom}-3,5), 133.0 (C_{arom}-1), 131.7 (C_{arom}-1′), 108.6 (C_{arom}-2,6), 106.9 (C_{arom}-2′,6′), 105.3 (C_{arom}-4′), 103.6 (C-1), 100.9 (C-1′), 77.8, 77.7, 73.0, 71.5, 71.3, 69.7 and 69.5 (C-2, C-2′, C-3, C-3′, C-4, C-4′, C-5, C-5′), 67.5 ($OCH_2CH_2CH_2N_{triazole}$), 67.0 ($OCH_2CH_2NH$), 61.2 and 60.7 (C-6, C-6′), 47.5 ($CH_2N_{triazole}$), 39.2 and 35.7 ($C(O)CH_2CH_2C_{triazole}$) and 21.7 ($OCH_2CH_2CH_2N_{triazole}$). MALDI ToF MS for $C_{114}H_{170}N_{18}O_{58}$ (M, 2719.0906): found $[M + Na]^+$ 2743.20, calcd. 2743.65.

Octavalent galabiose dendrimer (20c). The general "click" procedure was applied. Protected octavalent galabiose dendrimer was obtained as a white foam (131 mg, 66%). ^{1}H NMR (300 MHz, $CDCl_3$): δ = 7.68 (8H, bs, $CH_{triazole}$), 7.46 and 7.30 (8H and 6H, 2 × bs, C(O)NH), 7.07 (CH_{arom}-2,6), 6.89 (12H, s, CH_{arom}-2′,6′, 2″,6″), 6.69 (1H, s, CH_{arom}-4), 6.40 (6H, bs, CH_{arom}-4′, CH_{arom}-4″), 5.57 (4H, d, H-4′, $J_{3',4'}$ = 2.7 Hz), 5.41 (4H, dd, H-3′, $J_{2',3'}$ = 11.0 Hz, $J_{3',4'}$ = 3.3 Hz), 5.23–5.15 (8H, m, H-2, H-2′), 5.00 (4H, d, H-1′, $J_{1',2'}$ = 3.7 Hz), 4.83 (4H, d, H-3, $J_{2,3}$ = 10.8 Hz), 4.55–4.30, 4.20–4.00 and 3.90–3.70 (40H, 45H, 46H, 3 × m, H-1, H-4, H-5′, H-6, H-6′, $CH_2N_{triazole}$, OCH_2CH_2NH, OCH_2CH_2NH, CH_2O_{Gal}, $C(O)OCH_3$), 3.53 (16H, bs, OCH_2CH_2NH), 3.45 (8H, m, H-5), 2.19–2.01 (16H, m, $OCH_2CH_2CH_2N_{triazole}$), 2.14, 2.13, 2.10, 2.08, 2.05, 2.04 and 1.99 (7 × 12H, 7 × s, $C(O)CH_3$). ^{13}C NMR (75.5 MHz, $CDCl_3$): δ = 170.5, 170.3, 170.0, 169.9 and 169.2 ($C(O)CH_3$), 167.6 (C(O)NH), 166.4 ($C(O)OCH_3$), 159.4 (C_{arom}-3,5, 3′,5′, 3″,5″), 136.3 (C_{arom}-1′, 1″), 131.9 (C_{arom}-1), 108.2, 106.0 and 104.4 (C_{arom}-4, 4′, 4″, C_{arom}-2,6, 2′,6′, 2″,6″), 100.9 (C-1), 99.4 (C-1′), 72.5, 71.8, 68.6, 68.4, 67.7, 67.2 and 67.0 (C-2, C-2′, C-3, C-3′, C-4, C-4′, C-5, C-5′), 66.7 ($OCH_2CH_2CH_2N_{triazole}$), 65.7 ($OCH_2CH_2NH$), 61.8 and 60.4 (C-6, C-6′), 30.0 and 29.5 ($C(O)CH_2CH_2C_{triazole}$) and 20.5 ($C(O)CH_3$). The general deacetylation procedure yielded compound **20c** as a white foam (54.5 mg, 77%). ^{1}H NMR (300 MHz, D_2O): δ = 7.67 (8H, s, $CH_{triazole}$), 6.73 (10H, s, CH_{arom}-2,6, 2′,6′, 2″,6″), 6.42 (6H, t, CH_{arom}-4, 4′, 4″), 4.95 (8H, d, H-1′, $J_{1,2}$ = 3.6 Hz), 4.37–4.30 (25H, m), 4.01–3.43 (140H, m), 2.87 and 2.51 (2 × 16H, 2 × bs, $C(O)CH_2CH_2C_{triazole}$) and 2.01 (16H, m, $OCH_2CH_2CH_2N_{triazole}$). ^{13}C NMR (75.5 MHz, D_2O): δ = 175.2, 169.3 and 169.1 (C(O)NH), 167.9 ($C(O)OCH_3$), 159.9 (C_{arom}-3″,5″), 103.6 (C-1), 100.9 (C-1′), 77.8, 77.7, 75.7, 73.0, 71.5, 71.3, 69.7 and 69.5 (C-2, C-2′, C-3, C-3′, C-4, C-4′, C-5, C-5′), 67.5 ($OCH_2CH_2CH_2N_{triazole}$), 67.0 ($OCH_2CH_2NH$), 61.2 and 60.7 (C-6, C-6′), 47.5 ($CH_2N_{triazole}$), 39.2 and 35.5 ($C(O)CH_2CH_2C_{triazole}$) and 21.7 ($OCH_2CH_2CH_2N_{triazole}$). MALDI ToF MS for $C_{238}H_{350}N_{38}O_{118}$ (M, 5628.2555): found $[M + Na]^+$ 5654.46, calcd. 5654.50.

Tetravalent trisaccharide dendrimer (19d). The general "click" procedure was applied. Protected tetravalent dendrimer was obtained as a white foam (201 mg, 79%). ^{1}H NMR (300 MHz, $CDCl_3$): δ = 7.45 (4H, bs, $CH_{triazole}$), 7.36 (2H, bs, C(O)NH), 7.14 (2H, s, CH_{arom}-2,6), 6.94 (8H, bs, CH_{arom}-2′,6′ and C(O)NH), 6.70 (1H, bs, CH_{arom}-4), 6.48 (2H, bs, CH_{arom}-4′), 5.56 (4H, d, H-4″, $J_{3'',4''}$ = 2.7 Hz), 5.40 (4H, dd, H-3″, $J_{2'',3''}$ = 11.1 Hz, $J_{3',4'}$ = 3.3 Hz), 5.31–5.15 (12H, m, H-2, H-2′, H-2″), 5.00 (4H, d, H-1″, $J_{1'',2''}$ = 3.6 Hz), 4.97 (4H, d, H-1′, $J_{1',2'}$ = 1.8 Hz), 4.81 (4H, d, H-3, $J_{2,3}$ = 9.9 Hz), 4.56–4.30, 4.22–3.98 and 3.82–3.75 (25H, 24H, 8H, 3 × m, H-1, H-4, H-4′, H-5′, H-5″, H-6, H-6′, H-6″, OCH_2CH_2NH, OCH_2CH_2NH, $CH_2N_{triazole}$, CH_2O_{Gal}), 3.87 (3H, s, OCH_3), 3.57 (6H, bs, OCH_2CH_2NH), 3.44 (4H, bs, H-5), 3.01 and 2.65 (2 × 8H, 2 × bs, $C(O)CH_2CH_2C_{triazole}$), 2.20–2.00 (8H, m, $OCH_2CH_2CH_2N_{triazole}$), 2.14, 2.12, 2.09, 2.07, 2.06, 2.03 and 1.99 (10 × 12H, 10 × s, $C(O)CH_3$). ^{13}C NMR (75.5 MHz, $CDCl_3$): δ = 170.6, 170.4, 170.2, 170.1, 169.9 and 169.2 ($C(O)CH_3$), 167.2 (C(O)NH), 166.4 ($C(O)OCH_3$), 159.5 (C_{arom}-3″,5″), 136.4 (C_{arom}-1″), 131.7 (C_{arom}-1), 108.3, 108.0, 106.3, 106.1 and 104.7 (C_{arom}), 101.0 (C-1), 99.6 and 99.3 (C-1′, C-1″), 72.5, 72.3, 72.1, 71.9, 69.0, 68.7, 68.4, 67.8, 67.5 and 66.8 (C-2, C-2′, C-2″, C-3, C-3′, C-3″ C-4, C-4′, C-4″, C-5, C-5′, C-5″), 65.6 (OCH_2CH_2NH), 62.1, 61.0 and 60.3 (C-6, C-6′, C-6″), 52.1 ($C(O)OCH_3$), 46.5 ($CH_2N_{triazole}$), 39.5 and 38.6 (OCH_2CH_2NH), 35.3 and 30.0 ($C(O)CH_2CH_2C_{triazole}$), 20.6 and 20.5 ($C(O)CH_3$). HRMS for $C_{218}H_{290}N_{18}O_{118}$ (M, 5047.7245): found $[M + Na]^+$ 5072.99, calcd. 5073.6748. General deacetylation procedure yielded compound **19d** as a white foam (28.4 mg, 57%). ^{1}H NMR (300 MHz, D_2O): δ = 7.70 (4H, s, $CH_{triazole}$), 6.84 (2H, s, CH_{arom}-2,6), 6.79 (4H, s, CH_{arom}-2′,6′), 6.51 (3H, t, CH_{arom}-4, 4′), 5.01–4.97 (8H, m, H-1′, H-1″), 4.41 (4H, t), 4.29 (16H, m), 4.11–3.60 (86H, m), 3.55–3.40 (18H, m), 2.91 and 2.54 (2 × 8H, 2 × bs, $C(O)CH_2CH_2C_{triazole}$) and 2.00 (8H, m, $OCH_2CH_2CH_2N_{triazole}$). ^{13}C NMR (75.5 MHz, D_2O): δ = 175.3 and 169.7 (C(O)NH), 168.3 ($C(O)OCH_3$), 160.0 (C_{arom}-3′,5′), 159.8 (C_{arom}-3,5), 136.2 (C_{arom}-1′), 106.8 (C_{arom}), 103.5 (C-1), 101.1 and 100.8 (C-1′, C-1″), 79.6, 77.5, 75.6, 72.8, 71.6, 71.4, 69.8, 69.5 and 69.2 (C-2, C-2′, C-2″, C-3, C-3′, C-3″, C-4, C-4′, C-4″, C-5, C-5′, C-5″), 67.4 ($OCH_2CH_2CH_2N_{triazole}$), 66.9 ($OCH_2CH_2NH$), 61.2 and 60.5 (C-6, C-6′, C-6″), 47.7 ($CH_2N_{triazole}$), 39.2 and 35.4 ($C(O)CH_2CH_2C_{triazole}$), 30.1 (OCH_2CH_2NH) and 21.5 ($OCH_2CH_2CH_2N_{triazole}$). MALDI ToF MS for $C_{138}H_{210}N_{18}O_{78}$ (M, 3367.3019): found $[M + Na]^+$ 3391.87, calcd. 3392.21.

Hemagglutination

Hemagglutination assays were performed as described previously.[4b] Briefly, equal volumes of bacteria and 5% sialidase-treated human erythrocytes were mixed and hemagglutination was visually recorded after 1 h incubation on ice. For inhibition assays, 2-fold dilutions of galabiose compounds (25 μL) were mixed with bacteria (25 μL). After 5 min of incubation at room temperature, 50 μL of the erythrocytes was added. The hemagglutination was recorded as described and the MIC values (the lowest concentration completely inhibiting the hemagglutination) were recorded.

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