Synthesis of a Sialyl Lewis x Mimic with Fixed Carboxylic Acid Group: Chemical Approach toward the Elucidation of the Bioactive Conformation of Sialyl Lewis x

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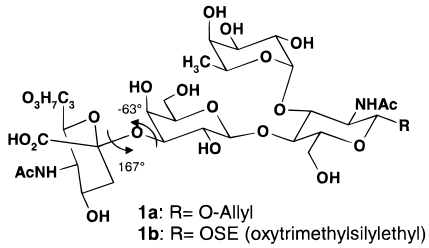
The relation of the solution and bioactive conformation of sialyl Lewis x (sLe^x) has been addressed by chemical means. To mimic the preferred solution conformation of sLe^x **1**, the more rigid analog **2** has been designed and synthesized. The sialic acid residue of **1** was replaced by a carboxylic acid function which is fixed in the equatorial position of a six membered ring acetal fused to galactose. Due to entropic considerations, an increased biological activity could be expected if the preferred solution conformation and bound form of sLe^x were similar. Since mimic **2** was found to be inactive in an E-selectin binding assay, the bound form of sLe^x most probably differs from the prevailing solution conformation.

Introduction

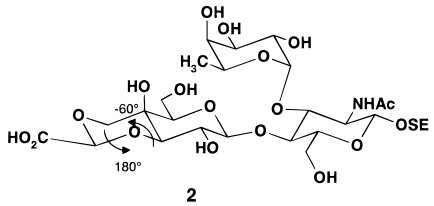
The recruitment of leukocytes to sites of inflammation is a protective response of the organism. This crucial process is mediated by multiple adhesion molecules such as integrins and super-immunoglobulins which interact on the basis of protein−protein recognition.[1] A third family of leukocyte adhesion receptors, the selectins,[2] is involved in an early state of the leukocyte recruitment cascade, the so-called rolling.[3] Contrary to integrins and super-immunoglobulins, the selectins recognize complex carbohydrate structures in a Ca^{2+}-dependent manner. Three members have been reported to date. L-Selectin is expressed constitutively on leukocytes and mediates their migration from the bloodstream to the lymphatic system.[4] P-Selectin is stored in secretory granules of the endothelium and, upon activation, transported to the cell surface, inducing leucocyte rolling.[5] E-Selectin is *de novo*-synthesized following stimulation by cytokines and also expressed on endothelial cells.[6] The interaction of E-selectin with complex carbohydrates is of pharmaceutical interest since cronic expression occurs in certain inflammatory conditions, such as psoriasis and rheumatoid arthritis. In addition, acute disorders like reperfusion injury or asthma caused by excessive leucocyte recruitment represent an important target.

A major E-selectin ligand on murine myeloid cells has been identified to be a 150 kD glycoprotein.[7] Very recently, the amino acid sequence has been determined.[8] The carbohydrate part which is crucial for binding has not been fully elucidated,[9] but the sialyl Lewis x (sLe^x) epitope **1** appears to be an important feature and is known to be a weak ligand itself.[10] The conformation of sLe^x **1** is of great interest and has been investigated by both NMR and computational means.[11] Accordingly, the Lewis x trisaccharide core is rather rigid, whereas the sialic acid shows more flexibility. Among several low energy conformations, structure **1** (Chart 1) is most consistent with computational and NMR data.[11c]

Chart 1



1a: R= O-Allyl
1b: R= OSE (oxytrimethylsilylethyl)



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A variety of sLe^x analogs has already been synthesized.[12] Whereas substitution of GlcNAc by glucose is beneficial to E-selectin binding, modifications of the fucose residue are generally deleterious. Interestingly, replacement of the sialic acid residue by lactic acid or

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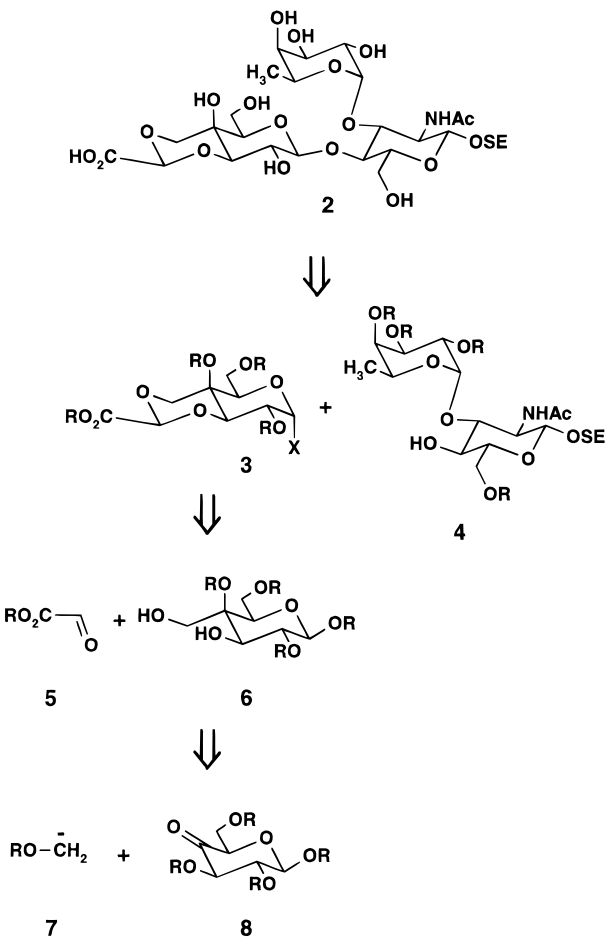
acetic acid decreases binding but does not completely abolish biological activity. On the other hand, removal of the carboxylic acid function results in inactivity. A negative charge in the appropriate position seems to be a requirement for E-selectin recognition. Knowledge of the bioactive conformation of sLe^x could support the rational design of potent analogs. The more rigid sLe^x analog **2**, matching the preferred solution conformation **1**, was designed to probe a possible resemblance of the bioactive form (Chart 1). The sialic acid residue is replaced by a carboxylic acid group which is fixed in the equatorial position of a six-membered ring acetal fused to galactose. Since compound **2** mimics sLe^x conformation **1**, an enhancement of the binding to E-selectin would be expected on entropic grounds if bioactive and solution conformations were similar. A drop in activity would indicate different conformations of sLe^x in solution and bound form. In the course of our work, bioactive sLe^x conformations have been proposed on the basis of transferred nuclear Overhauser enhancements, studying the sLe^x–E-selectin complex by high-field NMR spectroscopy.[13ab] Accordingly, the torsion angle of the glycosidic link between the sialyl and galactosyl residue of sLe^x changes upon binding.[13a] Interestingly, the bioactive conformation resembles one of the less preferred local minima. Therefore, it has been suggested that E-selectin recognizes only one of several sLe^x conformers present in solution and that binding causes only minor structural changes concerning the fucose residue.[13b] A third report describes deviating results[13c] by implying that the bioactive and solution conformations are similar.

Results and Discussion

In order to approach target molecule **2**, we decided to synthesize a galactosyl donor such as **3** which already contains the fused six-membered ring acetal and subsequently link this building block to the GlcNAc-Fuc glycosyl acceptor **4**[14] (see Scheme 1). The six-membered ring acetal of donor **3** can be disconnected to an α-keto acid **5** and a diol **6** which in turn is available *via* stereoselective addition of a hydroxymethyl anion synthon **7** to a sugar ketone such as **8**. The carbonyl compound **8** can be obtained by oxidation of a suitably protected glucose or galactose with a free 4-hydroxyl group.

Scheme 1



The synthesis of a suitable glycosyl donor such as **3** according to the retrosynthetic analysis is depicted in Scheme 2. The known glucose derivative **9**[15] was deacetylated using Amberlite IRA 910 ion exchange resin and crude **10** treated with benzaldehyde dimethyl acetal to furnish 4,6-benzylidene derivative **11** in 89% yield. Next, the free hydroxyl groups of **11** were protected as benzyl ethers, applying benzyl bromide/NaH in DMF to give **12** (82%). Acidic cleavage of the benzylidene acetal furnished **13**, where the primary hydroxyl group was selectively silylated to give **14**. The 4-hydroxyl group of **14** was oxidized using DMSO/acetic anhydride. The resulting sugar ketone **15** is stable toward chromatography but purification did not improve the yield of the following step.

Crude **15** was treated with vinylmagnesium bromide at low temperature in THF. Branched galactose derivative **16** was obtained in 72% yield. NMR analysis of the crude reaction mixture indicated small amounts of the C-4 epimer of **16** which could be isolated only in trace amounts. The galactose/glucose selectivity appears to be better than 10:1. This has been explained for similar systems by chelation of the magnesium atom of the Grignard reagent with the C-4 carbonyl oxygen and the C-3 oxygen atom. The chelated oxo sugar adopts a $^4C_1$-conformation (Chart 2, **A**), and equatorial attack of the nucleophile dominates over the sterically hindered axial attack.[16] Structure **16** was assigned by NOE measure-

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(14) A disaccharide such as **4** (R = Bn, compound **26** in Scheme 4) was generously provided by Dr. N. Cooke, CIBA-Basel. The synthesis is not covered in the Experimental Section and will be published elsewhere.

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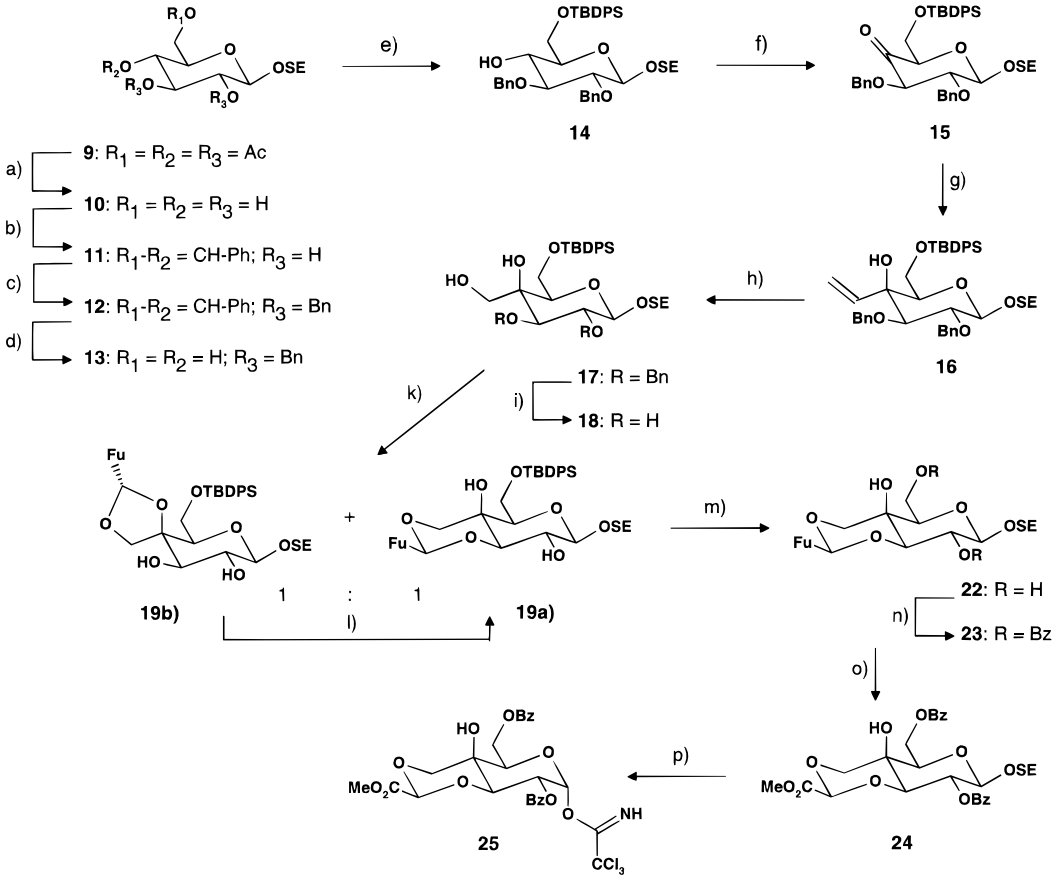
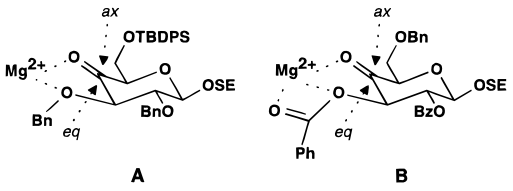
Scheme 2[a]

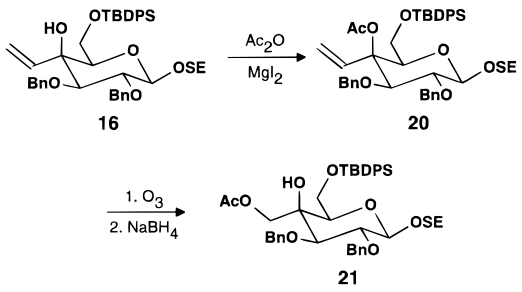


[a] Key: (a) Amberlite IRA 910, methanol, rt, 2 h (**10**); (b) benzaldehyde dimethyl acetal, PTSA, MeCN, rt, 3 h (**11**, 89% over two steps); (c) NaH, DMF, rt, 2 h, BnBr, 0 °C, 2 h (**12**, 82%); (d) HCl/MeOH, rt, 2 h (**13**); (e) TBDPS, imidazole, DMF, rt, 3 h (**14**); (f) DMSO/Ac_2O, 65 °C, 2 h (**15**); (g) $CH_2CHMgBr$, THF, −78 °C, 3 h (**16**, 72% over four steps); (h) (1) O_3, MeOH, 78 °C; (2) $NaBH_4$, −78 → rt, 2 h (**17**, 79%); (i) Pd/C (10%), MeOH/AcOH (99:1), 45 °C (**18**, 98%); (k) furaldehyde diethyl acetal (1.5 equiv), PPTS, benzene, 60 °C, 45 min (**19a**/**19b**, (1:1), 81%); (l) furaldehyde diethyl acetal (0.2 equiv), PPTS, benzene, 60 °C, 16 h; (m) Bu_4NF, THF, rt, 150 min (**22**, quant); (n) BzCl, Py, DMAP (**23**, 94%); (o) (1) O_3, MeOH, −78 °C; (2) H_2O_2, MeOH, −78 °C → rt, 16 h; (3) CH_2N_2, ether, 0 °C (**24**, 80%); (p) (1) TFA, CH_2Cl_2, 0 °C, 45 min, (2) Cl_3CCN, Cs_2CO_3, CH_2Cl_2, rt, 16 h (**25**, 54% over two steps).

Chart 2



Scheme 3



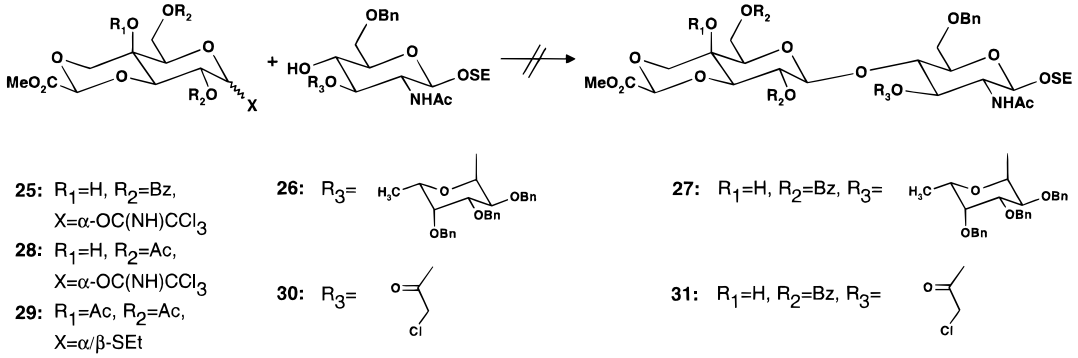
ments. The internal vinyl proton showed a strong NOE to H-3 and H-5. Since both H-3 and H-5 are in axial positions of the six-membered ring, the vinyl group has to be in the equatorial position to achieve proximity to these protons.

Ozonolysis of **16** followed by reductive workup gave alcohol **17** (66%), and subsequent catalytic hydrogenation furnished **18** in 98% yield. According to the retrosynthetic analysis (Scheme 1), compound **18** was reacted with glyoxylic acid derivatives in order to form the desired 1,3-dioxane bearing a carboxylic acid. Since all direct approaches failed, we decided to introduce an acetal containing a functionality which could be easily converted into an acid, such as furan. Thus, reaction of **18** with furaldehyde diethyl acetal and PPTS in benzene at 60 °C gave a 1:1 mixture of six-membered ring acetal **19a** and five-membered ring acetal **19b** in 81% yield. The isomers could easily be separated by flash chromatography. Variation of solvent, catalyst, and reaction temperature did not alter the product ratio. Pure five-membered ring acetal **19b** can be equilibrated to a 1:1 mixture of **19a** and **19b** by applying small amounts of furaldehyde diethyl acetal and PPTS. Structures **19a** and **19b** were assigned by ^{1}H-NOE measurements.

In order to avoid five-membered ring acetal formation, we tried to acetylate the free hydroxyl group of **16**. The teriary allylic alcohol was inert toward standard reaction conditions, but treatment with acetic anhydride and magnesium iodide[17] gave fully protected **20** in almost quantitative yield. Unfortunately, under the basic conditions applied for the reduction of the ozonide derived from **20**, the acetate migrates to the primary hydroxyl group leading to **21** (Scheme 3).

(16) Miljkovic, M.; Gligorijevic, M.; Satoh, T.; Miljkovic, D. *J. Org. Chem.* **1974**, *39*, 1379.

Scheme 4

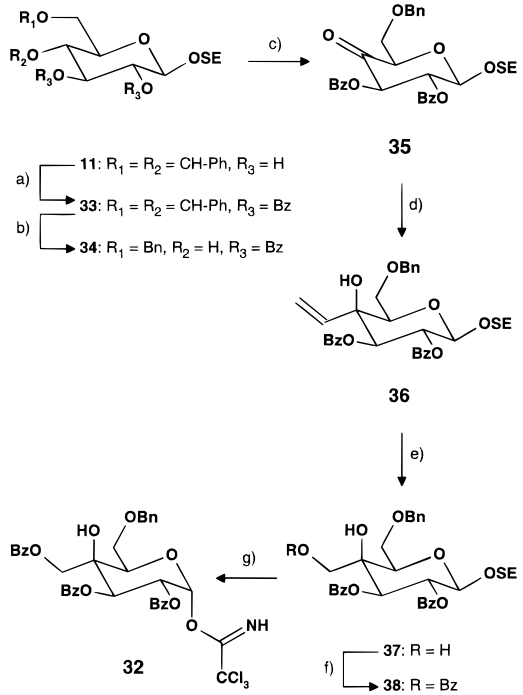


The silyl protecting group of **19a** was removed with fluoride to yield quantitatively triol **22** and subsequently benzoylated to give **23** in 94% yield. Ozonolysis of the furan ring followed by treatment with diazomethane furnished methyl ester **24** in 80% yield. The (trimethylsilyl)ethyl glycoside was cleaved under acidic conditions and the intermediate treated with trichloroacetonitrile and cesium carbonate. The desired glycosyl donor **25** (54% over two steps) was unstable and always accompanied by decomposition products which could not be removed by chromatography. Attempts to further purify compound **25** gave no improvement but led to a great loss of material. Therefore, the donor **25** was immediately used after preparation. The β-epimer of **25** could not be isolated. Using DBU instead of cesium carbonate offered no improvement. Starting from glucose derivative **9**, the bicyclic galactose derivative **25** could be prepared in 14 steps in an overall yield of 6.6%.

Next, we attempted to link trichloroacetimidate **25** to acceptor **26**.[14] Both TMS triflate and BF_3 etherate were tried as mediators. We observed rapid consumption of **25** but were unable to detect any glycosylation product such as **27** (Scheme 4). The acceptor **26** could be recovered. In some cases, when TMS triflate had been used, we observed silylation of the 4-hydroxyl group of **26**. We also synthesized bicyclic glycosyl donors **28** and **29**,[18] but all attempts to achieve linkage to acceptor **26** failed.[19]

Hence, we changed our strategy to assemble the target molecule **2** (see Chart 1). Sterically less hindered monosaccharide **30**[20] was used as glycosyl acceptor for **25**. The fucose residue should be introduced at a later stage. Glycosylation furnished a mixture which contained the desired product **31**, but due to the very low yield (>10%) and the demanding purification we abandoned this approach as well. We believe that the rigid bicyclic core of donor **25** renders sp^2 hybridization of a cationic intermediate more difficult, causing the disappointing results in glycosylation reactions.

Scheme 5[a]



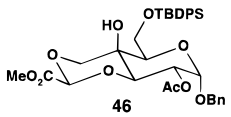
[a] Key: (a) BzCl, DMAP, Py, 0 °C → rt, 2 h (**33**, 96%); (b) $NaCNBH_3$, THF; HCl in ether, 0 °C (**34**, 93%); (c) DMSO, P_2O_5, DMF, 50 °C, 2 h (**35**); (d) $CH_2CHMgBr$, THF, −78 °C (**36**); (e) (1) O_3, MeOH, −78 °C; (2) $NaCNBH_3$, −78 °C → rt (**37**); (f) BzCl, DMAP, Py, 0 °C → rt, 2 h (**38**, 70% over four steps); (g) (1) CF_3COOH, CH_2Cl_2, 0 °C, (2) Cl_3CCN, Cs_2CO_3, CH_2Cl_2, rt, 4 h (**32**, 81% over two steps).

In order to circumvent these problems, we decided to link a monocyclic galactose derivative such as **32** to GlcNAc-Fuc building block **26** (see Scheme 5) prior to acetal formation. Starting from glucose derivative **11**, the synthesis of C-4-branched galactose **32** has been accomplished in eight steps in an overall yield of 52%. First, the hydroxyl groups were protected as benzoates (→ **33**, 96%). The benzylidene acetal was selectively opened under reductive conditions to give **34** (93%). Oxidation of the 4-hydroxyl group was attempted under various conditions. In some cases, we observed elimination to an α,β-unsaturated ketone. Oxosugar **35** could finally be obtained by applying DMSO and P_2O_5. Treatment of **35** with a slight excess of vinylmagnesium bromide at low temperature resulted exclusively in equatorial attack at the carbonyl function leading to olefin **36**. This Grignard addition has to be monitored carefully by TLC since excess reagent leads to partial benzoate cleavage. The galactose configuration of **36** at C-4 was proven by NOE measurements. The C-4 epimer of **36** could not be detected by ^{1}H-NMR of the crude

(17) Chowdhury, P. K. *J. Chem. Res., Synop.* **1993**, 338.

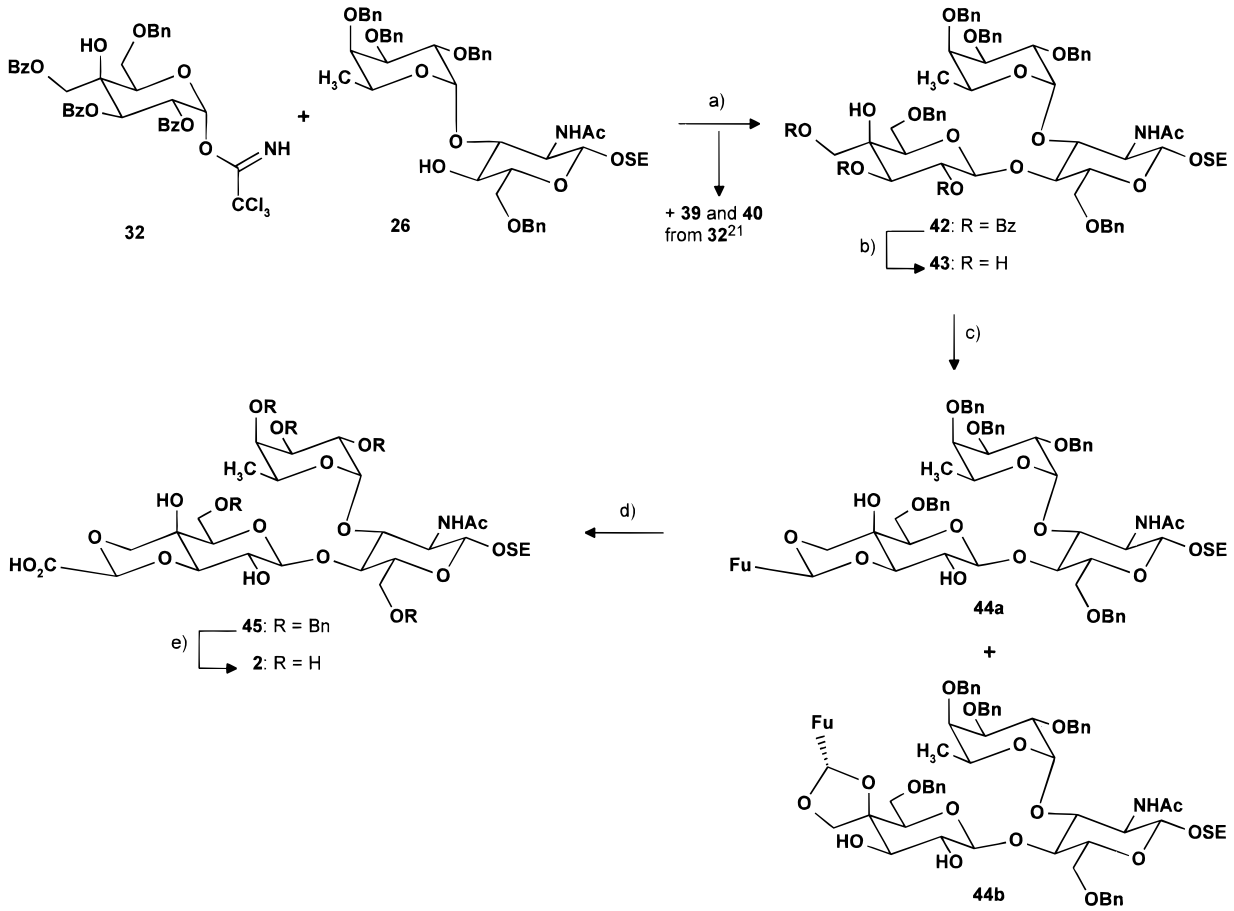
(18) The synthesis of **28** and **29** is not covered in the Experimental Section.

(19) In an earlier attempt toward a bicyclic glycosyl donor such as **3** we had prepared advanced intermediate **46**. Unfortunately, we were unable to remove the axial anomeric benzyl group.



(20) Compound **30** was generously provided by Dr. George Papandreou. The synthesis of **30** is not covered in the Experimental Section and will be published elsewhere.

Scheme 6[a]



[a] Key: (a) slow addition of a concd CH_2Cl_2 solution of **32** (2 equiv) to a concd CH_2Cl_2 solution of **26** and BF_3 OEt_2, MS 4 Å, rt, 2 h (**42**, 55%); (b) NaOMe, MeOH, rt, 2 h (**43**, 84%); (c) furaldehyde diethyl acetal, PPTS, 60 °C, 1 h (**44a**, 33%; **44b**, 41%); (d) (1) O_3, −78 °C; (2) H_2O_2/THF, rt, 18 h (**45**, 66%); (e) H_2, Pd/C, dioxane/H_2O, rt (**2**, 94%).

mixture. As in the Grignard addition to **15** (see Chart 2, **A**), Mg-chelation could be a plausible explanation for the striking stereoselectivity.[16] The ester substituent in the 3-position of **33** might be an even better ligand than the ether-oxygen in **15** (see Chart 2, **B**). Ozonolysis of **36** followed by reductive workup gave diol **37**, and benzoylation of the primary hydroxyl group furnished **38**. The last four steps could be done without chromatography of the intermediates in a satisfying overall yield of 70%. Finally, the (trimethylsilyl)ethyl glycoside was cleaved and the crude material transformed into the trichloroacetimidate **32** (81%). All attempts to block the axial 4-hydroxyl group of **36** or **37** as an ether failed.

Glycosylation of GlcNAc-Fuc building block **26** was carried out in CH_2Cl_2 with BF_3 etherate as mediator (see Scheme 6). First attempts gave unsatisfying results, but a detailed study of the side products **39**−**41**[21] led to optimized conditions that furnished **42** in a moderate yield of 55% (with respect to applied **26**). Approximately 40% of acceptor **26** was reisolated unchanged. Complete consumption of **26** could not be achieved even when 4 equiv of **32** was used. The α-glycoside could not be detected. Other mediators or solvents gave no improvement. Debenzoylation of **42** (→ **43**, 84%) and subsequent reaction with furaldehyde diethyl acetal gave a 1:1.2 mixture of the desired six-membered ring acetal **44a** and the five-membered ring acetal **44b**. The selectivity could not be improved by variation of the reaction conditions. The structures **44a** and **44b** were proven by NOE measurements. Other acetals were not isolated. The furyl substituent of 1,3-dioxane **44a** was transformed into a carboxylic acid functionality *via* ozonolysis followed by oxidative workup leading to **45** (66%). Hydrogenolysis furnished the rigid sLe^x mimic **2** in 94% yield.

Table 1. NMR Data of s Le^x Analog 2 (500 MHz, D_2O)

	Gal		GlcNAc		Fuc	
assigned	H	C	H	C	H	C
1	4.58	103.0	4.56	101.6	5.09	100.2
2	3.68	70.1	3.87	57.1	3.68	69.9
3	3.80	82.7	3.86	76.4	3.89	70.6
4		69.2	3.93	74.6	3.79	73.3
5	3.58	76.5	3.56	76.6	4.87	68.1
6	3.68/3.68	60.8	3.88/3.99	61.0	1.18	16.6
7	3.91/3.92	72.7				
C*H*CO	4.99	99.9				
*C*OOH		173.7				
C(O)CH_3			2.02	23.6		
C(O)CH_3				175.6		
OCH_2−			3.67/4.02	69.8		
−CH_2Si			0.87/0.98	18.5		
−Si(CH_3)$_3$			0.01	−1.1		

The product was characterized unambiguously by applying various NMR techniques such as H,H-COSY and TOCSY (H-assignment), inverse H,C-COSY (C-assignment), and ROESY (assignment of the carboxylic acid function in the 2-equatorial position of the 1,3-dioxane). The data are depicted in Table 1.

Analog **2** was found to be inactive in a competitive E-selectin binding assay up to 10 mM concentration, whereas sLe^x derivative **1b** showed an IC_{50} of approximately 1 mM.[22] Therefore, we assume that the position of the carboxylic acid in the bioactive sLe^x conformation differs decisively from the preferred solution conformation. Our results support the findings by

transfer NOE measurements.[13a,b] The design of new rigid sLe^x analogs should therefore be based on the bioactive conformation as determined by NMR.

Experimental Section

General.[23] Solvents were purified and dried according to standard procedures.[24] All reactions were carried out under an atmosphere of dry argon. The ^{1}H and ^{13}C NMR spectra were recorded at 298 K. The multiplicity of ^{13}C NMR spectra was determined by DEPT measurements. HR FAB mass spectometry was performed by adding lithium ions in the form of lithium chloride or lithium carbonate.

2-(Trimethylsilyl)ethyl β-D-Glucopyranoside (10). To a solution of **9**[15](10.0 g, 22.3 mmol) in 200 mL of methanol was added 45 mL of Amberlite IRA 910 (Fluka). After the mixture was stirred for 2 h at 25 °C, the ion exchange resin was filtered off and the solvent evaporated. Crude **10** (6.30 g, quant) was used without purification: ^{1}H-NMR (250 MHz, D_2O) δ 0.00 (9 H, s, $-$Si(CH_3)$_3$), 1.00 (2 H, m, OCH$_2$CH_2Si(CH$_3$)$_3$), 3.21 (1 H, t, 8.5 Hz, *H*-2), 3.31 (3 H, m, *H*-3, *H*-4, *H*-5), 3.69 (1 H, dd, 12.0/5.0 Hz, *H*-6$_a$), 3.73 (1 H, ddd, 12.0/10.0/6.0 Hz, OCH_aH$_b$CH$_2$Si(CH$_3$)$_3$), 3.89 (1 H, dd, 12.0/1.5 Hz, *H*-6$_b$), 4.01 (1 H, ddd, 12.0/10.0/6.0 Hz, OCH$_a$$H_bCH_2$Si(CH$_3$)$_3$), 4.44 (1 H, d, 8.5 Hz, *H*-1); ^{13}C-NMR (62.5 MHz, D_2O) δ 0.0 (3 C, p), 20.1 (s), 63.2 (s), 70.9 (s), 72.1 (t), 75.7 (t), 78.4 (2 C, t), 104.1 (t).

2-(Trimethylsilyl)ethyl 4,6-*O*-Benzylidene-β-D-glucopyranoside (11). A suspension of **10** (20.3 g, 72.5 mmol), benzaldehyde dimethyl acetal (14.7 g, 96.6 mmol), and *p*-toluenesulfonic acid (0.70 g, 4.05 mmol) in 270 mL of acetonitrile was stirred for 1 h at 25 °C. Additional benzaldehyde dimethyl acetal (2.20 g, 14.5 mmol) was added and stirring continued for 2 h. TLC (ether/methanol 99:1) indicated almost complete consumption of **10**. Chloroform (400 mL) was added followed by extraction with saturated $NaHCO_3$ (3 × 150 mL) and brine (2 × 100 mL). The organic layer was dried with Na_2SO_4 and the solvent evaporated. The residue was suspended in pentane (600 mL) and stirred for 15 min. The solvent was filtered off and the residue washed carefully with additional pentane. The remaining colorless solid (**11**, 23.6 g, 89%) was used without further purification.

11: ^{1}H-NMR (250 MHz, $CDCl_3$) δ 0.02 (9 H, s, $-$Si(CH_3)$_3$), 0.99 (2 H, m, OCH$_2$CH_2Si(CH$_3$)$_3$), 2.58 (1 H, s (br), O*H*), 2.77 (1 H, s (br), O*H*), 3.38−3.64 (4 H, m, OCH_aH$_b$CH$_2$Si(CH$_3$)$_3$, *H*-2, *H*-4, *H*-5), 3.75 (1 H, t, 10.0 Hz, *H*-3), 3.81 (1 H, dd, 11.0/2.0 Hz, *H*-6$_a$), 3.97 (1 H, m, OCH_aH$_b$CH$_2$Si(CH$_3$)$_3$), 4.33 (1 H, dd, 11.0/4.5 Hz, *H*-6$_b$), 4.38 (1 H, d, 8.0 Hz, *H*-1), 5.50 (1 H, C*H*-Ph), 7.32−7.48 (5 H, m, Ar*H*); ^{13}C-NMR (62.5 MHz, $CDCl_3$) δ −1.4 (3 C, CH_3), 18.3 (CH_2), 66.3 (CH), 67.9 (CH_2), 68.7 (CH_2), 73.1 (CH), 74.6 (CH), 80.6 (CH), 101.9 (CH), 102.6 (CH), 126.2 (2 C, CH), 128.3 (2 C, CH), 129.3 (CH), 136.9 (C); MS/HR calcd for $C_{18}H_{29}O_6Si$ (M + H$^+$) 369.1733, found 369.1706.

2-(Trimethylsilyl)ethyl 2,3-Di-*O*-benzyl-4,6-*O*-benzylidene-β-D-glucopyranoside (12). To a solution of **11** (11.9 g, 32.2 mmol) in 100 mL of DMF was added oilfree NaH (4.63 g, 193 mmol) in small portions. The temperature was kept at approximately 20 °C. The suspension was stirred for 2 h and then cooled to 0 °C. A solution of benzyl bromide (13.2 g, 77.2 mmol) in 30 mL of DMF was added within 2 h. The mixture was stirred for 2 h at 25 °C. Additional benzyl bromide (1.38 g, 8.05 mmol) was added and stirring continued for 1 h. The reaction mixture was quenched at 0 °C with 30 mL of methanol/water 2:1. Water (150 mL) was added and the mixture extracted with ethyl acetate (3 × 150 mL). The organic layer was washed with water (3 × 100 mL) and dried over Na_2SO_4. The solvent was evaporated and the residue subjected to flash chromatography (SiO_2, eluted with diethyl ether/hexane 1:9 → 1:5) to yield 14.5 g (82%) of **12** as a colorless solid.

12: ^{1}H-NMR (250 MHz, $CDCl_3$) δ 0.02 (9 H, s, $-$Si(CH_3)$_3$), 1.01 (2 H, m, OCH$_2$CH_2Si(CH$_3$)$_3$), 3.32−3.44 (2 H, m, *H*-2, *H*-5), 3.60 (1 H, td, 9.5/8.0 Hz, OCH_aH$_b$CH$_2$Si(CH$_3$)$_3$), 3.65−3.80 (3 H, m, *H*-3, *H*-4, *H*-6a), 3.97 (1 H, m, OCH_aH$_b$CH$_2$Si(CH$_3$)$_3$), 4.33 (1 H, dd, 11.0/4.5 Hz, *H*-6$_b$), 4.48 (1 H, d, 8.0 Hz, *H*-1), 4.74 (1 H, d, 11.0 Hz, CH_2Ph), 4.77 (1 H, d, 11.0 Hz, CH_2Ph), 4.88 (2 H, d, 11.0 Hz, CH_2Ph), 5.54 (1 H, C*H*Ph), 7.22−7.48 (15 H, m, Ar*H*); ^{13}C-NMR (62.5 MHz, $CDCl_3$) δ −1.4 (3 C, CH_3), 18.6 (CH_3), 66.0 (CH), 68.1 (CH_2), 68.8 (CH_2), 75.1 (CH_2), 75.4 (CH_2), 80.9 (CH), 81.5 (CH), 82.3 (CH), 101.1 (CH), 103.7 (CH), 126.0−128.9 (9 signals, CH), 137.3 (C), 129.3 (CH), 138.4 (C), 138.5 (C); MS (CI) 566 (M + NH$_4^+$).

2-(Trimethylsilyl)ethyl 2,3-Di-*O*-benzyl-β-D-glucopyranoside (13). A suspension of **12** (14.5 g, 26.4 mmol) in 200 mL of methanol and 71 mL of 0.5 M HCl was heated under reflux for 2 h. The clear solution was diluted with 250 mL of methanol and cooled to 0 °C followed by the slow addition of $NaHCO_3$ (9.0 g). The solvent was removed in vacuo and the residue partitioned in $CHCl_3$/water (500 mL/250 mL). The aqueous layer was extracted with chloroform (2 × 150 mL), and the combined organic extracts were washed with brine (200 mL) and dried over Na_2SO_4. After removal of the solvent, **13** (12.1 g, quant) was isolated as a colorless solid. The crude material was used without further purification.

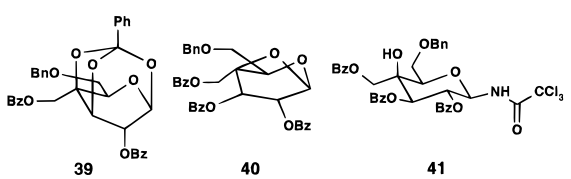
13: ^{1}H-NMR (250 MHz, $CDCl_3$) δ 0.02 (9 H, s, $-$Si(CH_3)$_3$), 1.00 (2 H, m, OCH$_2$CH_2Si(CH$_3$)$_3$), 2.03 (1 H, t, 6.5 Hz, C$_6$-O*H*), 2.27 (1 H, s (br), C$_4$-O*H*), 3.25−3.98 (8 H, m), 4.43 (1 H, d, 7.5 Hz, *H*-1), 4.63 (1 H, d, 11.0 Hz, CH_2Ph), 4.70 (1 H, d, 11.0 Hz, CH_2Ph), 4.94 (2 H, d, 11.0 Hz, CH_2Ph), 7.25−7.37 (10 H, m, Ar*H*); ^{13}C-NMR (62.5 MHz, $CDCl_3$) δ −1.5 (3 C, CH_3), 18.6 (CH_3), 62.7 (CH_3), 67.9 (CH_2), 70.4 (CH), 74.7 (CH_2), 74.7 (CH), 75.2 (CH_2), 82.0 (CH), 83.9 (CH), 103.4 (CH), 127.8−128.6 (five signals, CH), 138.4 (C), 138.5 (C); MS (CI) 478 (M + NH$_4^+$).

2-(Trimethylsilyl)ethyl 2,3-Di-*O*-benzyl-6-*O*-(*tert*-butyldiphenylsilyl)-β-D-glucopyranoside (14). To a solution of **13** (12.0 g, 26.1 mmol) and imidazole (3.92 g, 57.6 mmol) in 80 mL of DMF was added at 25 °C *tert*-butyldiphenylsilyl chloride (7.14 g, 26.0 mmol) in 20 mL of DMF within 10 min. The mixture was stirred for 4 h followed by the addition of further *tert*-butyldiphenylsilyl chloride (0.50 g, 1.82 mmol) in 2 mL of DMF. After being stirred for 1 h, the solution was diluted with 1 L of ether, washed with water (4 × 400 mL) and brine (400 mL), and dried over Na_2SO_4. The solvent was removed to furnish **14** (18.5 g, quant) as a colorless oil. The crude material was used without further purification.

14: ^{1}H-NMR (250 MHz, $CDCl_3$) δ 0.02 (9 H, s, $-$Si(CH_3)$_3$), 1.03 (9 H, s, $-$Si(CH_3)$_3$), 1.03 (2 H, m, OCH$_2$CH_2Si(CH$_3$)$_3$), 2.59 (1 H, d, 2.0 Hz, C$_4$-O*H*), 3.33−3.67 (5 H, m, *H*-2, *H*-3, *H*-4, *H*-5, OCH_aH$_b$CH$_2$Si(CH$_3$)$_3$), 3.81−4.05 (3 H, m, *H*-6a, *H*-6b, OCH$_a$$H_bCH_2$Si(CH$_3$)$_3$), 4.41 (1 H, d, 7.0 Hz, *H*-1), 4.71 (1 H, d, 11.5 Hz, CH_2Ph), 4.74 (1 H, d, 11.5 Hz, CH_2Ph), 4.92 (1 H, d, 11.5 Hz, CH_2Ph), 4.97 (1 H, d, 11.5 Hz, CH_2Ph), 7.26−7.71 (20 H, m, Ar*H*); ^{13}C-NMR (62.5 MHz, $CDCl_3$) δ −1.4 (3 C, CH_3), 18.6 (CH_2), 19.2 (C), 26.8 (3C, CH_3), 64.5 (CH_2), 65.9 (CH_2), 67.4 (CH_2), 71.8 (CH), 74.8 (CH), 75.3 (CH), 82.0 (CH), 84.2 (CH), 103.1 (CH), 127.6−135.6 (11 signals, CH), 133.0 (C), 133.1 (C), 138.6 (C), 138.7 (C); MS (CI) 716 (M + NH$_4^+$).

2-(Trimethylsilyl)ethyl 2,3-Di-*O*-benzyl-6-*O*-(*tert*-butyldiphenylsilyl)-β-D-*xylo*-hexopyranosid-4-ulose (15). A solution of **14** (18.2 g, 26.0 mmol) in 265 mL of DMSO/acetic anhydride (10:7) was heated at 65 °C for 2 h. The solvents were removed in vacuo (0.1 mbar) at 50 °C. The residue was diluted with 1 L of ether, extracted with water (5 × 500 mL), and washed with brine (500 mL). The organic layer was dried

(21) In addition to the glycosylation product **42**, we isolated unprecedented orthoester **39** and 1,4-anhydrogalactose derivative **40**. When BF_3 etherate was added to a mixture of donor **32** and acceptor **26** we also obtained N-glycoside **41** in up to 40% yield and isolated much lower yields (10 −20%) of glycosylation product **42**. A mechanistic analysis will be published elsewhere.



39 40 41

(22) The biological testing was done at GlycoTech Corp., Rockville, MD 20850.

(23) See: Hafner, A.; Duthaler, R. O.; Marti, R.; Rihs, G.; Rothe-Streit, P.; Schwarzenbach, F. *J. Am. Chem. Soc.* **1992**, *114*, 2321.

(24) Perrin, D. D.; Armarego, W. L. F.; Perrin, D. R. *Purification of Laboratory Chemicals*; Pergamon Press: Oxford, 1980.

over Na_2SO_4 and the solvent removed in vacuo to give **15** (18.3 g, quant) as a colorless oil. The crude material was used without further purification.

15: ^{1}H-NMR (250 MHz, $CDCl_3$) δ 0.02 (9 H, s, $-Si(CH_3)_3$), 1.03 (9 H, s, $-Si(CH_3)_3$), 1.04 (2 H, m, $OCH_2CH_2Si(CH_3)_3$), 3.61 (1 H, m, $OCH_aH_bCH_2Si(CH_3)_3$), 3.70 (1 H, dd, 9.0/7.0 Hz, *H*-2), 3.87 (1 H, dd, 10.5/7.0 Hz, *H*-6a), 3.96−4.13 (5 H, m, *H*-3, *H*-4, *H*-5, *H*-6b, $OCH_aH_bCH_2Si(CH_3)_3$), 4.59 (1 H, d, 11.5 Hz, CH_2-Ph), 4.72 (1 H, d, 11.5 Hz, CH_2Ph), 4.75 (1 H, d, 7.0 Hz, *H*-1), 4.85 (1 H, d, 11.5 Hz, CH_2Ph), 4.88 (1 H, d, 11.5 Hz, CH_2Ph), 7.25−7.71 (20 H, m, Ar*H*); ^{13}C-NMR (62.5 MHz, $CDCl_3$) δ −1.4 (3 C, CH_3), 18.4 (CH_2), 19.2 (C), 26.7 (3C, CH_3), 62.2 (CH_2), 67.5 (CH_2), 73.7 (CH_2), 74.7 (CH_2), 78.1 (CH), 83.3 (CH), 83.6 (CH), 102.4 (CH), 127.7−135.6 (eight signals, CH), 133.0 (C), 133.4 (C), 137.5 (C), 138.1 (C), 201.6 (C); MS (CI) 714 ($M + NH_4^+$).

2-(Trimethylsilyl)ethyl 2,3-Di-*O*-benzyl-4-*C*-vinyl-6-*O*-(*tert*-butyldiphenylsilyl)-*β*-D-galactopyranoside (16). To a solution of **15** (5.71 g, 8.20 mmol) in THF was added at −78 °C within 2 h 32.8 mL of a 0.5 M solution of vinylmagnesium bromide (16.4 mmol) in THF. The clear solution becomes a brown suspension. After the mixture was stirred for 2 h at −78 °C, TLC (ether/hexane 1:3) indicated complete consumption of **15**. The reaction was quenched with 30 mL of phosphate buffer (pH 7), warmed to 25 °C, and diluted with 200 mL of ether. The aqueous layer was extracted with ether (2 × 100 mL), and the combined organic extracts were washed with brine (200 mL) and dried over Na_2SO_4. The solvent was removed and the residue subjected to flash chromatography (SiO_2, ether/hexane 1:5 → 1−3) to yield the C-4 epimer of **16** (0.20 g) and **16** (4.26 g, 72%).

16: ^{1}H-NMR (500 MHz, $CDCl_3$) δ 0.03 (9 H, s, $-Si(CH_3)_3$), 1.05 (9 H, s, $-Si(CH_3)_3$), 1.10 (2 H, m, $OCH_2CH_2Si(CH_3)_3$), 3.31 (1 H, s, C_4-O*H*), 3.32 (1 H, dd, 6.0/2.0 Hz, *H*-5), 3.36 (1 H, d, 9.0 Hz, *H*-3), 3.66 (1 H, td, 10.0/7.0 Hz, $OCH_aH_bCH_2Si(CH_3)_3$), 3.75 (1 H, t, 9.0 Hz, *H*-2), 3.87, (1 H, dd, 11.0/2.0 Hz, *H*-6a), 3.95 (1 H, dd, 11.0/6.0 Hz, *H*-6b), 4.15 (1H, td, 10.0/7.0 Hz, $OCH_aH_bCH_2Si(CH_3)_3$), 4.46 (1 H, d, 9.0 Hz, *H*-1), 4.62 (1 H, d, 11.0 Hz, CH_2Ph), 4.73 (1 H, d, 11.0 Hz, CH_2Ph), 4.76 (1 H, d, 11.0 Hz, CH_2Ph), 4.99 (1 H, d, 11.0 Hz, CH_2Ph), 5.23 (1 H, dd, 10.0/3.0 Hz, $-CH=CH_aH_b$), 5.49 (1 H, dd, 17.0/3.0 Hz, $-CH=CH_aH_b$), 5.55 (1 H, dd, 17.0/10.0 Hz, $-CH=CH_aH_b$), 7.24−7.72 (20 H, m, Ar*H*); ^{13}C-NMR (62.5 MHz, C_6D_6) δ −0.4 (3 C, CH_3), 19.7 (CH_2), 20.3 (C), 27.9 (3C, CH_3), 64.3 (CH_2), 67.8 (CH_2), 75.9 (CH_2), 76.7 (CH_2), 77.6 (C), 79.0 (CH), 81.6 (CH), 84.2 (CH), 104.5 (CH), 117.2 (CH_2), 128.4−140.7 (11 signals, CH), 134.5 (C), 135.0 (C), 139.6 (C), 140.7 (C); MS/HR calcd for $C_{43}H_{56}O_6Si_2Li$ ($M + Li^+$) 731.3776, found 731.3776.

The configuration of C-4 was proven by NOE measurements.

2-(Trimethylsilyl)ethyl 2,3-di-*O*-benzyl-4-*C*-vinyl-6-*O*-(*tert*-butyldiphenylsilyl)-*β*-D-glucopyranoside (C-4 epimer of 16): ^{1}H-NMR (500 MHz, $CDCl_3$) δ 0.00 (9 H, s, $-Si(CH_3)_3$), 1.02 (9 H, s, $-Si(CH_3)_3$), 1.05 (2 H, m, $OCH_2CH_2Si(CH_3)_3$), 3.41 (1 H, dd, 10.0/8.0 Hz, *H*-2), 3.43 (1 H, s, C_4-O*H*), 3.58 (2 H, m, *H*-5, $OCH_aH_bCH_2Si(CH_3)_3$), 3.64 (1 H, d, 10.0 Hz, *H*-3), 3.71 (1 H, dd, 11.0/6.0 Hz, *H*-6a), 3.81 (1 H, dd, 11.0/6.0 Hz, *H*-6b), 3.96 (1H, td, 9.0/8.0 Hz, $OCH_aH_bCH_2Si(CH_3)_3$), 4.49 (1 H, d, 8.0 Hz, *H*-1), 4.71 (1 H, d, 11.0 Hz, CH_2Ph), 4.83 (1 H, d, 11.5 Hz, CH_2Ph), 4.87 (1 H, d, 11.0 Hz, CH_2Ph), 4.91 (1 H, d, 11.5 Hz, CH_2Ph), 5.46 (1 H, dd, 11.0/2.0 Hz, $-CH=CH_aH_b$), 5.62 (1 H, dd, 17.5/2.0 Hz, $-CH=CH_aH_b$), 6.12 (1 H, dd, 17.5/11.0 Hz, $-CH=CH_aH_b$), 7.28−7.72 (20 H, m, Ar-*H*); ^{13}C-NMR (62.5 MHz, $CDCl_3$) δ −1.4 (3 C, CH_3), 18.6 (CH_2), 19.0 (C), 26.7 (3C, CH_3), 63.7 (CH_2), 67.7 (CH_2), 75.1 (CH_2), 75.3 (CH_2), 75.5 (CH), 78.3 (C), 81.1 (CH), 86.0 (CH), 103.7 (CH), 117.3 (CH_2), 127.5−135.6 (15 signals, CH), 132.3 (C), 132.4 (C), 138.7 (C), 139.0 (C).

2-(Trimethylsilyl)ethyl 2,3-Di-*O*-benzyl-4-*C*-(hydroxymethyl)-6-*O*-(*tert*-butyldiphenylsilyl)-*β*-D-galactopyranoside (17). Ozone was bubbled through a solution of **16** (3.98 g, 5.50 mmol) in 200 mL of CH_2Cl_2 at −78 °C until TLC (ether/hexane 1:3) indicated complete consumption (∼40 min). Excess ozone was removed by bubbling argon through the mixture for 1 h. Methanol (15 mL) and $NaBH_4$ (0.42 g, 11.0 mmol) were added and stirring continued at −78 °C for 1 h. The mixture was quenched with 250 mL of phosphate buffer (pH 7) and warmed to 25 °C. The organic layer was extracted with phosphate buffer (3 × 100 mL), washed with brine (100 mL), and dried over Na_2SO_4. The solvent was removed and the residue subjected to flash chromatography (SiO_2, ether/hexane 1:3 → 1:1) to give **17** (3.16 g, 79%) as a colorless oil.

17: ^{1}H-NMR (250 MHz, $CDCl_3$) δ 0.02 (9 H, s, $-Si(CH_3)_3$), 1.00 (2 H, m, $OCH_2CH_2Si(CH_3)_3$), 1.02 (9 H, s, $-Si(CH_3)_3$), 1.55 (1 H, t, 6.5 Hz, C_7-O*H*), 3.28 (1 H, s, C_4-O*H*), 3.38 (1 H, t (br), 6.5 Hz, *H*-5), 3.50 (1 H, d, 9.5 Hz, *H*-3), 3.55 (3 H, m, OCH_aH_b-$CH_2Si(CH_3)_3$, *H*-7a, *H*-7b), 3.79 (1 H, dd, 9.5/8.0 Hz, *H*-2), 3.87, (1 H, dd, 11.5/4.0 Hz, *H*-6a), 4.00 (1H, m, $OCH_aH_bCH_2Si$-$(CH_3)_3$), 4.04 (1 H, dd, 11.5/5.0 Hz, *H*-6b), 4.33 (1 H, d, 8.0 Hz, *H*-1), 4.67 (1 H, d, 11.5 Hz, CH_2Ph), 4.72 (1 H, d, 11.5 Hz, CH_2-Ph), 4.93 (1 H, d, 11.5 Hz, CH_2Ph), 4.98 (1 H, d, 11.5 Hz, CH_2-Ph), 7.25−7.69 (20 H, m, Ar*H*); ^{13}C-NMR (62.5 MHz, $CDCl_3$) δ −1.4 (3 C, CH_3), 18.5 (CH_2), 19.0 (C), 26.7 (3C, CH_3), 62.8 (CH_2), 63.3 (CH_2), 67.2 (CH_2), 74.3 (CH), 75.0 (CH), 75.1 (C), 75.3 (CH), 78.3 (CH), 81.2 (CH), 103.2 (CH), 127.6−135.7 (11 signals, CH), 132.3 (C), 132.5 (C), 138.1 (C), 138.8 (C); MS (FAB/EI) 727 ($M - H^-$).

2-(Trimethylsilyl)ethyl 4-*C*-Hydroxymethyl-6-*O*-(*tert*-butyldiphenylsilyl)-*β*-D-galactopyranoside (18). A solution of **17** (3.45 g, 4.74 mmol) in 70 mL of methanol containing three drops of acetic acid was hydrogenated in the presence of 350 mg of Pd/C (10%) at 50 °C for 24 h. Additional catalyst (100 mg) and a few drops of acetic acid were added, and the hydrogenation continued until starting material and monodebenzylated intermediates were completely transformed into product **18**. The catalyst was filtered off and the solvent removed in vacuo to yield crude **18** (2.55 g, 98%), which was used without further purification.

18: ^{13}C-NMR (62.5 MHz, $CDCl_3$) δ −1.4 (3 C, CH_3), 18.2 (CH_2), 19.0 (C), 26.7 (3C, CH_3), 62.9 (CH_2), 63.3 (CH_2), 67.0 (CH_2), 72.3 (CH), 73.3 (CH), 74.7 (C), 75.1 (CH), 102.2 (CH), 127.8 (2 C, CH), 127.9 (2 C, CH), 129.9 (CH), 130.0 (CH), 132.4 (C), 132.6 (C), 135.6 (2 C, CH), 135.7 (2 C, CH).

(2*S*,5*S*,6*R*,8*R*,9*R*,10*R*)-6-[[(*tert*-Butyldiphenylsilyl)oxy]-methyl]-2-(furan-2-yl)-8-[2-(trimethylsilyl)ethoxy]-1,3,7-trioxabicyclo[4.4.0]decane-5,9-diol (19a) and (2*S*,5*R*,6*R*,8*R*,9*R*,10*R*)-6-[[(*tert*-Butyldiphenylsilyl)oxy]methyl]-2-(furan-2-yl)-8-[2-(trimethylsilyl)ethoxy]-1,3,7-trioxaspiro-[4.5]decane-9,10-diol (19b). A solution of **18** (650 mg, 1.19 mmol), furaldehyde diethyl acetal (222 mg, 1.31 mmol), and pyridinium *p*-toluenesulfonate (30.0 mg, 0.12 mmol) in 30 mL of benzene was heated at 60° C for 1 h. TLC (ether/hexane 4:1) indicated complete consumption and formation of two products. The reaction was quenched with 5 mL of 10% $NaHCO_3$, the layers were separated, the aqueous layer was extracted with benzene (10 mL), and the combined organic layers were washed with brine (15 mL) and dried over Na_2SO_4. The solvent was removed and the residue subjected to flash chromatography (SiO_2, ether/hexane 1:1 → 3:1). Six-membered ring acetal **19a** (298 mg, 40%) eluted first followed by five-membered ring acetal **19b** (297 mg, 40%).

19a: ^{1}H-NMR (500 MHz, $CDCl_3$) δ 0.02 (9 H, s, $-Si(CH_3)_3$), 1.00 (2 H, m, $OCH_2CH_2Si(CH_3)_3$), 1.06 (9 H, s, $-Si(CH_3)_3$), 2.35 (1 H,s (br), C_2-O*H*), 3.22 (1 H, s, C_4-O*H*), 3.41 (1 H, t (br), 5.5 Hz, *H*-5), 3.55 (1 H, ddd, 11.5/9.5/5.5 Hz, $OCH_aH_bCH_2Si(CH_3)_3$), 3.72 (1 H, d, 10.0 Hz, *H*-3), 3.76, (1 H, dd, 11.0/4.5 Hz, *H*-6a), 3.83 (1 H, d, 11.5 Hz, *H*-7axial), 3.87 (1 H, dd, 10.0/8.0 Hz, *H*-2), 3.97 (1 H, ddd, 11.5/9.5/5.5 Hz, $OCH_aH_bCH_2Si(CH_3)_3$), 4.09 (1 H, dd, 11.0/7.0 Hz, *H*-6b), 4.31 (1 H, d, 11.5 Hz, *H*-7equatorial), 4.32 (1 H, d, 8.0 Hz, *H*-1), 5.72 (1 H, s, C*H*-Fu), 6.39 (1 H, m, Fu(*H*-4)), 6.52 (1 H, m, Fu(*H*-3)), 7.38−7.70 (11 H, Ar*H*, Fu(*H*-5)); ^{13}C-NMR (62.5 MHz, $CDCl_3$) δ −1.4 (3 C, CH_3), 18.2 (CH_2), 19.1 (C), 26.8 (3C, CH_3), 61.8 (CH_2), 67.2 (CH_2), 67.9 (C), 69.2 (CH), 72.9 (CH_2), 74.9 (CH), 82.8 (CH), 96.6 (CH), 102.5 (CH), 108.5 (CH), 110.3 (CH), 127.8 (4 C, CH), 129.9 (2 C, CH), 132.7 (C), 132.9 (C), 135.6 (4 C, CH), 142.9 (CH), 149.4 (C); MS/HR calcd for $C_{33}H_{46}O_8Si_2Li$ ($M + Li^+$) 633.2891, found 633.2890.

19b: ^{1}H-NMR (500 MHz, $CDCl_3$) δ 0.01 (9 H, s, $-Si(CH_3)_3$), 1.00 (2 H, m, $OCH_2CH_2Si(CH_3)_3$), 1.05 (9 H, s, $-Si(CH_3)_3$), 2.48 (1 H,s (br), C_3-O*H*), 2.65 (1 H, s (br), C_3-O*H*), 3.44 (1 H, d (br), 10.0 Hz, *H*-3), 3.48 (2 H, m, *H*-5, *H*-6a), 3.58 (1 H, m, OCH_aH_b-$CH_2Si(CH_3)_3$), 3.65 (1 H, dd, 10.0/7.5 Hz, *H*-2), 3.77 (1 H, d, 8.5 Hz, *H*-7a), 4.05 (2 H,m, *H*-6b, $OCH_aH_bCH_2Si(CH_3)_3$), 4.12 (1 H, d, 8.5 Hz, *H*-7b), 4.27 (1 H, d, 7.5 Hz, *H*-1), 5.90 (1 H, s,

C*H*-Fu), 6.22 (2 H, m, Fu(*H*-3), Fu(*H*-4)), 7.19 (1 H, m, Fu (H-5)), 7.33−7.73 (10 H, Ar*H*); ^{13}C-NMR (62.5 MHz, $CDCl_3$) δ −1.4 (3 C, CH_3), 18.2 (CH_2), 19.2 (C), 26.8 (3C, CH_3), 62.9 (CH_2), 67.1 (CH_2), 67.6 (CH_2), 73.5 (CH), 74.2 (CH), 78.9 (CH), 81.8 (C), 100.0 (CH), 101.8 (CH), 109.9 (CH), 110.0 (CH), 127.7 (4 C, CH), 129.6 (CH), 129.7 (CH), 133.4 (C), 133.9 (C), 135.6 (2 C, CH), 135.7 (2 C, CH), 143.2 (CH), 148.8 (C); MS/HR calcd for $C_{33}H_{46}O_8Si_2Li$ (M + Li^+) 633.2891, found 633.2901.

(2*S*,5*S*,6*R*,8*R*,9*R*,10*R*)-6-(Hydroxymethyl)-2-(furan-2-yl)-8-[2-(trimethylsilyl)ethoxy]-1,3,7-trioxabicyclo[4.4.0]-decane-5,9-diol (22). A solution of **19a** (390 mg, 0.62 mmol) and tetrabutylammonium fluoride (393 mg, 1.25 mmol) in 8 mL of THF was stirred at 25 °C for 3 h. Silica gel (1 g) was added and the solvent removed in vacuo. The residue was subjected to flash chromatography (SiO_2, ether/methanol 98:2) to give **22** (240 mg, quant) as a colorless solid.

22: ^{1}H-NMR (250 MHz, $CDCl_3$) δ −0.10 (9 H, s, −Si(CH_3)$_3$), 0.90 (2 H, m, OCH$_2$CH_2Si(CH$_3$)$_3$), 2.11 (1 H, t, 10.0 Hz, C$_6$-O*H*), 2.32 (1 H,s (br), C$_2$-O*H*), 3.21 (1 H, s, C$_4$-O*H*), 3.35 (1 H, dd, 6.5/5.5 Hz, *H*-5), 3.49 (1 H, ddd, 10.5/9.0/6.5 Hz, OCH_aH$_b$-CH$_2$Si(CH$_3$)$_3$), 3.61 (1 H, d, 9.5 Hz, *H*-3), 3.65, (1 H, m, *H*-6a), 3.71 (1 H, d, 11.5 Hz, *H*-7axial), 3.80 (2 H, m, *H*-2, *H*-6b), 3.92 (1 H, d, 11.5 Hz, *H*-7equatorial), 3.93 (1 H, ddd, 10.5/9.0/6.5 Hz, OCH_aH$_b$CH$_2$Si(CH$_3$)$_3$), 4.28 (1 H, d, 7.5 Hz, *H*-1), 5.58 (1 H, s, C*H*-Fu), 6.25 (1 H, m, Fu(*H*-4)), 6.40 (1 H, m, Fu(*H*-3)), 7.30 (1 H, Fu(*H*-5)); ^{13}C-NMR (62.5 MHz, $CDCl_3$) δ −1.4 (3 C, CH_3), 18.2 (CH_2), 60.6 (CH_2), 67.6 (CH_2), 68.0 (C), 69.2 (CH), 72.3 (CH_2), 74.4 (CH), 82.7 (CH), 96.8 (CH), 102.8 (CH), 108.7 (CH), 110.3 (CH), 143.0 (CH), 149.1 (C).

(2*S*,5*S*,6*R*,8*R*,9*R*,10*R*)-6-[(Benzoyloxy)methyl]-2-(furan-2-yl)-8-[2-(trimethylsilyl)ethoxy]-9-(benzoyloxy)-1,3,7-trioxabicyclo[4.4.0]decan-5-ol (23). To a solution of **22** (660 mg, 1.70 mmol) in 7 mL of pyridine were added at 0 °C benzoyl chloride (956 mg, 6.80 mmol) and 4-(dimethylamino)pyridine (83 mg, 0.68 mmol). The mixture was warmed to 25 °C and stirred for 16 h. Ether (100 mL) was added followed by extraction with 0.1 M HCl (5 × 25 mL) and 10% $NaHCO_3$ (3 × 25 mL). The organic layer was washed with brine (50 mL) and dried over Na_2SO_4. The solvent was removed and the residue stirred with 30 mL of pentane for 15 min. Filtration followed by pentane washings afforded **23** (950 mg, 94%) as a colorless solid.

23: ^{1}H-NMR (250 MHz, $CDCl_3$) δ 0.01 (9 H, s, −Si(CH_3)$_3$), 0.97 (2 H, m, OCH$_2$CH_2Si(CH$_3$)$_3$), 3.58 (1 H, d, 0.5 Hz, C$_4$-O*H*), 3.67 (1 H, td, 10.0/6.5 Hz, OCH_aH$_b$CH$_2$Si(CH$_3$)$_3$), 3.93 (1 H, t (br), 6.0 Hz, *H*-5), 4.04 (1 H, d, 11.5 Hz, *H*-7axial), 4.11 (1 H, td, 10.0/6.5 Hz, OCH_aH$_b$CH$_2$Si(CH$_3$)$_3$), 4.12 (1 H, d, 10.0 Hz, *H*-3), 4.34 (1 H, d, 11.5 Hz, *H*-7equatorial), 4.74 (2 H, m, *H*-6a, *H*-6b), 4.81 (1 H, d, 8.0 Hz, *H*-1), 5.64 (1 H, dd, 10.0/8.0 Hz, *H*-2), 5.75 (1 H, s, C*H*-Fu), 6.40 (1 H, m, Fu(*H*-4)), 6.54 (1 H, m, Fu(*H*-3)), 7.45 (1 H, Fu(*H*-5)), 7.49−8.17 (10 H, m, Ar-*H*); ^{13}C-NMR (62.5 MHz, $CDCl_3$) δ −1.4 (3 C, CH_3), 18.0 (CH_2), 62.3 (CH_2), 67.3 (CH_2), 68.2 (C), 70.1 (CH), 72.4 (CH_2), 72.5 (CH), 81.2 (CH), 96.9 (CH), 100.8 (CH), 108.5 (CH), 110.4 (CH), 128.4 (2 C, CH), 128.7 (2 C, CH), 129.6 (C), 129.7 (2 C, CH), 129.9 (2 C, CH), 130.1 (C), 133.1 (CH), 133.5 (CH), 142.9 (CH), 149.2 (C), 165.2 (C), 166.3 (C); MS/HR calcd for $C_{31}H_{36}O_{10}SiLi$ (M + Li^+) 602.2238, found 603.2224.

(2*S*,5*S*,6*R*,8*R*,9*R*,10*R*)-6-[(Benzoyloxy)methyl]-2-(methoxycarbonyl)-8-[2-(trimethylsilyl)ethoxy]-9-(benzoyloxy)-1,3,7-trioxabicyclo[4.4.0]decan-5-ol (24). Ozone was bubbled through a solution of **23** (72.0 mg, 0.12 mmol) in 6 mL of methanol/CH_2Cl_2 1:1 at −78 °C for approximately 2 min. TLC (ether/hexane 4:1) indicated complete consumption. Excess ozone was removed by bubbling argon through the mixture for 30 min. Then, hydrogen peroxide (0.1 mL of a 30% solution) was added at −78 °C and the mixture warmed to 25 °C and stirred for 3 h. The solvents were removed in vacuo and the residue dissolved in ether (10 mL). The mixture was cooled to 0 °C, and a solution of diazomethane in ether was added dropwise until the yellow color remained. Stirring was continued for 1 h at 25 °C. The solvent was removed and the residue subjected to flash chromatography (SiO_2, ether/hexane 2:1) to yield **24** (57.0 mg (80%) as a colorless foam.

24: ^{1}H-NMR (250 MHz, $CDCl_3$) δ −0.10 (9 H, s, −Si(CH_3)$_3$), 0.88 (2 H, m, OCH$_2$CH_2Si(CH$_3$)$_3$), 3.48 (1 H, s, C$_4$-O*H*), 3.56 (1 H, m, OCH_aH$_b$CH$_2$Si(CH$_3$)$_3$), 3.76 (3 H, s, −CO$_2$CH_3), 3.80 (1 H, t (br), 6.0 Hz, *H*-5), 3.87 (1 H, d, 11.5 Hz, *H*-7axial), 3.96 (1 H, d, 10.0 Hz, *H*-3), 3.98 (1 H, m, OCH_aH$_b$CH$_2$Si(CH$_3$)$_3$), 4.26 (1 H, d, 11.5 Hz, *H*-7equatorial), 4.62 (2 H, m, *H*-6a, *H*-6b), 4.70 (1 H, d, 8.0 Hz, *H*-1), 5.10 (1 H, s, C*H*CO$_2$CH$_3$), 5.52 (1 H, dd, 10.0/8.0 Hz, *H*-2), 7.40−8.07 (10 H, m, Ar*H*); ^{13}C-NMR (62.5 MHz, $CDCl_3$) δ −1.6 (3 C, CH_3), 18.8 (CH_2), 52.9 (CH_3), 62.0 (CH_2), 67.2 (CH_2), 68.2 (C), 69.8 (CH), 72.2 (CH_2), 72.3 (CH), 81.0 (CH), 97.0 (CH), 100.6 (CH), 128.3 (2 C, CH), 128.5 (2 C, CH), 129.4 (C), 129.6 (2 C, CH), 129.8 (C), 129.9 (2 C, CH), 133.0 (CH), 133.4 (CH), 164.8 (C), 165.2 (C), 166.2 (C); MS/HR calcd for $C_{29}H_{36}O_{11}SiLi$ (M + Li^+) 595.2187, found 595.2195.

(2*S*,5*S*,6*R*,8*R*,9*R*,10*R*)-2-Carboxy-5,9-bis(benzoyloxy)-6-[(benzoyloxy)methyl]-1,3,7-trioxabicyclo[4.4.0]dec-8-yl] Trichloroacetimidate (25). A solution of **24** (397 mg, 0.67 mmol) in 12 mL of CH_2Cl_2/trifluoroacetic acid 1:1 was stirred at 0 °C for 1 h. TLC (ethyl acetate/hexane 2:1) indicated complete consumption and the formation of two products. The mixture was diluted with 25 mL of ethyl acetate and 40 mL of toluene and evaporated under reduced pressure (bath temperature 35 °C). The residue was coevaporated with toluene (5 × 40 mL). The remaining colorless foam was dissolved in CH_2Cl_2 (10 mL) followed by the addition of trichloroacetonitrile (144 mg, 1.00 mmol) and cesium carbonate (107 mg, 0.33 mmol). The mixture was stirred for 16 h at 25 °C and filtered, the solvent removed in vacuo, and the residue subjected to flash chromatography (SiO_2, ethyl acetate/hexane 1:2) to yield **25** (225 mg, 54%) as a colorless foam.

25: ^{1}H-NMR (250 MHz, $CDCl_3$) δ 3.55 (1 H, s, C$_4$-O*H*), 3.80 (3 H, s, −CO$_2$CH_3), 4.01 (1 H, d, 11.5 Hz, *H*-7axial), 4.25 (1 H, d, 11.5 Hz, *H*-7equatorial), 4.26 (1 H, t (br), 6.0 Hz, *H*-5), 4.45 (1 H, d, 10.0 Hz, *H*-3), 4.51 (1 H, dd, 11.5/6.5 Hz, *H*-6a), 4.63 (1 H, dd, 11.5/6.5 Hz, *H*-6b), 5.26 (1 H, s, C*H*CO$_2$CH$_3$), 5.77 (1 H, dd, 10.0/3.5 Hz, *H*-2), 6.75 (1 H, d, 3.5 Hz, *H*-1), 7.38−8.06 (10 H, m, Ar*H*), 8.57 (1 H, s, =N*H*).

2-(Trimethylsilyl)ethyl 2,3-Di-*O*-benzoyl-4,6-*O*-benzylidene-*β*-D-glucopyranoside (33). To a solution of **22** (6.25 g, 17.0 mmol) in 60 mL of pyridine was added at 0 °C benzoyl chloride (9.56 g, 68.0 mmol) and 4-(dimethylamino)-pyridine (0.86 g, 6.80 mmol). The mixture was warmed to 25 °C and stirred for 2 h. Ether (1 L) was added followed by extraction with 0.1 M HCl (5 × 250 mL) and 10% $NaHCO_3$ (3 × 250 mL). The organic layer was washed with brine (500 mL) and dried over Na_2SO_4. The solvent was removed and the residue stirred with 500 mL of pentane for 15 min. Filtration followed by pentane washings afforded **33** (9.35 g, 96%) as a clorless solid.

33: ^{1}H-NMR (250 MHz, $CDCl_3$) δ −0.10 (9 H, s, −Si(CH_3)$_3$), 0.87 (2 H, m, OCH$_2$CH_2Si(CH$_3$)$_3$), 3.57 (1 H, m, OCH_aH$_b$CH$_2$-Si(CH$_3$)$_3$), 3.67 (1 H, td, 6.5/5.0 Hz, *H*-5), 3.86 (1 H, t, 10.0 Hz, *H*-6a), 3.89 (1 H, t, 9.5 Hz, *H*-4), 3.97 (1 H, m, OCH_aH$_b$CH$_2$-Si(CH$_3$)$_3$), 4.74 (1 H, dd, 10.5/5.0 Hz, *H*-6b), 4.88 (1 H, d, 7.5 Hz, *H*-1), 5.44 (1 H, dd, 9.5/8.0 Hz, *H*-2), 5.52 (1 H, s, C*H*-Ph), 5.74 (1 H, d, 9.5 Hz, *H*-3), 7.29−8.00 (15 H, m, Ar-*H*); ^{13}C-NMR (62.5 MHz, $CDCl_3$) δ −1.5 (3 C, CH_3), 18.1 (CH_2), 66.6 (CH), 67.3 (CH_2), 68.0 (CH_2), 68.7 (CH_2), 72.2 (CH), 72.6 (CH), 78.9 (CH), 101.2 (CH), 101.4 (CH), 126.1−133.1 (eight signals, CH, C), 136.8 (C), 165.2 (C), 165.6 (C); MS (CI) 594 (M + NH_4^+).

2-(Trimethylsilyl)ethyl 2,3-Di-*O*-benzoyl-6-*O*-benzyl-*β*-D-glucopyranoside (34). Compound **33** (8.06 g, 14.0 mmol), $NaCNBH_4$ (8.82 g, 140 mmol), and molecular sieves (4 Å, powdered, 8.0 g) were suspended in 200 mL of THF at 0 °C. A saturated solution of HCl in ether was added dropwise and the reaction carefully monitored by TLC (ether/hexane 2:1). After complete consumption of **33**, the mixture was filtered, the residue was washed with ether (2 × 100 mL), and the combined organic layers were extracted with phosphate buffer (pH 7, 2 × 300 mL), washed with brine (300 mL), and dried over Na_2SO_4. The solvent was removed in vacuo, and the residue was subjected to flash chromatography (SiO_2, ether/hexane 1:1) to yield **34** (7.56 g, 93%) as a colorless solid.

34: ^{1}H-NMR (500 MHz, $CDCl_3$) δ −0.04 (9 H, s, −Si(CH_3)$_3$), 0.90 (2 H, m, OCH$_2$CH_2Si(CH$_3$)$_3$), 3.27 (1 H, d, 3.5 Hz, C$_4$-O*H*), 3.59 (1 H, m, OCH_aH$_b$CH$_2$Si(CH$_3$)$_3$), 3.71 (1 H, dt, 9.0/4.5 Hz, *H*-5), 3.87 (2 H, m, *H*-6a, *H*-6b), 3.96 (1 H, td, 9.0/3.5 Hz, *H*-4), 4.03 (1 H, m, OCH_aH$_b$CH$_2$Si(CH$_3$)$_3$), 4.62 (1 H, d, 12.0 Hz, −CH_2Ph), 4.66 (1 H, d, 12.0 Hz, −CH_2Ph), 4.71 (1 H, d, 7.5

Hz, *H*-1), 5.44 (2 H, m, *H*-2, *H*-3), 7.30−8.00 (15 H, m, Ar*H*); ^{13}C-NMR (62.5 MHz, $CDCl_3$) δ −1.5 (3 C, CH_3), 18.0 (CH_2), 67.5 (CH_2), 70.2 (CH_2), 71.3 (CH), 71.5 (CH), 73.8 (CH_2), 74.5 (CH), 76.9 (CH), 100.5 (CH), 127.7−133.4 (nine signals, CH), 129.0 (C), 129.6 (C), 137.7 (C), 165.2 (C), 167.3 (C); MS (CI) 613 ($M + Cl^-$), 578 (M^-).

2-(Trimethylsilyl)ethyl 2,3-Di-*O*-benzoyl-6-*O*-benzyl-*β*-D-*xylo*-hexopyranosid-4-ulose (35). A suspension of **34** (4.49 g, 7.75 mmol), 1.5 g of P_2O_5, and 3 mL of DMSO in 18 mL of DMF was heated at 50 °C for 2 h. TLC (acetone/hexane 1:3) indicated complete consumption of **34**. Phosphate buffer (pH 7, 600 mL) was added and the mixture extracted with ether (4 × 250 mL). The combined organic layers were extracted with water (4 × 250 mL), washed with brine (250 mL), and dried over Na_2SO_4. The solvent was removed in vacuo to give **35** (4.50 g) as a yellow oil. Crude **35** was used without further purification.

35: ^{1}H-NMR (250 MHz, $CDCl_3$) δ 0.00 (9 H, s, −Si(C*H*$_3$)$_3$), 0.95 (2 H, m, OCH$_2$C*H*$_2$Si(CH$_3$)$_3$), 3.72 (1 H, m, OC*H*$_a$H$_b$CH$_2$-Si(CH$_3$)$_3$), 3.81 (1 H, dd, 11.0/7.0 Hz, *H*-6a), 4.06 (1 H, dd, 11.0/3.0 Hz, *H*-6b), 4.09 (1 H, m, OC*H*$_a$H$_b$CH$_2$Si(CH$_3$)$_3$), 4.49 (1 H, dd, 7.0/3.0 Hz, *H*-5), 4.63 (1 H, d, 12.0 Hz, −C*H*$_2$Ph), 4.68 (1 H, d, 12.0 Hz, −C*H*$_2$Ph), 5.17 (1 H, d, 6.0 Hz, *H*-1), 5.72 (1 H, dd, 9.0/6.0 Hz, *H*-2), 5.88 (1 H, d, 9.0 Hz, *H*-3), 7.30−8.10 (15 H, m, Ar*H*); ^{13}C-NMR (62.5 MHz, $CDCl_3$) δ −1.4 (3 C, CH_3), 17.9 (CH_2), 67.6 (CH_2), 68.3 (CH_2), 73.7 (CH_2), 74.1 (CH), 75.9 (CH), 77.3 (CH), 99.8 (CH), 127.8−133.6 (7 signals, CH), 128.6 (C), 129.2 (C), 137.7 (C), 164.8 (C), 165.4 (C), 196.1 (C).

2-(Trimethylsilyl)ethyl 2,3-Di-*O*-benzoyl-3-*C*-vinyl-6-*O*-benzyl-*β*-D-galactopyranoside (36). To a solution of crude **35** (4.50 g) in 60 mL of THF was added at −78 °C vinylmagnesium bromide (19.4 mL of a 0.8 M solution in THF, 15.5 mmol) within 2 h. After 1 h of stirring, TLC (ether/hexane 1:1) indicated complete consumption of **35**. The reaction was quenched at −78 °C by addition of 50 mL of saturated NH_4Cl and warmed to 25 °C. The mixture was diluted with 300 mL of ether and transferred into a separation funnel. The aqueous layer was exracted with ether (2 × 50 mL), and the combined organic layers were washed with brine (200 mL) and dried over Na_2SO_4. Evaporation of the solvent furnished **36** (4.70 g) as a yellow/brown oil. Crude **36** was used without further purification.

36: ^{1}H-NMR (500 MHz, $CDCl_3$) δ −0.05 (9 H, s, −Si(C*H*$_3$)$_3$), 0.93 (2 H, m, OCH$_2$C*H*$_2$Si(CH$_3$)$_3$), 3.62 (1 H, s, C$_4$-O*H*), 3.63 (1 H, m, OC*H*$_a$H$_b$CH$_2$Si(CH$_3$)$_3$), 3.72 (1 H, t, 3.5 Hz, *H*-5), 3.85 (2 H, m, *H*-6a, *H*-6b), 4.09 (1 H, m, OC*H*$_a$H$_b$CH$_2$Si(CH$_3$)$_3$), 4.55 (1 H, d, 12.0 Hz, −C*H*$_2$Ph), 4.63 (1 H, d, 12.0 Hz, −C*H*$_2$Ph), 4.77 (1 H, d, 8.0 Hz, *H*-1), 5.23 (1 H, dd, 10.5/1.5 Hz, −CH=C*H*$_a$H$_b$), 5.45 (1 H, d, 10.0 Hz, *H*-3), 5.52 (1 H, dd, 17.0/1.5 Hz, −CH=CH$_a$*H*$_b$), 5.76 (1 H, dd, 17.0/10.5 Hz, −C*H*=CH$_a$H$_b$), 5.78 (1 H, dd, 10.0/8.0 Hz, *H*-2), 7.30−7.95 (15 H, m, Ar-*H*); ^{13}C-NMR (62.5 MHz, $CDCl_3$) δ −1.4 (3 C, CH_3), 18.0 (CH_2), 67.4 (CH_2), 69.5 (CH_2), 70.7 (CH), 74.0 (CH_2), 74.8 (CH), 76.1 (CH), 77.3 (C), 101.0 (CH), 118.0 (CH_2), 127.8−136.1 (13 signals, CH, C), 137.4 (C), 165.2 (C), 166.0 (C); MS/CI 604 (M^-).

The galactose configuration at C-4 was proven by NOE measurements (strong NOE between the axial ring protons H-3 and H-5 and the internal vinyl proton). The C-4 epimer of **36** could not be detected.

2-(Trimethylsilyl)ethyl 2,3-Di-*O*-benzoyl-4-*C*-(hydroxymethyl)-6-*O*-benzyl-*β*-D-galactopyranoside (37). Ozone was bubbled through a solution of crude **36** (4.70 g) in 200 mL of CH_2Cl_2 at −78 °C until TLC (acetone/hexane 1:2) indicated complete consumption (∼40 min). Excess ozone was removed by bubbling argon through the mixture for 1 h. Methanol (15 mL) and $NaBH_4$ (0.88 g, 23.3 mmol) were added, and stirring was continued at −78 °C for 3 h. The mixture was quenched with 500 mL of phosphate buffer (pH 7) and warmed to 25 °C. The organic layer was extracted with phosphate buffer (3 × 150 mL), washed with brine (150 mL), and dried over Na_2SO_4. The solvent was removed in vacuo to give **37** (4.60 g) as a yellow oil. Crude **37** was used without further purification.

37: ^{1}H-NMR (250 MHz, $CDCl_3$) δ −0.02 (9 H, s, −Si(C*H*$_3$)$_3$), 0.96 (2 H, m, OCH$_2$C*H*$_2$Si(CH$_3$)$_3$), 3.30 (1 H, s (br), C$_7$-O*H*), 3.55 (2 H, m, C$_4$-O*H*, *H*-5), 3.68 (1 H, td, 10.0/6.5 Hz, OC*H*$_a$H$_b$-CH$_2$Si(CH$_3$)$_3$), 4.02 (2 H, m, *H*-7a, *H*-7b), 4.10 (3 H, m, *H*-6a, *H*-6b,, OC*H*$_a$H$_b$CH$_2$Si(CH$_3$)$_3$), 4.61 (1 H, d, 12.0 Hz, −C*H*$_2$Ph), 4.76 (1 H, d, 8.0 Hz, *H*-1), 4.77 (1 H, d, 12.0 Hz, −C*H*$_2$Ph), 5.48 (1 H, d, 10.0 Hz, *H*-3), 5.94 (1 H, dd, 10.0/8.0 Hz, *H*-2), 7.30−8.07 (15 H, m, Ar*H*).

2-(Trimethylsilyl)ethyl 2,3-Di-*O*-benzoyl-4-*C*-[(benzoyloxy)methyl]-6-*O*-benzyl-*β*-D-galactopyranoside (38). To a solution of crude **37** (4.60 g) in 25 mL of pyridine was added at 0 °C benzoyl chloride (2.13 g, 15.2 mmol) and 4-(dimethylamino)pyridine (0.19 g, 1.52 mmol). The mixture was warmed to 25 °C and stirred for 2 h. Ether (200 mL) was added followed by extraction with 0.1 M HCl (5 × 100 mL) and 10% $NaHCO_3$ (3 × 100 mL). The organic layer was washed with brine (100 mL) and dried over Na_2SO_4. The solvent was removed and the residue subjected to flash chromatography (SiO_2, ethyl acetate/hexane 1:2) to yield **38** (3.86 g, 70%) as a colorless foam.

38: ^{1}H-NMR (250 MHz, $CDCl_3$) δ −0.02 (9 H, s, −Si(C*H*$_3$)$_3$), 0.95 (2 H, m, OCH$_2$C*H*$_2$Si(CH$_3$)$_3$), 3.68 (1 H, td, 10.0/6.5 Hz, OC*H*$_a$H$_b$CH$_2$Si(CH$_3$)$_3$), 3.95 (1 H, t (br), 3.0 Hz, *H*-5), 4.10 (3 H, m, *H*-6a, *H*-6b, OC*H*$_a$H$_b$CH$_2$Si(CH$_3$)$_3$), 4.31 (1 H, s, C$_4$-O*H*), 4.32 (1 H, d, 12.0 Hz, *H*-7a), 4.49 (1 H, 12.0 Hz, *H*-7b), 4.65 (1 H, d, 12.0 Hz, −C*H*$_2$Ph), 4.75 (1 H, d, 12.0 Hz, −C*H*$_2$Ph), 4.82 (1 H, d, 7.5 Hz, *H*-1), 5.81 (1 H, d, 9.5 Hz, *H*-3), 5.89 (1 H, dd, 9.5/7.5 Hz, *H*-2), 7.35−8.12 (20 H, m, Ar*H*); ^{13}C-NMR (62.5 MHz, $CDCl_3$) δ −1.5 (3 C, CH_3), 18.0 (CH_2), 63.2 (CH_2), 67.4 (CH_2), 69.6 (CH_2), 71.0 (CH), 72.3 (CH), 73.4 (CH), 74.2 (CH_2), 74.5 (C), 76.1 (CH), 77.3 (C), 101.0 (CH), 118.0 (CH_2), 127.8−136.1 (13 signals, CH, C), 137.4 (C), 165.2 (C), 166.0 (C); MS/HR calcd for $C_{40}H_{44}O_{10}SiLi$ ($M + Li^+$) 719.2864, found 719.2822.

2,3-Di-*O*-benzoyl-4-*C*-[(benzoyloxy)methyl]-6-*O*-benzyl-α-D-galactopyranosyl) trichloroacetimidate (32). A solution of **38** (3.12 g, 4.40 mmol) in 75 mL of CH_2Cl_2/trifluoroacetic acid 1:1 was stirred at 0 °C for 2 h. TLC (acetone/hexane 1:1) indicated complete consumption and the formation of two products. The mixture was diluted with 150 mL of ethyl acetate and 250 mL of toluene and evaporated under reduced pressure (bath temperature 35 °C). The residue was coevaporated with toluene (5 × 200 mL). The remaining yellow foam was dissolved in CH_2Cl_2 (100 mL) followed by the addition of trichloroacetonitrile (0.95 g, 6.60 mmol) and cesium carbonate (0.29 g, 0.88 mmol). The mixture was stirred for 4 h at 25 °C and filtered, the solvent removed in vacuo, and the residue subjected to flash chromatography (SiO_2, ethyl acetate/hexane/CH_2Cl_2 1:6:1) to yield **32** (2.69 g, 81%) as a colorless foam.

32: ^{1}H-NMR (250 MHz, $CDCl_3$) δ 3.96 (1 H, dd, 11.5/2.5 Hz, *H*-6a), 4.19 (1 H, dd, 11.5/2.5 Hz, *H*-6b), 4.29 (1 H, d, 11.5 Hz, *H*-7a), 4.44 (1 H, d, 11.5 Hz, *H*-7b), 4.45 (1 H, t, 6.0 Hz, *H*-5), 4.57 (1 H, d, 11.5 Hz, −C*H*$_2$Ph), 4.72 (1 H, d, 11.5 Hz, −C*H*$_2$-Ph), 4.88 (1 H, s, C$_4$-O*H*), 5.97 (1 H, dd, 10.0/3.5 Hz, *H*-2), 6.34 (1 H, d (br), 10.0 Hz, *H*-3), 6.88 (1 H, d, 3.5 Hz, *H*-1), 7.30−8.10 (20 H, m, Ar*H*), 8.55 (1 H, s, =N*H*); ^{13}C-NMR (62.5 MHz, $CDCl_3$) δ 62.7 (CH_2), 68.4 (CH), 69.3 (CH), 69.7 (CH_2), 70.8 (CH), 73.4 (CH), 74.6 (CH_2), 75.1 (C), 90.8 (C), 94.0 (CH), 127.9−133.4 (nine signals, CH), 128.8 (C), 129.0 (C), 129.2 (C) 136.3 (C), 160.3 (C), 165.5 (2 C, C), 166.1 (C).

2-(Trimethylsilyl)ethyl 6-*O*-Benzyl-2-deoxy-2-acetamido-3-*O*-(2,3,4-tri-*O*-benzyl-α-L-fucopyranosyl)-4-*O*-(2,3-di-*O*-benzoyl-4-*C*-[(benzoyloxy)methyl]-6-*O*-benzyl-*β*-D-galactopyranosyl)-*β*-D-glucopyranoside (42), (3*S*,4*R*,6*S*,7*R*,8*R*)-Benzoic Acid 7-(Benzoyloxy)-4-[(benzyloxy)methyl]-1-phenyl-2,5,9,10-tetraoxatricyclo[4.3.1.0^{3,8}]dec-3-yl Methyl Ester (39), 2,3-Di-*O*-benzoyl-4-*C*-[(benzoyloxy)methyl]-6-*O*-benzyl-1,4-anhydro-D-galactose (40), and 2,3-Di-*O*-benzoyl-4-*C*-[(benzoyloxy)methyl]-6-*O*-benzyl-*β*-D-galactopyranosyl) trichloroacetamide (41). To a solution of **26**[14] (192 mg, 0.231 mmol) in CH_2Cl_2 (1 mL) was added molecular sieves (4 Å, powdered, 500 mg) and the mixture stirred at 25 °C for 2 h followed by the addition of BF_3 etherate (33.0 mg, 0.23 mmol). A solution of **32** (350 mg, 0.46 mmol) in CH_2Cl_2 (3 mL) was added dropwise within 2 h and stirring continued for 30 min. The mixture was filtered and extracted with $NaHCO_3$ (2 × 25 mL). The solvent was removed and the residue subjected to flash chromatography (SiO_2, acetone/hexane 1:4 → 1:2) to yield (in order of elution) **39** and **40** (190 mg of a inseparable 10:1 mixture, 69% with respect to **32**), unconsumed **26** (75.0 mg, 40%), and **42** (180 mg, 55% with respect to **26**).

39: ^{1}H-NMR (250 MHz, $CDCl_3$) δ 3.77 (1 H, dd, 10.0/4.5 Hz,

H-6a), 3.99 (1 H, dd, 10.0/7.0 Hz, *H*-6b), 4.56 (2 H, m, *H*-7a, *H*-7b), 4.63 (2 H, m, $-CH_2Ph$), 4.72 (1 H, dd, 7.0/4.5 Hz, *H*-5), 4.97 (1 H, t, 2.0 Hz, *H*-3), 5.54 (1 H, dd, 3.0/2.0 Hz, *H*-2), 5.78 (1 H, dd, 3.0/2.0 Hz, *H*-1), 7.25−8.10 (20 H, m, Ar*H*); ^{13}C-NMR (62.5 MHz, $CDCl_3$) δ 64.0 (CH_2), 67.2 (CH), 69.5 (CH_2), 72.0 (CH), 73.5 (CH_2), 73.6 (CH), 82.1 (C), 94.3 (CH), 118.0 (C), 126.2−133.3 (11 signals, CH), 129.3 (C), 132.9 (C), 137.4 (C), 164.9 (C), 165.5 (C); MS/CI 594 (M^-).

40: ^{1}H-NMR (250 MHz, $CDCl_3$) δ 3.52 (1 H, dd, 10.5/5.0 Hz, *H*-6a), 3.63 (1 H, dd, 10.5/7.0 Hz, *H*-6b), 4.21 (1 H, dd, 7.0/5.0 Hz, *H*-5), 4.48 (2 H, m, *H*-7a, *H*-7b), 4.79 (1 H, d, 11.5 Hz, $-CH_2Ph$), 4.87 (1 H, d, 11.5 Hz, $-CH_2Ph$), 5.13 (1 H, dd, 2.5/1.5 Hz, *H*-2), 5.58 (1 H, d, 1.5 Hz, *H*-1), 5.98 (1 H, d, 2.5 Hz, *H*-3), 7.20−8.12 (20 H, m, Ar-*H*); ^{13}C-NMR (250 MHz, $CDCl_3$) δ 58.5 (CH_2), 68.4 (CH_2), 73.6 (CH_2), 76.5 (CH), 76.7 (CH), 82.4 (CH), 87.0 (C), 100.4 (CH), 127.7−133.6 (11 signals, CH), 129.6 (C), 129.8 (C), 129.9 (C), 137.2 (C), 165.3 (C), 165.5 (C), 165.8 (C); MS/CI (FAB) 595 ($M + H^+$).

41:[21] ^{1}H-NMR (250 MHz, $CDCl_3$) δ 4.04 (2 H, m, *H*-5, *H*-6a), 4.15 (1 H, dd, 12.0/2.5 Hz, *H*-6b), 4.31 (1 H, d, 12.0 Hz, *H*-7a), 4.41 (1 H, d, 12.0 Hz, *H*-7b), 4.57 (1 H, d, 11.5 Hz, $-CH_2Ph$), 4.71 (1 H, d, 11.5 Hz, $-CH_2Ph$), 4.75 (1 H, s, C_4-O*H*), 5.35 (1 H, t, 9.0 Hz, *H*-1), 5.84 (1 H, t, 9.5 Hz, *H*-2), 5.95 (1 H, d, 10.0 Hz, *H*-3), 7.30−8.08 (21 H, m, N*H*, Ar*H*); ^{13}C-NMR (62.5 MHz, $CDCl_3$) δ 62.9 (CH_2), 69.8 (CH_2), 70.3 (CH), 71.5 (CH), 74.4 (CH_2), 74.8 (CH), 75.0 (C), 80.9 (CH), 91.7 (C), 94.0 (CH), 127.4−136.3 (17 signals, CH, C), 162.3 (C), 165.6 (2 C, C), 167.2 (C); MS/CI 755 (M^-).

42: ^{1}H-NMR (500 MHz, $CDCl_3$) δ −0.04 (9 H, s, $-Si(CH_3)_3$), 0.73 (1 H, ddd, 15.0/10.0/6.0 Hz, $OCH_2CH_2Si(CH_3)_3$), 0.82 (1 H, ddd, 15.0/10.0/6.0 Hz, $OCH_2CH_2Si(CH_3)_3$), 1.20 (3 H, d, 7.0 Hz, 3 × *H*-6 Fuc), 1.86 (3 H, s, $C(O)CH_3$), 3.16 (1 H, td, 10.0/6.0 Hz, $OCH_aH_bCH_2Si(CH_3)_3$), 3.49 (1 H, q, 5.0 Hz, H-5 GlcNAc), 3.62 (1 H, d (br), 2.5 Hz, *H*-4 Fuc), 3.66 (1 H, dd, 10.5/5.0 Hz, *H*-6a GlcNac), 3.67 (1 H, td, 10.5/6.0 Hz, OCH_aH_b-$CH_2Si(CH_3)_3$), 3.71 (1 H, t, 3.0 Hz, *H*-5 Gal), 3.72 (1 H, dd, 10.5/5.0 Hz, *H*-6b GlcNAc), 3.75 (1 H, m, *H*-2 GlcNAc), 3.90 (1 H, dd, 10.5/2.5 Hz, *H*-3 Fuc), 3.94 (2 H, d, 3.0 Hz, *H*-6a Gal, *H*-6b Gal), 4.08 (1 H, s, C_4-O*H* Gal), 4.09 (2 H, m, *H*-3 GlcNAc, *H*-4 GlcNAc), 4.12 (1 H, dd, 10.5/4.0 Hz, *H*-2 Fuc), 4.23 (1 H, q (br), 7.0 Hz, *H*-5 Fuc), 4.28 (1 H, d, 12.0 Hz, *H*-7a Gal), 4.43 (1 H, d, 12.0 Hz, *H*-7b Gal), 4.43 (1 H, d, 7.0 Hz, *H*-1 GlcNac), 4.44 (1 H, d, 12.0 Hz, $-CH_2Ph$), 4.50 (1 H, d, 11.5 Hz, $-CH_2$-Ph), 4.52 (1 H, d, 12.0 Hz, $-CH_2Ph$), 4.57 (1 H, d, 11.5 Hz, $-CH_2Ph$), 4.60 (1 H, d, 11.5 Hz, $-CH_2Ph$), 4.69 (1 H, d, 11.5 Hz, $-CH_2Ph$), 4.77 (1 H, d, 12.0 Hz, $-CH_2Ph$), 4.79 (1 H, d, 11.5 Hz, $-CH_2Ph$), 4.82 (1 H, d, 12.0 Hz, $-CH_2Ph$), 4.88 (1 H, d, 7.5 Hz, *H*-1 Gal), 4.93 (1 H, d, 11.5 Hz, $-CH_2Ph$), 5.24 (1 H, d, 4.0 Hz, *H*-1 Fuc), 5.72 (1 H, d, 10.0 Hz, *H*-3 Gal), 5.76 (1 H, dd, 10.0/7.5 Hz, *H*-2 Gal), 6.12 (1 H, d, 8.0 Hz, N-*H* GlcNAc), 7.18−7.98 (40 H, m, Ar-*H*); ^{13}C-NMR (62.5 MHz, $CDCl_3$) δ −1.4 (3 C, CH_3), 16.8 (CH_3), 17.8 (CH_2), 23.2 (CH_3), 54.5 (CH), 63.3 (CH_2), 66.4 (CH_2), 66.9 (CH), 69.2 (CH_2), 69.5 (CH_2), 71.2 (CH), 72.0 (CH), 72.7 (CH_2), 73.0 (CH_2), 73.2 (CH), 73.3 (CH_2), 73.6 (CH), 74.1 (CH_2), 74.3 (C), 74.7 (CH), 74.8 (CH_2), 75.4 (CH), 76.7 (CH), 78.0 (CH), 79.2 (CH), 97.1 (CH), 99.1 (CH), 99.9 (CH), 127.2−133.2 (16 signals, CH), 128.9 (C), 129.2 (C), 129.3 (C), 136.6 (C), 138.0 (C), 138.7 (C), 138.8 (C), 138.9 (C), 165.6 (C), 165.7 (C), 166.8 (C), 169.9 (C), MS/HR calcd for $C_{82}H_{91}NO_{19}SiLi$ ($M + Li^+$) 1428.6115, found 1428.6131.

2-(Trimethylsilyl)ethyl 6-*O*-Benzyl-2-deoxy-2-acetamido-3-*O*-(2,3,4-tri-*O*-benzyl-α-L-fucopyranosyl)-4-*O*-[4-*C*-(hydroxymethyl)-6-*O*-benzyl-*β*-D-galactopyranosyl]-*β*-D-glucopyranoside (43). A solution of **42** (130.0 mg, 0.091 mmol) in absolute methanol (1.5 mL) was treated with NaOMe (0.01 mmol) at 25 °C for 3 h. Dowex W X 8 ion exchange resin (100 mg) was added and the resulting mixture stirred for 5 min. The solution was filtered, the resin washed with methanol, and the solvent removed in vacuo. The residue was subjected to flash chromatography (SiO_2, acetone/hexane 1:2 → 2:1) to yield **43** (85.0 mg, 84%) as a colorless foam.

43: ^{13}C-NMR (62.5 MHz, $CDCl_3$) δ −1.4 (3 C, CH_3), 16.8 (CH_3), 17.9 (CH_2), 23.2 (CH_3), 58.4 (CH), 63.3 (CH_2), 66.9 (CH_2), 67.0 (CH), 68.8 (CH_2), 68.9 (CH_2), 72.2 (CH_2), 72.4 (CH), 73.2 (CH_2), 73.3 (CH), 73.5 (CH_2), 73.6 (C), 73.9 (CH), 74.2 (CH_2), 74.5 (CH), 74.8 (CH_2), 75.1 (CH), 76.1 (CH), 76.8 (CH), 77.8 (CH), 79.8 (CH), 98.1 (CH), 99.0 (CH), 100.8 (CH), 127.2−128.6 (11 signals, CH), 137.3 (C), 138.2 (C), 138.6 (C), 138.8 (2 C, C), 170.8 (C); MS/EI 1132 ($M + Na^+$).

2-(Trimethylsilyl)ethyl 6-*O*-Benzyl-2-deoxy-2-acetamido-3-*O*-(2,3,4-tri-*O*-benzyl-α-L-fucopyranosyl)-4-*O*-[(2*S*,5*S*,6*R*,8*R*,9*R*,10*R*) 2-(furan-2-yl)-6-[(benzyloxy)methyl]-5,9-dihydroxy-1,3,7-trioxabicyclo[4.4.0]dec-8-yl]-*β*-D-glucopyranoside (44a) and 2-(Trimethylsilyl)ethyl 6-*O*-Benzyl-2-deoxy-2-acetamido-3-*O*-(2,3,4-tri-*O*-benzyl-α-L-fucopyranosyl)-4-*O*-[(2*S*,5*R*,6*R*,8*R*,9*R*,10*R*)-6-[(benzyloxy)methyl]-2-(furan-2-yl)-9,10-dihydroxy-1,3,7-trioxaspiro[4.5]dec-8-yl]-*β*-D-glucopyranoside (44b). A solution of **43** (130 mg, 0.12 mmol), furaldehyde diethyl acetal (60.0 mg, 0.35 mmol), and pyridinium p-toluenesulfonate (30.0 mg, 0.12 mmol) in 4 mL of benzene was heated at 60 °C for 1 h. TLC (acetone/hexane 1:1) indicated complete consumption and formation of two products. The reaction was quenched with 5 mL of 10% $NaHCO_3$, the layers were separated, the aqueous layer was extracted with benzene (5 mL), and the combined organic layers were washed with brine (5 mL) and dried over Na_2SO_4. The solvent was removed and the residue subjected to flash chromatography (SiO_2, acetone/hexane 1:3). Six-membered ring acetal **44a** (46.0 mg, 33%) eluted first followed by five-membered ring acetal **44b** (57.0 mg, 41%).

44a: ^{1}H-NMR (500 MHz, $CDCl_3$) δ −0.02 (9 H, s, $-Si(CH_3)_3$), 0.90 (2 H, m, $OCH_2CH_2Si(CH_3)_3$), 1.15 (3 H, d, 6.5 Hz, 3 × *H*-6 Fuc), 1.63 (3 H, s, $C(O)CH_3$), 3.09 (1 H, d, 1.5 Hz, C_4-O*H* Gal), 3.19 (1 H, q (br), 8.5 Hz, *H*-2 GlcNAc), 3.34 (1 H, ddd, 8.5/4.0/1.5 Hz, *H*-5 Gal), 3.36 (1 H, s (br), C_2-O*H* Gal), 3.50 (1 H, m, $OCH_aH_bCH_2Si(CH_3)_3$), 3.53 (1 H, d, 9.5 Hz, *H*-3 Gal), 3.58 (1 H, m, H-5 GlcNAc), 3.59 (1 H, dd, 10.0/4.0 Hz, *H*-6a Gal), 3.71 (1 H, d, 12.0 Hz, *H*-7axial Gal), 3.74 (1 H, m, *H*-4 Fuc), 3.76 (1 H, dd, 9.5/7.5 Hz, *H*-2 Gal), 3.84 (1 H, dd, 11.5/1.5 Hz, *H*-6a GlcNac), 3.89 (1 H, dd, 10.0/8.5 Hz, *H*-6b Gal), 3.93 (2 H, m, $OCH_aH_bCH_2Si(CH_3)_3$, *H*-6b GlcNAc), 3.98 (1 H, dd, 10.0/2.5 Hz, *H*-3 Fuc), 4.00 (1 H, t, 9.0 Hz, *H*-4 GlcNAc), 4.09 (1 H, dd, 10.0/4.0 Hz, *H*-2 Fuc), 4.14 (1 H, d, 12.0 Hz, *H*-7equatorial Gal), 4.33 (1 H, t, 9.0 Hz, *H*-3 GlcNAc), 4.39 (2 H, m, $-CH_2Ph$), 4.45 (1 H, q (br), 6.5 Hz, *H*-5 Fuc), 4.53 (1 H, d, 12.5 Hz, $-CH_2Ph$), 4.60 (1 H, d, 7.5 Hz, *H*-1 Gal), 4.61 (1 H, d, 11.5 Hz, $-CH_2Ph$), 4.65 (1 H, d, 11.5 Hz, $-CH_2Ph$), 4.72 (1 H, d, 12.5 Hz, $-CH_2Ph$), 4.72 (1 H, d, 12.0 Hz, $-CH_2Ph$), 4.76 (1 H, d, 12.0 Hz, $-CH_2Ph$), 4.92 (1 H, d, 11.5 Hz, $-CH_2Ph$), 4.95 (1 H, d, 8.5 Hz, *H*-1 GlcNAc), 4.95 (1 H, d, 11.5 Hz, $-CH_2$-Ph), 5.08 (1 H, d, 4.0 Hz, *H*-1 Fuc), 5.78 (1 H, d, 8.0 Hz, N*H* GlcNAc), 5.66 (1 H, s, C*H*-Fu), 6.39 (1 H, m, Fu(*H*-4)), 6.54 (1 H, m, Fu(*H*-3)), 7.21−7.38 (25 H, Ar-*H*), 7.43 (1 H, m, Fu(*H*-5)); ^{13}C-NMR (75 MHz, $CDCl_3$) δ −1.4 (3 C, CH_3), 16.9 (CH_3), 18.0 (CH_2), 23.3 (CH_3), 58.7 (CH), 66.9 (CH), 67.0 (CH_2), 67.7 (CH_2), 67.9 (CH_2), 68.7 (C), 69.3 (CH), 72.2 (CH_2), 72.8 (CH_2), 72.9 (CH), 73.2 (CH_2), 73.4 (CH_2), 74.3 (CH_2), 74.5 (CH), 75.1 (CH_2), 75.7 (CH), 77.7 (CH), 79.9 (CH), 82.7 (CH), 96.7 (CH), 97.9 (CH), 99.2 (CH), 101.2 (CH), 108.5 (CH), 110.3 (CH), 127.2−128.7 (14 signals, CH), 137.7 (C), 138.3 (C), 138.7 (2 C, C), 138.8 (C), 143.0 (CH), 149.5 (C), 170.4 (C), the two missing tertiary signals might be covered by the chloroform signals; MS/HR calcd for $C_{66}H_{81}NO_{17}SiLi$ ($M + Li^+$) 1194.5434, found 1194.5433.

44b: ^{1}H-NMR (500 MHz, $CDCl_3$) δ −0.01 (9 H, s, $-Si(CH_3)_3$), 0.90 (2 H, m, $OCH_2CH_2Si(CH_3)_3$), 1.09 (3 H, d, 6.5 Hz, 3 × *H*-6 Fuc), 1.60 (3 H, s, $C(O)CH_3$), 2.55 (1 H, s (br), C_3-O*H* Gal), 3.07 (1 H, q (br), 8.5 Hz, *H*-2 GlcNAc), 3.36 (1 H, d (br), 9.5 Hz, *H*-3 Gal), 3.46 (1 H, s (br), *H*-4 Fuc), 3.49 (1 H, t, 5.0 Hz, *H*-5 Gal), 3.51 (1 H, m, $OCH_aH_bCH_2Si(CH_3)_3$), 3.51 (2 H, m, H-5 GlcNAc, *H*-2 Gal), 3.76 (1 H, dd, 10.5/5.0 Hz, *H*-6a Gal), 3.79 (1 H, dd, 11.5/2.0 Hz, *H*-6a GlcNac), 3.93 (3 H, m, OCH_aH_b-$CH_2Si(CH_3)_3$, *H*-6b GlcNAc, C_2-O*H* Gal), 3.99 (1 H, dd, 10.0/2.5 Hz, *H*-3 Fuc), 4.02 (1 H, t, 10.0 Hz, *H*-4 GlcNAc), 4.05 (1 H, dd, 10.0/3.5 Hz, *H*-2 Fuc), 4.10 (1 H, dd, 10.5/5.0 Hz, *H*-6b Gal), 4.17 (1 H, d, 8.5 Hz, *H*-7a Gal), 4.20 (1 H, d, 8.5 Hz, *H*-7b Gal), 4.34 (1 H, d, 11.5 Hz, $-CH_2Ph$), 4.36 (1 H, t, 9.0 Hz, *H*-3 GlcNAc), 4.45 (1 H, q (br), 6.5 Hz, *H*-5 Fuc), 4.51 (1 H, d, 8.0 Hz, *H*-1 Gal), 4.52 (1 H, d, 12.0 Hz, $-CH_2Ph$), 4.54 (1 H, d, 12.0 Hz, $-CH_2Ph$), 4.56 (1 H, d, 12.0 Hz, $-CH_2Ph$), 4.62 (1 H, d, 12.0 Hz, $-CH_2Ph$), 4.66 (1 H, d, 11.5 Hz, $-CH_2Ph$), 4.69 (1 H, d, 12.0 Hz, $-CH_2Ph$), 4.71 (1 H, d, 11.5 Hz, $-CH_2Ph$), 4.80 (1 H, d, 11.5 Hz, $-CH_2Ph$), 4.92 (1 H, d, 12.0 Hz, $-CH_2Ph$), 5.01 (1 H, d, 3.5 Hz, *H*-1 Fuc), 5.07 (1 H, d, 8.0 Hz, *H*-1

GlcNAc), 5.77 (1 H, d, 2.0 Hz, N-*H* GlcNAc), 6.03 (1 H, s, C*H*-Fu), 6.33 (1 H, m, Fu(*H*-4)), 6.49 (1 H, m, Fu(*H*-3)), 7.21−7.38 (26 H, Ar*H*, Fu(*H*-5)); ^{13}C-NMR (75 MHz, $CDCl_3$) δ −1.4 (3 C, CH_3), 16.7 (CH_3), 17.9 (CH_2), 23.2 (CH_3), 59.3 (CH), 66.8 (CH), 66.9 (CH_2), 67.1 (CH_2), 68.7 (CH_2), 69.2 (CH_2), 72.1 (CH_2), 73.2 (CH), 73.3 (CH_2), 73.4 (CH_2), 74.1 (CH_2), 74.2 (CH), 74.3 (CH), 74.4 (CH), 75.3 (CH_2), 75.6 (CH), 75.9 (CH), 76.4 (CH), 78.3 (CH), 79.7 (CH), 81.7 (C), 97.9 (CH), 98.7 (CH), 99.8 (CH), 100.1 (CH), 110.3 (CH), 110.4 (CH), 127.1−128.6 (12 signals, CH), 138.2 (2 C, C), 138.7 (2 C, C), 138.9 (C), 143.4 (CH), 149.4 (C), 170.5 (C); MS/HR calcd for $C_{66}H_{81}NO_{17}SiLi$ ($M + Li^+$) 1194.5434, found 1194.5441.

2-(Trimethylsilyl)ethyl 6-*O*-Benzyl-2-deoxy-2-acetamido-3-*O*-(2,3,4-tri-*O*-benzyl-α-L-fucopyranosyl)-4-*O*-[(2*S*,5*S*,6*R*,8*R*,9*R*,10*R*)-2-carboxy-6-[(benzyloxy)methyl]-5,9-dihydroxy-1,3,7-trioxabicyclo[4.4.0]dec-8-yl]-*β*-D-glucopyranoside (45). Ozone was bubbled through a solution of **44a** (34.0 mg, 0.029 mmol) in 2 mL of CH_2Cl_2 at −78 °C for approximately 2 min. TLC (ether/hexane 4:1) indicated complete consumption. Excess ozone was removed by bubbling argon through the mixture for 30 min. Then, hydrogen peroxide (100 μL of a 30% solution) and THF (2 mL) were added at −78 °C, and the mixture was warmed to rt and stirred for 16 h. The mixture was diluted with CH_2Cl_2 (5 mL), washed with brine (3 mL), and dried over Na_2SO_4. The solvent was removed and the residue subjected to flash chromatography (SiO_2, ethyl acetate/ methanol/acetic acid 80:19:1) to yield **45** (22.0 mg, 66%) as a colorless solid.

45: ^{13}C-NMR (62.5 MHz, CD_3OD) δ −0.3 (3 C, CH_3), 18.0 (CH_3), 20.0 (CH_2), 22.1 (CH_3), 58.7 (CH), 68.6 (CH), 68.9 (CH_2), 69.9 (C), 70.2 (CH_2), 70.5 (CH_2), 71.1 (CH), 74.2 (CH_2), 74.5 (CH_2), 75.1 (CH_2), 75.2 (CH_2), 75.3 (CH_2), 75.6 (CH), 76.6 (CH), 77.4 (CH), 77.5 (CH_2), 78.0 (CH), 80.9 (CH), 81.1 (CH), 85.1 (CH), 98.7 (CH), 101.0 (CH), 103.3 (CH), 104.1 (CH), 129.3−130.5 (12 signals, CH), 140.5 (C), 140.8 (C), 140.9 (C), 141.3 (C), 141.6 (C), 174.1 (2 C, C); MS/MALDI-TOF calcd for $C_{63}H_{78}NO_{18}SiNa$ (sodium salt of **42**) 1188.3, found 1188.7.

2-(Trimethylsilyl)ethyl 2-Deoxy-2-acetamido-3-*O*-(α-L-fucopyranosyl)-4-*O*-[(2*S*,5*S*,6*R*,8*R*,9*R*,10*R*)-2-carboxy-5,9-dihydroxy-6-(hydroxymethyl)-1,3,7-trioxabicyclo[4.4.0]-dec-8-yl]-*β*-D-glucopyranoside (2). A solution of **45** (21.0 mg, 0.02 mmol) in 3 mL of dioxane/water 2:1 was hydrogenated in the presence of 50 mg of Pd/C (10%) at 25 °C for 24 h. Additional catalyst (20 mg) was added and the hydrogenation continued for 24 h. The catalyst was filtered off and washed with methanol and the solvent removed in vacuo to give **2** (12.2 mg, 94%) as a colorless solid. The crude material was passed through a RP 18 column (methanol/water 1:4 → 1.1). Product-containing fractions were combined, the solvent was removed, and the residue was dissolved in water and lyophilized: MS/HR calcd for $C_{28}H_{49}NO_{18}SiNa$ (sodium salt of **2**) 738.2616, found 738.2619. NMR data are shown in Table 1.

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Supporting Information Available: ^{1}H-NMR spectra of compounds **11**−**14**, **16**, C-4 epimer of **16**, **17**, **19a**,**b**, **22**−**25**, **32**−**34**, **36**−**38**, **41**, **42**, **44a**,**b**, and **2**; ^{13}C-NMR spectra of compounds **10**, **15**, **18**, **35**, **39**, **40**, **43**, and **45** (32 pages). This material is contained in libraries on microfiche, immediately follows this article in microfilm version of the journal, and can be ordered from the ACS; see any current masthead page for ordering information.

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