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Synthesis of *N*-acetylglucosamine containing Lewis A and Lewis X building blocks based on *N*-tetrachlorophthaloyl protection—synthesis of Lewis X pentasaccharide

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Abstract

Phenyl 6-*O*-benzyl-2-deoxy-2-tetrachlorophthalimido-1-thio-β-D-glucopyranoside (**5a**) and thexyldimethylsilyl 6-*O*-benzyl-2-deoxy-2-tetrachlorophthalimido-β-D-glucopyranoside (**5b**) gave with *O*-(2,3,4,6-tetra-*O*-acetyl-α-D-galactopyranosyl)trichloroacetimidate (**8**) in the presence of $BF_3{\cdot}Et_2O$ as catalyst exclusively lactosamine derivatives **7a** and **7b**, respectively, in high yields. Ensuing reaction with *O*-(3, 4-di-*O*-acetyl-2-*O*-benzyl-α-L-fucopyranosyl)trichloroacetimidate (**9**) in the presence of TMSOTf as catalyst afforded Le^X trisaccharide intermediates **10a,b**. With fucosyl donor **9** and **5a,b** as acceptors in the presence of TMSOTf as catalyst glycosylation either at the 3-*O* or the 4-*O* was observed, thus leading to mixtures of disaccharides **11a/12a** and **11b/12b**, respectively; their reaction with **8** furnished Le^X trisaccharide intermediates **10a,b** and Le^a trisaccharide intermediates **14a,b**. Transformation of **10b** into the corresponding trichloroacetimidate **17** and reaction with lactose acceptor **19** in the presence of $Zn(OTf)_2$ as catalyst gave protected Le^X pentasaccahride intermediate **21**, which on deprotection led to unprotected Le^X pentasaccharide **1**.

Keywords: Glycosylation; Trichloroacetimidates; Protection; *N*-tetrachlorophthaloyl; Disaccharide, Trisaccharide building blocks ; Lewis X; Lewis A

1. Introduction

The Lewis A (Le^a) and Lewis X (Le^x) trisaccharide moieties (Scheme 1) are found as constituents of various glycoconjugates and also in human milk oligosaccharides [1]. A central structural unit of these two epitopes and also of most other glycoconjugates is 2-amino-2-deoxy-D-glucose which is mainly found as *N*-acetyl derivative in β-glycosidic linkage [2]. Chemical glycoside bond formation with glycosyl donors derived from *N*-acetylglucosamine (GlcNAc) occurs generally via neighboring group participation to give a 1,3-oxazolinium intermediate [3], which due to its stability exhibits only weak donor properties. Therefore, various glucosamine derived donors have been investigated having, for instance, a phthalimido

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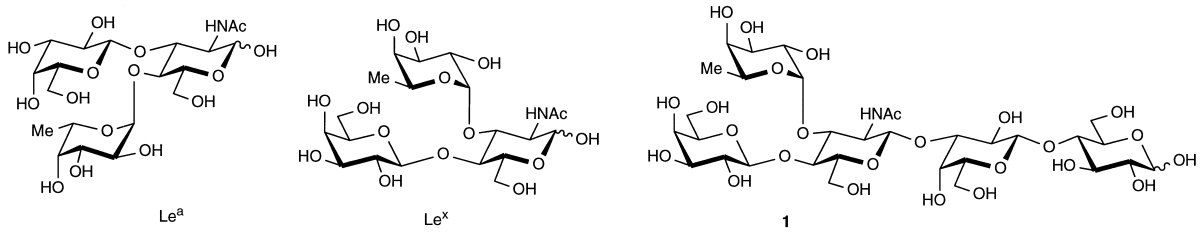


Scheme 1.

[2,3], an *N,N*-diacetylamino [4], an *N*-acetyl-*N*-trichloroethoxycarbonylamino [5], an *N*-trichloroethoxycarbonylamino [5,6], or an *N,N*-dithiasuccinylimido group [7] in 2-position, thus supporting formation of the β-anomer. Because of strong electron withdrawing character of these *N*-substituents, these compounds generally exhibit high glycosyl donor properties. Also, the 2-azido group has gained wide use for β-selective glycosylation reactions [8–10]. However, all these groups exhibit also some disadvantages, therefore the tetrachlorophthalimido group was proposed [11,12] which can be readily introduced with the help of tetrachlorophthalic anhydride. This group is also compatible with trichloroacetimidate activation, thus leading to powerful glycosyl donors [11–14]. In order to further study the usefulness of this group, both in a glycosyl acceptor and in a glycosyl donor situation, we selected the synthesis of Le^a and Le^x building blocks and the synthesis of Lewis X pentasaccharide (Scheme 1, **1**) in which GlcNAc possesses in terms of synthesis design a central role.

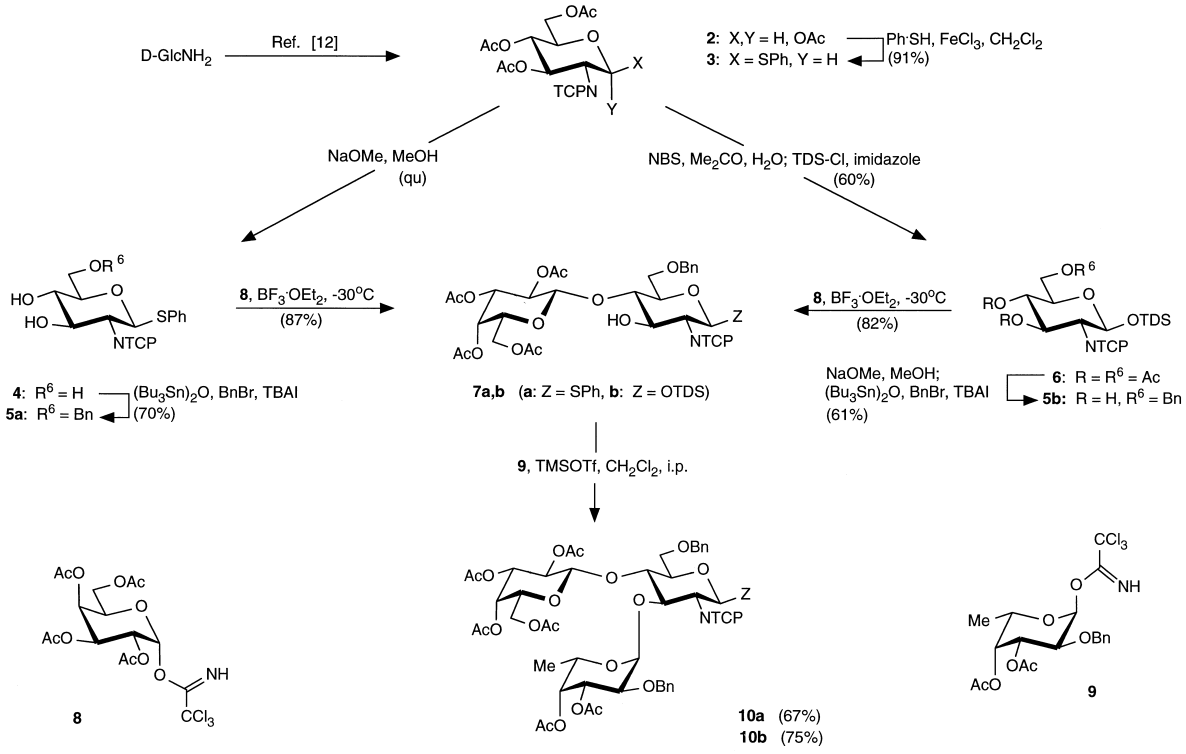
Quite a few approaches to the synthesis of Le^a and Le^x epitopes have been reported [15,16]. Following a simple strategy [9], first attachment of either the galactosyl or the fucosyl residue to the 3- or alternatively the 4-hydroxy group, of the glucosamine moiety and subsequent attachment of either the fucosyl or the galactosyl residue, respectively, to the remaining hydroxy group of the disaccharide intermediate was envisaged. Because of the steric demand of the tetrachlorophthaloyl (TCP) group it was anticipated that a 3-*O*,4-*O*-unprotected acceptor derived from *N*-TCP protected glucosamine will exhibit higher reactivity for the 4-hydroxy than for the 3-hydroxy group, thus offering the desired simple regiocontrol for convenient syntheses of Le^a and Le^x building blocks. Ensuing ligation of the trisaccharide building block, thus obtained, to a lactose moiety and then deprotection would conclude, for instance, the synthesis of Le^x pentasaccharide **1**.

2. Results and discussion

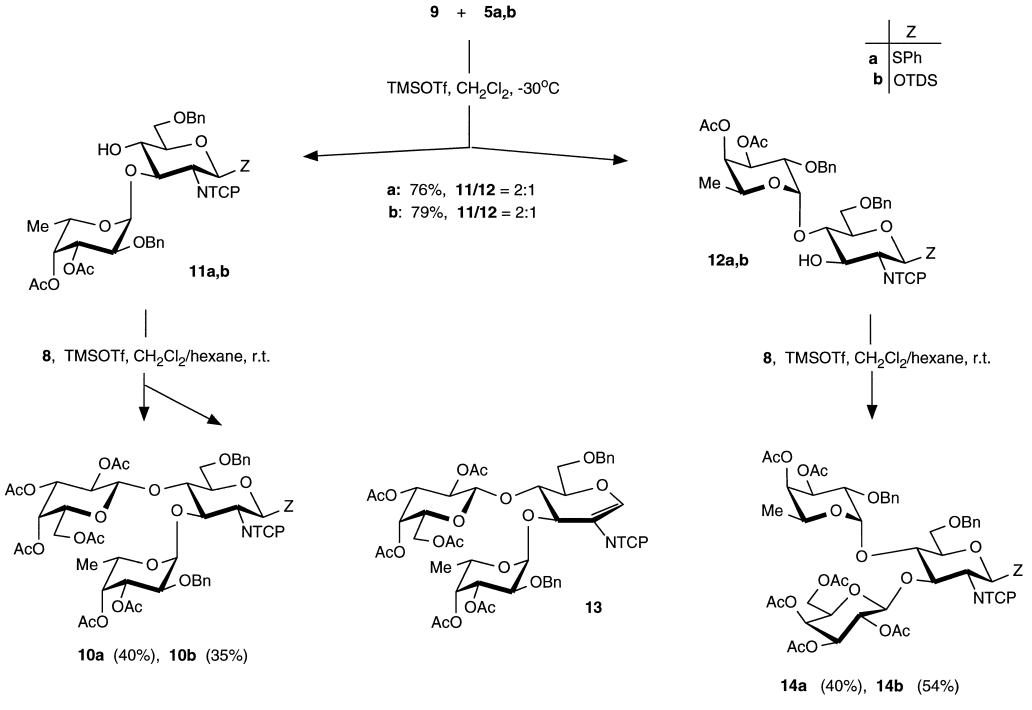
To this aim, 2-amino-2-deoxy-D-glucose was transformed into known tetra-*O*-acetyl-*N*-TCP protected glucosamine **2** [12] (Scheme 2), which gave with thiophenol in the presence of ferric chloride as promoter thioglycoside **3** in 91% yield. Removal of all *O*-acetyl groups could be performed under Zemplén conditions [17] at 0 °C (→**4**); then reaction with bis(tributyltin)oxide followed by benzyl bromide in the presence of tetrabutylammonium iodide (TBAI) afforded the desired 3,4-*O*-unprotected 6-*O*-benzyl protected acceptor **5a** in 70% yield. Treatment of **3** with *N*-bromosuccinimide (NBS) in acetone-water and then with thexyldimethylsilyl (TDS) chloride in the presence of imidazole furnished 1-*O*-TDS protected derivative **6**; after removal of the *O*-acetyl groups under Zemplén conditions the product was subjected to the same reaction sequence as **4**, thus affording the desired 3,4-*O*-unprotected acceptor **5b**. Reaction of **4a** with known galactosyl donor **8** [18] in the presence of 0.05 equivalents of boron trifluoride diethyl etherate as catalyst afforded exclusively the expected β(1–4)-connected disaccharide **7a**. Similarly, from **4b** and **8** under the same reaction conditions disaccharide **7b** was obtained again in very high yield (82%). Though accessibility of the 3^I-hydroxy group in **7a,b** could be limited, reaction with the known fucosyl donor **9** [19] in the presence of trimethylsilyl trifluoromethanesulfonate (TMSOTf) as catalyst gave the desired Le^x trisaccharide intermediates **10a** and **10b** in 67 and 75% yields, respectively, thus exhibiting the usefulness of the TCP group in the reaction control.

In order to apply this approach to the synthesis of the corresponding Le^a trisaccharide intermediates, as outlined above the sequence of glycosylations needs to be changed. Therefore, reaction of **5a** with **9** was carried out (Scheme 3); in the presence of TMSOTf as catalyst at −30 °C the

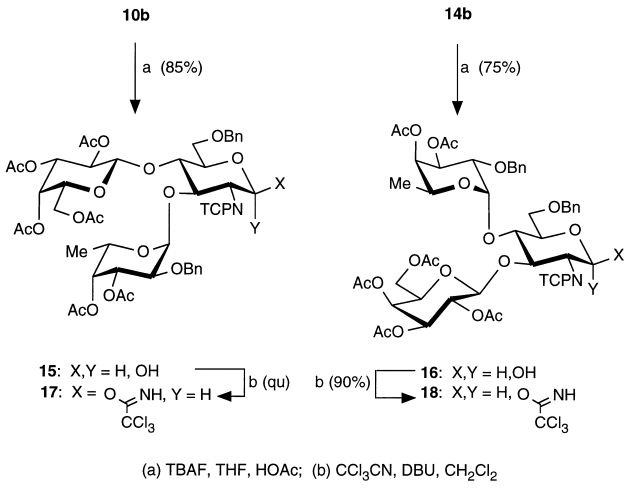
desired α-linkage was also obtained, yet, contrary to the expectations, not only the α-(1→4)-connected disaccharide **12a** but also the α-(1→3)-connected disaccharide **11a** was obtained; both compounds could be readily separated. Similar results were found for the reaction of **4b** with **9** leading to **11b** and **12b** in high overall yield. Obviously, glycosylation with **9** in the presence of



Scheme 2.



Scheme 3.

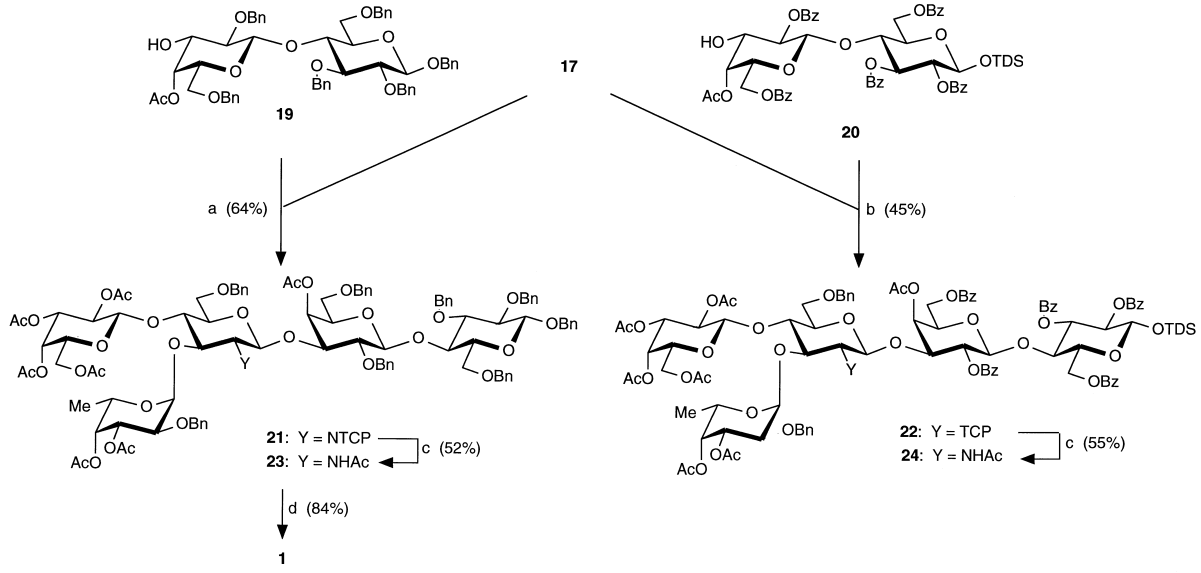


Scheme 4.

TMSOTf as catalyst favors an S_N1-type mechanism, thus being less sensitive to the steric effect of the TCP group than **8**, which due to neighboring group participation favors an S_N2-type mechanism. In the ensuing galactosylation reaction of **11a,b** and **12a,b** with donor **8** in the presence of TMSOTf as catalyst Le^x-building blocks **10a,b** and Le^a-building blocks **14a,b** were obtained; yet, only for the 1-*O*-TDS protected disaccharides **11b** and **12b** good yields of trisaccharides **10b** and **14b** were obtained. Obviously, due to instability of the thioglycosidic linkage under the reaction conditions, formation of glycal derivative **13** was found as major byproduct (36% yield).

In order to demonstrate the ready access to trisaccharide donors, **10b** was desilylated with tetrabutylammonium fluoride (TBAF) to furnish 1-*O*-unprotected derivative **15** (Scheme 4) which on treatment with trichloroacetonitrile in presence of 1,8-diazabicyclo[5.4.0]undec-7-ene (DBU) as base afforded trichloroacetimidate **17**; only the β-anomer was obtained. Similarly, from **14b** 1-*O*-unprotected derivative **16** was obtained which gave with CCl_3CN/DBU trichloroacetimidate **18** in good overall yield (α/β-ratio, 1:2).

The usefulness of these glycosyl donors was demonstrated for one case, namely the synthesis of Le^x pentasaccharide **1**. To this end, two different lactose acceptors were probed. Known $3^{II},4^{II}$-*O*-unprotected benzyl $2^I,3^I,6^I,2^{II},6^{II}$-penta-*O*-benzoyl-lactoside [20] was transformed by treatment with ortho acetate and *p*-toluenesulfonic acid [21] into 4^{II}-*O*-acetyl derivative **19** [16] in practically quantitative yield (Scheme 5). Similarly, from known thexyldimethylsilyl $2^I,3^I,6^I,2^{II},6^{II}$-penta-*O*-benzoyl-lactoside [22] 4^{II}-*O*-acetyl derivative **20** was obtained. As expected, **19** exhibited good reactivity in the glycosylation with **17**: catalysis of the reaction with $Zn(OTf)_2$ in acetonitrile as solvent gave the desired β-(1→3)-linked pentasaccharide **21** in 64% yield. For the reaction of **17** with *O*-acyl protected **20** catalysis with TMSOTf was required which led to pentasaccharide **22** in only 45% yield; to some extent decomposition of glycosyl donor **17** was observed under these forcing



Scheme 5.

conditions, thus exibiting also limitations of the TCP group.

Removal of the TCP group in **21** and **22** followed standard procedures. Treatment with ethylenediamine in dry ethanol at elevated temperature, as introduced by Hindsgaul et al. for the phthaloyl group [23], and ensuing *N,O*-acetylation with acetic anhydride in pyridine furnished *N,O*-acetyl derivatives **23** and **24**, respectively. Deacylation of **23** under Zemplén conditions and ensuing hydrogenolytic debenzylation with palladium as catalyst, which was generated in situ from palladium (II) hydroxide, furnished unprotected pentasaccharide **1** in high yield. The structure of all compounds could be assigned by their ^{1}H NMR data. For **1** also comparison with material obtained via a different approach [16] was available.

3. Experimental

Solvents were purified in the usual way. Melting points are uncorrected. Thin layer chromatography was performed on plastic foil plates Silica Gel 60 F_{254} (E. Merck, layer thickness 0.2 mm); high performance TLC was performed on glass plates silica gel 60 F_{254} (E. Merck); the detection was achieved by treatment with a solution of 20 g of ammonium molybdate and 0.4 g of cerium (IV) sulfate in 400 mL of 10% sulfuric acid or with 15% sulfuric acid, and heating at 120 °C. Flash chromatography was carried out on silica gel (Baker, 30–60 mm). Optical rotations were determined at 20 °C with a Perkin–Elmer 241/MC polarimeter (1 dm cell). NMR spectra were recorded with a Bruker AC 250 (250 MHz), Bruker AC 300 (300 MHz), and a Bruker 600 DRX (600 MHz) instruments, using tetramethylsilane as internal standard.

Phenyl 3,4,6-tri-O-*acetyl-2-deoxy-2-tetrachlorophthalimido-1-thio*-β-D-*glucopyranoside* (**3**).—To a solution of **2** [12] (9.44 g, 15.34 mmol) in dry CH_2Cl_2 (150 mL), thiophenol (2.35 mL, 23.01 mmol) and, after stirring for 30 min, anhyd $FeCl_3$ (2.51 g, 15.49 mmol) as added. The mixture was stirred at room temperature for 1 h, then filtered over Celite into a cold saturated aq solution of $NaHCO_3$ (200 mL) with stirring for 2 h (pale yellow organic phase). After separation, the organic phase was washed with brine (200 mL), dried ($MgSO_4$), filtered and the solvent evaporated. Crystallization from isopropanol gave **3** (9.32 g, 91%) as a white powdery solid: mp 181–183 °C; $[\alpha]_D$ +55.6° (*c* 1, $CHCl_3$). TLC (9:1 toluene–acetone): R_f 0.47; ^{1}H NMR (250 MHz, $CDCl_3$): δ 7.41–7.22 (m 5 H, C_6H_5), 5.69 (dd, 1 H, $J_{3,2}$ 9.9 Hz, H-3) 5.64 (d, 1 H, $J_{1,2}$ 10.5 Hz, H-1), 5.12 (dd, 1 H, $J_{4,5}$ 10.1, $J_{4,3}$ 9.2 Hz, H-4), 4.30 (t, 1 H, H-2), 4.27 (dd, 1 H, $J_{6b,5}$ 5.0 Hz, H-6b), 4.17 (dd, 1 H, $J_{6a,5}$ 2.4, J_{gem} 12.3 Hz, H-6a), 3.83 (ddd, 1 H, H-5), 2.08 (s, 3 H, CH_3CO), 2.00 (s, 3 H, CH_3CO), 1.85 (s, 3 H, CH_3CO). Anal. Calcd for $C_{26}H_{21}Cl_4NO_9S$: C, 46.94; H, 3.18; N, 2.11. Found: C, 46.61; H, 3.22; N, 2.31.

Phenyl 6-O-*benzyl-2-deoxy-2-tetrachlorophthalimido-1-thio*-β-D-*glucopyranoside* (**5a**).—Compound **3** (4 g, 6.01 mmol) was suspended in dry MeOH (50 mL) at 0 °C, then 1 M NaOMe solution (0.6 mL) was added. The mixture was stirred until the **3** was completely dissolved and TLC (9:1 CH_2Cl_2-MeOH) showed its disappearance (2 h). Neutralization with Amberlite IR-120, filtration and evaporation of the solvent gave crude **4**, as confirmed by its ^{1}H NMR spectrum (disappearance of the signals of the acetyl groups). The crude product was suspended in toluene (200 mL), then $(Bu_3Sn)_2O$ (3.2 mL, 6.31 mmol) was added and the mixture heated under reflux for 3 h using a Dean–Stark apparatus. After reducing the volume until 100 mL, the mixture was cooled to 60 °C, then benzyl bromide (3.57 mL, 30.05 mmol) and tetrabutylammonium iodide (2.33 g, 6.31 mmol) were added. The reaction mixture was heated to 95 °C for 16 h, then concentrated under reduced pressure. Flash chromatography (9:1 toluene–acetone) gave **5a** (2.65 g, 70%) as a foam: $[\alpha]_D$ +27.0° (*c* 1, $CHCl_3$). TLC (85:15 toluene–acetone): R_f 0.50; ^{1}H NMR (250 MHz, $CDCl_3$): δ 7.43–7.15 (m, 10 H, 2 C_6H_5), 5.54 (d, 1 H, $J_{1,2}$ 10.0 Hz, H-1), 4.62, 4.55 (2 d, 2 H, J_{gem} 11.8 Hz, CH_2Ph), 4.30 (br.dd, 1 H, H-3), 4.20 (t, 1 H, H-2), 3.86–3.73 (m, 2 H, H-4, H-5), 3.64–3.61 (m, 2 H, 2 H-6), 3.33 (br.s, 1 H, OH, exch. with D_2O), 2.93 (br.s, 1 H, OH, exch. with D_2O); after acetylation, the signals corresponding to H-3 and H-4 were shifted from 4.30 and 3.73 to 5.71 and 5.16 ppm, respectively. Anal. Calcd for $C_{27}H_{21}Cl_4NO_6S$: C, 51.53; H, 3.36; N, 2.23. Found: C, 51.82; H, 3.62; N, 2.21.

Thexyldimethylsilyl 6-O-*benzyl-2-deoxy-2-tetrachlorophthalimido*-β-D-*glucopyranoside* (**5**).—Compound **6** (9 g, 12.58 mmol) was suspended in dry MeOH (160 mL) at 0 °C, then 0.8 M NaOMe solution (1.6 mL) was added. The mixture was stirred until **6** was completely dissolved and TLC (9:1 CH_2Cl_2-MeOH) showed its disappearence (3 h). Neutralization with Amberlite IR-120, filtration

and evaporation of the solvent gave a crude triol, as confirmed by ^{1}H NMR spectrum (disappearance of the signals of the acetyl groups). The crude product was suspended in toluene (600 mL), then $(Bu_3Sn)_2O$ (7.05 mL, 13.83 mmol) was added and the mixture heated under reflux for 3 h using a Dean–Stark apparatus. After reducing the volume to 200 mL, the mixture was cooled to 60 °C, then benzyl bromide (10.5 mL, 88.06 mmol) and tetrabutylammonium iodide (5.1 g, 13.83 mmol) were added. The reaction mixture was heated to 95 °C for 16 h, then concentrated under reduced pressure. Flash chromatography (2:1→4:3 petroleum ether–EtOAc, gradient elution) gave **5b** (5.47 g, 64%) as a foam: $[\alpha]_D$ −22.5° (*c* 2, CHC_3). TLC (2:1 petroleum ether–EtOAc): R_f 0.20; ^{1}H NMR (250 MHz, $CDCl_3$): δ 7.38–7.29 (m, 5 H, C_6H_5), 5.37 (d, 1 H, $J_{1,2}$ 7.9 Hz, H-1), 4.63, 4.56 (2 d, 2 H, J_{gem} 11.9 Hz, CH_2Ph), 4.31 (br. dd, 1 H, H-3), 4.05 (dd, 1 H, $J_{2,3}$ 11.1 Hz, H-2), 3.84–3.69 (m, 2 H, H-4, H-5), 3.63–3.57 (m, 2 H, 2 H-6), 3.31, 2.82 (2 br.s, 2 H, 2 OH, exch. with D_2O), 1.40 (q, 1 H, $CH[CH_3]_2$ texyl), 0.69–0.62 (m, 12 H, $CH[CH_3]_2$ texyl, $SiC[CH_3]_2$), 0.09, −0.01 (2 s, 6 H, $Si[CH_3]_2$]; after acetylation, the signals corresponding to H-3 and H-4 were shifted to 5.72 and 5.16 ppm, respectively. Anal. Calcd for $C_{29}H_{35}Cl_4NO_7Si$: C, 51.26; H, 5.19; N, 2.06. Found: C, 51.25; H, 5.43; N, 2.20.

Thexyldimethylsilyl 3,4,6-tri-O-*acetyl-2-deoxy-2-tetrachlorophthalimido*-β-D-*glucopyranoside* (**6**).—Compound **3** (16.76 g, 25.16 mmol) was dissolved in 4:1 acetone–water (350 mL) and *N*-bromosuccinimide (18 g, 100.77 mmol) was added. After 15 min the reaction mixture was concentrated under reduced pressure until turbidity was observed, then diluted with EtOAc (1.5 L) and washed with an aq saturated solution of $NaHCO_3$ (3×800 mL) and water (3×700 mL); after drying ($MgSO_4$) and filtration, the solvent was removed under reduced pressure. The crude intermediate was dissolved in dry *N,N*-dimethylformamide (170 mL) and imidazole (8.6 g, 125.95 mmol) and thexyldimethylchlorosilane (5.9 mL, 30.23 mmol) were added. After 6 h at room temperature the mixture was concentrated under reduced pressure, then diluted with EtOAc (1.2 l) and washed with an aq saturated solution of NH_4Cl (3×700 mL); the aq phases were reextracted with EtOAc (3×700 mL), then the combined organic phases were dried, filtered and evaporated. Flash chromatography (4:1→7:2 petroleum ether–EtOAc, gradient elution) afforded **6** (10.8 g, 60%) as a white solid: mp 68–70 °C; $[\alpha]_D$ +26.8° (*c* 1, $CHCl_3$). TLC (9:1 toluene–acetone); R_f 0.56; ^{1}H NMR (250 MHz, $CDCl_3$): δ 5.71 (dd, 1 H, $J_{3,2}$ 10.7, $J_{3,4}$ 8.9 Hz, H-3), 5.52 (d, 1 H, $J_{1,2}$ 8.0 Hz, H-1), 5.11 (dd, 1 H, $J_{4,5}$ 10.2 Hz, H-4), 4.23 (dd, 1 H, $J_{6b,5}$ 6.0 Hz, H-6b), 4.22 (dd, 1 H, H-2), 4.13 (dd, 1 H, $J_{6a,5}$ 2.5, J_{gem} 12.0 Hz, H-6a), 3.81 (ddd, 1 H, H-5), 2.09, 2.01, 1.88 (3 s, 9 H, 3 CH_3CO), 1.42 (m, 1 H, $CH[CH_3]_2$ texyl), 0.70–0.60 (m, 12 H, $CH[CH_3]_2$ texyl, $SiC[CH_3]_2$), 0.10–0.03 (2 s, 6 H, $Si[CH_3]_2$). Anal. Calcd for $C_{28}H_{35}Cl_4NO_{10}Si$: C, 47.00; H, 4.93; N, 1.96. Found: C, 47.20; H, 4.90; N, 2.04.

Phenyl O-*(2,3,4,6-tetra*-O-*acetyl*-β-D-*galactopyranosyl)-(1→4)-6*-O-*benzyl-2-deoxy-2-tetrachlorophthalimido-1-thio*-β-D-*glucopyranoside* (**7a**).—Compound **5a** (3.5 g, 5.56 mmol) and **8** [18] (2.79 g, 5.66 mmol) were dissolved in 1:1 dry CH_2Cl_2-dry *n*-hexane (24 mL); the mixture was cooled to −30 °C, then a freshly prepared 1 M solution of $BF_3{\cdot}Et_2O$ in dry CH_2Cl_2 (278 μL) was added. After 20 min the mixture was neutralized with Et_3N and concentrated under reduced pressure. Flash chromatography (95:5 toluene–acetone) afforded **7a** (4.63 g, 87%) as a white powder: mp 143–145 °C; $[\alpha]_D$ +24.2° (*c* 1, $CHCl_3$). TLC (85:15 toluene–acetone): R_f 0.52; ^{1}H NMR (250 MHz, $CDCl_3$): δ 7.44–7.15 (m, 10 H, 2 C_6H_5), 5.54 (d, 1 H, $J_{1,2}$ 10.2 Hz, H-1^I), 5.33 (br.dd, 1 H, H-4^{II}), 5.18 (dd, 1 H, H-2^{II}), 4.93 (dd, 1 H, $J_{3,4}$ 3.4, $J_{3,2}$ 10.4 Hz, H-3^{II}), 4.69, 4.52 (2 d, 2 H, J_{gem} 11.9 Hz, CH_2Ph), 4.48 (d, 1 H, $J_{1,2}$ 8.0 Hz, H-1^{II}), 4.41–4.33 (m, 1 H, H-3^I), 4.23 (t, 1 H, H-2^I), 4.06–4.04 (m, 2 H, 2 H-6^{II}), 3.93–3.88 (m, 1 H, H-5^{II}), 3.78–3.63 (m, 4 H, H-4^I, H-5^I, 2 H-6^I), 2.12–1.96 (4 s, 12 H, 4 CH_3CO); after derivatization with $Cl_3CCONCO$, the signal corresponding to H-3^I was shifted from 4.37 to 5.61 ppm. Anal. Calcd for $C_{41}H_{39}Cl_4NO_{15}S$: C, 51.31; H, 4.10; N, 1.46. Found: C, 50.98; H, 4.05; N, 1.40.

Thexyldimethylsilyl O-*(2,3,4,6-tetra*-O-*acetyl*-β-D-*galactopyranosyl)-(1→4)-6*-O-*benzyl-2-deoxy-2-tetrachlorophthalimido*-β-D-*glucopyranoside* (**7b**).—Compound **5b** (3.14 g, 4.62 mmol) and **8** [18] (2.62 g, 5.31 mmol) were dissolved in 1:1 dry CH_2Cl_2-dry *n*-hexane (24 mL); the mixture was cooled to 30 °C, then a freshly prepared 1 M solution of $BF_3{\cdot}Et_2O$ in dry CH_2Cl_2 (231 μL) was added. After 15 min, the mixture was neutralized with Et_3N and concentrated under reduced pressure. Flash chromatography (95:5 toluene–acetone) afforded **7b** (3.84 g, 82%) as a foam: $[\alpha]_D$ +7.5° (*c* 2, $CHCl_3$). TLC (9:1 toluene–acetone); R_f

0.42; ^{1}H NMR (250 MHz, $CDCl_3$): δ 7.45–7.15 (m, 5 H, C_6H_5), 5.38 (d, 1 H, $J_{1,2}$ 8.1 Hz, H-1^I), 5.34 (br.dd, 1 H, H-4^{II}), 5.19 (dd, 1 H, $J_{2,3}$ 10.4 Hz, H-2^{II}), 4.96 (dd, 1 H, $J_{3,4}$ 3.4 Hz), 4.73, 4.57 (2 d, 2 H, J_{gem} 12.2 Hz, CH_2Ph), 4.52 (d, 1 H, $J_{1,2}$ 8.0 Hz, H-1^{II}), 4.38 (dd, 1 H, $J_{3,2}$ 10.9 Hz, H-3^I), 4.11 (dd, 1 H, H-2^I), 4.08–4.04 (m, 2 H, H-6^{II}), 3.96–3.92 (m, 2 H, H-5^{II}, OH), 3.75–3.58 (m, 4 H, H-4^I, H-5^I, 2 H-6^I), 2.16–2.00 (4 s, 12 H, 4 CH_3CO), 1.47 (m, 1 H, $CH[CH_3]_2$ texyl), 0.75–0.63 (m, 12 H, $CH[CH_3]_2$ and $SiC[CH_3]_2$), 0.15, 0.02 (2 s, 6 H, $Si[CH_3]_2$); after derivatization with $Cl_3CCONCO$, the signal corresponding to H-3^I was shifted from 4.38 to 5.63 ppm. Anal. Calcd for $C_{43}H_{53}Cl_4NO_{16}Si$: C, 51.15; H, 5.29; N, 1.39. Found: C, 49.85; H, 5.28; N, 1.70.

Phenyl O-*(2,3,4,6-tetra*-O-*acetyl*-β-D-*galacto-pyranosyl)-(1→4)-[(3,4-di*-O-*acetyl-2*-O-*benzyl*-α-L-*fucopyranosyl)-(1→3)]-6*-O-*benzyl-2-deoxy-2-tetrachlorophthalimido-1-thio*-β-D-*glucopyranoside* (**10a**).—*(a) From* **7a**. To a solution of **7a** (184 mg, 0.192 mmol) in dry CH_2Cl_2 (1 mL) cooled at 0 °C a freshly prepared 0.1 M solution of trimethylsilyl trifluoromethanesulfonate (20 μL) in dry CH_2Cl_2 was added and thereafter a solution of **9** [19] (185 mg, 0.384 mmol) in dry CH_2Cl_2 (5 mL) was added dropwise with stirring at room temperature. The mixture was neutralized with Et_3N and concentrated under reduced pressure. Flash chromatography (9:1:1 petroleum ether–EtOAc–MeOH) gave trisaccharide **10a** (164 mg, 67% as a foam: $[\alpha]_D$ −13.0° (*c* 1.5, $CHCl_3$). TLC (8:2 toluene–EtOAc); R_f 0.15; ^{1}H NMR (600 MHz, $CDCl_3$): δ 7.40–6.87 (m, 15 H, 3 C_6H_5), 5.43 (d, 1 H, $J_{1,2}$ 10.4 Hz, H-1^I), 5.28 (br.s, 1 H, H-4^{III}), 5.25 (br.s, 1 H, H-4^{II}), 5.08 (dd, 1 H, $J_{3,4}$ 2.9 Hz, H-3^{II}), 5.00 (br.t, 1 H, H-2^{III}), 4.86 (br.q, 1 H, H-5^{II}), 4.82 (d, 1 H, $J_{1,2}$ 3.3 Hz, H-1^{II}), 4.79 (dd, 1 H, H-3^{III}), 4.76 (d, 1 H, 1/2 CH_2Ph), 4.68 (d, 1 H, $J_{1,2}$ 8.2 Hz, H-1^{III}), 4.60–4.54 (m, 2 H, H-3^I, 1/2 CH_2Ph), 4.49 (d, 1 H, J_{gem} 11.9 Hz, 1/2 CH_2Ph), 4.44 (t, 1 H, $J_{2,3}$ 10.4 Hz, H-2^I), 4.35–4.30 (m, 2 H, H-6^{III}, 1/2 CH_2Ph), 4.23 (dd, 1 H, $J_{6,5}$ 7.5, J_{gem} 11.3 Hz, H-6^{III}), 4.12 (t, 1 H, $J_{4,5}=J_{4,3}$ 9.4 Hz, H-4^I), 3.83–3.76 (m, 2 H, 2 H-6^I), 3.70 (dd, 1 H, $J_{2,3}$ 10.5 Hz, H-2^{II}), 3.56 (m, 1 H, H-5^{III}), 3.52 (m, 1 H, H-5^I), 2.08–1.75 (6 s, 18 H, 6 CH_3CO), 1.12 (d, 3 H, $J_{6,5}$ 6.5 Hz, CH_3). ^{13}C NMR (150.86 MHz, $CDCl_3$): δ 99.56 (d, C-1^{III}), 98.13 (d, C-1^{II}), 83.48 (d, C-1^I), 79.55 (d, C-5^I), 74.35 (d, C-3^I), 74.30 (d, C-4^I), 71.94 (d, C-2^{II}), 71.79 (d, C-4^{II}), 71.04 (d, C-3^{III}), 70.97 (d, C-5^{III}), 70.78 (d, C-3^{II}), 69.13 (d, C-2^{III}), 67.48 (t, C-6^I), 66.90 (d, C-4^{III}), 64.68 (d, C-5^{II}), 60.91 (t, C-6^{III}), 56.14 (d, C-2^I), 15.76 (q, C-6^{II}). Anal. Calcd for $C_{58}H_{59}Cl_4NO_{21}S$: C, 54.42; H, 4.64; N, 1.09. Found: C, 54.33; H, 4.58; N, 1.08.

(b) From **11a**. To a solution of **11a** (200 mg, 0.21 mmol) and **8** [18] (265 mg, 0.537 mmol) stirred at room temperature in 1:1 dry *n*-hexane:dry CH_2Cl_2 (2 mL), a 0.1 M solution of trimethylsilyl trifluoromethanesulfonate in dry CH_2Cl_2 (168 μL) was added. After 15 min the mixture was neutralized with triethylamine and concentrated under reduced presssure. Flash chromatography (4:1 toluene–EtOAc) gave a mixture of **10a** and a byproduct, detectable only on high performance TLC. The two compounds were separated by medium pressure chromatography (8:1:1 petroleum ether–EtOAc–MeOH); the faster moving product was identified by NMR and MALDI-TOF as glycal trisaccharide **13** (88 mg, 36%). Further elution gave **10a** (107 mg, 40%), which was indentical with the material obtained from **7a**.

13. MS MALDI-TOF (1169.8): $[M+Na]^+$ 1193; ^{1}H NMR (600 MHz, $CDCl_3$): δ 7.36–6.84 (m, 10 H, 2 C_6H_5), 6.65 (s, 1 H, H-1^I), 5.38 (br.d, 1 H, H-4^{III}), 5.21 (dd, 1 H, $J_{2,3}$ 10.3 Hz, H-2^{III}), 5.10 (br.d, 1 H, H-4^{II}), 5.07 (dd, 1 H, $J_{3,4}$ 3.1 Hz, H-3^{II}), 5.01 (d, 1 H, $J_{1,2}$ 3.4 Hz, H-1^{II}), 4.98 (dd, 1 H, $J_{3,4}$ 3.3 Hz, H-3^{III}), 4.71 (br.d, 1 H, H-3^I), 4.70 (d, 1 H, $J_{1,2}$ 8.2 Hz, H-1^{III}), 4.60, 4.54 (2 d, 2 H, J_{gem} 11.7 Hz, CH_2Ph), 4.44 (m, 1 H, H-5^I), 4.40, 4.28 (2 d, 2 H, J_{gem} 13.1 Hz, CH_2Ph), 4.26 (br.dd, 1 H, H-4^I), 4.20 (d, 2 H, H-6^{III}), 4.13 (m, 1 H, H-5^{II}), 3.90–3.87 (m, 2 H, H-5^{III}, H-6^I), 3.79 (dd, 1 H, $J_{6,5}=5.6$, J_{gem} 10.3 Hz, H-6^I), 3.64 (dd, 1 H, $J_{2,3}$ 10.5 Hz, H-2^{II}), 2.16–1.76 (6 s, 18 H, 6 CH_3CO), 0.79 (d, 3 H, $J_{6,5}$ 6.5 Hz, CH_3). ^{13}C NMR (150.86 MHz, $CDCl_3$): δ 146.65 (d, C-1^I), 106.88 (s, C-2^I), 100.63 (d, C-1^{III}), 99.07 (d, C-1^{II}), 75.98 (d, C-5^I), 74.96 (d, C-4^I), 74.54 (d, C-2^{II}), 72.21 (d, C-3^I) 71.33 (d, C-4^{II}), 71.16 (d, C-5^{III}), 70.88 (2 d, C-3^{III}, C-3^{II}), 68.63 (d, C-2^{III}), 67.01 (d, C-4^{III}), 66.42 (t, C-6^I), 65.22 (d, C-5^{II}), 61.38 (t, C-6^{III}), 15.67 (q, C-6^{II}). Anal. Calcd for $C_{52}H_{53}Cl_4NO_{21}$: C, 53.39; H, 4.57; N, 1.20. Found: C, 53.21; H, 4.71; N, 1.46.

Thexyldimethylsilyl O-*(2,3,4,6-tetra*-O-*acetyl*-β-D-*galactopyranosyl)-(1→4)-[(3,4-di-O-acetyl-2-O-benzyl*-α-L-*fucopyranosyl)-(1→3)]-6*-O-*benzyl-2-deoxy-2-tetrachlorophthalimido*-β-D-*glucopyranoside* (**10b**).—*(a) From* **7b**. To a solution of **7b** (564 mg, 0.558 mmol) in dry CH_2Cl_2 (4 mL) cooled at 0 °C, a freshly prepared 0.1 M solution of trimethylsiyl trifluoromethanesulfonate (56 μL) in dry CH_2Cl_2

was added and thereafter a solution of **9** [19] (674 mg, 1.396 mmol) in dry CH_2Cl_2 (10 mL) was added dropwise with stirring at room temperature. The mixture was neutralized with Et_3N and concentrated under reduced pressure. Flash chromatography (7:3→6:4 petroleum ether–EtOAc acetate gradient elution) gave **10b** (556 mg, 75%) as a foam: $[\alpha]_D$ −6.6° (*c* 1, $CHCl_3$). TLC (75:25 toluene–EtOAc); R_f 0.32; ^{1}H NMR (600 MHz, $CDCl_3$): δ 7.40–6.88 (m, 10 H, 2 C_6H_5), 5.31 (br.d, 1 H, H-4^{III}), 5.28 (br.s, 1 H, H-4^{II}), 5.26 (d, 1 H, $J_{1,2}$ 8.0 Hz, H-1^{I}), 5.13 (dd, 1 H, $J_{3,4}$ 2.9 Hz, H-3^{II}), 5.03 (t, 1 H, H-2^{III}), 4.90 (m, 1 H, H-5^{II}), 4.83 (m, 2 H, H-1^{II}, H-3^{III}), 4.77 (d, 1 H, J_{gem} 12.1 Hz, 1/2 CH_2Ph), 4.72 (d, 1 H, $J_{1,2}$ 8.2 Hz, H-1^{III}), 4.56–4.51 (m, 3 H, H-3^{I}, CH_2Ph), 4.37–4.24 (m, 4 H, H-2^{I}, 2 H-6^{III}, 1/2 CH_2Ph), 4.11 (t, 1 H, $J_{4,3}$ 9.3 Hz, H-4^{I}), 3.82 (br.dd, 1 H, H-6^{I}), 3.72 (dd, 1 H, $J_{1,2}$ 3.4, $J_{2,3}$ 10.6 Hz, H-2^{II}), 3.69 (br.d, 1 H, H-6^{I}), 3.64 (br.t, 1 H, H-5^{III}), 3.48 (br.d, 1 H, H-5^{I}), 2.10–1.77 (6 s, 18 H, 6 CH_3CO), 1.36–1.34 (m, 1 H, $CH[CH_3]_2$ texyl), 1.14 (d, 3 H, $J_{6,5}$ 6.5 Hz, CH_3), 0.63–0.59 (m, 12 H, $CH[CH_3]_2$ texyl, $SiC[CH_3]_2$), 0.10, −0.06 (2 s, 6 H, $Si[CH_3]_2$]. ^{13}C NMR (150.86 MHz, $CDCl_3$): δ 99.68 (d, C-1^{III}), 97.93 (d, C-1^{II}), 93.10 (d, C-1^{I}), 75.24 (d, C-5^{I}), 74.73 (d, C-4^{I}), 72.90 (d, C-3^{I}), 72.14 (d, C-2^{II}), 71.89 (d, C-4^{II}), 71.11 (d, C-5^{III}), 71.03 (d, C-3^{III}), 70.74 (d, C-3^{II}), 69.16 (d, C-2^{III}), 67.56 (t, C-6^{I}), 67.01 (d, C-4), 64.53 (d, C-5^{II}), 61.06 (t, C-6^{III}), 59.01 (d, C-2^{I}), 15.77 (q, C-6^{II}). Anal. Calcd for $C_{60}H_{73}Cl_4NO_{22}Si$: C, 54.18; H, 5.53; N, 1.05. Found: C, 53.93; H, 5.56; N, 1.11.

(b) From **11b**. To a solution of **11b** (1.85 g, 1.85 mmol) and **8** [18] (1.82 g, 3.70 mmol) stirred at room temperature in 1:1 dry *n*-hexane:dry CH_2Cl_2 (12 mL) a 0.5 M solution of trimethylsilyl trifluoromethanesulfonate in dry CH_2Cl_2 (148 μL) was added dropwise. After 15 min, the mixture was neutralized with triethylamine and concentrated under reduced pressure. Flash chromatography (7:3- > 6:4 petroleum ether–EtOAc gradient elution) afforded trisaccharide **10b** (2.13 g, 86%), which was identical with the material obtained from **7b**.

Phenyl O-*(3,4-di*-O-*acetyl-2*-O-*benzyl*-α-L-*fucopyranosyl)-(1→3)-6*-O-*benzyl-2-deoxy-2-tetrachlorophthalimido-1-thio*-β-D-*glucopyranoside* (**11a**) *and phenyl* O-*(3,4-di*-O-*acetyl-2*-O-*benzyl*-α-L-*fucopyranosyl)-(1→4)-6*-O-*benzyl-2-deoxy-2-tetrachlorophthalimido-1-thio*-β-D-*glucopyranoside* (**12a**).—To a solution of **5a** (4 g, 6.35 mmol) and **9** [19] (3.98 g, 8.26 mmol) in dry CH_2Cl_2 (12 mL) cooled at −20 °C, a freshly prepared 0.1 M solution of trimethylsilyl trifluoromethanesulfonate in dry CH_2Cl_2 (1.27 mL) was added dropwise. After 10 min, TLC (9:1 toluene–EtOAc) showed the disappearance of **5a** and formation of two products with higher R_f value. The mixture was neutralized with Et_3N and concentrated under reduced pressure. Flash chromatography (95:5→9:1 toluene–EtOAc gradient elution) gave **12a** (1.62 g, 27%) as foam: $[\alpha]_D$ −37.3° (*c* 2, $CHCl_3$). TLC (9:1 toluene–EtOAc); R_f 0.37; further elution afforded **11a** (3.13 g, 52%) as a foam: $[\alpha]_D$ +18.7° (*c* 2, $CHCl_3$). TLC (9:1 toluene–EtOAc); R_f 0.20.

12a. ^{1}H NMR (250 MHz, $CDCl_3$): δ 7.45–7.10 (m, 15 H, 3 C_6H_5), 5.54 (d, 1 H, $J_{1,2}$ 9.8 Hz, H-1^{I}), 5.27–5.22 (m, 2 H, H-3^{II}, H-4^{II}), 5.01 (d, 1 H, $J_{1,2}$ 3.7 Hz, H-1^{II}), 4.61 (s, 2 H, CH_2Ph), 4.38 (s, 2 H, CH_2Ph), 4.34–4.20 (m, 3 H, H-2^{I}, H-3^{I}, H-5^{II}), 4.08 (br.d, 1 H, OH, exch. with D_2O), 3.88–3.82 (m, 3 H, 2 H-6^{I}, H-2^{II}), 3.72 (dt, 1 H, H-5^{I}), 3.61 (t, 1 H, H-4^{I}), 2.11, 2.00 (2 s, 6 H, 2 $COCH_3$), 1.06 (d, 3 H, $J_{6,5}$ 6.5 Hz, CH_3). After derivatization with $Cl_3CCONCO$, the signal corresponding to H-3^{I} was shifted from 4.34–4.20 to 5.64 ppm. Anal. Calcd for $C_{44}H_{41}Cl_4NO_{12}S$: C, 55.64; H, 4.35; N, 1.47. Found: C, 55.12; H, 4.03; N, 1.54.

11a. ^{1}H NMR (250 MHz, $CDCl_3$): δ 6.80–6.70, 7.44–7.12 (2 m, 15 H, 3 C_6H_5), 5.49 (d, 1 H, $J_{1,2}$ 10.1 Hz, H-1^{I}), 5.27 (br.dd, 1 H, H-4^{II}), 5.13 (dd, 1 H, $J_{3,4}$ 3.3, $J_{3,2}$ 10.6 Hz, H-3^{II}), 4.99 (d, 1 H, $J_{1,2}$ 3.6 Hz, H-1^{II}), 4.66, 4.60 (2 d, 2 H, J_{gem} 12.0 Hz, CH_2Ph), 4.43–4.28 (m, 4 H, H-2^{I}, H-3^{I}, 1/2 CH_2Ph, H-5^{II}), 4.18 (br.s, 1 H, OH, exch. with D_2O), 4.13 (d, 1 H, J_{gem} 13.6 Hz, 1/2 CH_2Ph), 3.93 (br.dd, 1 H, H-6^{I}), 3.79 (dd, 1 H, $J_{6,5}$ 5.0, J_{gem} 10.7 Hz, H-6^{I}), 3.75–3.58 (m, 3 H, H-2^{II}, H-4^{I}, H-5^{I}), 2.08, 1.79 (2 s, 6 H, 2 $COCH_3$), 1.12 (d, 3 H, $J_{6,5}$ 6.5 Hz, CH_3). After derivatization with $Cl_3CCONCO$, the signal corresponding to H-4^{I} was shifted from 3.75–3.58 to 5.08 ppm. Anal. Calcd for $C_{44}H_{41}Cl_4NO_{12}S$: C, 55.64; H, 4.35; N, 1.47. Found: C, 55.67; H, 4.55; N, 1.45.

Thexyldimethylsilyl O-*(3,4*-O-*acetyl-2*-O-*benzyl*-α-L-*fucopyranosyl)-(1→3)-6*-O-*benzyl-2-deoxy-2-tetrachlorophthalimido*-β-D-*glucopyranoside* (**11b**) *and Thexyldimethylsilyl* O-*(3,4-di*-O-*acetyl-2*-O-*benzyl*-α-L-*fucopyranosyl)-(1→4)-6*-O-*benzyl-2-deoxy-2-tetrachlorophthalimido*-β-D-*glucopyranoside* (**12b**).—To a solution of **5b** (1.257 g, 1.85 mmol) and **9** [19] (1.25 g, 2.59 mmol) in dry CH_2Cl_2 (4 mL) cooled at −30°C, a freshly prepared 0.1 M solution of trimethylsilyl trifluoromethanesulfonate in dry

CH_2Cl_2 (185 mL) was added dropwise. After 10 min TLC (9:1 toluene–EtOAc) showed disappearance of the diol **5b** and formation of two products with higher R_f value. The mixture was neutralized with NEt_3 and concentrated under reduced pressure. Flash chromatography (19:1→10:1 toluene–EtOAc gradient elution) gave **12b** (481 mg, 26%) as a foam: $[\alpha]_D$ −63.5° (*c* 1, $CHCl_3$). TLC (9:1 toluene–EtOAc); R_f 0.38; further elution afforded **11b** (1.035 g, 56%) as a foam: $[\alpha]_D$ −11.3° (*c* 1, $CHCl_3$). TLC (9:1 toluene–EtOAc); R_f 0.24.

12b. ^{1}H NMR (250 MHz, $CDCl_3$): δ 7.38–7.15 (m, 10 H, 2 C_6H_5), 5.39 (d, 1 H, $J_{1,2}$ 7.9 Hz, H-1^I), 5.29–5.23 (m, 2 H, H-3^{II}, H-4^{II}), 5.03 (d, 1 H, $J_{1,2}$ 3.7 Hz, H-1^{II}), 4.62, 4.42 (2 br.s, 4 H, 2 CH_2Ph), 4.34–4.25 (m, 2 H, H-5^{II}, H-3^I), 4.11 (dd, 1 H, $J_{2,3}$ 10.8 Hz, H-2^I), 4.03 (br.d, 1 H, OH, exch. with D_2O), 3.88–3.81 (m, 2 H, H-2^{II}, H-6^I), 3.75 (br.dd, 1 H, H-6^I), 3.65–3.57 (m, 2 H, H-4^I, H-5^I), 2.11, 1.99 (2 s, 6 H, 2 $COCH_3$), 1.44 (q, 1 H, $CH[CH_3]_2$ texyl), 1.07 (d, 3 H, $J_{6,5}$ 6.5 Hz, CH_3), 0.70–0.65 (m, 12 H, $CH[CH_3]_2$ texyl, $SiC[CH_3]_2$), 0.15, 0.03 (2 s, 6 H, $Si[CH_3]_2$). After derivatization with $Cl_3CCONCO$, the signal corresponding to H-3^I was shifted from 4.30 to 5.10 ppm. Anal. Calcd for $C_{46}H_{55}Cl_4NO_{13}Si$: C, 55.35; H, 5.56; N, 1.40. Found: C, 55.45; H, 5.74; N, 1.73.

11b. ^{1}H NMR (250 MHz, $CDCl_3$): δ 6.80–6.73, 7.41–7.10 (2 m, 10 H, 2 C_6H_5), 5.32–5.26 (m, 2 H, H-1^{II}, H-4^{II}), 5.18 (dd, 1 H, $J_{3,2}$ 10.5, $J_{3,4}$ 3.3 Hz, H-3^{II}), 5.02 (d, 1 H, $J_{1,2}$ 3.7 Hz, H-1^{II}), 4.68, 4.62 (2 d, 2 H, J_{gem} 12.2 Hz, CH_2Ph), 4.43–4.32 (m, 3 H, H-3^I, H-5^{II}, 1/2 CH_2Ph), 4.26–4.16 (m, 2 H, H-2^I, 1/2 CH_2Ph), 4.13 (br.s, 1 H, OH, exch. with D_2O), 3.86 (br.dd, 1 H, H-6^I), 3.79–3.70 (m, 2 H, H-5^I, H-2^{II}), 3.63–3.58 (m, 2 H, H-4^I, H-6^I), 2.08, 1.74 (2 s, 6 H, 2 $COCH_3$), 1.47–1.36 (m, 1 H, $CH[CH_3]_2$ texyl), 1.14 (d, 3 H, $J_{6,5}$ 6.5 Hz, CH_3), 0.68–0.59 (m, 12 H, $CH[CH_3]_2$ texyl and $SiC[CH_3]_2$). After derivatization with $Cl_3CCONCO$, the signal corresponding to H-4^I was shifted from 3.63–3.58 to 5.05 ppm. Anal. Calcd for $C_{46}H_{55}Cl_4NOSi$: C, 55.26; H, 5.54; N, 1.40. Found: C, 55.45; H, 5.74; N, 1.73.

Phenyl O-*(3,4-di*-O-*acetyl-2*-O-*benzyl*-α-L-*fucopyranosyl)-(1→4)-[(2,3,4,6-tetra*-O-*acetyl*-β-D-*galactopyranosyl)-(1→3)]-6*-O-*benzyl-2-deoxy-2-tetrachlorophthalimido-1-thio*-β-D-*glucopyranoside* (**14a**).—To a solution of **12a** (137 mg, 0.144 mmol) and **8** [18] (142 mg, 0.288 mmol) stirred at room temperature in 1:1 dry *n*-hexane-dry CH_2Cl_2 (2 mL) a 0.1 M solution of trimethylsilyl trifluoromethanesulfonate in dry CH_2Cl_2 (144 μL) was added dropwise. After 15 min, the mixture was neutralized with triethylamine and concentrated under reduced pressure. Flash chromatography (2:1 petroleum ether–EtOAc) afforded trisaccharide **14a** not pure enough for complete characterization. Medium pressure chromatography (8:1:1 petroleum ether–EtOAc-MeOH) gave pure **14a** (73 mg, 40%) as a white solid: $[\alpha]_D$ −33.3° (*c* 1, $CHCl_3$). TLC (8:1:1 petroleum ether-EtOAc-MeOH); R_f 0.34; ^{1}H NMR (600 MHz, $CDCl_3$): δ 7.35–7.14 (m, 15 H, 3 C_6H_5), 5.36 (br.s, 1 H, H-4^{III}), 5.28 (br.d, 1 H, H-4^{II}), 5.21 (d, 1 H, $J_{1,2}$ 3.5 Hz, H-1^{III}), 5.18 (dd, 1 H, $J_{3,4}$ 3.0 Hz, H-3^{III}), 4.98–4.90 (m, 2 H, H-5^{III}, H-2^{II}), 4.78 (t, 1 H, H-3^I), 4.65 (dd, 1 H, $J_{3,4}$ 3.6 Hz, H-3^{II}), 4.53–4.49 (2 d, 2 H, CH_2Ph), 4.62, 4.45 (2 d, 2 H, J_{gem} 12.2 Hz, CH_2Ph), 4.39 (dd, 1 H, $J_{6,5}$ 6.3, J_{gem} 11.5 Hz, H-6^{II}), 4.35–4.31 (m, 2 H, H-2^I, H-6^{II}), 4.16 (d, 1 H, $J_{1,2}$ 8.1 Hz, H-1^{II}), 3.99 (t, 1 H, $J_{4,3}=J_{4,5}$ 9.6 Hz, H-4^I), 3.91 (br.dd, 1 H, H-6^I), 3.89 (br.dd, 1 H, $J_{2,3}$ 10.7 Hz, H-2^{III}), 3.66 (br.d, 1 H, H-6^I), 3.61–3.55 (m, 2 H, H-5^I, H-5^{II}), 2.12–1.86 (6 s, 18 H, 6 $COCH_3$), 1.21 (d, 3 H, $J_{6,5}$ 6.5 Hz, CH_3). ^{13}C NMR (150.86 MHz, $CDCl_3$): δ 100.53 (d, C-1^{II}), 97.25 (d, C-1^{III}), 83.00 (d, C-1^I), 80.07 (d, C-5^I), 74.69 (d, C-3^I), 73.38 (d, C-2^{III}), 72.71 (d, C-4^I), 72.10 (d, C-4^{III}), 71.23 (d, C-5^{II}), 70.93 (d, C-3^{II}), 70.86 (d, C-3^{III}), 68.43 (d, C-2^{II}), 67.22 (t, C-6^I), 66.57 (d, C-4^{II}), 64.38 (d, C-5^{III}), 60.78 (t, C-6^{II}), 56.30 (d, C-2^I), 15.88 (q, C-6^{III}). Anal. Calcd for $C_{58}H_{59}Cl_4NO_{21}S$: C, 54.43; H, 4.65; N, 1.09. Found: C, 54.29; H, 4.69; N, 1.31.

Thexyldimethylsilyl-O-*(3,4-di*-O-*acetyl-2*-O-*benzyl*-α-L-*fucopyranosyl)-(1→4)-[(2,3,4,6-tetra*-O-*acetyl*-β-D-*galactopyranosyl)-(1→3)]-6*-O-*benzyl-2-deoxy-2-tetrachlorophthalimido*-β-D-*glucopyranoside* (**14b**). To a solution of **12b** (298 mg, 0.298 mmol) and **8** [18] (367 mg, 0.745 mmol) stirred at 0 °C in dry CH_2Cl_2 (5 mL) trimethylsilyl trifluoromethanesulfonate was added. After 10 min the mixture was neutralized with Et_3N and concentrated under reduced pressure. Flash chromatography (7:3→7:4 petroleum ether–EtOAc gradient elution) afforded trisaccharide **14b** (250 mg, 63%) as a white foam: $[\alpha]_D$ −28.3° (*c* 1, $CHCl_3$). TLC (75:25 toluene–EtOAc); R_f 0.21; ^{1}H NMR (300 MHz, $CDCl_3$): δ 7.47–7.22 (m, 10 H, 2 C_6H_5), 5.37 (br.d, 1 H, H-4^{III}), 5.29 (br.d, 1 H, H-4^{II}), 5.25 (d, 1 H, $J_{1,2}$ 3.9 Hz, H-1^{III}), 5.24 (dd, 1 H, $J_{3,2}$ 10.5, $J_{3,4}$ 3.3 Hz, H-3^{III}), 5.16 (d, 1 H, $J_{1,2}$ 8.02 Hz, H-1^I), 4.97 (m, 1 H, H-5^{III}), 4.95 (dd, 1 H, $J_{2,3}$ 10.8 Hz, H-2^{II}),

4.76 (dd, 1 H, $J_{3,2}$ 10.8 Hz, H-3^{I}), 4.71 (dd, 1 H, $J_{3,4}$ 3.6 Hz, H-3^{II}), 4.65, 4.56 (2 d, 2 H, J_{gem} 11.8 Hz, CH_2Ph), 4.56, 4.49 (2 d, 2 H, J_{gem} 12.5 Hz, CH_2Ph), 4.40, 4.34 (2 dd, 2 H, $J_{6,5}$ 6.7, J_{gem} 11.6 Hz, 2 H-6^{II}), 4.23 (d, 1 H, $J_{1,2}$ 8.1 Hz, H-1^{II}), 4.19 (dd, 1 H, H-2^{I}), 4.00 (t, 1 H, $J_{4,5}=J_{4,3}$ 9.4 Hz, H-4^{I}), 3.92 (dd, 1 H, $J_{6,5}$ 2.8 Hz, J_{gem} 11.8 Hz, H-6^{I}), 3.91 (dd, 1 H, H-2^{III}), 3.65–3.60 (m, 2 H, H-6^{I}, H-5^{II}), 3.56–3.50 (m, 1 H, H-5^{I}), 2.14–1.89 (6 s, 18 H, 6 CH_3CO), 1.40 (m, 1 H, $CH[CH_3]_2$, texyl), 1.21 (d, 3 H, $J_{6,5}$ 6.5 Hz, CH_3), 0.70–0.60 (m, 12 H, $C[CH_3]_2$, $CH[CH_3]_2$, texyl), 0.10, −0.08 (2 s, 6 H, $Si[CH_3]_2$). ^{13}C NMR (75.43 MHz, $CDCl_3$): δ 100.40 (d), 97.10 (d), 92.95 (d), 75.61 (d), 73.58 (d), 72.89 (d), 72.26 (d), 71.28 (d), 70.92 (d), 68.69 (d), 67.47 (t), 66.77 (d), 64.35 (d), 60.94 (t), 59.27 (d), 15.87 (q). Anal. Calcd for $C_{60}H_{73}Cl_4NO_{22}Si$: C, 54.18; H, 5.53; N, 1.05. Found: C, 54.06; H, 5.49; N, 1.04.

O-*(2,3,4,6-tetra*-O-*acetyl*-β-D-*galactopyranosyl)-(1→4)*-O-*[3,4-di*-O-*acetyl-2*-O-*benzyl*-α-L-*fucopyranosyl)-(1→3)]-6*-O-*benzyl-2-deoxy-2-tetrachlorophthalimido*-β-D-*glucopyranose* (**15**).—To a solution of **10b** (2.066 g, 1.553 mmol) in dry tetrahydrofuran (35 mL) cooled at −40 °C glacial acetic acid (133 μL, 2.329 mmol) and tetrabutylammonium fluoride (1 M in tetrahydrofuran, 2.33 mL, 2.329 mmol) were added. The temperature was slowly allowed to rise until −10 °C; after 8 h the mixture was diluted with ethyl acetate (500 mL) and washed with brine (3×300 mL). The aqueous layers were reextracted with EtOAc (200 mL), then the organic phases were dried ($MgSO_4$), filtered, and the solvent removed under reduced pressure. Flash chromatography (1:1 petroleum ether-EtOAc) gave **15** (1.567 g, 85%) as a foam: $[\alpha]_D$ −11.9° (*c* 1, $CHCl_3$). TLC (1:1 petroleum ether–EtOAc); R_f 0.21; ^1H NMR (250 MHz, $CDCl_3$): δ 7.47–6.88 (m, 10 H, 2 C_6H_5), 5.31–5.23 (m, 3 H, H-1^{I}, H-4^{II}, H-4^{III}), 5.13 (dd, 1 H, $J_{3,2}$ 10.6, $J_{3,4}$ 3.1 Hz, H-3^{II}), 5.00 (dd, 1 H, $J_{2,1}$ 8.2 Hz, H-2^{III}), 4.94–4.87 (m, 1 H, H-5^{II}), 4.84 (d, 1 H, $J_{1,2}$ 3.6 Hz, H-1^{II}), 4.75 (dd, 1 H, $J_{3,2}$ 10.3, $J_{3,4}$ 3.6 Hz, H-3^{III}), 4.62 (t, 1 H, H-3^{I}), 4.60 (d, 1 H, H-1^{III}), 4.83, 4.47 (2 d, 2 H, J_{gem} 11.9 Hz, CH_2Ph), 4.38 (dd, 1 H, $J_{6,5}$ 6.5 Hz, H-6^{III}), 4.55, 4.35 (2 d, 2 H, J_{gem} 13.1 Hz, CH_2Ph), 4.26 (dd, 1 H, $J_{2,1}$ 8.5, $J_{2,3}$ 10.4 Hz, H-2^{I}), 4.13 (t, 1 H, $J_{4,3}=J_{4,5}$ 9.4 Hz, H-4^{I}), 3.87–3.75 (m, 2 H, 2 H-6^{I}), 3.59–3.52 (m, 2 H, H-5^{I}, H-5^{III}), 3.08 (br.s, 1 H, OH, exch. with D_2O), 2.11–1.79 (6 s, 18 H, 6 $COCH_3$), 1.16 (d, 3 H, $J_{6,5}$ 6.6 Hz, CH_3). Anal. Calcd for $C_{52}H_{55}Cl_4NO_{22}$: C, 52.28; H, 4.67; N, 1.18. Found: C, 52.31; H, 4.78; N, 1.34.

O-*(3,4-di*-O-*acetyl-2*-O-*benzyl*-α-L-*fucopyranosyl)-(1→4)*-O-*[(2,3,4,6-tetra*-O-*acetyl*-β-D-*galactopyranosyl)-(1→3)]-6*-O-*benzyl-2-deoxy-2-tetrachlorophthalimido*-β-D-*glucopyranose* (**16**).—To a solution of **14b** (260 mg, 0.195) in dry tetrahydrofuran (7 mL) cooled at −35 °C glacial AcOH (22 μL, 0.39 mmol) and tetrabutylammonium fluoride (1 M in tetrahydrofuran, 390 μL, 0.39 mmol) were added. The temperature was slowly allowed to rise unti −25 °C; after 48 h the mixture was diluted with EtOAc (100 mL) and washed with brine (3×50 mL). The aq layers were reextracted with EtOAc (50 mL), then the organic phases were dried (Na_2SO_4), filtered, and the solvent removed under reduced pressure. Flash chromatography (6:4 petroleum ether–EtOAc) gave **16** (178 mg, 77%) as a foam: $[\alpha]_D$ −28.2° (*c* 1, $CHCl_3$). TLC (6:4 petroleum ether–EtOAc); R_f 0.29; ^1H NMR (300 MHz, $CDCl_3$): δ 7.39–7.20 (m, 10 H, 2 C_6H_5), 5.35 (br.d, 1 H, H-4^{III}), 5.28 (br.d, 1 H, H-4^{II}), 5.21 (dd, 1 H, $J_{3,4}$ 3.2, $J_{3,2}$ 10.7 Hz, H-3^{III}), 5.17 (br.d, 1 H, H-1^{I}), 5.11 (d, 1 H, $J_{1,2}$ 3.7 Hz, H-1^{III}), 4.94 (dd, 1 H, H-2^{II}), 4.95 (m, 1 H, H-5^{III}), 4.80 (dd, 1 H, $J_{3,2}$ 10.5, $J_{3,4}$ 9.3 Hz, H-3^{I}), 4.69 (dd, 1 H, $J_{3,4}$ 3.7, $J_{3,2}$ 10.4 Hz, H-3^{II}), 4.60 (d, 1 H, J_{gem} 11.8 Hz, 1/2 CH_2Ph), 4.50 (d, 1 H, J_{gem} 12.4 Hz, 1/2 CH_2Ph), 4.49 (d, 1 H, 1/2 CH_2Ph), 4.40 (dd, 1 H, $J_{6,5}$ 6.4, J_{gem} 11.5 Hz, H-6^{II}), 4.35 (d, 1 H, 1/2 CH_2Ph), 4.33 (dd, 1 H, $J_{6,5}$ 7.2 Hz, H-6^{II}), 4.20 (d, 1 H, $J_{1,2}$ 8.2 Hz, H-1^{II}), 4.15 (dd, 1 H, $J_{1,2}$ 8.4 Hz, H-2^{I}), 3.97 (t, 1 H, $J_{4,3}=J_{4,5}$ 9.3 Hz, H-4^{I}), 3.87 (dd, 1 H, H-2^{III}), 3.86 (dd, 1 H, $J_{6,5}$ 3.9, J_{gem} 10.6 Hz, H-6^{I}), 3.63–3.59 (m, 3 H, H-5^{I}, H-5^{II}, H-6^{I}), 3.44 (br.s, 1 H, OH exch. with D_2O), 2.13–1.88 (6 s, 18 H, 6 CH_3CO), 1.20 (d, 3 H, $J_{6,5}$ 6.5 Hz, CH_3). Anal. Calcd for $C_{52}H_{55}Cl_4NO_{22}$: C, 52.58; H, 4.67; N, 1.18. Found: C, 52.43; H, 4.58; N, 1.11.

O-*(2,3,4,6-tetra*-O-*acetyl*-β-D-*galactopyranosyl)-(1→4)-[(3,4-di*-O-*acetyl-2*-O-*benzyl*-α-L-*fucopyranosyl)-(1→3)]-6*-O-*benzyl-2-deoxy-2-tetrachlorophthalimido*-β-D-*glucopyranosyl trichloroacetimidate* (**17**).—To a solution of **15** (1.155 g, 0.972 mmol) in dry CH_2Cl_2 (25 mL), stirred at room temperature, trichloroacetonitrile (4.9 mL, 48.6 mmol) and four drops of DBU were added. After 3 h, the mixture was concentrated under reduced pressure and chromatographed (1:1 petroleum ether–EtOAc) giving β-trichloroacetimidate **17** (1.29 g, qu) as an amorphous mass: $[\alpha]_D$ −4.8° (*c* 1, $CHCl_3$). TLC (4:6 petroleum ether–EtOAc); R_f 0.61; ^1H NMR (250 MHz, $CDCl_3$): δ 8.58 (s, 1 H, NH), 7.43–6.88 (m, 10 H, 2 C_6H_5), 6.33 (d, 1 H, $J_{1,2}$ 8.2 Hz, H-1^{I}),

5.31–5.27 (m, 2 H, H-4^{II}, H-4^{III}), 5.14 (dd, 1 H, $J_{3,2}$ 10.6 Hz, $J_{3,4}$ 3.2 Hz, H-3^{II}), 5.03 (dd, 1 H, $J_{2,1}$ 8.2, $J_{2,3}$ 10.2 Hz, H-2^{III}), 4.89–4.75 (m, 4 H, H-1^{II}, H-5^{II}, H-3^{III}, 1/2 CH_2Ph), 4.54 (d, 1 H, J_{gem} 13.4 Hz, CH_2Ph), 4.50 (d, 1 H, J_{gem} 11.9 Hz, CH_2Ph), 4.39–4.20 (m, 4 H, 1/2 CH_2Ph, H-3^{I}, 2 H-6^{III}), 3.86–3.71 (m, 5 H, H-2^{II}, H-5^{I}, H-4^{I}, 2 H-6^{I}), 3.54 (br.dt, 1 H, H-5^{III}), 2.11–1.78 (6 s, 18 H, 6 $COCH_3$), 1.17 (d, 3 H, $J_{6,5}$ 6.6 Hz, CH_3). Anal. Calcd for $C_{54}H_{55}Cl_7N_2O_{22}$: C, 48.69; H, 4.16; N, 2.10. Found: C, 48.51; N, 4.08; N,1.98.

O-*(3,4-di*-O-*acetyl-2*-O-*benzyl*-α-L-*fucopyranosyl)-(1→4)-[(2,3,4,6-tetra*-O-*acetyl*-β-D-*galactopyranosyl)-(1→3)]-6*-O-*benzyl-2-deoxy-2-tetrachlorophthalimido*-α, β-D-*glucopyranosyl trichloroacetimidate* (**18**).—To a solution of **16** (115 mg, 0.097 mmol) in dry CH_2Cl_2 (5 mL) stirred at room temperature, trichloroacetonitrile (485 μL, 4.84 mmol) and four drops of DBU were added. After 3 h, the mixture was concentrated under reduced pressure and chromatographed (6:4 petroleum ether–EtOAc + 1% Et_3N) to give **18** (α, β mixture, 116 mg, 90%) as a foam. ^{1}H NMR spectrum showed a α : β ratio 36:64; $[\alpha]_D$ −2.8° (*c* 1, $CHCl_3$). TLC (6:4 petroleum ether–EtOAc); R_f 0.39 [α], R_f 0.32 [β]; ^{1}H NMR (300 MHz, $CDCl_3$): δ 8.54 (s, 0.64 H, NH, β anomer), 8.48 (s, 0.36 H, NH α anomer), 7.40–7.22 (m, 10 H, 2 C_6H_5), 6.60 (d, 0.36 H, $J_{1,2}$ 3.8 Hz, H-1^{I}, α anomer), 6.19 (d, 0.64 H, $J_{1,2}$ 8.9 Hz, H-1^{I}, β anomer), 5.46 (dd, 0.36 H, H-3^{I}, α anomer), 5.36 (br.d, 1 H, H-4^{III}, α + β), 5.29 (br.d, 1 H, H-4^{II}, α + β), 5.25 (d, 1 H, $J_{1,2}$ 3.7 Hz, H-1^{III}, β anomer), 5.21 (dd, 1 H, $J_{3,4}$ 3.6, $J_{3,2}$ 10.4 Hz, H-3^{III}, β anomer), 5.04–4.88 (m, 2.64 H, H-2^{II}, H-5^{III}, H-3^{I}, β anomer), 4.78–4.67 (m, 1.36 H, H-3^{II}, H-2^{I}, α anomer), 4.63–4.44 (m, 4.64 H, H-2^{I}, β anomer, 2 CH_2Ph), 4.40, 4.35 (2 br.dd, 2 H, H-6^{II}, α + β), 4.22 (d, 1 H, $J_{1,2}$ 8.0 Hz, H-1^{II}, α + β), 4.11 (t, 1 H, $J_{4,3} = J_{4,5}$ 9.4 Hz, H-4^{I}, α + β), 3.95–3.86 (m, 2 H, H-2^{III}, H-6^{I}, α + β), 3.73–3.56 (m, 3 H, H-5^{I}, H-5^{II}, H-6^{I}, α + β), 2.15–1.89 (6 s, 18 H, 6 CH_3CO, α + β), 1.24 (d, 3 H, $J_{6,5}$ 6.6 Hz, CH_3, α + β). Anal. Calcd for $C_{54}H_{55}Cl_7N_2O_{22}$: C, 49.39; H, 4.22; N, 2.13. Found: C, 49.28; H, 4.20; N, 2.09.

Benzyl O-*(4*-O-*acetyl-2,6-di*-O-*benzyl*-β-D-*galactopyranosyl)-(1→4)-2,3,6-tri*-O-*benzyl*-β-D-*glucopyranoside* (**19**).—To a solution of benzyl 2^{I},3^{I},6^{I},2^{II},6^{II}-penta-*O*-benzyl-β-lactoside [20] (550 mg, 0.623 mmol) in ME_3CN (7 mL) at room temperature $CH_3C(OCH_3)_3$ (235 μL, 1.868 mmol) and a catalytic amount of *p*-toluenesulfonic acid monohydrate were added. The mixture was stirred for 10 min, then a 80% aq solution of HOAc (11 mL) was added. After stirring 15 min, the mixture was diluted with CH_2Cl_2 (120 mL) and washed with a saturated aq solution of $NaHCO_3$ (2×90 mL) and H_2O (2×100 mL). After drying (Na_2SO_4) and evaporation of the solvent, flash chromatography (7:3 petroleum ether–EtOAc) gave compound **19** (559 mg, 97%) as a syrup: MS MALDI-TOF (925.09): $[M + Na]^+$ 948; $[\alpha]_D$ −11.2° (*c* 1, $CHCl_3$). TLC (6:4 petroleum ether–EtOAc); R_f 0.51; ^{1}H NMR (300 MHz, $CDCl_3$): δ 7.45–7.15 (m, 30 H, 6 C_6H_5), 5.34 (br.dd, 1 H, H-4^{II}), 4.98, 4.91 (2 d, 2 H, J_{gem} 10.6 Hz, CH_2Ph), 4.95 (d, 1 H, 1/2 CH_2Ph), 4.80 (d, 1 H, J_{gem} 11.5 Hz, 1/2 CH_2Ph), 4.75 (d, 1 H, J_{gem} 10.6 Hz, 1/2 CH_2Ph), 4.73 (d, 1 H, 1/2 CH_2Ph), 4.67 (d, 1 H, 1/2 CH_2Ph), 4.66 (d, 1 H, J_{gem} 12.0 Hz, 1/2 CH_2Ph), 4.62 (d, 1 H, J_{gem} 12.4 Hz, 1/2 CH_2Ph), 4.49 (d, 1 H, $J_{1,2}$ 7.2 Hz, H-1^{I}), 4.48 (d, 1 H, $J_{1,2}$ 7.4 Hz, H-1^{II}), 4.46 (d, 1 H, 1/2 CH_2Ph), 4.45 (d, 1 H, 1/2 CH_2Ph), 4.25 (d, 1 H, J_{gem} 12.1 Hz, 1/2 CH_2Ph), 4.02 (t, 1 H, $J_{4,3} = J_{4,5}$ 9.0 Hz, H-4^{I}), 3.82 (dd, 1 H, $J_{6,5}$ 4.0, J_{gem} 11.0 Hz, H-6^{I}), 3.75 (br.dd, 1 H, H-6^{I}), 3.64 (dd, 1 H, $J_{3,2}$ 9.6, $J_{3,4}$ 3.6 Hz, H-3^{II}), 3.57 (t, 1 H, $J_{3,2} = J_{3,4}$ 9.0 Hz, H-3^{I}), 3.52 (br.t, 1 H, H-5^{II}), 3.49 (t, 1 H, H-2^{I}), 3.41 (dd, 1 H, H-2^{II}), 3.39–3.33 (m, 3 H, H-5^{I}, 2 H-6^{II}), 2.05 (s, 3 H, CH_3CO). Anal. Calcd for $C_{56}H_{60}O_{12}$: C, 72.71; H, 6.54. Found: C, 72.68; H, 6.49.

Thexyldimethylsilyl O-*(4*-O-*acetyl-2,6-di*-O-*benzoyl*-β-D-*galactopyranosyl)-(1→4)-2,3,6-tri*-O-*benzoyl*-β-D-*glucopyranoside* (**20**).—To a solution of thexyldimethylsilyl 2^{I},3^{I},6^{I},2^{II},6^{II}-penta-*O*-benzoyl-β-lactoside [22] (1.57 g, 1.56 mmol) in CH_3CN (16 mL) at room temperature, $CH_3C(OCH_3)_3$ (589 mL, 4.68 mmol) and a catalytic amount of *p*-toluenesulfonic acid monohydrate were added. The mixture was stirred for 10 min, then a 80% aq solution of HOAc (25 mL) was added. After stirring 15 min, the mixture was diluted with CH_2Cl_2 (250 mL) and washed with a saturated aqueous solution of $NaHCO_3$ (2×180 mL) and H_2O (150 mL). After drying ($MgSO_4$) and evaporation of the solvent, flash chromatography (9:1 toluene-acetone) gave compound **20** (1.58 g, 97%) as a foam: $[\alpha]_D$ +18.9° (*c* 1, $CHCl_3$). TLC (8:2 toluene–acetone); R_f 0.58; ^{1}H NMR (250 MHz, $CDCl_3$): δ 8.09–7.30 (m, 25 H, 5 C_6H_5), 5.68 (t, 1 H, $J_{3,2} = J_{3,4}$ 9.8 Hz, H-3^{I}), 5.38 (dd, $J_{2,3}$ 9.8 Hz, H-2^{I}), 5.23 (br.d, 1 H, H-4^{II}), 5.16 (dd, 1 H, $J_{2,3}$ 9.8 Hz, H-2^{II}), 4.93 (d, 1 H, $J_{1,2}$ 7.6 Hz, H-1^{I}), 4.66 (d, 1 H, $J_{1,2}$ 7.8 Hz, H-1^{II}), 4.60 (dd, 1 H, $J_{6,5}$ 1.4 Hz, H-6^{I}),

4.49 (dd, 1 H, $J_{6,5}$ 5.7, J_{gem} 11.8 Hz, H-6^{I}), 4.10 (t, 1 H, $J_{4,3}=J_{4,5}$ 9.8 Hz, H-4^{I}), 3.87–3.82 (m, 2 H, H-3^{II}, H-5^{I} or H-5^{II}), 3.78–3.73 (m, 1 H, H-6^{II}), 3.65 (br.t, 1 H, H-5^{I} or H-5^{II}), 3.56 (dd, 1 H, $J_{6,5}$ 6.3, J_{gem} 10.5 Hz, H-6^{II}), 2.55 (br.d, 1 H, OH exch. with D_2O), 2.02 (s, 3 H, CH_3CO), 1.43 (m, 1 H, $CH[CH_3]_2$ texyl), 0.70–0.61 (m, 12 H, $CH[CH_3]_2$, $C[CH_3]_2$ texyl), 0.08, 0.00 (2 s, 6 H, $Si[CH_3]_2$). Anal. Calcd for $C_{57}H_{62}O_{17}Si$: C, 65.38; H, 5.97. Found: C, 65.35; H, 5.90.

Benzyl O-*(2,3,4,6-tetra*-O-*acetyl*-β-D-*galactopyranosyl)-(1→4)-[(3,4-di*-O-*acetyl-2*-O-*benzyl*-α-L-*fucopyranosyl)-(1→3)]-(6*-O-*benzyl-2-deoxy-2-tetrachlorophthalimido*-β-D-*glucopyranosyl)-(1→3)-(4*-O-*acetyl-2,6-di*-O-*benzyl*-β-D-*galactopyranosyl)-(1→4)-2,3,6-tri*-O-*benzyl*-β-D-*glucopyranoside* (**21**).—Compounds **17** (144 mg, 0.108 mmol) and **19** (50 mg, 0.054 mmol) were dissolved in dry MeCN (2.5 mL); freshly activated powder molecular sieves (4 Å) were added and the mixture was stirred for 1 h at room temperature, then a solution of zinc trifluoromethanesulfonate in dry MeCN (0.1 M, 324 μL) was added. After 2.5 h, the mixture was neutralized with Et_3N, filtered over a Celite pad and concentrated under reduced pressure. Flash chromatography (3:2→55:45 petroleum ether–EtOAc gradient elution) gave pentasaccharide **21** (73 mg, 64%) as a white foam: $[\alpha]_D$ −14.0° (c 1, $CHCl_3$). TLC (55:45 petroleum ether–EtOAC); R_f 0.53; ^{1}H NMR (600 MHz, $CDCl_3$): δ 7.38–6.70 (m, 40 H, 8 C_6H_5), 5.37 (br.d, 1 H, H-4^{II}), 5.26 (br.d, 1 H, H-4^{V}), 5.19 (br.d, 1 H, H-4^{IV}), 5.16 (d, 1 H, $J_{1,2}$ 8.3 Hz, H-1^{III}), 5.02 (dd, 1 H, $J_{3,4}$ 3.4 Hz, H-3^{IV}), 4.93–4.18 (16 d, 16 H, 8 CH_2Ph), 4.96 (dd, 1 H, $J_{2,3}$ 10.2 Hz, H-2^{V}), 4.82 (m, 1 H, H-5^{IV}), 4.72 (dd, 1 H, $J_{3,4}$ 3.6 Hz, H-3^{V}), 4.68 (d, 1 H, $J_{1,2}$ 3.5 Hz, H-1^{IV}), 4.65 (d, 1 H, $J_{1,2}$ 7.9 Hz, H-1^{V}), 4.48 (br.dd, 1 H, H-3^{III}), 4.32 (br.dd, 1 H, H-2^{III}), 4.30 (d, 1 H, $J_{1,2}$ 7.2 Hz, H-1^{I}), 4.27 (d, 1 H, $J_{1,2}$ 7.4 Hz, H-1^{II}), 4.29, 4.21 (2 dd, 2 H-6^{III}), 4.12 (t, 1 H, $J_{4,3}=J_{4,5}$ 9.2 Hz, H-4^{III}), 3.89 (t, 1 H, $J_{4,5}=J_{4,3}$ 9.1 Hz, H-4^{I}), 3.79 (dd, 1 H, H-6^{III}), 3.77 (dd, 1 H, H-6^{III}), 3.60 (dd, 1 H, $J_{2,3}$ 10.5 Hz, H-2^{IV}), 3.55–3.25 (m, 11 H, H-2^{I}, H-3^{I}, 2 H-6^{I}, H-2^{II}, H-3^{II}, H-5^{II}, 2 H-6^{II}, H-5^{III}, H-5^{V}), 2.86 (m, 1 H, H-5^{I}), 1.12 (d, 3 H, $J_{6,5}$ 6.5 Hz, CH_3). ^{13}C NMR (150.86 MHz, $CDCl_3$): δ 102.37, (d, C-1^{II}), 101.87 (d, C-1^{I}), 99.41 (d, C-1^{V}), 99.20 (d, C-1^{III}), 97.76 (d, C-1^{IV}), 82.57, 81.55, 80.96, 78.28 (4 d, C-5^{II}, C-2^{II}, C-2^{I}, C-3^{I}), 75.37 (d, C-4^{I}), 74.91 (d, C-3^{II}), 74.55 (d, C-5^{I}), 74.11 (d, C-4^{III}), 72.94 (d, C-5^{V}), 71.77 (d, C-4^{IV}), 71.71 (d, C-2^{IV}), 71.05 (d, C-3^{V}), 70.88 (d, C-5^{III}), 70.57 (d, C-3^{IV}), 69.66 (d, C-4^{II}), 69.14 (d, C-2^{V}), 68.78, 67.51 (2 t, C-6^{I}, C-6^{II}), 67.25 (t, C-6^{III}), 66.86 (d, C-4^{V}), 64.58 (d, C-5^{IV}), 60.83 (t, C-6^{V}), 56.75 (d, C-2^{III}), 15.74 (q, C-6^{IV}). Anal. Calcd for $C_{108}H_{113}Cl_4NO_{33}$: C, 61.92; H, 5.44; N, 0.67. Found: C, 61.84; H, 5.38; N, 0.66.

Thexyldimethylsilyl O-*(2,3,4,6-tetra*-O-*acetyl*-β-D-*galactopyranosyl)-(1→4)-[(2,3-di*-O-*acetyl-2*-O-*benzyl*-α-L-*fucopyranosyl)-(1→3)]-(6*-O-*benzyl-2-deoxy-2-tetrachlorophthalimido*-β-D-*glucopyranosyl)-(1→3)-(4*-O-*acetyl-2,6-di*-O-*benzoyl*-β-D-*galactopyranosyl) - (1→4) -2,3,6-tri*-O-*benzoyl*-β-D-*glucopyranoside* (**22**).—To a solution of **17** (190 mg, 0.142 mmol) and acceptor **20** (100 mg, 0.095 mmol) in dry MeCN (2.8 mL) cooled at −20 °C a 0.1 M solution of trimethylsilyl trifluoromethanesulfonate in MeCN (95 mL) was added. After 15 min, the mixture was neutralized with Et_3N and concentrated under reduced pressure. Flash chromatography (6:4→1:1 petroleum ether–EtOAc gradient elution) gave a compound not pure enough for characterization; medium pressure chromatography (3:2 petroleum ether–EtOAc) afforded pentasaccharide **22** (95 mg, 45%) as an amorphous mass: $[\alpha]_D$ +6.5° (*c* 1, $CHCl_3$). TLC (3:2 petroleum ether–EtOAc); ^{1}H NMR (300 MHz, $CDCl_3$); δ 8.10–6.80 (m, 35 H, 7 C_6H_5), 5.56 (t, 1 H, $J_{3,2}=J_{3,4}$ 9.6 Hz, H-3^{I}), 5.32 (br.d, 1 H, H-4^{II}), 5.29 (dd, 1 H, H-2^{I}), 5.25 (br.d, 1 H, H-4^{V}), 5.20 (dd, 1 H, H-2^{II}), 5.17 (br.d, 1 H, H-4^{IV}), 5.05 (d, 1 H, $J_{1,2}$ 8.2 Hz, H-1^{III}), 4.96 (dd, 1 H, $J_{3,4}$ 3.7 Hz, H-3^{IV}), 4.92 (dd, 1 H, H-2^{V}), 4.80 (d, 1 H, $J_{1,2}$ 7.5 Hz, H-1^{I}), 4.74–4.67 (m, 2 H, H-5^{IV}, H-3^{V}), 4.71 (d, 1 H, J_{gem} 12.4 Hz, 1/2 CH_2Ph), 4.62 (d, 1 H, $J_{1,2}$ 3.5 Hz, H-1^{IV}), 4.60 (d, 1 H, $J_{1,2}$ 7.9 Hz, H-1^{V}), 4.46–4.35 (m, 4 H, H-1^{II}, H-3^{III}, CH_2Ph), 4.26–4.10 (m, 4 H, 2 H-6^{I}, H-2^{III}, 1/2 CH_2Ph), 4.04 (t, 1 H, $J_{4,3}=J_{4,5}$ 9.7 Hz, H-4^{III}), 4.02 (dd, 1 H, H-6^{III}), 3.87 (t, 1 H, $J_{4,3}=J_{4,5}$ 9.6 Hz, H-4^{I}), 3.76–3.63 (m, 3 H, H-3^{II}, 2 H-6^{V}), 3.60–3.45 (m, 6 H, H-5^{I}, H-5^{II}, H-6^{II}, H-5^{III}, H-6^{III}, H-2^{IV}), 3.38 (m, 1 H, H-5^{V}), 3.13 (dd, 1 H, H-6^{II}), 2.05–1.70 (7 s, 21 H, 7 CH_3CO), 1.39 (m, 1 H, $CH[CH_3]_2$ texyl), 1.06 (d, 3 H, $J_{6,5}$ 6.5 Hz, CH_3), 0.69–0.60 (m, 12 H, $CH[CH_3]_2$, $C[CH_3]_2$ texyl), −0.01, −0.09 (2 s, 6 H, $Si[CH_3]_2$). ^{13}C NMR (75.46 MHz, $CDCl_3$): δ 100.67 (d), 99.36 (d), 98.75 (d), 97.57 (d), 95.83 (d), 78.19 (d), 75.80 (d), 75.01 (2 d), 74.43 (d), 74.15 (d), 73.52 (d), 72.83 (d), 72.42 (d), 72.14 (d), 71.75 (d), 71.41 (d), 70.99 (2 d), 70.48 (d), 69.14 (d), 68.84 (d), 67.25 (t), 66.88 (d), 64.53 (d), 62.67 (t), 62.26 (t), 69.85 (t), 56.42 (d), 15.71 (q). Anal. Cald for $C_{109}H_{115}Cl_4NO_{38}Si$: C, 59.05;

H, 5.23; N, 0.63. Found: C, 58.96; H, 5.18; N, 0.60.

Benzyl O-*(2,3,4,6-tetra*-O-*acetyl*-β-D-*galactopyranosyl)-(1→4)-[(3,4-di*-O-*acetyl-2*-O-*benzyl*-α-L-*fucopyranosyl)-(1→3)]-(6*-O-*benzyl-2-deoxy-2-acetamido*-β-D-*glucopyranosyl)-(1→3)-(4*-O-*acetyl-2,6-di*-O-*benzyl*-β-D-*galactopyranosyl)-(1→4)-2,3,6-tri*-O-*benzyl*-β-D-*glucopyranoside* (**23**).—**21** (72 mg, 0.034 mmol) was suspended in dry EtOH (2 mL) then a 1 M solution of ethylenediamine in dry EtOH (204 μL) was added and the mixture was heated at 60 °C. After 30 h the solvent was co-evaporated under reduced pressure with toluene. The residue was dissolved in dry pyridine (2 mL), then acetic anhydride (2 mL) was added and the mixture was stirred at room temperature for 12 h. Few drops of water and 6 mL of EtOH were added then the mixture was concentrated under reduced pressure. Flash chromatography (4:6 petroleum ether–EtOAc) afforded compound **23** (33 mg, 52%) as a white foam: FAB MS (1869.05): 1862 [M + Na^+]; $[\alpha]_D$ −31.3° (*c* 1, $CHCl_3$). TLC (5:7 petroleum ether–EtOAc); R_f 0.30; ^{1}H NMR (300 MHz, $CDCl_3$); δ 7.42–7.21 (m, 40 H, 8 C_6H_5), 5.49 (br.d, 1 H, H-4^{II}), 5.41 (d, 1 H, J 8.0 Hz, NH), 5.30 (2 br.d, 2 H, H-1^{IV}, H-4^{V}), 5.28 (br.d, 1 H, H-4^{IV}), 5.21 (dd, 1 H, $J_{3,4}$ 3.4, $J_{3,2}$ 10.3 Hz, H-3^{IV}), 5.11 (d, 1 H, $J_{1,2}$ 5.1 Hz, H-1^{III}), 5.03–4.24 (16 d, 16 H, 8 CH_2Ph), 4.94 (dd, 1 H, $J_{2,3}$ 10.5 Hz, H-2^{V}), 4.88 (m, 1 H, H-5^{IV}), 4.71 (dd, 1 H, H-3^{V}), 4.50 (dd, 1 H, H-6^{V}), 4.48 (d, 1 H, $J_{1,2}$ 8.1 Hz, H-1^{V}), 4.46 (d, 1 H, $J_{1,2}$ 7.6 Hz, H-1^{I}), 4.43 (d, 1 H, $J_{1,2}$ 7.4 Hz, H-1^{II}), 4.28–4.21 (m, 3 H, J_{gem} 11.7 Hz, H-4^{III}, H-6^{V}, 1/2 CH_2Ph), 4.00 (2 br.t, 2 H, H-4^{I}, H-3^{III}), 3.86 (dd, 1 H, $J_{2,2}$ 3.7 Hz, H-2^{IV}), 3.80–3.64 (m, 6 H, 2 H-6^{I}, H-3^{II}, 2 H-6^{III}, H-5^{V}), 3.63–3.28 (m, 8 H, H-2^{I}, H-3^{I}, H-5^{I}, H-2^{II}, H-5^{II}, 2 H-6^{II}, H-5^{III}), 2.12–1.90 (8 s, 24 H, 8 CH_3CO), 1.12 (d, 3 H, $J_{6,5}$ 6.6 Hz, CH_3). ^{13}C NMR (75.46 MHz, $CDCl_3$): δ 170.64–169.01 (8 s), 102.51 (d, C-1^{I}), 102.11 (d, C-1^{II}), 99.64 (d, C-1^{V}), 98.94 (d, C-1^{III}), 95.58 (d, C-1^{IV}), 82.83 (d), 81.73 (d), 80.34 (d), 77.22 (d), 76.10 (d), 75.65 (d), 75.05 (d), 74.38 (d), 73.17 (2 d), 72.82 (d), 72.02 (d), 71.00 (d), 70.60 (d), 70.07 (d), 69.29 (d), 69.09 (d), 68.17 (2 t), 67.39 (t), 66.83 (d), 64.05 (d), 60.63 (t), 57.30 (d), 15.78 (q). Anal. Calcd for $C_{102}H_{117}NO_{32}$: C, 65.55; H, 6.31; N, 0.75. Found: C, 65.32; H, 6.28; N, 0.71.

Thexyldimethylsilyl O-*(2,3,4,6-tetra*-O-*acetyl*-β-D-*galactopyranosyl)-(1→4)-[(3,4-di*-O-*acetyl-2*-O-*benzyl*-α-L-*fucopyranosyl)-(1→3)]-(6*-O-*benzyl-2-deoxy-2-acetamido*-β-D-*glucopyranosyl)-(1→3)-(4*-O-*acetyl-2,6-di*-O-*benzoyl*-β-D-*galactopyranosyl)-(1→4)-2,3,6-tri*-O-*benzoyl*-β-D-*glucopyranoside* (**24**).—**22** (158 mg, 0.0712 mmol) was suspended in dry EtOH (4 mL), then a 1 M solution of ethylenediamine in dry EtOH (428 μL) was added and the mixture was heated at 60 °C. After 36 h, the solvent was co-evaporated under reduced pressure with toluene. The residue was dissolved in dry pyridine (4 mL), then acetic anhydride (4 mL) was added and the mixture was stirred at room temperature for 36 h. Few drops of water and 10 mL of EtOH were added then the mixture was concentrated under reduced pressure. Flash chromatography (2:3 petroleum ether–EtOAc) afforded compound **24** (78 mg, 55%) as a glass: FAB MS (199.16): 2014 [M + Na^+]; $[\alpha]_D$ −3.2° (*c* 1, $CHCl_3$). TLC (4:6 petroleum ether–EtOAc); R_f 0.26; ^{1}H NMR (300 MHz, $CDCl_3$): δ 8.11–7.20 (m, 35 H, 7 C_6H_5), 5.66 (t, 1 H, $J_{3,2} = J_{3,4}$ 9.5 Hz, H-3^{I}), 5.34 (2 dd, 2 H, H-2^{I}, H-2^{II}), 5.28–5.20 (m, 4 H, H-4^{II}, H-4^{IV}, H-4^{V}, NH), 5.13 (dd, 1 H, $J_{3,4}$ 3.3, $J_{3,2}$ 10.4 Hz, H-3^{IV}), 5.05 (d, 1 H, $J_{1,2}$ 7.6 Hz, H-1^{III}), 4.86 (br.t, 1 H, H-2^{V}), 4.88 (d, 1 H, $J_{1,2}$ 7.6 Hz, H-1^{I}), 4.84 (m, 1 H, H-5^{IV}), 4.83 (d, 1 H, $J_{1,2}$ 4.1 Hz, H-1^{IV}), 4.69 (dd, 1 H, $J_{3,4}$ 3.5 Hz, H-3^{V}), 4.66 (d, 1 H, J_{gem} 12.0 Hz, 1/2 CH_2Ph), 4.62 (d, 1 H, J_{gem} 11.8 Hz, 1/2 CH_2Ph), 4.53 (2 d, 2 H, $J_{1,2} = J_{1,2}$ 8.0 Hz, H-1^{II}, H-1^{V}), 4.46 (d, 1 H, 1/2 CH_2Ph), 4.37–4.28 (m, 4 H, 2 H-6^{I}, H-6^{V}, 1/2 CH_2Ph), 4.20 (dd, 1 H, $J_{6,5}$ 5.6, J_{gem} = 11.9 Hz, H-6^{V}), 4.19 (t, 1 H, $J_{3,2} = J_{3,4}$ 9.3 Hz, H-3^{III}), 4.01 (t, 1 H, $J_{4,3} = J_{4,5}$ 9.5 Hz, H-4^{I}), 3.97 (dd, 1 H, $J_{6,5}$ 4.7, J_{gem} 11.6 Hz, H-6^{III}), 3.85 (t, 1 H, $J_{4,3} = J_{4,5}$ 9.3 Hz, H-4^{III}), 3.82–3.69 (m, 3 H, H-5^{I}, H-3^{II}, H-2^{IV}), 3.68–3.56 (m, 3 H, H-5^{II}, H-6^{II}, H-6^{III}), 3.45 (br.t, 1 H, H-5^{V}), 3.29–3.19 (m, 2 H, H-6^{II}, H-5^{III}), 2.92 (br.dd, 1 H, H-2^{III}), 2.11–1.90 (8 s, 24 H, 8 CH_3CO), 1.40 (m, 1 H, $CH[CH_3]_2$ texyl), 1.10 (d, 3 H, $J_{6,5}$ 6.6 Hz, CH_3), 0.70–0.60 (m, 12 H, $CH[CH_3]_2$ texyl), 0.02, −0.02 (2 s, 6 H, $Si[CH_3]_2$). ^{13}C NMR (75.46 MHz, $CDCl_3$): δ 100.78 (d, C-1^{V} or C-1^{II}), 99.42 (2 d, C-1^{III}, C-1^{II} or C-1^{V}), 96.93 (d, C-1^{I}), 95.94 (d, C-1d^{IV}), 77.62 (d), 75.85 (d), 74.58 (d), 73.93 (d), 73.63 (2 d), 72.97 (2 d), 72.64 (d), 72.09 (d), 71.87 (d), 71.46 (d), 70.99 (d), 70.88 (d), 70.42 (d), 69.14 (d), 68.85 (d), 67.46 (t), 66.95 (d), 64.12 (d), 62.78 (t), 62.21 (t), 60.82 (t), 59.15 (d), 15.70 (q). Anal. Calcd for $C_{103}H_{119}NO_{37}Si$: C, 62.13; H, 6.02; N, 0.70. Found: C, 62.02; H, 5.91; N, 0.66.

O-*(*β-D-*galactopyranosyl)-(1→4)-[(*α-L-*fucopyranosyl)-(1→3)]-(2-acetamido-2-deoxy*-β-D-*glucopyranosyl)-(1→3)-(*β-D-*galactopyranosyl)-(1→4)-*α, β-D-*glucopyranose* (**1**).—**23** (40 mg, 0.021 mmol)

was suspended in dry MeOH (1 mL), then a 0.9 M solution of NaOMe in dry MeOH (15 μL) was added. The mixture was stirred for 24 h at room temperature, then 12 h at 50 °C. Neutralization with Amberlite IR-120, filtration and evaporation of the solvent gave the *O*-deacetylated pentasaccharide (TLC: 5:1 toluene–EtOH, R_f 0.16; ^{1}H NMR spectrum showed complete disappearance of the *O*-acetyl groups) which was purified by flash chromatography (5:1 toluene–EtOH). The product was dissolved in a mixture of 1:1 MeOH–water (1.6 mL); glacial acetic acid (two drops) and palladium hydroxide (25 mg) were added, then, after stirring for 10 min, the mixture was stirred in a H_2 atmosphere. After 20 h, the mixture was filtered over a Celite pad and concentrated under reduced pressure. Lyophilization afforded pentasaccharide **25** (15 mg, 84%) as an amorphous mass: $[\alpha]_D$ −5.5° (t 0), −5.0° (t 16 h), (*c* 1, $CHCl_3$). TLC (1:1:1 EtOAc–2-propanol–water); R_f 0.32; ^{1}H NMR (300 MHz, D_2O): 5.02 (d, 1 H, $J_{1,2}$ 4.0 Hz, H-1^{IV}), 4.72 (m, 1 H, H-5^{IV}), 4.64 (d, 1 H, $J_{1,2}$ 6.4 Hz), 4.55 (d, 1 H, $J_{1,2}$ 7.9 Hz, H-1^{I}), 4.37–4.29 (m, 2 H, H-1^{II}, H-1^{V}), 4.04 (br.d, 1 H, H-4^{II}), 3.89–3.75 (m, 8 H, H-2^{III}, H-3^{III}, H-4^{III}, 2 H-6^{III}, H-3^{IV}, H-3^{V}, H-4^{V}), 3.75–3.44 (m, 16 H, H-3^{I}, H-4^{I}, H-5^{I}, 2 H-6^{I}, H-2^{II}, H-3^{II}, H-5^{II}, 2 H-6^{II}, H-5^{III}, H-2^{IV}, H-4^{IV}, H-5^{V}, 2 H-6^{V}), 3.39 (dd, 1 H, $J_{2,1}$ 7.7, $J_{2,3}$ 9.6 Hz, H-2^{V}), 3.18 (dd, 1 H, H-2^{I}), 1.91 (s, 3 H, CH_3CO), 1.07 (d, 3 H, $J_{6,5}$ 6.6 Hz, CH_3). Anal. Calcd for $C_{32}H_{55}NO_{25}$: C, 45.00; H, 6.50; N, 1.64. Found: C, 44.92; H, 6.40; N, 1.61. The physical data are in accordance with those obtained for **1** synthesized via a different route [16].

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