Total Synthesis of Sialylgalactosylglobоside: Stage-Specific Embryonic Antigen 4

José M. Lassaletta,*,† Karin Carlsson,† Per J. Garegg,‡ and Richard R. Schmidt†

Fakultät für Chemie, Universität Konstanz, Postfach 5560 M 725, D-78434 Konstanz, Germany

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A versatile total synthesis of sialylgalactosylglobоside (SGG, **1**), carrying the stage-specific embryonic antigen 4 (SSEA-4) is reported, illustrating a more general strategy for the synthesis of complex *globo*-series glycosphingolipids. Starting from readily available building blocks **7**, **8**, and **10**, two different approaches to the synthesis of the key tetrasaccharide **6** have been developed in a highly convergent manner. Further glycosylations with galactosyl trichloroacetimidate (**5**) and sialyl phosphite (**2**) donors successively afforded the penta- and hexasaccharides **3** and **11**. The latter was finally converted into the target molecule (SGG, **1**) with the help of a azidosphingosine glycosylation procedure, favored in this case by the stereocontrolling properties of the 2a-*O*-pivaloyl protecting group. Valuable intermediates **6** and **3**, having the oligosaccharidic skeletons of Gb_4 and Gb_5 (SSEA-3), respectively, were obtained in the course of the synthesis.

Glycosphingolipids (GLS's) of the *globo* series are membrane-associated antigens possessing as structural feature a Galα1→4Gal (galabiose-like) linkage which is responsible for their specific roles in recognition and cell differentiation. They are recognized by proteins of pathogenic *Escherichia coli* in human epithelial cells of the urinary tract.[1] They are also receptors for Shiga toxin[2] and verotoxin (Shiga-like toxin)[3] and constitute the basis of the P-blood group system.[4] Many of them have been described as tumor-associated antigens.[5] Sialylgalactosylglobоside (SGG, **1**), a ganglioside belonging to this series, was first isolated in 1983 from chicken pectoral muscles.[6] In the same year, Solter *et al.*[7] identified SGG with a developmentally regulated antigen, the stage-specific embryonic antigen 4 (SSEA-4), and found SSEA-3 (previously found to be expressed as Gb_5)[8] and SSEA-4 to be epitopes of this unique *globo*-series ganglioside isolated from human teratocarcinoma cells. More recent studies have shown that *globo*-series antigens SEEA-3 and SSEA-4 are expressed in different forms on human and murine teratocarcinoma cells[9] and are a hallmark of the former.[10] SSEA-4 has also been reported to bind human parvovirus B19 capsids.[11]

The great interest in this family of GLS's and the difficulties for their isolation in sufficient quantities from natural sources has stimulated interest in their chemical synthesis. Table 1 summarizes the most significant contributions that have appeared up to now in this field.

We describe herein a general strategy for the synthesis of complex *globo*-series glycosphingolipids, as illustrated for the detailed synthesis of SGG, carrying the SSEA-4 antigen, and including the Gb4 and Gb5 oligosaccharidic skeletons as valuable intermediates. A preliminary account of this work[17] and a different approach to the synthesis of SGG have recently appeared.[18]

Results and Discussion

The retrosynthetic view of the target compound **1** outlined in Scheme 1 suggests six convenient disconnections designed in such a way that useful intermediates would be obtained within the course of the synthesis. Thus, the access to the target molecule is visualized from compound **3**, having the oligosaccharidic skeleton of galactosylglobоside (Gb5, SSEA-3) and known building blocks **2**[19] and **4**[20] (disconnections 1−3). Likewise, com-

* Author to whom correspondence should be addressed. Current address: Departamento de Química Orgánica, Facultad de Química, Universidad de Sevilla, Apartado de Correos No. 553, E-41071, Seville, Spain. FAX: 34-5-4624952. E-mail: ffernan@obelix.cica.es.

† Universität Konstanz.

‡ Department of Organic Chemistry, Arrhenius Laboratory, Stockholm University, S-106 91 Stockholm, Sweden.

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(1) Lanne, B.; Olsson, B.-M.; Jovalp, P.-Å.; Ångström, J.; Linder, H.; Marklund, B.-I.; Bergström, J.; Karlsson K.-A. *J. Biol. Chem.* **1995**, *270*, 9017, and references cited therein. Our synthetic SGG is currently being used in this laboratory for further investigations on this topic.

(2) Lindberg, A. A.; Brown, J. E.; Strömbreg, N.; Westling-Ryd, M.; Schultz, J. E.; Karlsson, K. A. *J. Biol. Chem.* **1987**, *262*, 1779.

(3) Linwood, C. A.; Law, H.; Richardson, S.; Petric, M.; Brunton, J. L.; De Grandis, S.; Karmali, M. *J. Biol. Chem.* **1987**, *262*, 8834.

(4) (a) Naiki, M.; Marcus, D. M. *Biochem. Biophys. Res. Commun.* **1974**, *60*, 1105. (b) Id. *Biochemistry* **1975**, *14*, 4837. (c) Marcus, D. M.; Naiki, M.; Kundu, S. K. *Proc. Natl. Acad. Sci. U.S.A.* **1976**, *73*, 3263.

(5) Kalisiak, A.; Minniti, J. G.; Oosterwijk, E.; Old, L. J.; Scheinberg, D. A. *Int. J. Cancer* **1991**, *49*, 837.

(6) Chien, J.-L.; Hogan, E. L. *J. Biol. Chem.* **1983**, *258*, 10727.

(7) Kannagi, R.; Cochran, N. A.; Ishigami, F.; Hakomori, S.-i.; Andrews, P. W.; Knowles, B. B.; Solter, D. *EMBO J.* **1983**, *2*, 2355.

(8) (a) Kannagi, R.; Levery, S. B.; Ishigami, F.; Hakomori, S.-i., Shevinski, L. H.; Knowles, B. B.; Solter, D. *J. Biol. Chem.* **1983**, *258*, 8934. (b) Shevinski, L. H.; Knowles, B. B., Damjanov, I.; Solter, D. *Cell* **1982**, *30*, 697.

(9) Krupnick, J. G.; Damjanov, I.; Damjanov, A.; Zhu, Z. M.: Fenderson, B. A. *Int. J. Cancer* **1994**, *59*, 692.

(10) Wenk, J.; Andrews, P. W., Casper, J.; Hata, J. I.; Pera, M. F.; Vonkeitz, A., Damjanov, I.; Fenderson, B. A. *Int. J. Cancer* **1994**, *58*, 108.

(11) Cooling, L. L. V.; Koerner, T. A. W.; Naides, S. J. *J. Infect. Dis.* **1995**, *172*, 1198.

(12) (a) Shapiro, D.; Acher, A. J.; *Chem. Phys. Lipids* **1978**, *22*, 197. (b) Koike, K.; Sugimoto, M.; Sato, S.; Ito, Y.; Nakahara, Y.; Ogawa, T. *Carbohydr. Res.* **1987**, *163*, 189. (c) Nicolaou, K. C.; Caulfield, T.; Kataoka, H.; Kumazawa, T. *J. Am. Chem. Soc.* **1988**, *110*, 7910. (d) Qiu, D.; Schmidt, R. R. *Liebigs Ann. Chem.* **1992**, 217.

(13) Leontein, K.; Nilsson, M.; Norberg, T. *Carbohydr. Res.* **1985**, *144*, 231.

(14) Magnusson, G.; Nilsson, U.; Ray, A. K.; Taylor, K. G. *ACS Symp. Ser.* **1993**, *519*, 92, and references therein.

(15) Nunomura, S.; Ogawa, T. *Tetrahedron Lett.* **1988**, *29*, 5681.

(16) (a) Bilodeau, M. T.; Park, T. K.; Hu, S.; Randolph, J. T.; Danishefsky, S. J.; Livingston, P. O.; Zhang, S. *J. Am. Chem. Soc.* **1995**, *117*, 7840. (b) Lassaletta, J. M.; Schmidt, R. R. *Liebigs Ann. Chem.*, submitted.

(17) Lassaletta, J. M.; Schmidt, R. R. *Tetrahedron Lett.* **1995**, *36*, 4209.

(18) Ishida, H.; Miyawaki, R.; Kiso, M.; Hasegawa, A. *J. Carbohydr. Chem* **1996**, *15*, 163.

(19) Martin, T. J.; Brescello, R.; Toepfer, A.; Schmidt, R. R. *Glycoconjugate J.* **1993**, 16, and references cited therein.

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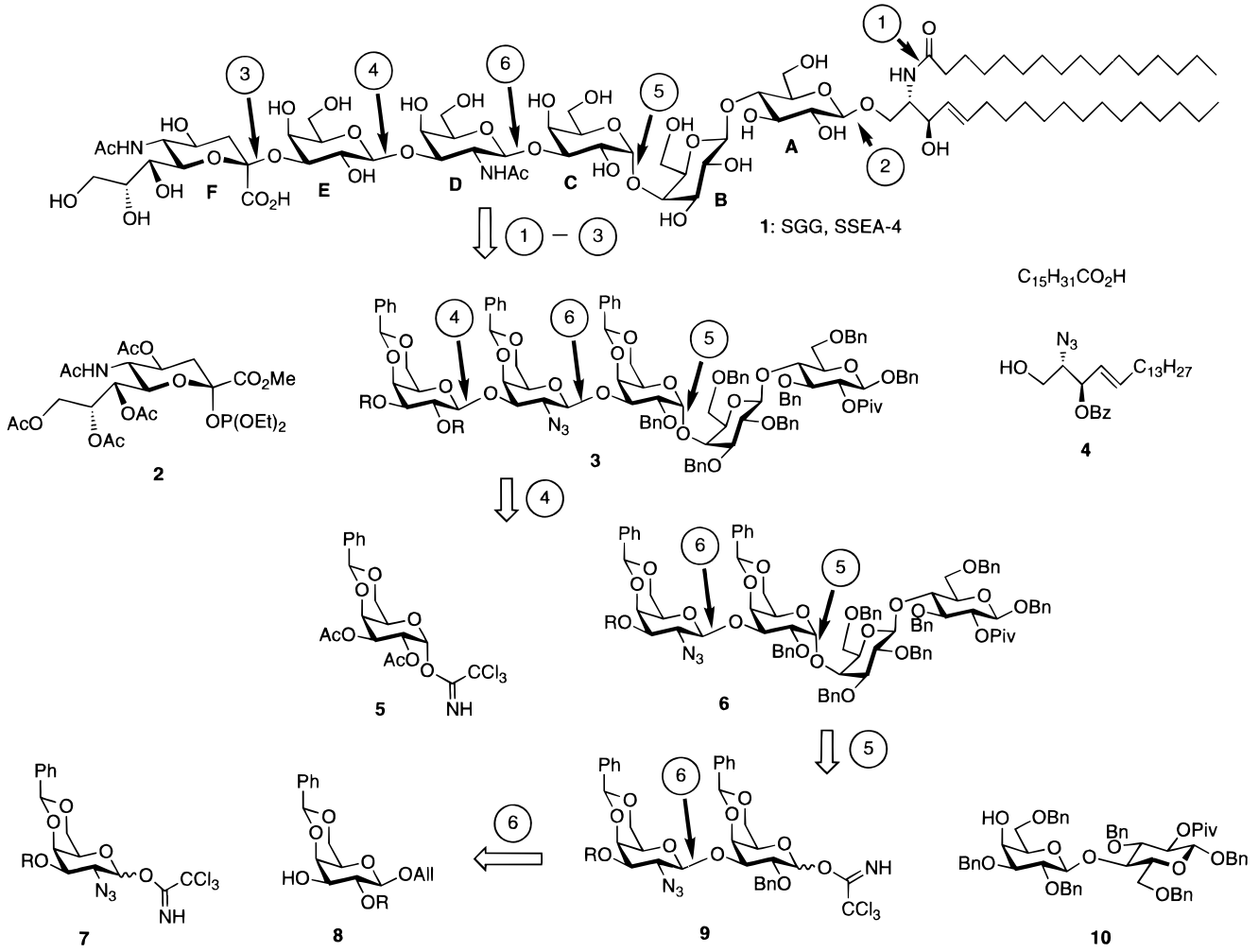
Table 1. Chemically Synthesized *Globo*-Series Glycosphingolipids

globoside	antigen	ref
Galα1→4Galβ1→4Glcβ1→1Cer (Gb_3)	P^k	12
GalNAcβ1→3Galα1→4Galβ1→4Glcβ1→1Cer (Gb_4)	P	13
GalNAcα1→3GalNAcβ1→3Galα1→4Galβ1→4Glcβ1→1Cer (Forssman)	Forssman	14
Galβ1→3GalNAcβ1→3Galα1→4Galβ1→4Glcβ1→1Cer (Gb_5)	SSEA-3	15
Fucα1→2Galβ1→3GalNAcβ1→3Galα1→4Galβ1→4Glcβ1→1Cer (H-Gb_4)	MBr1	16
NeuNAcα2→3Galβ1→3GalNAcβ1→3Galα1→4Galβ1→4Glcβ1→1Cer (SGG)	SSEA-4	17, 18, this work

Scheme 1



pound **3** should be accessible starting from tetrasaccharide **6** (Gb4) and the readily available galactosyl donor **5**[21] (disconnection 4). A convergent retrosynthetic view for the former leads to compound **10** as lactose building block and disaccharide donor **9** (disconnection 5); evident disconnection (6) of the latter is proposed from galactose acceptor **8** and azidogalactose donor **7**.

Two different approaches for the synthesis of the globotetraose skeleton **6** have been tested (Scheme 2). The choice of an appropriate AB (lactose) building block was made considering the following requirements: (i) the low nucleophilicity of 4b-OH should be enhanced by benzyl-like protecting groups around this position; (b) a sterically demanding β-stereocontrolling group should be placed at the 2a-position, granting the formation of β-anomers only and avoiding the formation of orthoesters at the azidosphingosine glycosylation step.[22] Compound **10**,[23] fulfilling these requisites, was chosen for both approaches. For the first synthesis of the CD building block **9**, the known 3-*O*-monochloroacetyl-protected azidogalactosyl donor **7a**[24] was reacted with acceptor **8d**. The latter was synthesized starting from allyl galactoside **8a**[25] in three steps: selective *O*-benzoylation (BzCN, Et_3N), benzylation under neutral conditions (BnOTf),[26] and saponification of the 3-*O*-benzoyl group. The stereochemistry of the glycosylation reaction was β-directed by

(20) (a) Schmidt, R. R.; Zimmermann, P.; *Tetrahedron Lett.* **1986**, *27*, 481. (b) Zimmermann, P.; Bommer, R.; Bär, T.; Schmidt, R. R. *J. Carbohydr. Chem.* **1988**, *7*, 435.

(21) Greilich. U.; Zimmermann, P.; Jung, K.-H.; Schmidt, R. R. *Liebigs Ann. Chem.* **1993**, 859.

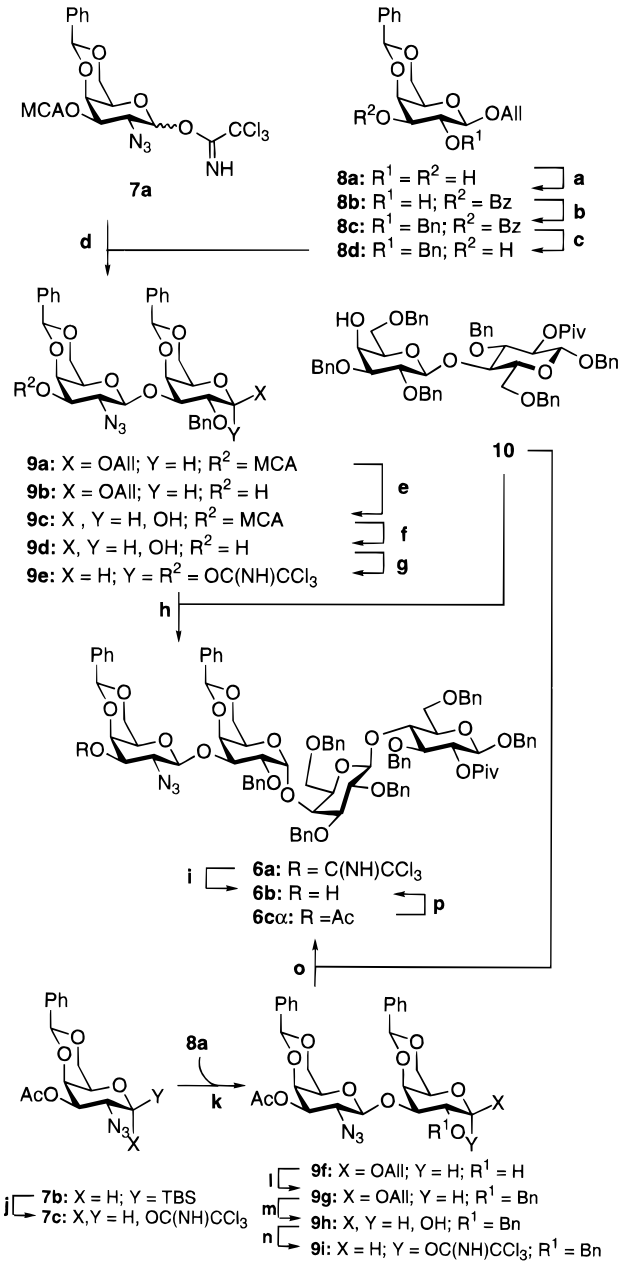
(22) (a) Schmidt, R. R.; Zimmermann, P. *Angew. Chem. Int. Ed. Engl.* **1986**, *25*, 725, and references therein. (b) Kunz, H.; Harreus, A. *Liebigs Ann. Chem.* **1982**, 41.

(23) This compound was first synthesized by Ogawa's group: Sato, S.; Nunomura, S.; Nakano, T.; Ito, Y.; Ogawa, T. *Tetrahedron Lett.* **1988**, *29*, 4097. The low overall yield and length (14 steps) of the synthesis, however, prompted us to develop a shorter, more efficient synthesis of this compound: Lassaletta, J. M.; Schmidt, R. R. *Synlett* **1995**, 925.

(24) (a) Grundler, G.; Schmidt, R. R. *Liebigs Ann. Chem.* **1984**, 1826. (b) Rademann, J. Diplomarbeit, University of Konstanz, 1994.

(25) This compound was obtained in good yield by direct anomeric *O*-alkylation of 4,6-*O*-benzylidenegalactopyranose (see Experimental Section).

Scheme 2[a]



[a] Reagents: (a) BzCN, Et_3N (75%); (b) BnOTf (81%); (c) K_2CO_3, MeOH/H_2O (85%); (d) TMSOTf, CH_3CN; (e) $PdCl_2$, NaOAc, AcOH/H_2O (71%); (f) NaOMe, MeOH (quant); (g) Cl_3CCN, DBU (76%); (h) TMSOTf, Et_2O, IP (62%); (i) HCl, MeOH/H_2O (51%); (j) (*i*) TBAF, AcOH (92%); (*ii*) CCl_3CN, DBU (88%); (k) TMSOTf, CH_3CN (84%, β); (l) BnBr, Ag_2O, DMF, 4 Å (81%); (m) $PdCl_2$, NaOAc, AcOH/H_2O (86%); (n) CCl_3CN, DBU (93%); (o) TMSOTf, IP (63%, $\alpha:\beta$ = 4:1); (p) NH_3/MeOH (quant).

using conditions (−40 °C, CH_3CN) in which the "nitrile effect" operates;[27] **9a** was isolated in 88% yield and no α-product could be detected. The allyloxy group of **9a** could not be isomerized under standard conditions (i.e., Wilkinson's catalyst in a protic solvent in the presence of a DBU-like base) because partial cleavage of the labile monochloroacetyl (MCA) group occurred (→**9b**). Use of the buffered Ogawa's reagent[28] ($PdCl_2$/AcOH/NaOAc), however, afforded directly the 1-*O*-deprotected disaccharide **9c** in good yield, conditions being mild enough to keep the acid-labile benzylidene protecting groups. The transformation of **9c** into the corresponding trichloroacetimidate donor again presented problems due to the lability of the MCA group, which did not survive the basic conditions required. To overcome this problem, **9c** was first quantitatively deprotected to diol **9d** and subsequently transformed into the bis-trichloroacetimidate **9e**. Reaction of the latter with acceptor **10** furnished, with the help of the inverse procedure (IP),[29] the desired tetrasaccharide **6a** in a yield of 62%, acceptable for this system. HCl-mediated hydrolysis of the 3d-*O*-trichloroacetimidoyl group afforded acceptor **6b** in moderate (51%) yield.

The general importance of the ABCD tetrasaccharide, having the core structure of globoside Gb4 and being the key for all higher globosides, merits an improved synthesis. Therefore, a second approach was designed to overcome the limitations referred to above. In this case, the known *tert*-butyldimethylsilyl 2-azido-4,6-*O*-benzylidene-β-D-galactopyranoside **7b**[24a] was converted into donor **7c** by treatment with (i) TBAF and (ii) Cl_3CCN/DBU, without isolation of the intermediate hemiacetal. Reaction of **7c** with diol **8a** proceeded regio- and stereoselectively, again taking advantage of the "nitrile effect"[27] and the much higher reactivity of 3-OH than 2-OH in the latter. Thus, the desired disaccharide **9f** was obtained as a single isomer and then transformed into trichloroacetimidate CD donor **9i** by benzylation (Ag_2O/BnBr, →**9g**), allyl cleavage ($PdCl_2$/AcOH/NaOAc, →**9h**) and imidate formation under established conditions. Reaction of this compound with acceptor **10**, again applying the inverse procedure,[29] afforded tetrasaccharide **6c** (63%, $\alpha:\beta$ = 4:1). Selective removal of the 3d-*O*-acetyl group to obtain **6b** was then accomplished quantitatively by means of methanolic ammonia, keeping the 2a-*O*-pivaloyl group untouched. This material proved to be identical with product **6b** obtained from **6a**. The second approach, however, proved to be more efficient, since the synthesis required fewer steps, and the overall yield was higher.

For the transformation of this ABCD fragment **6b** into the target **1** (Scheme 3), β-galactosylation was first achieved by using trichloroacetimidate donor **5** under established conditions, yielding the globopentaose derivative **3a** in almost quantitative yield. This material was converted into the ABCDE acceptor **3b** again using NH_3/MeOH for selective de-*O*-acylation. It is known[19] that sterically demanding sialyl donors can be attached in good yields to the 3 position of 2,3,4- or 2,3-*O*-unprotected galactose residues. Therefore, compound **3b** reacted with phosphite donor **2**,[14] affording an easily separable mixture **11aα/11aβ** in good yield (62%, $\alpha:\beta$ = 4:1).[30] The stereochemistry of both α and β sialylglycosides was assigned on the basis of empirical rules.[31] Compound **11a** was then converted into trichloroacetimidate **11d** in three convenient and high-yielding steps: (i) simultaneous hydrogenolytic cleavage of benzyl and benzylidene protecting groups and reduction of the 2d-azido group, best

(26) Lemieux, R. U.; Kondo, T. *Carbohydr. Res.* **1974**, *35*, C4. Other standard conditions (NaH/BnBr or Ag_2O/BnBr) led to benzoyl migration.

(27) Schmidt, R. R.; Behrendt, M.; Toepfer, A. *Synlett* **1990**, 694.

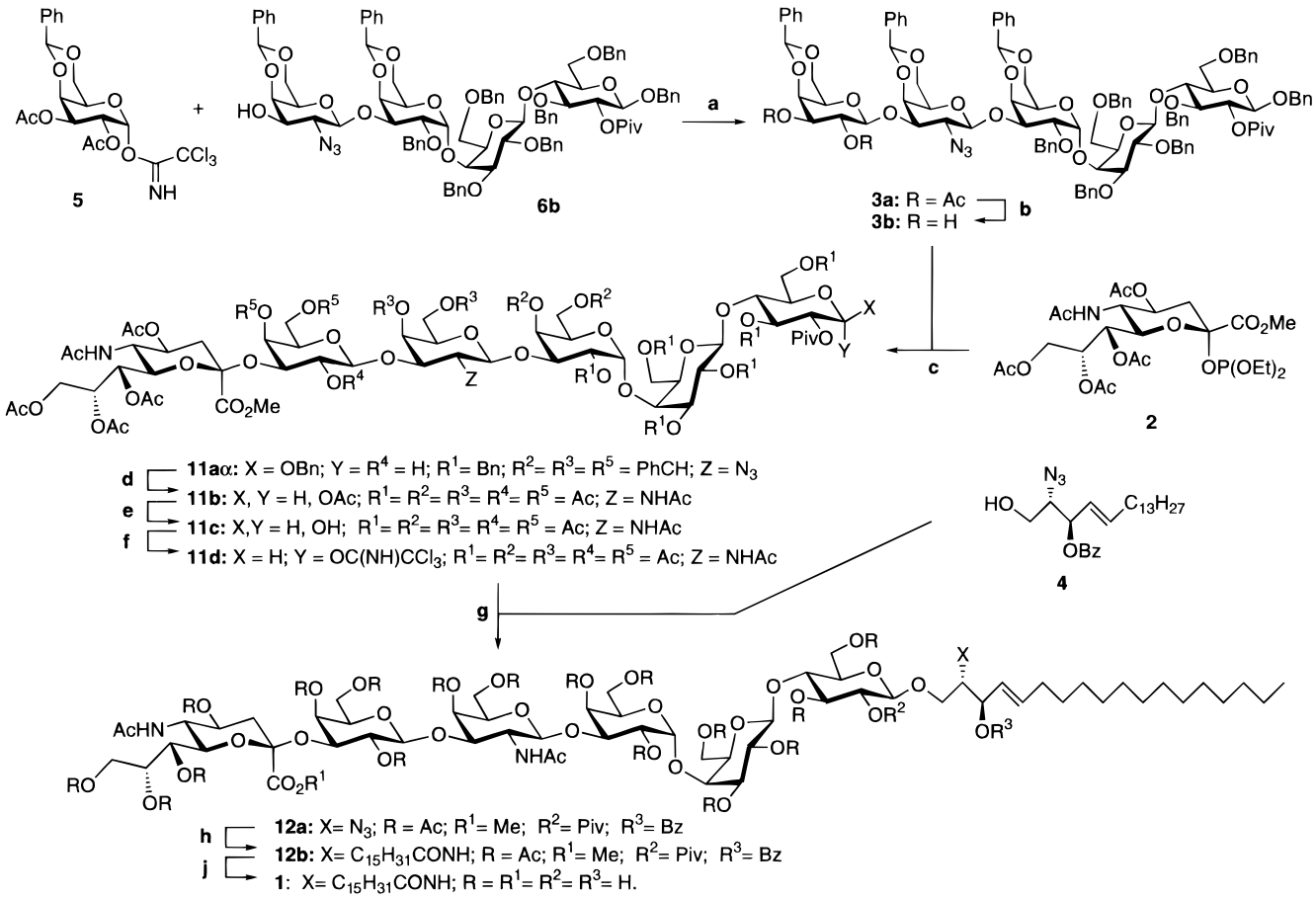
(28) Ogawa, T.; Nakabayashi, S. *Carbohydr. Res.* **1981**, *93*, C1.

(29) Schmidt, R. R.; Toepfer, A. *Tetrahedron Lett.* **1991**, *32*, 3353.

(30) Though the phosphite methodology (see ref 19) usually yields virtually complete α-selectivities, other rather unpredictable results have been observed for related systems. This result, however, can be considered as acceptable due to the high yield obtained.

(31) a) δ 3-H*eq*(α) > δ 3-H*eq*(β): Dabrowski, U.; Friebolin, H.; Brossmer, R.; Supp, M. *Tetrahedron Lett.* **1979**, 4637. (b) δ 4-H(α) < δ 4-H(β): Paulsen, H.; Tietz, H. *Carbohydr. Res.* **1984**, *125*, 47.

Scheme 3[a]



[a] Reagents: (a) TMSOTf (94%); (b) NH_3/MeOH (quant); (c) TMSOTf, CH_3CN (62%, α:β = 3.5:1); (d) (*i*) $Pd(OH)_2$/C, H_2, MeOH, (*ii*) Ac_2O/Py (85%, α:β = 1:1); (e) N_2H_4·AcOH, DMF (94%); (f) CCl_3CN, DBU (93%); (g) TMSOTf (72%); (h) (*i*) H_2S, Py/H_2O, (*ii*) $C_{15}H_{31}COOH$, WSC (87%); (j) (*i*) NaOMe/MeOH, (*ii*) KOH/H_2O, (*iii*) IRA 120 (H^+) (quant).

achieved by using freshly prepared Pearlman catalyst,[32] followed by peracetylation of the crude product (→**11b**, 85% of a 1:1 mixture of α- and β-acetates); (ii) regioselective removal of the anomeric 1-*O*-acetyl group by means of hydrazinium acetate[33] in DMF (→**11c**, 94%); and iii) imidate formation under established conditions (→**11d**, 93%). The final stages of the synthesis, i.e., the introduction of the ceramide aglycon, were accomplished by application of the azidosphingosine glycosylation procedure.[20] The importance of the pivaloyl protecting group chosen for the 2a position of **11d** was here demonstrated by the excellent yield (72%) observed for the TMSOTf-promoted β-glycosylation of azidosphingosine derivative **4**, which yielded the corresponding glycoside **12a**; no orthoester byproduct was detected in the reaction mixture. This azido compound was then reduced with H_2S in pyridine/water without acyl migration, and the crude product was immediately treated with palmitic acid in the presence of *N*-[3-(*N*,*N*-dimethylamino)propyl]-*N*′-ethylcarbodiimide hydrochloride (water soluble carbodiimide, WSC) as condensing agent to provide the protected glycosyl ceramide **12b** in 87% yield. Finally, the target **1** (SGG) was obtained quantitatively from the latter by methanolysis (NaOMe/MeOH) of all *O*-acyl protecting groups and subsequent hydrolysis (aqueous KOH) of the methyl ester moiety. The ^1H NMR data of this compound are in full agreement with those reported for the natural sample.[8a,34]

Conclusions

In summary, a versatile strategy has been described for the synthesis of complex *globo*-series glycolipids, based on powerful synthetic tools such as the trichloroacetimidate glycosylation procedure, the recently developed phosphite method for sialylation,[19] the azidosphingosine-based protocol for glycosphingolipid synthesis, and the stereocontrolling properties of a neighbor pivaloyl protecting group. An advantage of this strategy is the construction of the difficult galabiose-type α(1→4) glycosidic linkage in the first stages of the synthesis, thus avoiding this connection later during the synthesis. It should be also stressed that both **3b** and **6b**, bearing appropriate protecting groups, are not only precursors for the synthesis of Gb_4 and Gb_5 globosides but also for further elongation to several higher globosides other than the target SGG. Compound **6b**, for instance, could be alternatively glycosylated with an α-galactosamine donor for the synthesis of the Forssman antigen. Likewise, the considerable difference in reactivity between the 3d-OH

(32) Fieser, L. F.; Fieser, M. In *Reagents for Organic Synthesis*; John Wiley and Sons Inc.: New York, 1967; Vol. 1, p 782. The age of the catalyst was found to be of importance; in our hands, the use of old catalysts led to complex mixtures containing the desired product in low yield.

(33) Excoffier, G.; Gagnaire, G.; Utille, J.-P. *Carbohydr. Res.* **1975**, *39*, 368.

(34) The molecular formula and the ^1H NMR data reported for SGG in ref 18 are erroneous.

and 2d-OH of **3b** can be used for the synthesis of Globo-H[16] and Globo-A structures. Additionally, the lysoglycosphingolipid obtained after reduction of **12a** is another interesting intermediate, since it may have different biological properties to that of the corresponding ceramide derivative.[35]

Experimental Section

Melting points were measured in a metal block and are uncorrected. Thin layer chromatography (TLC) was performed on silica gel precoated plates. Purifications of the products were carried out by flash chromatography. The light petroleum ether used had boiling range 35−65 °C. ^{1}H NMR spectra were recorded at 250 MHz, using chloroform-*d* as solvent and tetramethylsilane as internal standard, unless noted otherwise.

Starting Materials. 4,6-*O*-Benzylidene-α,*β*-D-galactopyranose,[36] 5-acetamido-4,7,8,9-tetra-*O*-acetyl-3,5-dideoxy-1-(methoxycarbonyl)-D-*glycero*-α-D-*galacto*-2-nonulopyranosyl diethyl phosphite[19] (**2**), (2*S*,3*R*,4*E*)-2-azido-3-(benzoyloxy)-4-octadecen-1-ol[20] (**4**), 2,3-di-*O*-acetyl-4,6-*O*-benzylidene-α-D-galactopyranosyl trichloroacetimidate[21] (**5**), 2-azido-4,6-*O*-benzylidene-3-*O*-chloroacetyl-2-deoxy-α-D-galactopyranosyl trichloroacetimidate[24] (**7a**), *tert*-butyldimethylsilyl 2-azido-4,6-*O*-benzylidene-*β*-D-galactopyranoside[24a] (**7b**), and benzyl 3,6-di-*O*-benzyl-4-*O*-(2,3,6-tri-*O*-benzyl-*β*-D-galactopyranosyl)-2-*O*-pivaloyl-*β*-D-glucopyranoside[23] (**10**) were prepared according to literature procedures.

Allyl 4,6-*O*-Benzylidene-*β*-D-galactopyranoside (8a). To a stirred solution of 4,6-*O*-benzylidene-α,*β*-D-galactopyranose (33.8 g, 126 mmol) and AllBr (17 mL, 200 mmol) in 1:1 dry THF/DMF (300 mL) was added NaH (3.56 g, 141 mmol) in small portions. After 24 h MeOH (10 mL) was added and the mixture stirred for another 30 min. The solvent was then removed *in vacuo* and the residue extracted with acetone and purified by flash chromatography (3:1 toluene−acetone). Allyl 4,6-*O*-benzylidene-α-D-galactopyranoside (7.3 g, 13%) eluted first: mp 118−120 °C (lit.[37] mp 115−117 °C); $[\alpha]^{rt}_D$ +73.6° (*c* 1, $CHCl_3$) [lit.[37] $[\alpha]^{rt}_D$ +121 ° (*c* 1.9, $CHCl_3$)]. **8a** eluted second (22.8 g, 59%): mp 174 °C; $[\alpha]^{rt}_D$ −36.4° (*c* 1, $CHCl_3$); TLC (12:1 CH_2Cl_2−MeOH) R_f 0.57; ^{1}H-NMR δ 7.3−7.5 (m, 5H), 6.02−5.86 (m, 1H), 5.52 (s, 1H), 5.35−5.17 (m, 2H), 4.46−4.38 (m, 1H), 4.35−3.60 (m, 7H), 3.44 (br s, 1H), 2.65 (br s, 2H). Anal. Calcd for $C_{16}H_{20}O_6 \cdot {}^1/_4H_2O$: C, 61.43; H, 6.60. Found: C, 61.44; H, 6.49.

Allyl 3-*O*-Benzoyl-4,6-*O*-benzylidene-*β*-D-galactopyranoside (8b). To a stirred suspension of **8a** (18 g, 58 mmol) and BzCN (8.0 g, 1.03 eq) in dry CH_3CN (150 mL) was added Et_3N (10 drops). After 30 min MeOH (10 mL) was added and the mixture stirred for another 15 min. The solvent was then removed *in vacuo* and the residue dissolved in MeOH and concentrated two times. Crystallization from MeOH and flash chromatography [2:1 toluene−ethyl acetate (EA)] of the mother liquors yielded unreacted material (3 g) and **8b** (17.7 g, 75%): mp 177 °C; $[\alpha]^{rt}_D$ +76.8° (*c* 1, $CHCl_3$); TLC (4:1 toluene−acetone) R_f 0.38; ^{1}H-NMR δ 7.2−8.1 (m, 10H), 6.03−5.87 (m, 1H), 5.50 (s, 1H), 5.19−5.36 (m, 2H), 5.14 (dd, J = 3.7, 10.3 Hz, 1H), 4.51−4.05 (m, 7H), 3.57 (br s, 1H), 2.0 (br s, 1H). Anal. Calcd for $C_{23}H_{24}O_7$: C, 66.96; H, 5.87. Found: C, 66.86; H, 5.87.

Allyl 3-*O*-Benzoyl-2-*O*-benzyl-4,6-*O*-benzylidene-*β*-D-galactopyranoside (8c). To a solution of Tf_2O (14.26 mL, 85.6 mmol) in dry CH_2Cl_2 (40 mL) was added dropwise at −75 °C a solution of benzyl alcohol (9.0 mL, 85.6 mmol) and 2,6-di-*tert*-butylpyridine (18.8 mL, 85.6 mmol) in dry CH_2Cl_2 (70 mL) for over 30 min under an argon atmosphere. After stirring for 20 min, a solution of compound **8b** (11.6 g, 28.2 mmol) and 2,6-di-*tert*-butylpyridine (12.54 mL, 57 mmol) in CH_2Cl_2 (70 mL) was added dropwise (20 min) and the temperature was allowed to rise up to −40 °C. After 16 h, pyridine (20 mL) was added, and the mixture was warmed up to rt, washed with H_2O (3 × 100 mL), dried ($MgSO_4$), and concentrated *in vacuo*. The 2,6-di-*tert*-butylpyridine was finally removed by distillation (34 °C/0.4 mbar) and the residue purified by flash chromatography (18:1 toluene−EA) to give unreacted material (1.9 g) and crystalline **8c** (8.64 g, 73%): mp 51 °C; $[\alpha]^{rt}_D$ +143.8° (*c* 1, $CHCl_3$); TLC (3:1 toluene−acetone) R_f 0.47; ^{1}H-NMR δ 7.1−8.1 (m, 15H), 6.06−5.90 (m, 1H), 5.51 (s, 1H), 5.41−5.22 (m, 2H), 5.20 (dd, J = 3.6, 10.2 Hz, 1H), 4.92 (d, J = 10.1 Hz, 1H), 4.72 (d, J = 10.1 Hz, 1H), 4.61 (d, J = 7.8 Hz, 1H), 4−55−4−03 (m, 6H), 3.56 (br s, 1H). Anal. Calcd for $C_{30}H_{30}O_7 \cdot {}^1/_4H_2O$: C, 71.06; H, 5.96. Found: C, 70.90; H, 5.99.

Allyl 2-*O*-Benzyl-4,6-*O*-benzylidene-*β*-D-galactopyranoside (8d). To a solution of **8c** (11.22 g, 22.3 mmol) in 8:1 MeOH-H_2O was added K_2CO_3 (1M, 2 mL) and the mixture stirred for 7 h at rt. The solvent was then evaporated *in vacuo* and the residue extracted with acetone and purified by flash chromatography (7:1 toluene−acetone) to give **8d** (7.53 g, 85%): mp 69 °C; $[\alpha]^{rt}_D$ +9.3° (*c* 1, $CHCl_3$); TLC (7:1 toluene−acetone) R_f 0.19; ^{1}H-NMR δ 7.6−7.2 (m, 10H), 6.05−5.89 (m, 1H), 5.56 (s, 1H), 5.39−5.18 (m, 2H), 5.00 (d, J = 10.1 Hz, 1H), 4.73 (d, J = 10.1 Hz, 1H), 4.6−3.6 (m, 8H), 3.43−3.42 (m, 1H), 2.51 (d, J = 8.0 Hz, 1H). Anal. Calcd for $C_{23}H_{26}O_6 \cdot H_2O$: C, 66.33; H, 6.77. Found: C, 66.36; H, 6.51.

Allyl 3-*O*-(2-Azido-4,6-*O*-benzylidene-3-*O*-(chloroacetyl)-2-deoxy-*β*-D-galactopyranosyl)-2-*O*-benzyl-4,6-*O*-benzylidene-*β*-D-galactopyranoside (9a). To a cooled (−40 °C) solution of **8d** (5.33 g, 13.38 mmol) and **7a** (10.46 g, 20.07 mmol) in dry CH_3CN (100 mL) was added TMSOTf (2.6 mL, 0.1M in CH_3CN) under an argon atmosphere. After 1 h, $NaHCO_3$ (s, 0.1 g) and Et_2O (400 mL) were added, and the mixture was washed with saturated $NaHCO_3$ solution (100 mL) and H_2O (100 mL). The organic layer was dried ($MgSO_4$) and concentrated *in vacuo*, and the residue was purified by flash chromatography (7:1 toluene−EA) to afford **9a** (8.85 g, 88%): mp 112 °C; $[\alpha]^{rt}_D$ +25.4° (*c* 1, $CHCl_3$); TLC (7:1 toluene−acetone) R_f 0.50; ^{1}H-NMR δ 7.6−7.2 (m, 15H), 6.04−5.88 (m, 1H), 5.59 (s, 1H), 5.48 (s, 1H), 5.37−5.17 (m, 2H), 5.02 (d, J = 10.6 Hz, 1H), 4.97 (d, J = 7.2 Hz, 1H), 4.70 (d, J = 10.6 Hz, 1H), 4.65 (dd, J = 3.6, 10.9 Hz, 1H), 4.53−3.90 (m, 14H), 3.39 (br s, 1H), 3.31 (br s, 1H). Anal. Calcd for $C_{38}H_{40}ClN_3O_{11}$: C, 60.84; H, 5.37; N, 5.60. Found: C, 60.84; H, 5.55; N, 5.39.

Allyl 3-*O*-(2-Azido-4,6-*O*-benzylidene-2-deoxy-*β*-D-galactopyranosyl)-2-*O*-benzyl-4,6-*O*-benzylidene-*β*-D-galactopyranoside (9b). (a) To a solution of compound **9a** (50 mg, 67 μmol) in MeOH (1 mL) was added Et_3N (1 drop), the mixture was stirred for 1 h at rt and concentrated, and the residue purified by flash chromatography (2:1 EA-toluene) to give **9b** (43 mg, 96%): mp 120 °C; $[\alpha]^{rt}_D$ +3.9° (*c* 1, $CHCl_3$); TLC (2:1 EA-toluene) R_f 0.29; ^{1}H-NMR δ 7.6−7.2 (m, 15H), 6.04−5.90 (m, 1H), 5.59 (s, 1H), 5.52 (s, 1H), 5.37−5.17 (m, 2H), 5.00 (d, J = 10.1 Hz, 1H), 4.83 (d, J = 8.0 Hz, 1H), 4.74 (d, J = 10.1 Hz, 1H), 4.55−3.27 (m, 15H), 2.60 (d, J = 9.6 Hz, 1H). Anal. Calcd for $C_{36}H_{39}N_3O_{10} \cdot H_2O$: C, 62.51; H, 5.97; N, 6.07. Found: C, 62.58; H, 5.93; N, 6.00.

(b) A mixture of **9a** (50 mg, 67 μmol), $Rh(PPh_3)_3Cl$ (6 mg, 6.7 μmol), and 9:1 EtOH−DBU (10 μL) in 9:1 EtOH−H_2O (1 mL) was stirred at rt for 2 h. The solvent was removed *in vacuo* and the residue purified by flash chromatography (2:1 EA−toluene) to give **9b** (30 mg, 64%), identical with the product described above.

3-*O*-(2-Azido-4,6-*O*-benzylidene-3-*O*-(chloroacetyl)-2-deoxy-*β*-D-galactopyranosyl)-2-*O*-benzyl-4,6-*O*-benzylidene-α/*β*-D-galactopyranose (9c). Compound **9a** (6.24 g, 8.3 mmol), $PdCl_2$ (3.4 g, 19.2 mmol), and NaOAc (11.7 g, 125 mmol) were suspended in 9:1 AcOH−H_2O (200 mL) and stirred for 12 h at rt. The mixture was then filtered through Celite, slowly poured on saturated $NaHCO_3$ solution (1 L), and extracted with CH_2Cl_2 (3 × 300 mL). The organic layer was then dried ($MgSO_4$) and concentrated *in vacuo*, and the residue was purified by flash chromatography (2:1 toluene−EA) to yield **9c** (4.21 g, 71%); $[\alpha]^{rt}_D$ +43.4° (*c* 1, $CHCl_3$); TLC (2:1 EA−toluene) R_f 0.55; ^{1}H-NMR δ 7.6−7.2 (m, 15H), 5.59 (s, 1H), 5.50 and 5.48 (2 s, 1H), 5.36 (d, J = 2.0 Hz, 0.5H), 5.07 (d, J = 8.0 Hz, 0.5H), 5.0−3.3 (m, 18H). Anal. Calcd for $C_{35}H_{36}$-

(35) (a) Hannun, Y. A.; Bell, R. M. *Science* **1989**, *243*, 500. (b) Hakomori, S.-i. *J. Biol. Chem.* **1990**, *265*, 18713.
(36) Gros, E. G.; Deulofeu, V. *J. Org. Chem* **1964**, *29*, 3647.
(37) Gigg, R.; Warren, C. D. *J. Chem. Soc. (C)* **1968**, 1903.

$ClN_3O_{11}\cdot{}^1/_4H_2O$: C, 58.45; H, 5.19; N, 5.84. Found: C, 58.68; H, 5.24; N, 5.37.

3-*O*-(2-Azido-4,6-*O*-benzylidene-2-deoxy-*β*-D-galactopyranosyl)-2-*O*-benzyl-4,6-*O*-benzylidene-α/*β*-D-galactopyranose (9d). To a solution of **9c** (0.8 g, 1.1 mmol) in MeOH (10 mL) was added NaOMe (0.2 M in MeOH, few drops). After 5 min, ion exchange resin Amberlite IR 120 (H^+) (0.1 g) was added and the mixture was stirred for another 10 min, filtered, and concentrated *in vacuo* to give pure **9d** (0.68 g, quant); $[\alpha]^{rt}_D$ +47.2° (*c* 1, $CHCl_3$); TLC (5:2 toluene−acetone) R_f 0.26; ^{1}H-NMR δ 7.6−7.2 (m, 15H), 5.59 and 5.52 (2 s, 1H), 5.57 and 5.53 (2 s, 1H), 5.37 (d, J = 1.9 Hz, 0.7H), 4.96 (d, J = 7.9 Hz, 0.3H), 4.86−3.30 (m, 17H). Anal. Calcd for $C_{33}H_{35}N_3O_{10}\cdot{}^1/_4H_2O$: C, 62.11; H, 5.61; N, 6.58. Found: C, 62.16; H, 5.64; N, 6.39.

3-*O*-(2-Azido-4,6-*O*-benzylidene-2-deoxy-3-*O*-(trichloroacetimidoyl)-*β*-D-galactopyranosyl)-2-*O*-benzyl-4,6-*O*-benzylidene-α-D-galactopyranosyl Trichloroacetimidate (9e). To a solution of **9d** (120 mg, 0.19 mmol) and Cl_3CCN (0.4 mL) in dry CH_2Cl_2 was added DBU (1 drop) and the mixture was stirred for 2 h under an argon atmosphere. The solvent was then removed *in vacuo* and the residue purified by flash chromatography (8:1 toluene−acetone) to yield **9e** (130 mg, 76%) as a foam: TLC (8:1 toluene−acetone) R_f 0.31; ^{1}H-NMR δ 8.57 (s, 1H), 8.46 (s, 1H), 7.2−7.6 (m, 15H), 6.58 (d, J = 2.4 Hz, 1H), 5.60 (s, 1H), 5.55 (s, 1H), 4.93 (d, J = 8.0 Hz, 1H), 4.8−4.0 (m, 6H), 3.91 (br s, 1H), 3.46 (br s, 1H).

Benzyl *O*-(2-Azido-4,6-*O*-benzylidene-2-deoxy-3-*O*-(trichloroacetimidoyl)-*β*-D-galactopyranosyl)-(1→3)-*O*-(2-*O*-benzyl-4,6-*O*-benzylidene-α-D-galactopyranosyl)-(1→4)-*O*-(2,3,6-tri-*O*-benzyl-*β*-D-galactopyranosyl)-(1→4)-(3,6-di-*O*-benzyl-2-*O*-pivaloyl-*β*-D-glucopyranoside (6a). To a cooled (−10 °C) suspension of **9e** (100 mg, 0.11 mmol) and **10** (160 mg, 0.17 mmol) in dry Et_2O (0.2 mL) was added TMSOTf (0.01 M in Et2O, 11 μL) under an argon atmosphere. After stirring for 1 h, $NaHCO_3$ (s, 10 mg) and Et_2O were added, and the mixture was washed with saturated $NaHCO_3$ solution (5 mL) and H_2O (5 mL). The organic layer was dried (MgSO4), filtered, concentrated *in vacuo*, and the residue was purified by flash chromatography (9:1 toluene−EA) to afford **6a** (119 mg, 62%): mp 87 °C; $[\alpha]^{rt}_D$ +36.7° (*c* 1, $CHCl_3$); TLC (7:1 toluene−acetone) R_f 0.36; ^{1}H-NMR δ 8.45 (s, 1H), 7.6−7.1 (m, 45H), 5.40 (s, 1H), 5.39 (s, 1H), 5.17 (d, J = 2.9 Hz, 1H), 5.06 (dd, J = 7.9, 9.5 Hz, 1H), 4.90−3.20 (m, 40H), 1.11 (s, 9H). Anal. Calcd for $C_{94}H_{99}N_4O_{21}Cl_3$: C, 65.37; H, 5.78; N, 3.24. Found: C, 65.29; H, 5.82; N, 3.44.

3-*O*-Acetyl-2-azido-4,6-*O*-benzylidene-2-deoxy-α- and -*β*-D-galactopyranosyl Trichloroacetimidate (7c). To a solution of **7b**[24a] (9.3 g, 20.7 mmol) and AcOH (1.31 mL, 22.8 mmol) in dry THF (120 mL) at −20 °C was added dropwise TBAF (20.7 mL of a 1.1 M solution in THF). The mixture was then warmed up to 0 °C, diluted with Et_2O (500 mL), washed with saturated $NaHCO_3$ solution (300 mL) and brine (2 × 200 mL), dried ($MgSO_4$), and concentrated *in vacuo*. To a solution of this residue in dry CH_2Cl_2 (200 mL) was added Cl_3CCN (10 mL) and DBU (few drops). After stirring for 1 h, the solvent was removed *in vacuo* and the residue was purified by flash chromatography (8:1 toluene−acetone + 1% Et_3N) to yield **7c** (8.0 g, 81%) as a 1:3.5 α/*β* mixture: TLC (5:1 toluene−acetone) R_f, 0.60, ^{1}H NMR: δ 8.74 and 8.72 (2 s, 1H), 7.6−7.3 (m, 5H), 6.58 (d, J = 2.9 Hz, 0.22H), 5.67 (d, J = 8.2 Hz, 0.78H), 5.52 and 5.51 (2 s, 1H), 5.31 (dd, J = 3.5, 9.6 Hz, 0.22H), 4.81 (dd, J = 3.6, 9.6 Hz, 0.78H), 2.17 and 2.15 (2 s, 3H). Anal. Calcd for $C_{17}H_{17}N_4O_6Cl_3$: C, 42.56; H, 3.57; N, 11.68. Found: C, 42.30; H, 3.41; N, 11.76.

Allyl 3-*O*-(3-*O*-Acetyl-2-azido-4,6-*O*-benzylidene-2-deoxy-*β*-D-galactopyranosyl)-4,6-*O*-benzylidene-*β*-D-galactopyranoside (9f). To a suspension of **7c** (7.50 g, 15.6 mmol) and **8a** (5.78 g, 18.8 mmol) in dry CH_3CN (mL) was added TMSOTf (7.8 mL of a 0.1M solution in dry CH_3CN) at −20 °C under an argon atmosphere. After stirring for 2 h, the resulting clear solution was neutralized with $NaHCO_3$ (s, 1 g), filtered, and concentrated *in vacuo*. The residue was purified by flash chromatography (5:1 toluene−acetone) to give **9f** (8.22 g, 84%): $[\alpha]^{rt}_D$ +28.0° (*c* 1, $CHCl_3$); TLC (3:1 toluene−acetone) R_f 0.45, ^{1}H NMR: δ 7.6−7.2 (m, 10H), 5.94 (m, 1H), 5.57 (s, 1H), 5.48 (s, 1H), 5.35−5.15 (m, 2H), 4.96 (d, J = 8.0 Hz, 1H), 4.71 (dd, J = 3.5, 8.9 Hz, 1H), 4.5−3.99 (m, 11H), 3.85 (dd, J = 3.5, 9.9 Hz, 1H), 3.46 (br s, 1H), 3.41 (br s, 1H), 2.12 (s, 3H). Anal. Calcd for $C_{31}H_{35}N_3O_{11}\cdot{}^1/_2H_2O$: C, 58.67; H, 5.71; N, 6.62. Found: C, 58.67; H, 5.68; N, 6.15.

Allyl 3-*O*-(3-*O*-Acetyl-2-azido-4,6-*O*-benzylidene-2-deoxy-*β*-D-galactopyranosyl)-2-*O*-benzyl-4,6-*O*-benzylidene-*β*-D-galactopyranoside (9g). To a suspension of **9f** (6.51 g, 10.4 mmol), freshly prepared Ag_2O (1.8 g), and 4 Å molecular sieves in dry DMF (50 mL) was added BnBr (1.8 mL, 15.6 mmol), and the mixture was stirred for 12 h at rt, filtered through Celite, and concentrated. The resulting residue was purified by column chromatography (7:1 toluene−acetone) to yield **9g** (6.03 g, 81%): $[\alpha]^{rt}_D$ +34.6° (*c* 1, $CHCl_3$); TLC (4:1 toluene−acetone) R_f 0.51, ^{1}H NMR: δ 7.6−7.2 (m, 15H), 5.96 (m, 1H), 5.59 (s, 1H), 5.47 (s, 1H), 5.38−5.15 (m, 2H), 4.99 (d, J = 9.8 Hz, 1H), 4.93 (d, J = 8.0 Hz, 1H), 4.74 (d, J = 9.8 Hz, 2H), 4.63 (dd, J = 3.5, 10.9 Hz, 1H), 4.5−3.9 (m, 11H), 3.38 (br s, 1H), 3.32 (br s, 1H), 2.15 (s, 3H). Anal. Calcd for $C_{38}H_{41}N_3O_{11}$: C, 63.77; H, 5.77; N, 5.87. Found: C, 63.78; H, 5.84; N, 5.87.

3-*O*-(3-*O*-Acetyl-2-azido-4,6-*O*-benzylidene-2-deoxy-*β*-D-galactopyranosyl)-2-*O*-benzyl-4,6-*O*-benzylidene-α,*β*-D-galactopyranose (9h). A mixture of compound **9g** (5.00 g, 6.98 mmol), NaOAc (7.5 g, 83 mmol), and $PdCl_2$ (2.48 g, 14.0 mmol) in 9:1 AcOH−H_2O (100 mL) was stirred for 12h at 4 °C and then filtered through Celite. The filtrate was poured on ice-water (500 mL), extracted with CH_2Cl_2 (3 × 200 mL), washed with saturated $NaHCO_3$ solution (2 × 200 mL), and dried ($MgSO_4$). After removal of the solvent *in vacuo*, the resulting residue was purified by flash chromatography (7:1 toluene−acetone) to give **9h** (4.08 g, 86%): $[\alpha]^{rt}_D$ +63.2° (*c* 1, $CHCl_3$); TLC (4:1 toluene−acetone) R_f 0.27 and 0.18, ^{1}H NMR: δ 7.6−7.2 (m, 15H), 5.58 and 5.49 (2 s, 1H), 5.60 and 5.48 (2 s, 1H), 5.35 (d, J = 3.3 Hz, 1H), 5.0−3.9 (m, 16H), 3.43 (br s, 1H), 2.15 (s, 3H). Anal. Calcd for $C_{35}H_{37}N_3O_{11}\cdot{}^1/_2H_2O$: C, 61.39; H, 5.59; N, 6.14. Found: C, 61.57; H 5.69; N, 6.11.

3-*O*-(3-*O*-Acetyl-2-azido-4,6-*O*-benzylidene-2-deoxy-*β*-D-galactopyranosyl)-2-*O*-benzyl-4,6-*O*-benzylidene-α- and *β*-D-galactopyranosyl Trichloroacetimidate (9iα and 9i*β*). To a solution of **9h** (2.60 g, 3.85 mmol) in dry CH_2Cl_2 (50 mL) was added Cl_3CCN (2 mL) and DBU (1 drop). After stirring for 1 h, the solvent was removed *in vacuo* and the residue was purified by flash chromatography (5:2 PE−EA + 1% Et3N). **9i**α eluted first (2.71 g, 86%): $[\alpha]^{rt}_D$ +92.4° (*c* 1, $CHCl_3$); TLC (5:2 PE−EA) R_f 0.42; ^{1}H NMR: δ 8.58 (s, 1H), 7.6−7.2 (m, 15H), 6.64 (br s, 1H), 5.61 (s, 1H), 5.49 (s, 1H), 4.91 (d, J = 8.0 Hz, 1H), 4.72 (d, J = 10.9 Hz, 1H), 4.67 (d, J = 10.9 Hz, 1H), 4.62 (dd, J = 3.5, 10.8 Hz, 1H), 4.52 (br s, 1H), 4.4−3.9 (m, 9H), 3.39 (br s, 1H), 2.13 (s, 3H). Anal. Calcd for $C_{37}H_{37}N_4O_{11}Cl_3$: C, 54.19; H, 4.55; N, 6.83. Found: C, 54.02; H, 4.41; N, 6.87.

9i*β* eluted second (0.22 g, 7%): $[\alpha]^{rt}_D$ +40.8° (*c* 1, $CHCl_3$); TLC R_f (5:2 PE−EA) R_f 0.30, ^{1}H NMR: δ 8.67 (s, 1H), 7.6−7.2 (m, 15H), 5.81 (d, J = 8.1 Hz, 1H), 5.61 (s, 1H), 5.49 (s, 1H), 4.99 (d, J = 9.9 Hz, 1H), 4.91 (d, J = 8.0 Hz, 1H), 4.79 (d, J = 9.9 Hz, 1H), 4.63 (dd, J = 3.5, 10.9 Hz, 1H), 4.4−3.2 (m, 40H), 2.15 (s, 3H). Anal. Calcd for $C_{37}H_{37}N_4O_{11}Cl_3$: C, 54.19; H, 4.55; N, 6.83. Found: C, 54.23; H, 4.42; N, 6.92.

Benzyl *O*-(3-*O*-Acetyl-2-azido-4,6-*O*-benzylidene-2-deoxy-*β*-D-galactopyranosyl)-(1→3)-*O*-(2-*O*-benzyl-4,6-*O*-benzylidene-α- and -*β*-D-galactopyranosyl)-(1→4)-*O*-(2,3,6-tri-*O*-benzyl-*β*-D-galactopyranosyl)-(1→4)-2,6-di-*O*-benzyl-*β*-D-glucopyranoside (6cα and 6c*β*). To a solution of **10** (2 g, 2.1 mmol) in dry Et_2O (5 mL) was added TMSOTf (0.5 mL of a 0.1 M solution in dry Et_2O) under an argon atmosphere. A solution of **9i**α/*β* (2.5 g of a 12:1 α/*β* mixture, 3.1 mmol) in dry Et_2O (10 mL) was then added dropwise while the reaction stirred. After 30 min the mixture was neutralized with $NaHCO_3$ (s, 1 g), filtered, and concentrated *in vacuo*. The residue was purified by flash chromatography (4:1 PE−EA). **6c**α eluted first (1.71 g, 51%): $[\alpha]^{rt}_D$ +31.4° (*c* 1, $CHCl_3$); TLC (3:1 PE−EA) R_f 0.47, ^{1}H NMR: δ 7.5−7.0 (m, 45H), 5.43 (s, 1H), 5.35 (s, 1H), 5.20 (d, J = 2.7 Hz, 1H), 5.06 (dd, J = 8.0, 9.5 Hz, 1H), 4.9−3.2 (m, 40H), 2.11 (s, 3H), 1.11 (s, 9H). Anal. Calcd for $C_{94}H_{101}N_3O_{22}$: C, 69.48; H, 6.27; N, 2.59. Found: C, 69.77; H, 6.27; N, 2.84.

6cβ eluted second (0.40 g, 12%): $[\alpha]^{rt}_D$ +15.3° (*c* 1, $CHCl_3$); TLC (4:1 toluene−acetone) R_f 0.52, ^{1}H NMR: δ 7.7−6.7 (m, 45H), 5.48 (s, 1H), 5.16 (s, 1H), 5.13 (d, *J* = 10.2Hz, 1H), 5.06 (dd, *J* = 8.1, 9.5 Hz, 1H), 4.95−3.35 (m, 40H), 2.13 (s, 3H), 1.13 (s, 9H). Anal. Calcd for $C_{94}H_{101}N_3O_{22}$: C, 69.48; H, 6.27; N, 2.59. Found: C, 69.36; H, 6.35; N, 2.44.

Benzyl *O*-(2-Azido-4,6-*O*-benzylidene-2-deoxy-β-D-galactopyranosyl)-(1→3)-*O*-(2-*O*-benzyl-4,6-*O*-benzylidene-α-D-galactopyranosyl)-(1→4)-*O*-(2,3,6-tri-*O*-benzyl-β-D-galactopyranosyl)-(1→4)-3,6-di-*O*-benzyl-2-*O*-pivaloyl-β-D-glucopyranoside (6b). (a) To a solution of **6a** (100 mg, 57.9 μmol) in MeOH (5 mL) was added 1 N HCl (1 mL), and the mixture was stirred for 24 h at rt. After neutralization (saturated $NaHCO_3$ solution), the solvent was removed *in vacuo* and the residue extracted with acetone and purified by flash chromatography (3:1 PE−EA) to give **6b** (47 mg, 61%) as an amorphous powder: $[\alpha]^{rt}_D$ +21.7° (*c* 1, $CHCl_3$); TLC (2:1 PE−EA) R_f 0.35; ^{1}H-NMR δ 7.0−7.5 (m, 45H), 5.44 (s, 1H), 5.39 (s, 1H), 5.2 (d, *J* = 2.5 Hz, 1H), 5.08 (dd, *J* = 7.9, 9.6 Hz, 1H), 4.90−3.00 (m, 40H), 2.42 (d, *J* = 9.7 Hz, 1H), 1.12 (s, 9H). Anal. Calcd for $C_{92}H_{99}N_3O_{21}$: C, 69.81; H, 6.30; N, 2.65. Found: C, 69.83; H, 6.20; N, 2.87.

(b) To a solution of **6cα** (1.65 g, 1.02 mmol) in dry MeOH (5 mL) was added saturated methanolic ammonia solution (10 mL), and the mixture was stirred for 6 h at rt. After removal of the solvent, the residue was purified through a short silica gel column (2:1 PE−EA) to yield **6b** (1.61 g, quant), identical with the product described above.

Benzyl *O*-(2,3-Di-*O*-Acetyl-4,6-*O*-benzylidene-β-D-galactopyranosyl)-(1→3)-*O*-(2-azido-4,6-*O*-benzylidene-2-deoxy-β-D-galactopyranosyl)-(1→3)-*O*-(2-*O*-benzyl-4,6-*O*-benzylidene-α-D-galactopyranosyl)-(1→4)-*O*-(2,3,6-tri-*O*-benzyl-β-D-galactopyranosyl)-(1→4)-3,6-di-*O*-benzyl-2-*O*-pivaloyl-β-D-glucopyranoside (3a). To a stirred suspension of **6b** (1.5 g, 0.95 mmol) and **5** (0.71 g, 1.42 mmol) in dry Et_2O (5 mL) was added TMSOTf (0.47 mL of a 0.1 M solution in dry Et_2O) under an argon atmosphere. The mixture was stirred for 30 min at rt, $NaHCO_3$ (s, 1 g) was added, and the mixture was filtered and concentrated *in vacuo*. The residue was purified by flash chromatography (2:1 PE−EA) to yield **3a** (1.82 g, 94%): $[\alpha]^{rt}_D$ +44.8° (*c* 1, $CHCl_3$); TLC (7:4 PE−EA) R_f 0.22, ^{1}H NMR: δ 7.6−7.0 (m, 50H), 5.53 (s, 1H), 5.44 (s, 1H), 5.41 (s, 1H), 5.39 (dd, *J* = 8.0, 10.4 Hz, 1H), 5.18 (d, *J* = 2.9 Hz, 1H), 5.09 (dd, *J* = 8.0, 9.5 Hz, 1H), 4.99 (dd, *J* = 3.6, 10.4 Hz, 1H), 4.9−3.15 (m, 45H), 2.08 (s, 3H), 2.03 (s, 3H), 1.13 (s, 9H). Anal. Calcd for $C_{109}H_{117}N_3O_{28}$: C, 68.29; H, 6.15; N, 2.19. Found: C, 67.88; H, 6.27; N, 2.37.

Benzyl *O*-(4,6-*O*-Benzylidene-β-D-galactopyranosyl)-(1→3)-*O*-(2-azido-4,6-*O*-benzylidene-2-deoxy-β-D-galactopyranosyl)-(1→3)-*O*-(2-*O*-benzyl-4,6-*O*-benzylidene-α-D-galactopyranosyl)-(1→4)-*O*-(2,3,6-tri-*O*-benzyl-β-D-galactopyranosyl)-(1→4)-3,6-di-*O*-benzyl-2-*O*-pivaloyl-β-D-glucopyranoside (3b). To a solution of **3a** (533 mg, 0.28 mmol) in dry MeOH (3 mL) was added saturated methanolic ammonia solution (5 mL) and the mixture was stirred for 4 h at rt. After removal of the solvent, the residue was purified through a short silica gel column (4:1 toluene−acetone) to yield **3b** (510 mg, quant): $[\alpha]^{rt}_D$ + 48.0° (*c* 1, $CHCl_3$); TLC (4:1 toluene−acetone) R_f 0.30, ^{1}H NMR: δ 7.6−7.0 (m, 50H), 5.58 (s, 1H), 5.46 (s, 1H), 5.45 (s, 1H), 5.20 (d, *J* = 3.0 Hz, 1H), 5.10 (dd, *J* = 8.0, 9.6 Hz, 1H), 4.9−3.1 (m, 47H), 2.83 (br s, 1H), 2.52 (br s, 1H), 1.13 (s, 9H). Anal. Calcd for $C_{105}H_{113}N_3O_{26}$: C, 68.80; H, 6.21; N, 2.29. Found: C, 68.56; H, 6.30; N, 2.40.

Benzyl *O*-(Methyl 5-Acetamido-4,7,8,9-tetra-*O*-acetyl-3,5-dideoxy-D-*glycero*-α- and β-D-*galacto*-2-nonulopyranosylonate)-(2→3)-*O*-(4,6-*O*-benzylidene-β-D-galactopyranosyl)-(1→3)-*O*-(2-azido-4,6-*O*-benzylidene-2-deoxy-β-D-galactopyranosyl)-(1→3)-*O*-(2-*O*-benzyl-4,6-*O*-benzylidene-α-D-galactopyranosyl)-(1→4)-*O*-(2,3,6-tri-*O*-benzyl-β-D-galactopyranosyl)-(1→4)-3,6-di-*O*-benzyl-2-*O*-pivaloyl-β-D-glucopyranoside (11a and 11aβ). To a solution of **3b** (300 mg, 0.16 mmol of a 5:1 α/β mixture) and **2** (150 mg, 0.25 mmol) in dry CH_3CN (3 mL) was added TMSOTf (0.16 mL of a 0.1 M solution in dry CH_3CN) at −50 °C under an argon atmosphere. After stirring for 30 min, more **2** (50 mg, 0.08 mmol, solution in 0.5 mL of dry CH_3CN) was added and the mixture stirred for another 30 min. After addition of $NaHCO_3$ (s, 0.1 g), the reaction mixture was filtered and concentrated *in vacuo*, and the resulting residue was purified by flash chromatography (3:1 toluene−acetone). **11aβ** eluted first (49 mg, 13%): $[\alpha]^{rt}_D$ +23.1° (*c* 1, $CHCl_3$); TLC (4:1 toluene−acetone) R_f 0.40, ^{1}H NMR: δ 7.0−7.7 (m, 35H), 5.72 (s, 1H), 5.44 (s, 1H), 5.42 (s, 1H), 5.41 (m, 1H), 5.35 (m, 1H), 5.30 (m, 1H), 5.26 (dd, *J* = 2.3, 12.2 Hz, 1H), 5.18 (d, *J* = 3.0 Hz, 1H), 5.09 (dd, *J* = 7.9, 9.4 Hz, 1H), 4.66 (d, *J* = 7.7 Hz, 1H), 4.58 (d, *J* = 8.8 Hz, 1H), 4.48 (d, *J* = 8.6 Hz, 1H), 4.44 (d, *J* = 8.1 Hz, 1H), 3.97 (m, 1H), 3.78 (s, 3H), 2.74 (br s, 1H), 2.67 (dd, *J* = 4.4, 12.2 Hz, 1H), 2.14 (s, 3H), 2.08 (s, 3H), 2.03 (s, 3H), 2.00 (s, 3H), 1.90 (t, *J* = 13.1 Hz, 1H), 1.67 (s, 3H), 1.13 (s, 9H). Anal. Calcd for $C_{125}H_{140}N_4O_{38}$: C, 65.09; H, 6.12; N, 2.43. Found: C, 64.88; H 6.28; N, 2.64.

11aα eluted second (180 mg, 48%): $[\alpha]^{rt}_D$ +24.6° (*c* 1, $CHCl_3$), ^{1}H NMR: δ 7.5-7.0 (m, 50H), 5.45 (s, 2H), 5.40 (s, 1H), 5.43 (m, 1H), 5.30 (dd, *J* = 1.6, 9.2 Hz, 1H), 5.17 (d, *J* = 3.2 Hz, 1H), 5.16 (d, *J* = 8.7 Hz, 1H), 5.09 (dd, *J* = 8.0, 9.4 Hz, 1H), 4.88 (m, 1H), 4.66 (d, *J* = 7.7 Hz, 1H), 4.58 (d, *J* = 8.8 Hz, 1H), 4.48 (d, *J* = 8.6 Hz, 1H), 4.44 (d, *J* = 8.1 Hz, 1H), 4.35 (m, 1H), 4.02 (m, 1H), 3.50 (s, 3H), 2.74 (dd, *J* = 4.5, 12.7 Hz, 1H), 2.73 (br s, 1H), 2.21 (s, 3H), 2.16 (s, 3H), 2.01 (s, 3H), 1.99 (s, 3H), 2.03 (t, *J* = 12.8 Hz, 1H), 1.88 (s, 3H), 1.13 (s, 9H). Anal. Calcd for $C_{125}H_{140}N_4O_{38}$: C, 65.09; H, 6.12; N, 2.43. Found: C, 65.00; H 6.39; N, 3.05.

***O*-(Methyl 5-Acetamido-4,7,8,9-tetra-*O*-acetyl-3,5-dideoxy-D-*glycero*-α-D-*galacto*-2-nonulopyranosylonate)-(2→3)-*O*-(2,4,6-tri-*O*-acetyl-β-D-galactopyranosyl)-(1→3)-*O*-(2-acetamido-4,6-di-*O*-acetyl-2-deoxy-β-D-galactopyranosyl)-(1→3)-*O*-(2,4,6-tri-*O*-acetyl-α-D-galactopyranosyl)-(1→4)-*O*-(2,3,6-tri-*O*-acetyl-β-D-galactopyranosyl)-(1→4)-1,3,6-tri-*O*-acetyl-2-*O*-pivaloyl-α/β-D-glucopyranoside (11b).** A mixture of **11a** (145 mg, 62.8 mmol) and freshly prepared[32] $Pd(OH)_2$ (19% on carbon, 50 mg) in MeOH (50 mL) was stirred under H_2 (4 bar) at rt for 24 h. The mixture was filtered and washed with MeOH (50 mL). The filtrate was concentrated, and the resulting residue was coevaporated with toluene (2 × 10 mL), dissolved in 1:1 Py−Ac_2O (3 mL), and kept at rt for 24 h. The mixture was then poured on ice−water (50 mL) and extracted with CH_2Cl_2 (3 × 25 mL). The organic layer was washed with 1 M HCl (50 mL), saturated $NaHCO_3$ solution (50 mL), and brine (50 mL). After removal of the solvent *in vacuo*, the resulting residue was purified by flash chromatography (40:1 $CHCl_3$−MeOH) to yield **11b** (108 mg, 85%) as a 1:1 mixture of α and β anomers: TLC (30:1 $CHCl_3$−MeOH) R_f 0.29, ^{1}H NMR: δ 6.30 (d, *J* = 3.7 Hz), 4.05 (m, 1H), 3.85 (s, 3H), 2.58 (dd, *J* = 4.6, 12.7 Hz, 1H), 2.25−1.80 (m, 60H), 1.68 (t, *J* = 12.4 Hz, 1H), 1.13 and 1.14 (2 s, 9H); MS-FAB (thioglycerol matrix, NaI) *m*/*z* 2037 (MNa^+). Anal. Calcd for $C_{85}H_{118}N_2O_{53}$: C, 50.64; H, 5.90; N, 1.39. Found: C, 50.70; H 6.07; N, 1.01.

***O*-(Methyl 5-Acetamido-4,7,8,9-tetra-*O*-acetyl-3,5-dideoxy-D-*glycero*-α-D-*galacto*-2-nonulopyranosylonate)-(2→3)-*O*-(2,4,6-tri-*O*-acetyl-β-D-galactopyranosyl)-(1→3)-*O*-(2-acetamido-4,6-di-*O*-acetyl-2-deoxy-β-D-galactopyranosyl)-(1→3)-*O*-(2,4,6-tri-*O*-acetyl-α-D-galactopyranosyl)-(1→4)-*O*-(2,3,6-tri-*O*-acetyl-β-D-galactopyranosyl)-(1→4)-3,6-di-*O*-acetyl-2-*O*-pivaloyl-α,β-D-glucopyranose (11c).** A solution of **11b** (100 mg, 49.7 μmol) in dry DMF (3 mL) was stirred with NH_2NH_2·AcOH (8 mg) at 40 °C for 1 h. The mixture was then diluted with AcOEt (30 mL) and washed with brine (20 mL). The aqueous layer was washed (AcOEt, 2 × 15 mL) and the combined organic layer was concentrated *in vacuo* and purified by column chromatography (40:1 CH_2Cl_2−MeOH) to yield **11c** (92 mg, 94%): $[\alpha]^{rt}_D$ +55.6° (*c* 1, $CHCl_3$); TLC (20:1 $CHCl_3$−MeOH) R_f 0.44, ^{1}H NMR: 6.18 (d, *J* = 8.0 Hz, 1H), 3.81 (s, 3H), 2.54 (dd, *J* = 4.1, 12.2 Hz, 1H), 2.25−1.82 (m, 57H), 1.67 (t, *J* = 12.3 Hz, 1H), 1.15 (s, 9H); MS-FAB (thioglycerol matrix, NaI) *m*/*z* 1995 (MNa^+). Anal. Calcd for $C_{83}H_{116}N_2O_{52}$: C, 50.50; H, 5.92; N, 1.42. Found: C, 50.22; H 6.11; N, 1.25.

***O*-(Methyl 5-Acetamido-4,7,8,9-tetra-*O*-acetyl-3,5-dideoxy-D-*glycero*-α-D-*galacto*-2-nonulopyranosylonate)-(2→3)-*O*-(2,4,6-tri-*O*-acetyl-β-D-galactopyranosyl)-(1→3)-*O*-(2-acetamido-4,6-di-*O*-acetyl-2-deoxy-β-D-galactopyranosyl)-**

(1→3)-*O*-(2,4,6-tri-*O*-acetyl-α-D-galactopyranosyl)-(1→4)-*O*-(2,3,6-tri-*O*-acetyl-*β*-D-galactopyranosyl)-(1→4)-3,6-di-*O*-acetyl-2-*O*-pivaloyl-α-D-glucopyranosyl Trichloroacetimidate (11d). To a solution of **11c** (80 mg, 40 μmol) in dry CH_2Cl_2 (5 mL) was added Cl_3CCN (40 μL) and DBU (1 drop). After stirring for 2 h, the solvent was removed *in vacuo* and the residue was purified through a short silica gel column (50:1 CH_2Cl_2−MeOH) to afford **11d** (80 mg, 93%): $[\alpha]^{rt}_D$ +72.8° (*c* 1, $CHCl_3$); TLC (40:1 CH_2Cl_2−MeOH) R_f 0.28, ^{1}H NMR: δ 8.66 (s, 1H), 6.51 (d, *J* = 3.6 Hz, 1H), 3.84 (s, 3H), 2.58 (dd, *J* = 4.6, 12.9 Hz, 1H), 2.25−1.94 (m, 54H), 1.85 (s, 3H), 1.73 (s, 3H), 1.68 (t, *J* = 12.3 Hz, 1H), 1.14 (s, 9H). Anal. Calcd for $C_{85}H_{116}N_4O_{52}Cl_3$: C, 48.20; H, 5.52; N, 2.65. Found: C, 48.13; H, 5.61; N, 2.43.

***O*-(Methyl 5-Acetamido-4,7,8,9-tetra-*O*-acetyl-3,5-dideoxy-D-*glycero*-α-D-*galacto*-2-nonulopyranosylonate)-(2→3)-*O*-(2,4,6-tri-*O*-acetyl-*β*-D-galactopyranosyl)-(1→3)-*O*-(2-acetamido-4,6-di-*O*-acetyl-2-deoxy-*β*-D-galactopyranosyl)-(1→3)-*O*-(2,4,6-tri-*O*-acetyl-α-D-galactopyranosyl)-(1→4)-*O*-(2,3,6-tri-*O*-acetyl-*β*-D-galactopyranosyl)-(1→4)-3,6-di-*O*-acetyl-2-*O*-pivaloyl-*β*-D-glucopyranosyl-(1→1)-(2*S*,3*R*,4*E*)-2-azido-3-*O*-benzoyl-4-octadecene-1,3-diol (12a).** To a solution of **11d** (70 mg, 30 μmol) and (2*S*,3*R*,4*E*)-2-azido-3-(benzoyloxy)-4-octadecen-1-ol (**4**) (25 mg, 60 μmol) in dry CH_2Cl_2 (200 μL) was added TMSOTf (17 μL of a 0.01 M solution in dry CH_2Cl_2) under an argon atmosphere and the mixture was stirred at rt for 1 h. $NaHCO_3$ (s, 10 mg) was then added and the mixture was filtered, concentrated, and purified by flash chromatography (40:1 CH_2Cl_2−MeOH) to yield **23** (57 mg, 72%): $[\alpha]^{rt}_D$ +29.7° (*c* 1, $CHCl_3$); TLC (25:1 CH_2Cl_2−MeOH) R_f 0.45, ^{1}H NMR: δ 8.1−7.4 (m, 5H), 5.91 (dt, *J* = 6.5, 14.5, 1H), 5.75 (d, *J* = 7.4 Hz, 1H), 4.70 (d, *J* = 8.0 Hz, 1H), 3.85 (s, 3H), 3.34 (m, 1H), 2.59 (dd, *J* = 4.3, 12.4 Hz, 1H), 2.25−1.94 (m, 53H), 1.85 (s, 3H), 1.80 (s, 3H), 1.68 (t, *J* = 12.5 Hz, 1H), 1.4−1.2 (m, 22H), 1.17 (s, 9H), 0.88 (t, *J* = 6.6 Hz, 3H); MS-FAB (thioglycerol matrix + NaI) *m*/*z* 2406 (MNa^+). Anal. Calcd for $C_{108}H_{153}N_5O_{54}$: C, 54.38; H, 6.46; N, 2.94. Found: C, 54.66; H 6.47; N, 2.77.

***O*-(Methyl 5-Acetamido-4,7,8,9-tetra-*O*-acetyl-3,5-dideoxy-D-*glycero*-α-D-*galacto*-2-nonulopyranosylonate)-(2→3)-*O*-(2,4,6-tri-*O*-acetyl-*β*-D-galactopyranosyl)-(1→3)-*O*-(2-acetamido-4,6-di-*O*-acetyl-2-deoxy-*β*-D-galactopyranosyl)-(1→3)-*O*-(2,4,6-tri-*O*-acetyl-α-D-galactopyranosyl)-(1→4)-*O*-(2,3,6-tri-*O*-acetyl-*β*-D-galactopyranosyl)-(1→4)-3,6-di-*O*-acetyl-2-*O*-pivaloyl-α,*β*-D-glucopyranosyl-(1→1)-(2*S*,3*R*,4*E*)-2-hexadecanamido-3-*O*-benzoyl-4-octadecene-1,3-diol (12b).** H_2S was slowly bubbled through a solution of **23** (35 mg, 14.7 μmol) in 8:2 Py−H_2O (4 mL) for 2 h at rt. After stirring for 48 h, the solvent was concentrated *in vacuo*, the bath temperature being kept under 30 °C. To a solution of the residue in dry CH_2Cl_2 (3 mL) were added palmitic acid (9 mg, 34 μmol) and *N*-(3-(*N*,*N*-dimethylamino)propyl)-*N*′-ethylcarbodiimide hydrochloride (WSC) (9 mg, 46 μmol), and the mixture was stirred for 18 h at rt. The reaction mixture was then diluted with more CH_2Cl_2 (15 mL), washed with H_2O (2 × 5 mL), and concentrated *in vacuo*. The residue was purified by flash chromatography (40:1 CH_2Cl_2−MeOH) to yield **12b** (33 mg, 87%): $[\alpha]^{rt}_D$ +32.9° (*c* 1, $CHCl_3$); TLC (25:1 CH_2Cl_2−MeOH) R_f 0.50, ^{1}H NMR: δ 8.1−7.4 (m, 5H, Ph), 5.88 (dt, *J* = 6.6, 14.7, 1H, H-5cer), 5.75 (d, *J* = 8.2 Hz, 1H, NH-2d), 5.73 (d, *J* = 9.8 Hz, 1H, NH-2cer), 5.6−5.4 (m, 5H, H-8f, H-3cer, H-1c, H-4d, H-4cer), 5.37 (dd, *J* = 2.5, 8.8 Hz, 1H, H-7f), 5.18 (d, *J* = 8.7 Hz, 1H, H-1d), 4.69 (d, *J* = 7.8 Hz, 1H, H-1e), 4.48 (m, H-2cer), 4.47 (d, *J* = 8.3 Hz, 1H, H-1b), 4.44 (d, *J* = 8.0 Hz, 1H, H-1a), 3.85 (s, 3H, CO_2Me), 2.59 (dd, *J* = 4.5, 12.5 Hz, 1H, H-3f*eq*), 2.25−1.90 (m, 53H, 17 OAc, H-6cer, H-6′cer), 3.33 (m, 1H, H-2d), 1.85 (s, 3H, NAc), 1.73 (s, 3H, NAc), 1.63 (t, *J* = 13.3 Hz, 1H, H-3f*ax*), 1.4−1.2 (m, 48H, 24 CH_2), 1.15 (s, 9H, OPiv), 0.88 (t, *J* = 6.5 Hz, 6H, 2 CH_3); MS-FAB (thioglycerol matrix, NaI) *m*/*z* 2620 (MNa^+). Anal. Calcd for $C_{124}H_{186}N_3O_{55}$: C, 57.33; H, 7.18; N, 1.62. Found: C, 56.98; H 7.29; N, 1.45.

***O*-(5-Acetamido-3,5-dideoxy-D-*glycero*-α-D-*galacto*-2-nonulopyranosylonic Acid)-(2→3)-*O*-(*β*-D-galactopyranosyl)-(1→3)-*O*-(2-acetamido-2-deoxy-*β*-D-galactopyranosyl)-(1→3)-*O*-(α-D-galactopyranosyl)-(1→4)-*O*-(*β*-D-galactopyranosyl)-(1→4)-*β*-D-glucopyranosyl-(1→1)-(2*S*,3*R*,4*E*)-2-hexadecanamido-4-octadecene-1,3-diol (1).** To a solution of **12b** (22 mg, 8.5 μmol) in dry MeOH (1.5 mL) was added NaOMe (0.2 M in MeOH, 0.35 mL) and the mixture was stirred for 24 h at 40 °C. KOH (0.2 M in water, 0.4 mL) was added and the mixture stirred at rt for another 24 h. The solution was then neutralized with ion-exchange resin Amberlite IR 120 (H^+), filtered, and concentrated *in vacuo*. The residue was purified by column chromatography (1:1 CH_2Cl_2−EtOH) on Sephadex LH-20 (15 mL) to yield **1** (14.2 mg, quantitative) as a white powder: $[\alpha]^{rt}_D$ +8.5° (*c* 0.4, Py); TLC (8:4:3 *n*-BuOH−AcOH−H_2O) R_f 0.37, ^{1}H NMR (500 MHz, 95:5 DMSO-d_6/D_2O, 40 °C): δ 5.51 (dt, *J* = 6.8, 15.4, 1H, H-5cer), 5.33 (dd *J* = 7.1, 15.4 Hz, 1H, H-4cer), 4.79 (d, *J* = 4.0 Hz, 1H, H-1c), 4.56 (d, *J* = 7.3 Hz, 1H, H-1d), 4.24 (d, *J* = 7.7 Hz, 1H, H-1b or e), 4.22 (d, *J* = 7.9 Hz, 1H, H-1b or e), 4.16 (d, *J* = 7.8 Hz, 1H, H-1a), 3.86 (m, 1H, H-3cer), 3.53 (m, 1H, H-4f), 3.02 (dd *J* = 7.2, 8.2, 1H, H-2a), , 2.74 (dd *J* = 4.6, 11.8, 1 H, H-3f*eq*), 2.01 (t, *J* = 7.1 Hz, 2H, $COCH_2$), 1.91 (m, 2H, H-6cer, H-6′cer), 1.86 (s, 3H, NAc), 1.78 (s, 3H, NAc), 1.34 (t, *J* = 11.6 Hz, 1H, H-3f*ax*), 0.83 (t, *J* = 6.9 Hz, 6H, 2 CH_3). MS-FAB (thioglycerol/PNB matrix, NaI) *m*/*z* 1725 (M + $2Na^+$); (thioglycerol/PNB matrix, CsI) *m*/*z* 1945 (M + $2Cs^+$).

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Supporting Information Available: ^{1}H NMR spectrum for compound **1** (2 pages). This material is contained in libraries on microfiche, immediately follows this article in the microfilm version of the journal, and can be ordered from the ACS; see any current masthead page for ordering information.

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